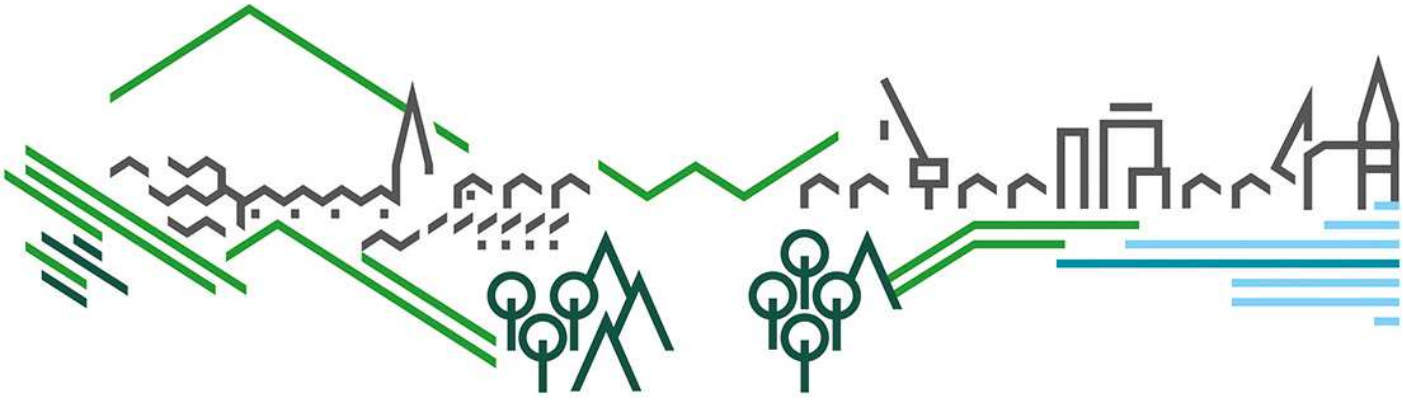
Cyfoeth Naturiol Cymru
Natural Resources Wales

Intertidal SAC monitoring *Zostera noltii* at Angle Bay, Pembrokeshire Marine SAC, 2013

Mollie Duggan-Edwards & D Paul Brazier

NRW Evidence Report

Report No: 55
March 2015



About Natural Resources Wales

Natural Resources Wales is the organisation responsible for the work carried out by the three former organisations, the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales. It is also responsible for some functions previously undertaken by Welsh Government.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, used and enhanced, now and in the future.

We work for the communities of Wales to protect people and their homes as much as possible from environmental incidents like flooding and pollution. We provide opportunities for people to learn, use and benefit from Wales' natural resources.

We work to support Wales' economy by enabling the sustainable use of natural resources to support jobs and enterprise. We help businesses and developers to understand and consider environmental limits when they make important decisions.

We work to maintain and improve the quality of the environment for everyone and we work towards making the environment and our natural resources more resilient to climate change and other pressures.

Published by: Natural Resources Wales
Maes y Ffynnon
Penrhosgarnedd
Bangor
LL57 2DW

03000 653000

Further copies of this report are available from the library

Email: library@cyfoethnaturiolcymru.gov.uk

Evidence at Natural Resources Wales

Natural Resources Wales is an evidence based organisation. We seek to ensure that our strategy, decisions, operations and advice to Welsh Government and others are underpinned by sound and quality-assured evidence. We recognise that it is critically important to have a good understanding of our changing environment.

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well-resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

This Evidence Report series serves as a record of work carried out or commissioned by Natural Resources Wales. It also helps us to share and promote use of our evidence by others and develop future collaborations. However, the views and recommendations presented in this report are not necessarily those of NRW and should, therefore, not be attributed to NRW.

Report series:	Evidence Report
Report number:	55
Publication date:	March 2015
Contract number:	FC 73-02-342
Contractor:	Aquatic Survey & Monitoring Ltd.
Contract Manager:	Jon Moore
Title:	Intertidal SAC monitoring, *Zostera noltii* in Angle Bay, **Pembrokeshire Marine SAC, 2013**
Author(s):	**Mollie Duggan-Edwards, Paul Brazier**
Approved By:	Paul Brazier
Restrictions:	None

Distribution List (core)

NRW Library, Bangor	2
National Library of Wales	1
British Library	1
Welsh Government Library	1
Scottish Natural Heritage Library	1
Natural England Library (Electronic Only)	1

Distribution List (others)

Anne Bunker	NRW
Lily Pauls	NRW
Sean Evans	NRW
Mike Camplin	NRW
Francis Bunker	MarineSeen
Sue Burton	MHWESG

Recommended citation for this volume:

Duggan-Edwards, M. & Brazier, D.P. 2015. Intertidal SAC monitoring *Zostera noltii* in Angle Bay, Pembrokeshire Marine SAC 2013. NRW Evidence Report No: 55, 38pp + xi, Natural Resources Wales, Bangor.

Contents

1 Introduction....1
1.1 Biology....1
1.1.1 Ecosystem Services....1
1.1.2 Threats....2
1.1.3 Bait Digging....2
1.1.4 Conservation....2
1.2 Background....3
1.2.1 Pembrokeshire Marine SAC....3
1.2.2 Survey Objectives....5
2 Methodology....5
2.1 Mapping....5
2.2 Recording Features....5
2.2.1 Cockle counts....6
2.2.2 Core samples....7
2.3 Healthy and Safety, logistics and permissions....7
2.4 Data Analysis....7
2.5 Quality Assurance....8
2.6 Photography....8
2.7 Species identification and nomenclature....8
3 Results....8
3.1 The distribution of *Zostera noltii* in Angle Bay....8
3.2 The sampling grid....9
3.3 Abundance of *Zostera noltii*....10
3.3.1 Extent of *Zostera noltii* bed....12
3.4 Core sediment samples....12
3.5 Quadrat data....13
4 Discussion....14
4.2 Mapping....14
4.3 Sampling....14
4.1 Results....14
4.4 Impacts....14
4.4.1 Bait Digging....15
5 Conclusions and Recommendations....15
6 References....15
Appendix 1 Recording Protocols....17
Appendix 2 Zostera noltii recording pro-forma....18
Appendix 3 Data from quadrat studies (physical and survey details)....19
Appendix 4 Data from quadrat studies (Species data)....22
Appendix 5 Catalogue of photographs....27
Appendix 6 ‘t-test’....31
Appendix 7 Species names and habitat description....32
Appendix 8 Data Archive Appendix....36

List of Figures

Figure 1 Location map for Angle Bay within the Pembrokeshire Marine SAC (blue boundary). 4

Figure 2 Ordnance survey map showing the southern entrance to Milford Haven and Angle Bay. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2014]..... 4

Figure 3 Surveyor Paul Brazier tracking the edges of the seagrass bed with a hand held GPS unit. 5

Figure 4 Quadrat positioned on the seagrass bed and photographed prior to sampling. 6

Figure 5 Quadrat positioned at Waypoint W1P prior to cockle search..... 6

Figure 6 Quadrat positioned at Waypoint W1P following cockle search..... 6

Figure 7 Core sediment sample prior to sieving. 7

Figure 8 Surveyor Paul Brazier sieving a core sediment sample in the field. 7

Figure 9 East side of Angle Bay showing the tracks produced by walking around the area colonised by *Zostera noltii* with a hand held GPS. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2014].. 9

Figure 10 East side of Angle Bay showing the area colonised by *Zostera noltii* (September 2013). Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2014]. 9

Figure 11 Grid created for quadrat sampling in and around the *Zostera noltii* bed. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2014]..... 10

Figure 12 Abundance of *Zostera noltii* in 2013 as determined in the field at grid stations on the east side of Angle Bay as shown by proportional circles (see scale on map). Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2014]..... 11

Figure 13 Abundance of *Zostera noltii* in 2008 as determined in the field at grid stations on the east side of Angle Bay as shown by proportional circles (see scale on map). Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2014]..... 12

Figure 14 Area of intensive bait digging to the north of the intertidal *Zostera noltii* bed 15

Figure 15 Bait hole as a result of bait digging in the intertidal *Zostera noltii* bed 15

List of Tables

Table 1 Mean percentage cover records of Zostera noltii in Angle Bay based on in situ records from quadrats by four groups of field surveyors. PB = Paul Brazier, CJ = Chloe Jennings, BW = Ben Wray, LP = Lily Pauls, NL = Natasha Lough and KB = Kathryn Birch. 10

Table 2 Mean percentage cover records of Zostera noltii in Angle Bay based on in situ records from quadrats by three groups of field surveyors in 2008. FB = Francis Bunker, LL = Lou Luddington, AB = Anne Bunker, PB = Paul Brazier, NC = Nicky Chapman and TM = Tom Mercer. 10

Table 3 Number of infaunal species recorded in five core sediment sample replicates at the coring station in the Zostera noltii bed, Angle Bay. 13

Table 4 Mean percentage of each substratum type across all sampled quadrats. ... 13

Table 5 Percentage frequency of the most abundant species across all sampled quadrats..... 14

Crynodeb Gweithredol

Yn ôl y Gyfarwyddeb Cynefinoedd dylai'r ffordd y chaiff Ardaloedd Cadwraeth Arbennig (ACA) eu rheoli anelu at sicrhau **statws cadwraeth ffafriol** i'r cynefinoedd a'r rhywogaethau a restrir yn Atodiad I ac Atodiad II. Ar gyfer ACA yng Nghymru, mae'n ofynnol i Cyfoeth Naturiol Cymru (CNC), Cyngor Cefn Gwlad (CCG) yng nghynt, lunio adroddiadau'n reolaidd yn nodi a oes gan y nodweddion statws cadwraeth ffafriol ai peidio. Er mwyn gwneud hyn, mae CNC wedi datblygu rhaglen ar gyfer **monitro cyflwr y nodweddion**. Mae *Aquatic Survey & Monitoring Ltd* (ASML) wedi derbyn cytundeb gan CNC i ddatblygu a rheoli'r rhaglen fonitro ar gyfer nodweddion rhynglanwol mewn ACA morol ar gyfer y cyfnod rhwng 2006 a 2014, gan weithio fel tîm gyda staff weithredol CNC.

Yn ACA Sir Benfro Forol mae nodweddion y cynefin rhynglanwol sy'n berthnasol i Atodiad I yn cynnwys gwastadeddau llaid a gwastadeddau tywod na chânt eu gorchuddio gan ddŵr môr pan fydd y llanw ar drai. Yr is-nodwedd benodol o ddiddordeb yn y fan hon yw'r gwely gwellty-gamlas bach *Zostera noltii* ym Mae Angle. Mae'r adroddiad hwn yn disgrifio'r astudiaethau a wnaed ar y gwely hwn yn 2013.

Cafodd y llecyn ym Mae Angle lle mae *Zostera noltii* yn tyfu ei fapio trwy ddefnyddio unedau Systemau Lleoli Byd-eang. Ar sail y map a gafwyd, cafodd grid o 112 o orsafoedd samplo ei greu, gyda phob un 50m oddi wrth ei gilydd. Cafodd gorchudd gwellt y gamlas (ar ffurf canran) ei amcangyfrif mewn cwadratau 0.25m² a leolwyd ym mhob gorsaf, a hefyd cafodd amryw o nodweddion eraill eu cofnodi. Roedd hyn yn cynnwys presenoldeb a nifer y cocos, unrhyw dystiolaeth o dyrchu am abwyd a'r biota arall a oedd yn bresennol.

Caiff canlyniadau'r astudiaeth eu cyflwyno yn yr adroddiad hwn, ynghyd â map yn dangos dosbarthiad *Zostera noltii* ym Mae Angle. Mae'r gwely *Zostera noltii* wedi tyfu dros 5 mlynedd (2008-2013), yn syml i adoddiadau eraill yn Nghymru sydd wedi nodi tyfiant mewn *Z.noltii*. Mae awgrymiadau yn cael eu gwneud i reoli bai palu a casglu cocos masnachol yn yr ardal i warchod y cynefin.

Executive Summary

The Habitats Directive establishes that the management of Special Areas of Conservation (SACs) should aim to achieve the **favourable conservation status** of habitat and species features listed within its Annex I and Annex II. For SACs in Wales, Natural Resources Wales (NRW), previously the Countryside Council for Wales (CCW), is required to report on a regular basis on whether features are in favourable conservation status. To do this NRW has developed a programme of **feature condition monitoring.** Aquatic Survey & Monitoring Ltd. (ASML) have been contracted by NRW to develop and manage the monitoring programme for the intertidal features in marine SAC's for the period 2006 to 2014; working as a team with NRW operational staff.

In the Pembrokeshire Marine SAC the relevant Annex I intertidal habitat features include mudflats and sandflats not covered by seawater at low tide. The specific area sub-feature of interest covered here is the bed of the dwarf seagrass *Zostera noltii* at Angle Bay. This report describes studies carried out on this seagrass bed in 2013.

The area colonised by *Zostera noltii* in Angle Bay was mapped using portable GPS units. Based on the map obtained, a grid of 112 sampling stations was created, each being 50 m apart. The percentage cover of seagrass was estimated in 0.25 m^2 quadrats placed at each station, and various other features were also recorded. These included the presence and abundance of cockles, any evidence of bait digging and other biota present.

The results of the study are presented in this report together including a map showing the distribution of *Zostera noltii* in Angle Bay. In conclusion, there has been an expansion of the *Zostera noltii* bed in Angle Bay over a 5 year period (2008-2013), and this is consistent with studies elsewhere in Wales where *Z. noltii* is expanding. It is recommended that bait digging and commercial cockling activities should be regulated within the area to preserve this habitat.

1 Introduction

1.1 Biology

Seagrass beds are amongst the most widespread and productive ecosystems on earth and range from the tropics to the boreal margins of every ocean (Boyes *et al*. 2008). They are a unique group of flowering plants that have adapted to survive fully submerged in marine water (Orth *et al.* 2006). Often growing in dense extensive beds or meadows, they are typically found in shallow coastal areas on sheltered sandy or muddy substrata up to a maximum depth of approximately 10m (depending on water clarity and light penetration) (Boyes *et al*. 2008). As noted by Davison & Hughes (1998), three species of the genus *Zostera* (eelgrass) occur within the British Isles;

- ***Zostera marina*** **(common eelgrass):** This is the largest of the three species, with leaves up to 1 m in length (although usually 20-50 cm). It typically occurs from the sublittoral (down to a depth of approximately 4 m) to lower littoral zone, in fully marine conditions and on relatively coarse sediments.

- ***Zostera angustifolia*** **(narrow-leafed eelgrass):** This plant is smaller in size than *Z. marina*, with leaf lengths 15-30 cm. It is typically found on the mid to lower shore, usually in poorly-draining muddy sediments, and in areas of variable salinity such as estuaries.

- ***Zostera noltii*** **(dwarf eelgrass):** *Z. noltii* is the smallest and hardiest of the species. It occurs higher on the shore than the other two species, typically on mixtures of sand and mud, and is often found adjacent to saltmarsh communities. Maximum leaf length is approximately 22 cm.

However, although most of the UK literature makes a specific distinction between *Z. marina* and *Z. angustifolia*, there is some debate as to whether *Z. angustifolia* is in fact a distinct species, or (as regarded by authorities outside the British Isles), a variety of *Z. marina* (Davison & Hughes 1998).

The distribution, extent, and density of *Zostera* are highly variable, with the beds being spatially dynamic and often expanding or receding at their edges. Such dynamics are dependent on a number of naturally occurring factors, including extreme weather conditions (i.e. storms, floods, frost), increases in turbidity thereby preventing photosynthesis, overgrazing by wildfowl, and excessive algal/epiphytic growth in the absence of sufficient grazing species (Boyes *et al*. 2008).

1.1.1 Ecosystem Services

Seagrass habitats influence the physical, chemical and biological environments in coastal waters, acting as important ecological engineers and providing numerous important ecosystem services to the marine environment (Orth *et al*. 2006). They are an important food source for wildfowl (e.g. Brent geese), and a critical habitat for many species including epiphytes, algae (which grow amongst the sea grass or as mats on the sediment), invertebrates, and fish (Beck *et al*. 2001). Seagrass beds are known to support a high diversity of juvenile organisms including commercially and recreationally important fish and crustacean species, thus acting as important nursery grounds (Davison & Hughes 1998). It is thought that the high abundance and variety of life in seagrass beds is due to the ease of predatory avoidance via the dense vegetative structures of the meadows providing sufficient shelter. The abundance of food and the interception of fish larvae also enable a variety of species to thrive in these habitats (Davison & Hughes 1998).

As a result of a dense and complex root structure, together with a certain degree of wave attenuation and the trapping of sediment particles which further encourages sedimentation, seagrass beds help to stabilise the underlying substratum. This enables seagrass beds to function as coastal flood defence systems, and to assist in the reduction of coastal erosion (Boyes *et al*. 2008). In addition to their biological function and conservation importance, they have considerable economic importance. As examples of costal marine habitats they are amongst the most biologically and economically important on earth (Constanza 1997).

1.1.2 Threats

Seagrass habitats are currently under threat from a variety of anthropogenic activities, crucially threatening the longevity of the multiple biological and economic services that they provide (Davison & Hughes 1998). Human influences affecting the abundance of *Zostera noltii* include land claim, nutrient and sediment run-off, physical disturbance (i.e. dredging, cockle harvesting, bait digging, construction of harbours and marinas, and boat mooring) and invasive species. These threats, along with pollution, have contributed to the alteration of the local hydrographic regime and sediment balance within seagrass habitats (Mazik & Boyes 2009). In addition, they have caused major changes in the abundance, species composition, and structure of marine communities. As a result, reported seagrass losses have accumulated, indicating the need for more conservation effort to protect these vital habitats (Mazik & Boyes 2009).

1.1.3 Bait Digging

A widespread activity in many parts of the world, bait digging is the collection of bait for recreational and commercial fishing purposes (Cunha *et al* 2005; Costa *et al* 2006). Bait digging involves the harvesting of polychaetes from intertidal mud or sand flats for their value as fishing bait (Cunha *et al* 2005). This activity directly exploits several families of polychaete, due to their high abundance and efficiency as fishing bait. The most notable target families are Arenicolidae, Glyceridae, Nereididae, Nephtyidae and Eunicidae (Fonseca *et al.* 2008). Species population abundances are immediately impacted by the disturbance at the time of bait collection, but their recovery will also be dependent on the longer term habitat damage caused. Seagrass habitats are notably exploited by bait digging activities, and thus are subjected to significant physical damage via uprooting of the sediment (Dyrynda & Lewis 1994). This physical damage inflicted by bait digging makes seagrass beds more susceptible to erosion, and hence reduces their natural resilience to extreme weather events.

1.1.4 Conservation

Zostera biotopes have been recognised within the European Union as a ‘subfeature’ within Special Areas of Conservation (SACs) under the EU Habitats Directive (Council Directive 92/43/EEC) of 1992. The European Community, as well as individual countries (including the UK) pledged to develop plans and legislation in order to conserve biological diversity. In 1994, the UK Government published the UK Biodiversity Action Plan. Both the EU directive and the UK Biodiversity Action Plan have lists of threatened habitats and the species found within them. These habitats, such as estuaries, lagoons and reefs, must be maintained in their present state, or where possible, restored to a more favourable state. Seagrass beds have been identified as a BAP habitat under the Biodiversity Conservation and a Section 42 habitat (NERC Act) on account of the declines and level of threat to this habitat.

1.2 Background

The Habitats Directive establishes that the management of Special Areas of Conservation (SACs) should aim to achieve the **favourable conservation status** of habitat and species features. In the case of SACs, the features are the habitats and/or species listed in Annex I and Annex II of the Habitats Directive for which the individual site has been selected.

Natural Resources Wales (NRW), previously the Countryside Council for Wales (CCW), has a statutory duty to produce advice under Regulation 35 of the Habitats Regulations 1994, which states:

"*As soon as possible after a site becomes a European marine site, [NRW / EN] shall advise other relevant authorities as to –*

the conservation objectives for that site, and any operations which may cause deterioration of natural habitats or disturbance of species, for which the site has been designated."

This Regulation 35 advice package is the foundation for **feature condition monitoring**, which is required in order for NRW to fulfil its function of reporting on whether features are in favourable conservation status.

NRW developed a programme of intertidal monitoring work across Wales during 2004 and 2005. These surveys were managed and implemented for CCW (at the time) by the Institute of Estuarine and Coastal Studies (IECS, University of Hull). These projects focused on a wide range of sensitive habitats such as *Zostera,* muddy gravels, caves, rockpools, algal-dominated rocky shores, *Sabellaria* reefs, under-boulders, and various rare habitats and species. In Pembrokeshire Marine SAC, IECS surveyed bedrock communities (Hull *et al.* 2008) and later ASML surveyed seagrass at Angle Bay (Bunker 2012).

Aquatic Survey & Monitoring Ltd. (ASML) have been contracted by NRW to continue development and management of the intertidal monitoring programme for each marine SAC for the period 2006 to 2014; working as a team with NRW operational staff.

1.2.1 Pembrokeshire Marine SAC

The results presented are from a *Zostera noltii* bed study at Angle Bay within the Pembrokeshire Marine SAC (see Figures 1 and 2) between 18th and 23rd September 2013. The seagrass bed is a sub-feature of the 'mudflat and sandflats not covered by seawater at low tide'.

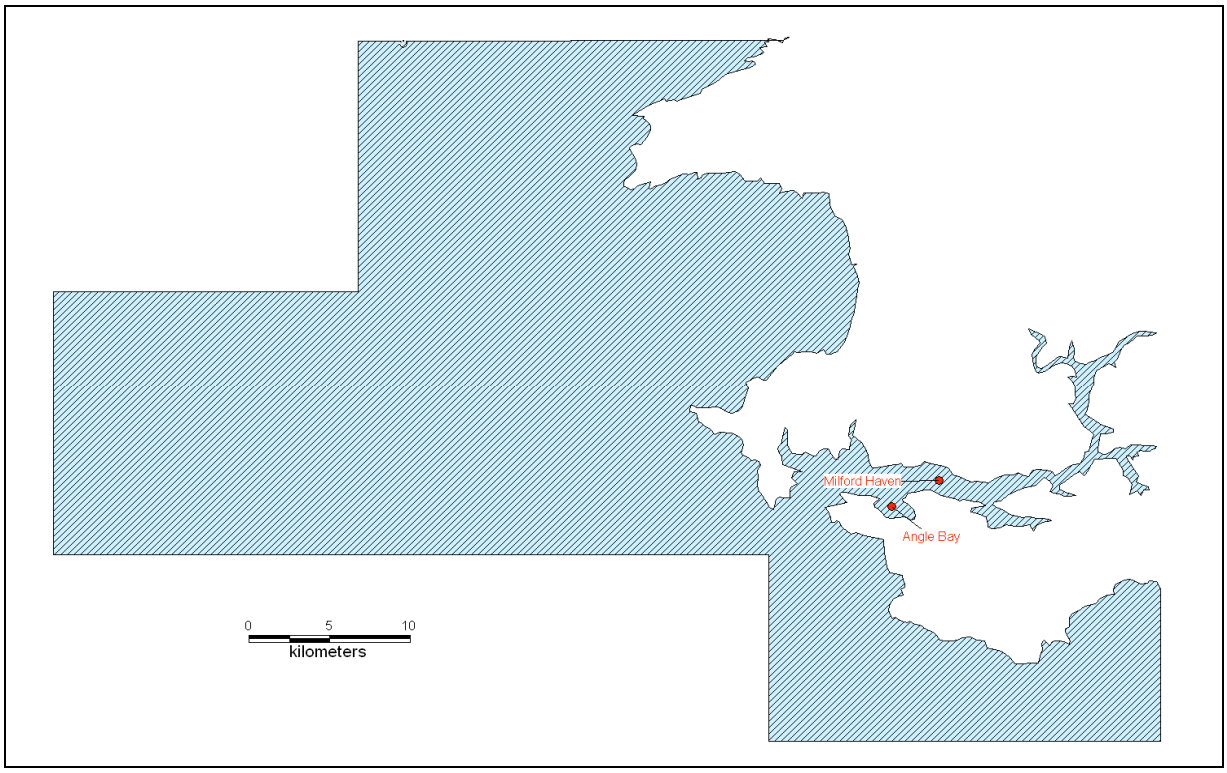


Figure 1 Location map for Angle Bay within the Pembrokeshire Marine SAC (blue boundary).

Phase 1 surveys of intertidal habitats in the SAC were carried out between 1999 and 2001 (Brazier *et al* 2007), providing detailed mapping of the intertidal biotopes with some information on characterising species. Considerable historical data exists on the intertidal habitats and communities present at many sites in the SAC. Methodological trials and surveys, designed for the purposes of SAC monitoring, have been carried out in recent years. Other areas of seagrass in the SAC are mapped for the purposes of the Water Framework Directive's (WFDs) Environmental Quality Status reporting.

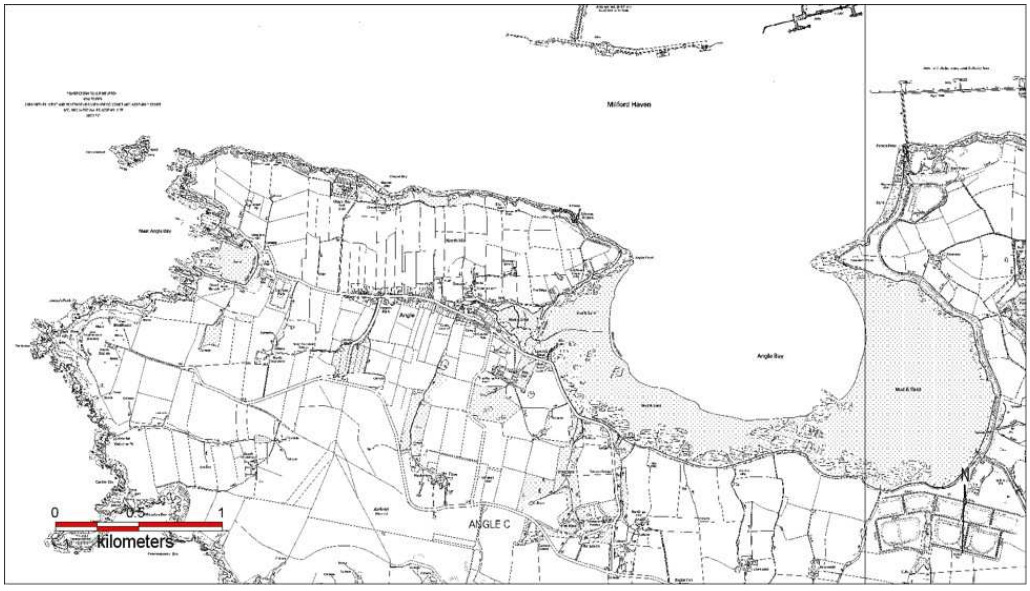


Figure 2 Ordnance survey map showing the southern entrance to Milford Haven and Angle Bay. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 2014.

1.2.2 Survey Objectives

The Pembrokeshire Marine SAC feature reported on here is:

Feature / attribute	Site(s)	Purpose
Mudflats and sandflats not covered by seawater at low tide	Angle Bay	To monitor the distribution, extent and abundance of dwarf eelgrass *Zostera noltii*

The primary objective of the survey was to map the intertidal bed of *Zostera noltii* on the east side of Angle Bay together with its various features. Also, to report on any observed impacts such as bait digging.

2 Methodology

2.1 Mapping

The methodology used here was adapted from Boyes and Mazik (2005). In the first instance surveyors walked along the shore with GPS units in tracking mode and followed the edges of the seagrass bed. Following the survey, the GPS units were downloaded and the tracks incorporated in the GIS software package, MapInfo. The edges of the bed shown by the tracks were then digitally traced to define the area covered by *Zostera noltii* in Angle Bay by a single polygon (Figure 3).

Figure 3 Surveyor Paul Brazier tracking the edges of the seagrass bed with a hand held GPS unit.

2.2 Recording Features

Within MapInfo, a grid of sampling stations 50 m apart east-west and 100m apart north-south was created over the area colonised by *Zostera noltii* (as determined by the mapping study). Four pairs of surveyors were allocated a section of the grid to

study, and portable GPS units were uploaded with positions of the sampling stations. Once a station was located using the handheld GPS, a 0.25 m² quadrat with a 0.01 m² grid was placed on the seagrass bed and a photograph was taken (see Figure 4). In situ recording of conspicuous species was undertaken at each of the located sampling stations.

A recording methodology is given in Appendix 1. The recording proforma used in the field is given in Appendix 2.

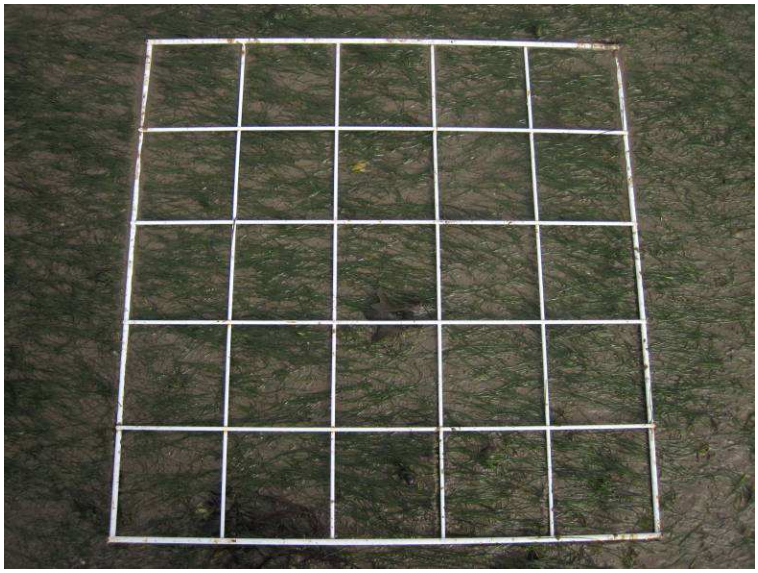


Figure 4 Quadrat positioned on the seagrass bed and photographed prior to sampling.

2.2.1 Cockle counts

Within each quadrat, *Cerastoderma edule* counts were made based on numbers found by searching with fingers in decimeter squares per quadrat. (Scale: None, <100 per m², >100 per m². The threshold was 1 per 10 x 10 cm). Figures 5 and 6 show before and after shots of quadrat cockle searching.

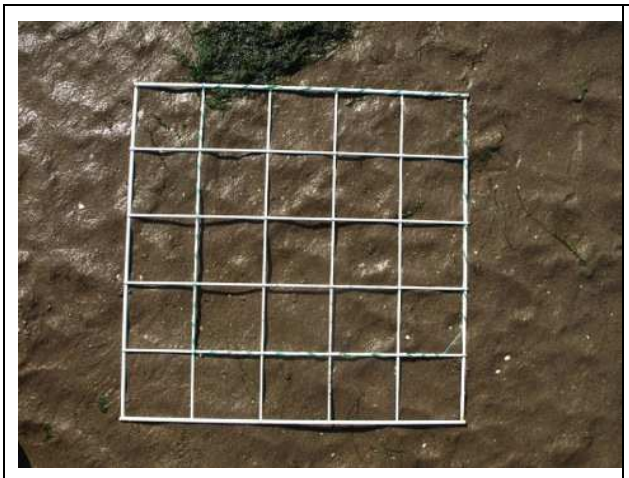


Figure 5 Quadrat positioned at Waypoint W1P prior to cockle search.

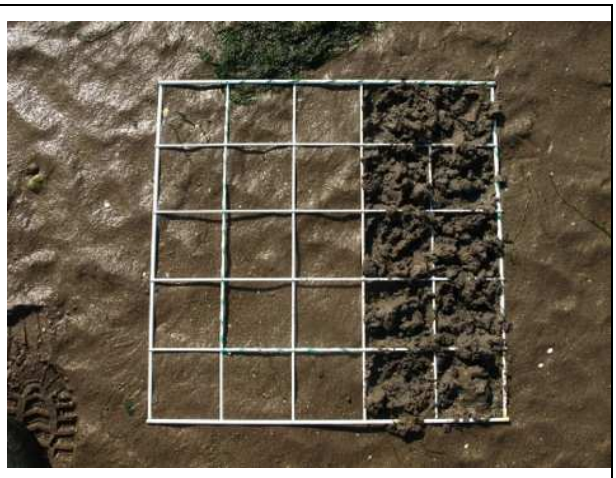


Figure 6 Quadrat positioned at Waypoint W1P following cockle search.

2.2.2 Core samples

At a single infaunal coring station, 5 replicates of core sediment samples were taken using a 0.01 m² corer (Figure 7). The cores were taken within a radius of approximately 5 m from the central mark of the sampling station, and randomly placed without reference to the surface features. Following extraction, each core sample was then sieved over a 0.5 mm mesh and the sieve contents were identified in the field (Figure 8). In addition, further sediment samples were collected, sieved and placed in containers for laboratory-based macrofauna and granulometric analyses by NRW.

Figure 7 Core sediment sample prior to sieving.

Figure 8 Surveyor Paul Brazier sieving a core sediment sample in the field.

2.3 Healthy and Safety, logistics and permissions

A Survey Plan and Risk Assessment was prepared and distributed to all the surveyors in advance of the survey. It included information on the survey location, work scope and plan, logistics, tide tables, potential hazards, assessment of risk from those hazards, actions/measures to minimise risk, contact details for emergency services, personnel and next of kin.

Field survey equipment provided by ASML and NRW included handheld GPS navigators (various makes and models, all set to British National Grid and OSGB36 datum), digital cameras (various makes and models, all set to high resolution and local time), corers (0.01 m²), sieves (0.5 mm mesh) and tape measures.

Microscopes, identification guides, laptop computers, laser printer and other field laboratory equipment were provided by ASML and NRW. GIS mapping software (MapInfo), Microsoft Office software, Apple Aperture photo-cataloguing software and various other utilities were used for daily survey planning, data entry, downloading GPS data and digital photographs and cataloguing files.

2.4 Data Analysis

This report presents the data obtained during the field survey in 2013. Data analysis is limited at present due to the size of the dataset, however it does include some

comparable analysis with the results of the distribution and abundance of *Zostera noltii* obtained from the 2008 survey (outlined in section 3.3 below).

The mean percentage cover of *Zostera noltii* was calculated using Microsoft Excel for the 2008 and 2013 data sets. Statistical analysis was carried out using a t-test in Microsoft Excel in order to compare the means (see Appendix 6 ‘t-test’).

The mean percentage cover data were plotted on individual Ordnance Survey 1:10,000 maps of Angle Bay as proportional circles in the GIS software, MapInfo.

2.5 Quality Assurance

All of the surveyors that participated in the field work were trained according to the same methodology in order to confirm consistency between results.

2.6 Photography

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

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

‘Date (year month day)’ underscore ‘Photographers Initials’, underscore ‘Survey location’ underscore ‘photograph number’

e.g. 20070905 _FDB_Angle_1408.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 this is included in Appendix 5 Catalogue of photographs.

2.7 Species identification and nomenclature

Within the data set (see Appendix 4 Data collected from quadrat studies (Part 2)), species have been named according to Howson and Picton (1997) in order that the data can be entered into the current version of Marine Recorder database software version 4.

3 Results

The results of the studies into the distribution and abundance of *Zostera noltii* in Angle Bay are presented below. Data pertaining to the quadrats including sediment characteristics and presence of associated biota are presented in Appendix 3 Data collected from quadrat studies (Part 1) and Appendix 4 Data collected from quadrat studies (Part 2).

A full catalogue of photographs taken during the survey and archived by NRW is given in Appendix 5 Catalogue of photographs.

3.1 The distribution of *Zostera noltii* in Angle Bay

A map showing the tracks created by walking around the area colonised by *Zostera noltii* with hand-held GPS units is given in Figure 9.

The final map produced of the *Zostera noltii* bed is shown in Figure 10.

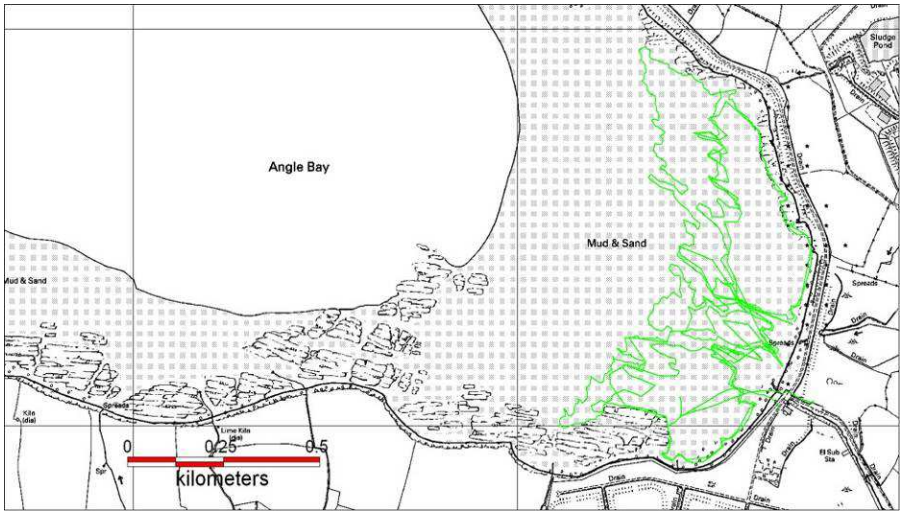


Figure 9 East side of Angle Bay showing the tracks produced by walking around the area colonised by *Zostera noltii* with a hand held GPS. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 2014.

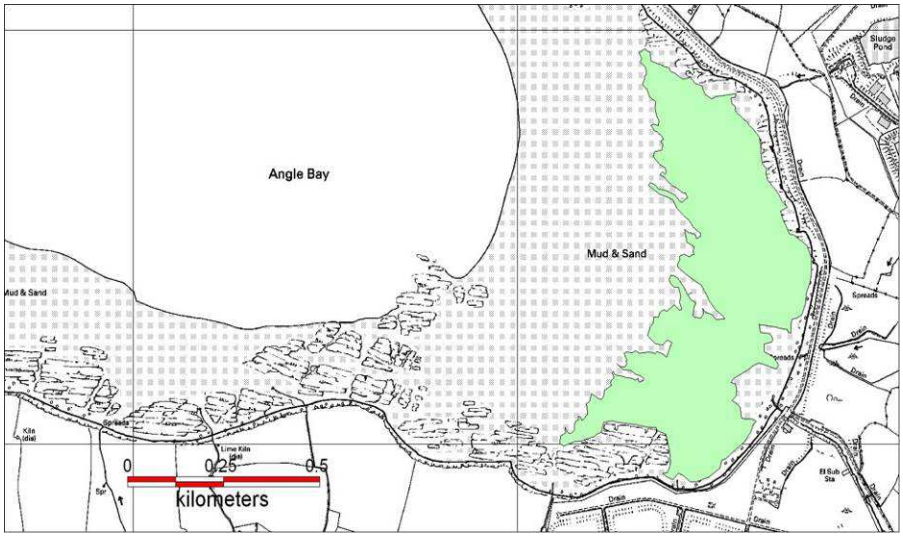


Figure 10 East side of Angle Bay showing the area colonised by *Zostera noltii* (September 2013). Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 2014.

3.2 The sampling grid

The grid of sampling stations created for quadrat sampling is shown in Figure 11. The results of the quadrat sampling are given in Appendix 3 Data collected from quadrat studies (Part 1) and Appendix 4 Data collected from quadrat studies (Part 2).

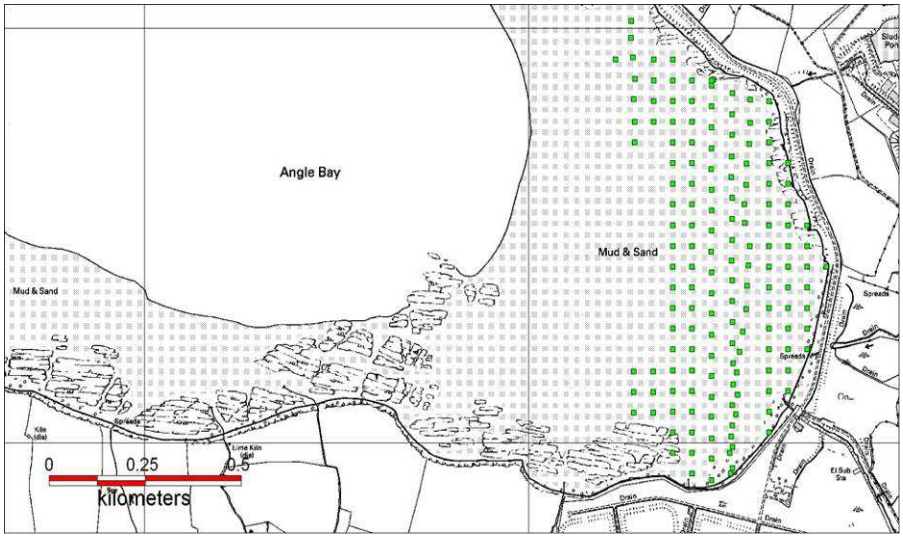


Figure 11 Grid created for quadrat sampling in and around the *Zostera noltii* bed. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2014].

3.3 Abundance of *Zostera noltii*

The mean percentage cover of *Zostera noltii* recorded by individual groups of field surveyors in 2013 is shown in Table 1. For comparison, the mean percentage cover of *Zostera noltii* recorded by individual groups of field surveyors during the 2008 survey is shown in Table 2.

Table 1 Mean percentage cover records of *Zostera noltii* in Angle Bay based on *in situ* records from quadrats by four groups of field surveyors. PB = Paul Brazier, CJ = Chloe Jennings, BW = Ben Wray, LP = Lily Pauls, NL = Natasha Lough and KB = Kathryn Birch.

Surveyor Groups	PB & CJ	BW & LP	PB & NL	PB & KB	**Overall Mean**
Mean percentage cover recorded *in situ*	39.0	46.45	46.31	42.95	**42.73**

Table 2 Mean percentage cover records of *Zostera noltii* in Angle Bay based on *in situ* records from quadrats by three groups of field surveyors in 2008. FB = Francis Bunker, LL = Lou Luddington, AB = Anne Bunker, PB = Paul Brazier, NC = Nicky Chapman and TM = Tom Mercer.

Surveyor Groups	FB & LL	AB & PB	NC & TM	**Overall Mean**
Mean percentage cover recorded *in situ*	17.95	8.38	25.37	**19.89**

The results of a paired samples t-test which statistically compares the overall mean percentage covers of *Zostera noltii* from the 2013 survey and the 2008 survey is given below. The calculation is based on records of % cover *Zostera* within the boundaries of the seagrass bed in 2013 and 2008 (as illustrated in Figures 12 & 13). Hence, the calculation does not take into account any records of % cover *Zostera*

outside the boundaries of the seagrass bed (where there may be small and scattered patches of low density).

The t-test showed that there was a statistically significant difference between the mean percentage covers of *Zostera noltii* from the 2013 survey (M=42.73; SD=29.42) and the 2008 survey (M=19.89; SD=32.98).

t = 0.000548 (p<0.01) therefore statistically significant

Details of this calculation are given in Appendix 6.

The abundance of *Zostera noltii* recorded from the different sampling stations is presented as proportional circles on the map given in Figure 12. Figure 13 represents the data from the 2008 survey.

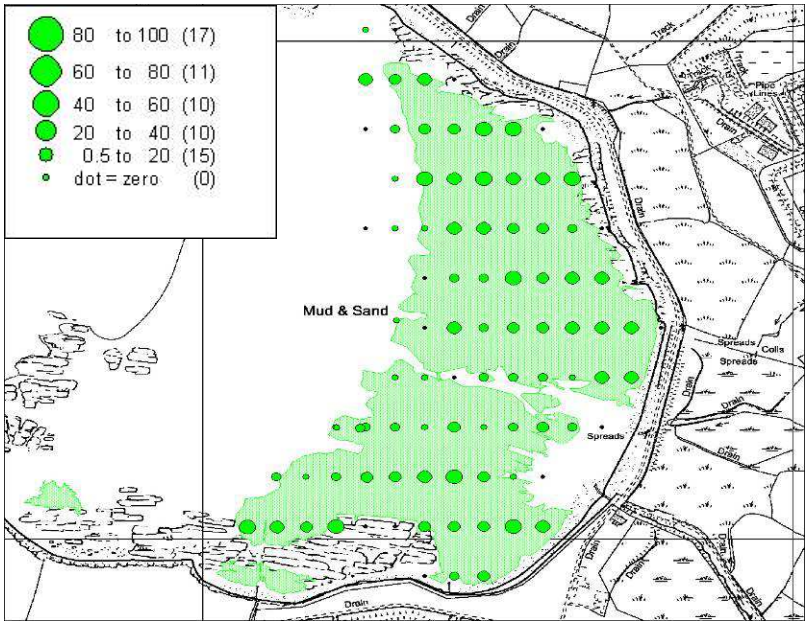


Figure 12 Abundance of *Zostera noltii* in 2013 as determined in the field at grid stations on the east side of Angle Bay as shown by proportional circles (see scale on map). Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 2014.

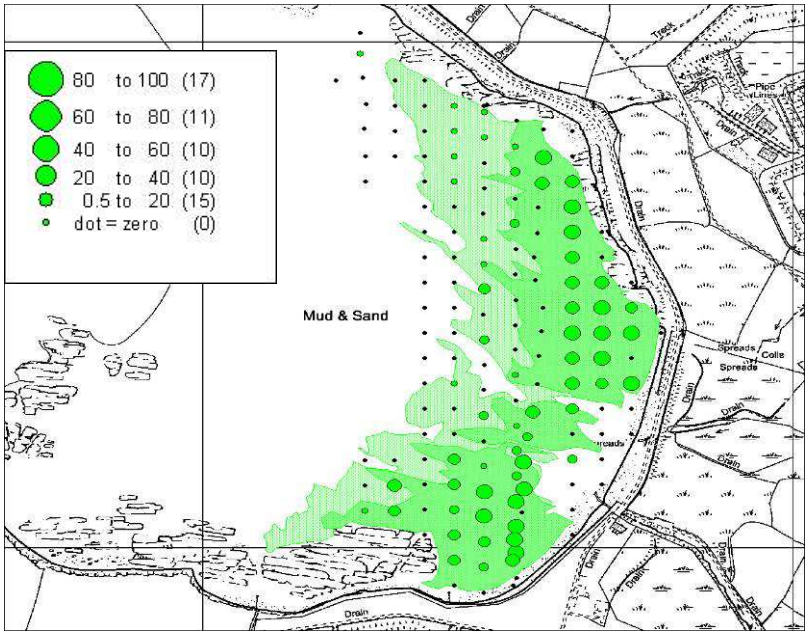


Figure 13 Abundance of *Zostera noltii* in 2008 as determined in the field at grid stations on the east side of Angle Bay as shown by proportional circles (see scale on map). Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 2014.

The map in Figure 12 shows a relatively evenly distributed abundance of *Zostera* across the various sampling stations. Comparing this with the data illustrated in Figure 13 it is clear that the *Zostera* is less evenly distributed, with areas of patchy and dense vegetation.

In 2008 there were more sampling stations than in 2013, and therefore more data points plotted on the map. In order to correlate the data from the 2008 survey with that of the 2013 survey, the sampling stations that were not surveyed in 2013 have been eliminated from further statistical analysis. Additionally, during the 2008 survey there was some overlap with surveyors recording the % abundance of *Zostera* at the same sampling stations. This was due to problems with different GPS units being set at different datum's which was not discovered until the work had been completed. As a result, at sampling stations where some overlap did occur, an average of the % abundance of *Zostera* was taken.

The following result is from a revised calculation of the paired samples t-test which statistically compares the overall mean percentage covers of *Zostera noltii* from the 2013 survey (M=37.85; SD=29.89) and the 2008 survey (M=20.85; SD=31.52).

t = 0.000619 (p<0.01) therefore statistically significant

Details of this calculation are given in Appendix 6.

3.3.1 Extent of *Zostera noltii* bed

In 2008 the total area covered by the *Zostera noltii* bed was 19.54 ha, and in 2013 the total area was 31.95 ha. This indicates a percentage extent expansion of 63.5% for the *Zostera* bed over a 5 year period.

3.4 Core sediment samples

Table 3 shows the number of infaunal species recorded in five core sediment sample replicates at the dedicated coring station on the *Zostera noltii* bed. Appendix 7 gives

a brief habitat and features description for the 11 infaunal species recorded in Table 3.

Table 3 Number of infaunal species recorded in five core sediment sample replicates at the coring station in the *Zostera noltii* bed, Angle Bay.

Species phyla	Species name	Juv-enile (J)	REP 1	REP 2	REP 3	REP 4	REP 5	Sum of Replicates
Annelida	*Anaitides mucosa*		1					**1**
	Nephtys hombergii		3	4	1	3	4	**15**
	Scoloplos armiger			1				**1**
	Pygospio elegans				1	2	2	**5**
	Cirriformia tentaculata				1			**1**
Crustacea	*Melitidae spp.*	J	1					**2**
	Idotea chelipes	?		2				**2**
Mollusca	*Littorina spp.*	J	1					**2**
	Peringia ulvae		705	665	540	455	600	**2965**
	Cerastoderma edule		2		3			**5**
	Abra tenuis				1		1	**2**

The results of the replicate core sediment samples show that there was a high abundance of *Peringia ulvae*, indicating that they were abundant in the sediment according to the SACFORN scale. *Nephtys hombergii* were observed in the sediment samples, closely followed by *Pygospio elegans* and *Cerastoderma edule* that were also observed in the sediment. The remaining species listed in Table 3 were rare in the sediment samples.

According to the Marine Habitat Classification for Britain and Ireland (Version 04.05) (Connor *et al* 2004), the biotope type characterised by the species in Table 3 is LS.LMp.LSgr.Znol (*Zostera noltii* beds in littoral muddy sand).

3.5 Quadrat data

Table 4 Mean percentage of each substratum type across all sampled quadrats.

Substratum type					
Mud	**Sand**	**Gravel**	**Cobble**	**Bedrock**	**Shell**
14.36	82.70	7.07	1.64	7.90	2.57

Table 5 Percentage frequency of the most abundant species across all sampled quadrats.

Species name						
Arenicola marina	***Lanice conchilega***	***Elminius modestus***	***Carcinus maenas***	***Peringia ulvae***	***Littorina littorea***	***Littorina saxatilis***
18.48	33.70	39.13	18.48	71.74	58.70	35.87

The quadrat data shows that the predominant substratum type was muddy sand. The most common species were *Peringia ulvae* and *Littorina littorea*, which are characteristic of this substratum type.

4 Discussion

The methodology employed in Angle Bay to study *Zostera noltii* is built on that trialled in North Wales by Boyes and Mazik (2005) and is considered to provide a good framework for further monitoring. Some aspects of the methodology and results obtained are discussed below.

4.2 Mapping

Walking around the boundary of the seagrass bed using portable GPS units set in tracking mode provides an easy method to create a map of the area colonised by *Zostera noltii*. This method works well in Angle Bay where the substrata are relatively firm. It would not work well on some other *Zostera* beds in the Pembrokeshire Marine SAC e.g. Pembroke River where there is soft mud. Post survey processing is minimal, but the positional accuracy of the GPS should be acknowledged.

4.3 Sampling

Pro-forma completion at each sampling station proved to be time consuming, and therefore in order to save time it is recommended that an estimation of the percentage cover of *Zostera* is made by examining the quadrat photographs after the fieldwork has been completed. It is recommended that one person should analyse all of the photographs after the fieldwork has been completed. This has the advantage of eliminating inconsistencies in recording, and cutting out possible transcription errors between the field recording sheets and the excel spreadsheets.

4.1 Results

According to the results, there was an expansion of the *Zostera noltii* bed in Angle Bay over a 5 year period (2008-2013). The mean percentage cover of *Zostera noltii* has increased, and there has been an expansion of the extent of the seagrass bed. This mirrors studies elsewhere in Wales where *Z. noltii* is expanding.

4.4 Impacts

Some of the main impacts on seagrass habitats have been physical damage inflicted by commercial cockling activities (Bunker, A and Camplin, M., NRW unpublished) and bait digging. Numerous locations, particularly on the north side of the seagrass bed, showed evidence of intensive bait digging activities (Figures 15 & 16). The type of survey technique used provided an effective method to document and map impacts such as these on the seagrass bed.

4.4.1 Bait Digging

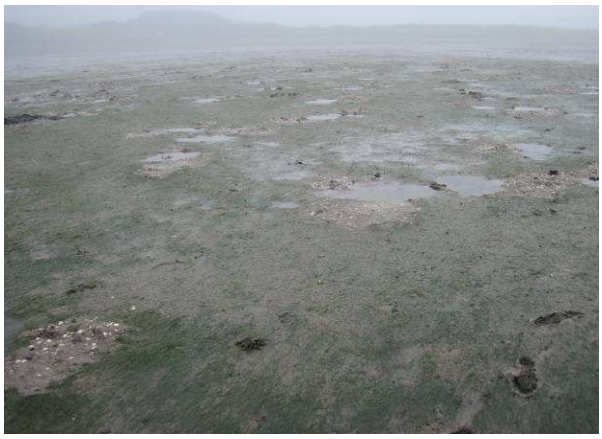


Figure 14 Area of intensive bait digging to the north of the intertidal *Zostera noltii* bed

Figure 15 Bait hole as a result of bait digging in the intertidal *Zostera noltii* bed

5 Conclusions and Recommendations

The following recommendations are made following this study:

The surveying methodology utilised here is repeated in the future. A five year interval is recommended to be acceptable (unless there are some known incidents which are likely to impact the area).

The impacts of bait digging and commercial cockling on such a small area of seagrass bed are not conducive with the aims of the SAC and the SSSI at Angle Bay and therefore it is recommended that these activities should be regulated within the area.

6 References

Beck, M. W., Heck, K. L., Able, K. W., Childers, D. L., Eggleston, D. B., Gillanders, B. M., Halpern, B., Hays, C. G., Hoshino, K., Minello, T. J., Orth, R. J., Sheridan, P. F. & Weinstein, M. R. 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience* 51**,** 633-641.

Boyes, S. & Mazik, K. 2005. Monitoring of *Zostera noltii* in the Menai Strait & Conwy Bay SAC 2005. Report to CCW. Institute of Estuarine and Coastal Studies, University of Hull. December 2005.

Boyes, S., Hemmingway, K. & Allen, J. H. 2008. Intertidal Monitoring of *Zostera marina* in Pen Llŷn a'r Sarnau SAC in 2004/2005. *CCW Marine Monitoring Report No. 28.* Countryside Council for Wales (CCW).

Brazier, P., Birch, K., Brunstrom, A., Bunker, A., Jones, M., Lough, N., Salmon, L. & G. Wyn. 2007. When the tide goes out. The biodiversity and conservation of the shores of Wales - results from a 10 year intertidal survey of Wales. Countryside Council for Wales. ISBN: 1 86961 152 1

Bunker, F. StP. D. 2012. Intertidal SAC monitoring *Zostera noltii* in Angle Bay, Pembrokeshire Marine SAC 2008. CCW Marine Monitoring Report No: 81, 51pp + ix, Countryside Council for Wales, Bangor.

Constanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., & Van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

Connor, D.W. Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. [On-line] Peterborough: Joint Nature Conservation Committee. [cited 23/04/2004]. Available from <http://www.jncc.gov.uk/marine/biotopes/default.htm>

Costa, P., Fidalgo, E., Gil, J., Passos, A.M., Pereira, P., Melo, P., Batista, F., & Cancela da Fonseca, L. 2006. The market features of imported non-indigenous polychaetes in Portugal and consequent ecological concerns. Scientia Marina 70, 287-292.

Coyer, J.A., Diekmann, O.E., Serrão, E.A., Procaccini, G., Milchakova, N.G.A., Pearson, S.W.T., & Olsen, J.L. 2004. Population genetics of dwarf eelgrass *Zostera noltii* throughout its biogeographic range. Marine Ecology Progress Series 281, 51 - 62.

Cunha, T., Hall, A., & Queiroga, H. 2005. Estimation of the Diopatra neapolitana annual harvest resulting from digging activity in Canal de Mira, Ria de Aveiro. Fisheries Research 76, 56-66.

Davison, D.M. & Hughes, D.J. 1998. *Zostera* biotopes (volume 1). An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association for Marine Science. (UK Marine SACs Project). 95pp.

Dyrynda, P. & Lewis, K. 1994. Sedimentary shores within Poole Harbour: Bait harvesting and other human impacts. Report to English Nature (South West Region) from the School of Biological Sciences, Swansea University.

Fonseca, L., Costa, P., & Fidalgo, E. (2008). Poliquetas: sua obtenção, impactos e medidas de gestão. *14º Congresso da Associação Portuguesa para o Desenvolvimento Regional - Ambiente e Conservação da Natureza*, Tomar, Portugal, pp 851.

Howson, C.M. and Picton, B.E. (eds.) 1997. The species directory of the marine fauna and flora of the British Isles and surrounding seas. Ulster Museum and the Marine Conservation Society. Belfast. 508 pp.

Hull, S.L, Tobin, M.L., Musk, W.A. & Brazier, D.P. 2008. Intertidal Monitoring of rocky reefs in Milford Haven, Pembrokeshire Marine SAC. CCW Marine Monitoring report No 42.

Mazik, K. & Boyes, S. 2009. Intertidal monitoring of eelgrass *Zostera noltii* in the Burry Inlet, Carmarthen Bay and Estuaries SAC. CCW Marine Monitoring Report No 53.

Orth, R.J., Tim, J.B., Carruthers, W.C., Dennison, C.M., & Duarte, J.W. 2006. A global crisis for seagrass ecosystems. Bioscience, 56: 12.

Appendix 1 Recording Protocols

Sampling points at each site are to be chosen based on a grid system with sampling

Stations 50 m apart.

GPS coordinate and photograph to be taken at each sampling point.

Data to be collected using a 0.25 m^2 quadrat gridded at 10 m intervals

within each quadrat the following information should be recorded (see recording pro-forma):

Z. noltii cover is to be expressed as percentage cover based on the area of sediment covered by plants. Where less than 5% cover is recorded, the number of plants comprising this percentage should be recorded as one, few or many

Cover of *Enteromorpha* sp., mussel crumble (small aggregations of mussels, cockles and shell debris) and the associated faunal species (visible on the surface, these parameters are to be expressed as percentage cover with presence/absence of faunal species being recorded.

A brief description of the substratum (including sediment type, signs of erosion, presence of standing water, ripples, shell debris).

Recording of quadrat data should cease (i.e. the extent of the grid sampling area) when four consecutive quadrats with no *Z. noltii* have been recorded. This will effectively give a 100m buffer zone around the *Zostera* bed. In cases where the *Z. noltii* bed has clearly ended (e.g. where unsuitable habitat can be seen for over 50m), it is not considered necessary to continue sampling along the transect.

Zostera may not be present within the quadrats but may be present in the surrounding area. It is suggested that the presence of sparse (up to 30 % cover) *Zostera* is recorded with a brief description of general / average density and the extent (if feasible). This will depend on the size of the mudflat and the area available for colonisation by *Zostera.* Any particularly dense patches (>50% cover) should be recorded as points (or mapped boundaries if the area is large enough) and the general characteristics recorded. Any distinctive / good quality patches of *Zostera* of significant size which occur between quadrats should be noted (GPS point, photograph, general description).

The characteristics (sediment type, algal cover, mussel crumble, associated fauna) of quadrats which do not contain *Zostera* should be recorded to give an indication of the extent of the habitat which could potentially become colonised by *Zostera.*

In order to remove any bias, the quadrat should consistently be placed in front of the right foot of the navigator.

Evidence of wasting disease, damage and the presence of epiphytes should be recorded as shown below. Damage should be assessed every 50 m (10 x 10 m area).

Appendix 2 Zostera noltii recording pro-forma

Sheet number:

Site Name: General OS grid ref:

Date: Surveyor(s):

Weather conditions:

Transect No							
Quatrat No							
Northing							
Easting							
Photo Nos							
Substratum type							
% Z. noltii							
< 5% scale							
% chlorophycota							
% mussel crumble							
% species A							
% species B							
% species C							
% species D							
% species E							
% species G							
% species H							
% species I							
% species J							
% species K							
% species L							
% species M							
% species N							
Notes							

Appendix 3 Data from quadrat studies (physical and survey details)

Report Station No	Easting	Northing	Date	Surveyors	Photo number	Bait Digging evidence	Mud %	Sand %	Gravel %	Cobble %	Bedrock %	Shell %	Standing Water %
A18	189225	202225	17/09/2013	BW/LP	3608		10	90					20
A18b (WP012)	189226	202224	21/09/2013	DPB/KB	3037			99				1	12
A20	189225	202125	17/09/2013	BW/LP	3607		10	89				1	30
A22	189225	202025	17/09/2013	BW/LP	3606	Y	70	30					30
B10	189275	202625	17/09/2013	DPB/CJ	893		1	97	0	0	0	2	65
B18	189275	202225	17/09/2013	BW/LP	3612	Y	2	91	1	2		4	0
B18b (WP011)	189266	202222	21/09/2013	DPB/KB	3036		1	99					
B2	189275	203025	17/09/2013	DPB/CJ	878		10	90	0	0	0	0	10
B20	189275	202125		BW/LP	3611		10	89				1	100
B20b (WP013)	189277	202124	21/09/2013	DPB/KB	3040	Y	1	99					92
B22	189275	202025	17/09/2013	BW/LP	3610			100					
B4	189275	202925	17/09/2013	DPB/CJ	880		5	95	0	0	0	0	20
B6	189275	202825	17/09/2013	DPB/CJ	890		1	94	0	0	0	5	30
C10	189325	202625	17/09/2013	DPB/CJ	894		0	98	0	0	0	2	1
C16	189325	202325	20/09/2013	DPB/NL	996			100					
C18	189325	202225	21/09/2013	DPB/KB	3035		1	98	1				52
C2	189325	203025	17/09/2013	DPB/CJ	879						100		
C20	189325	202125	21/09/2013	DPB/KB	3038		5	95					100
C22	189325	202025	21/09/2013	DPB/KB	3042		5	35		12	40	8	
C4	189325	202925	17/09/2013	DPB/CJ	881		20	79	0	0	0	1	10
C6	189325	202825	17/09/2013	DPB/CJ	889		1	99	0	0	0	0	35
C8	189325	202725	17/09/2013	DPB/CJ	891		1	91	0	0	0	8	90
D10	189375	202625	17/09/2013	DPB/CJ	895		0	92	0	0	0	8	50
D12	189375	202525	20/09/2013	DPB/NL	959 -60			70				30	100
D14	189375	202425	17/09/2013	DPB/CJ	903		0	100	0	0	0	0	20
D16	189375	202325	20/09/2013	DPB/NL	999			100					100
D18	189375	202225	21/09/2013	DPB/KB	3034		1	95	1			3	100
D20	189375	202125	17/09/2013	BW/LP	3618	Y	30	55		5		10	50
D22	189375	202025	21/09/2013	DPB/KB	3044		5	94		1			4
D24	189375	201925	21/09/2013	DPB/KB	3043		2	30	57	1	2	8	
D4	189375	202925	17/09/2013	DPB/CJ	883		20	80	0	0	0	0	0

Report Station No	Easting	Northing	Date	Surveyors	Photo number	Bait Digging evidence	Mud %	Sand %	Gravel %	Cobble %	Bedrock %	Shell %	Standing Water %
D6	189375	202825	17/09/2013	DPB/CJ	888		2	94	0	0	0	4	0
D8	189375	202725	20/09/2013	DPB/NL	957		2	98					50
E10	189425	202625	17/09/2013	DPB/CJ	896		1	99	0	0	0	0	0
E12	189425	202525	20/09/2013	DPB/NL	962		5	94				1	90
E14	189425	202425	17/09/2013	DPB/CJ	3020		1	95	0	0	0	4	100
E16	189425	202325	20/09/2013	DPB/NL	3001			100					45
E18	189425	202225	21/09/2013	DPB/KB	3032	Y	2	95	2			1	4
E20	189425	202125	17/09/2013	BW/LP	3617	Y	8	87		2		3	95
E22	189425	202025	21/09/2013	DPB/KB	3045		5	92	1			2	
E24	189425	201925	17/09/2013	BW/LP	3613		77	18	2			3	
E4	189425	202925	17/09/2013	DPB/CJ	884				5		95		
E6	189425	202825	17/09/2013	DPB/CJ	887		5	95	0	0	0	0	50
E8	189425	202725	20/09/2013	DPB/NL	955		10	90					
F10	189475	202625	17/09/2013	DPB/CJ	897		10	89	0	0	0	1	0
F12	189475	202525	20/09/2013	DPB/NL	964	Y	9	90				1	
F14	189475	202425	17/09/2013	DPB/CJ	3021		10	86	0	0	0	4	0
F16	189475	202325	20/09/2013	DPB/NL	3003	Y		99				1	
F18	189475	202225	21/09/2013	DPB/KB	3031			93	2	4		1	
F20	189475	202125	21/09/2013	DPB/KB	3047	Y	2	97				1	
F22	189475	202025	21/09/2013	DPB/KB	3046		2	96				2	96
F24	189475	201925	17/09/2013	BW/LP	3614		64	28	4			4	
F6	189475	202825	17/09/2013	DPB/CJ	886	Y	20	80	0	0	0	0	0
F8	189475	202725	20/09/2013	DPB/NL	953		20	78				2	
G10	189525	202625	17/09/2013	DPB/CJ	898		10	90	0	0	0	0	0
G12	189525	202525	20/09/2013	DPB/NL	992		2	98					
G14	189525	202425	17/09/2013	DPB/CJ	3022		1	98	0	0	0	1	0
G16	189525	202325	20/09/2013	DPB/NL	3005	Y		99				1	
G18	189525	202225	21/09/2013	DPB/KB	3030	Y	1	95	1			3	56
G20	189525	202125	17/09/2013	BW/LP	3616			97	1	1		1	
G22	189525	202025	17/09/2013	BW/LP	3615		79	20				1	75
G6	189525	202825	17/09/2013	DPB/CJ	885	Y	20	80	0	0	0	0	0
G8	189525	202725	20/09/2013	DPB/NL	951		20	80					
H10	189575	202625	17/09/2013	DPB/CJ	899		10	90	0	0	0	0	50
H12	189575	202525	20/09/2013	DPB/NL	994		2	98					

Report Station No	Easting	Northing	Date	Surveyors	Photo number	Bait Digging evidence	Mud %	Sand %	Gravel %	Cobble %	Bedrock %	Shell %	Standing Water %
H14	189575	202425	17/09/2013	DPB/CJ	3023	Y	5	95	0	0	0	0	0
H16	189575	202325	20/09/2013	DPB/NL	3007	Y		100					
H18	189575	202225	21/09/2013	DPB/KB	3029	Y	2	96				2	1
H20	189575	202125	21/09/2013	DPB/KB	3049		1	20	79				100
H22	189575	202025	21/09/2013	DPB/KB	3051		5	95					94
H6	189575	202825	20/09/2013	DPB/NL	950		2	23	75				
H8	189575	202725	20/09/2013	DPB/NL	948		20	80					
I10	189625	202625	17/09/2013	DPB/CJ	901		5	95	0	0	0	0	0
I12	189625	202525	21/09/2013	DPB/KB	3017		10	90					8
I14	189625	202425	21/09/2013	DPB/KB	3019		30	70					100
I16	189625	202325	20/09/2013	DPB/NL	3009			95	1	2		2	
I18	189625	202225	21/09/2013	DPB/KB	3028	Y		98				2	
I8	189625	202725	20/09/2013	DPB/NL	946		20	80					
J10	189675	202625	17/09/2013	DPB/CJ	902			95	5				
J12	189675	202525	21/09/2013	DPB/KB	3015		10	90					8
J14	189675	202425	21/09/2013	DPB/KB	3024	Y	10	90					96
J16	189675	202325	20/09/2013	DPB/NL	3011	Y	1	99					60
J18	189675	202225	17/09/2013	DPB/CJ	3027		0	20	61	15	0	4	36
K14	189725	202425	21/09/2013	DPB/KB	3025		10	90					96
K16	189725	202325	20/09/2013	DPB/NL	3013	Y	10	90					60
L14	189775	202425	21/09/2013	DPB/KB	3026		81		5	14			
WP11	189327	202439	17/09/2013	DPB/CJ	904		0	100	0	0	0	0	20
X22	189225	201925	17/09/2013	BW/LP	3602		70	30					100
Y20	189225	202125	17/09/2013	BW/LP	3609		20	79				1	90
Y22	189275	201925	17/09/2013	BW/LP	3603		69	30				1	100
Z20	189275	202125	17/09/2013	BW/LP	3605		30	69				1	50
Z22	189325	201925	17/09/2013	BW/LP	3604		68	30				2	90

Appendix 4 Data from quadrat studies (Species data)

All species are recorded as either 'Present' or per m^2, except Cerastoderma edule, which are recorded per $0.25m^2$.

Report Station No	A18	A18b	A20	A22	B10	B18	B18b	B2	B20	B20b	B22	B4	B6	C10	C16	C18	C2
Zostera_%	7	2	33	90	0	25	25	15	35	40	0	60	0	10	3	20	
Zostera <5% scale (1 F M)		M													m		
Chlorophycota (total) %																<1	
Cerastoderma edule <10mm				6.25	6.25										6.25	25	
Cerastoderma edule 10 - 20mm	6.25			6.25			12.5			6.25			6.25		12.5	12.5	
Cerastoderma edule >20mm		6.25			12.5		6.25	6.25		6.25						12.5	
Ulva (tubular)																	
Chlorophycota																	
Rhodophycota																	
Arenicola										1							
Lanice conchilega		2	P		7	P	1		P	1			7	5	2	1	
Elminius modestus		P	P	P	P	P							P	P		1%	
Carcinus maenas										P					1		
Scrobicularia plana																	
Hydrobia ulvae		500	80	800			2300		400	2600					4000	1200	
Hydrobia ulvae		P	P	P			P		P	P					P	P	
Littorina littorea			P	P	P	P			P					P	1	7	
Littorina obtusata																	
Spionidae (tubes)					P								P				
Semibalanus balanoides													P				
Bacillariophyceae																	
Akera bullata					P									P			
Littorina saxatilis																	
Crangon crangon			P													P	
Polyplacophora																	
Mytilus edulis																	
Polysiphonia fucoides																	
Nephtys																	
Amphipoda																	
Osilinus lineatus																	
Idotea sp.																	
Lepidochitona cinereus																	
Macoma baltica																	
Chaetomorpha linum																1	

Report Station No	C20	C22	C4	C6	C8	D10	D12	D14	D16	D18	D20	D22	D24	D4	D6	D8	E10	E12	E14
Zostera_%	50		50	30	<5	<5		0	10	4	75	40		75	40	85	60	30	75
Zostera <5% scale (1 F M)					F	M				M									
Chlorophycota (total) %					0.25					<1									
Cerastoderma edule <10mm									6.25										
Cerastoderma edule 10 - 20mm						12.5				12.5	31.3	125	6.25			6.25		6.25	12.5
Cerastoderma edule >20mm	12.5		6.25						6.25						6.25				
Ulva (tubular)						0.25													
Chlorophycota																			
Rhodophycota			P											1					
Arenicola										1	P	1							
Lanice conchilega	3			2	1	3	3		1		P	1				9	4		
Elminius modestus		40%			P	P				25%	P	1%	P						P
Carcinus maenas	P															2	P	1	
Scrobicularia plana																			
Hydrobia ulvae	2700	7500							2000	300		4600	4500	100		1700		5300	P
Hydrobia ulvae	P	P							P	P		P	P	P		P		P	P
Littorina littorea	4	3			P	P	1				P	6	6			8		2	P
Littorina obtusata														P					
Spionidae (tubes)				P															
Semibalanus balanoides																			
Bacillariophyceae					P														
Akera bullata																			
Littorina saxatilis	2	8									P	2	155			2		1	
Crangon crangon																			
Polyplacophora																			
Mytilus edulis																			
Polysiphonia fucoides																			
Nephtys									1										
Amphipoda																			
Osilinus lineatus																			
Idotea sp.																1			
Lepidochitona cinereus																			
Macoma baltica																			
Chaetomorpha linum										1									

Report Station No	E16	E18	E20	E22	E24	E4	E6	E8	F10	F12	F14	F16	F18	F20	F22	F24	F6	F8	G10
Zostera_%	0	50	85	50	33		50	70	75	20	20	25	6	55	55	40	80	80	50
Zostera <5% scale (1 F M)																			
Chlorophycota (total) %			0.25																
Cerastoderma edule <10mm	25	6.25										68.8	6.25						
Cerastoderma edule 10 - 20mm		31.3						6.25	6.25	6.25	12.5	12.5	6.25	12.5	43.8	6.25		6.25	6.25
Cerastoderma edule >20mm		12.5							12.5	6.25	6.25		18.8				6.25		6.25
Ulva (tubular)																			
Chlorophycota																			
Rhodophycota																			
Arenicola													1	1	1				
Lanice conchilega			P							1		2				P			
Elminius modestus		P	P	P					P				4	P	P	P			
Carcinus maenas			P							1									
Scrobicularia plana																			
Hydrobia ulvae		4700	800	6400	1200		100	3000		4300	P	3000	####	3500	200	800	100	2500	
Hydrobia ulvae		P	P	P	P		P	P		P	P	P	P	P	P	P	P	P	
Littorina littorea		4	P	12				2	P	3	P		3	4	14	P			P
Littorina obtusata																			
Spionidae (tubes)																			
Semibalanus balanoides																			
Bacillariophyceae																			
Akera bullata																			
Littorina saxatilis		2	P	3	P					1			2	3	5	P			
Crangon crangon	1																		
Polyplacophora																P			
Mytilus edulis				0.25												P			
Polysiphonia fucoides																			
Nephtys																			
Amphipoda			P																
Osilinus lineatus																			
Idotea sp.																			
Lepidochitona cinereus																			
Macoma baltica															1				
Chaetomorpha linum																			

Report Station No	G12	G14	G16	G18	G20	G22	G6	G8	H10	H12	H14	H16	H18	H20	H22	H6	H8	I10	I12
Zostera_%	80	40	20	30	0.25	80	80	60	50	55	40	25	40		75		75	30	60
Zostera <5% scale (1 F M)					F														
Chlorophycota (total) %													<1						
Cerastoderma edule <10mm									6.25			6.25							
Cerastoderma edule 10 - 20mm	31.3	25	25	6.25	6.25				18.8	25	12.5	25			12.5		6.25		12.5
Cerastoderma edule >20mm				6.25				6.25		12.5	6.25	6.25							
Ulva (tubular)																			
Chlorophycota																			
Rhodophycota																			
Arenicola				1	P	P						1			1				
Lanice conchilega																			
Elminius modestus				P	P	P										20%			P
Carcinus maenas	1		1	P										P		P			P
Scrobicularia plana																			
Hydrobia ulvae	4000	P	3000	6800	600	800	500	3000	P	2500	P	3000	1300	1100	300	1500	1000	P	7500
Hydrobia ulvae	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Littorina littorea	13		1	2		P		2		1	P			1	16	8	1	P	5
Littorina obtusata																			
Spionidae (tubes)																			
Semibalanus balanoides																			
Bacillariophyceae																			
Akera bullata																			
Littorina saxatilis				2	P								2	3	10	4			2
Crangon crangon																			
Polyplacophora																			
Mytilus edulis																			
Polysiphonia fucoides																			
Nephtys																			
Amphipoda																			
Osilinus lineatus																1			
Idotea sp.																			
Lepidochitona cinereus																			
Macoma baltica																			

Report Station No	I14	I16	I18	I8	J10	J12	J14	J16	J18	K14	K16	L14	WP11	X22	Y20	Y22	Z20	Z22
Zostera_%	60	2	20	95		70	75	75	0	75	70		6	80	22	70	18	50
Zostera <5% scale (1 F M)		m																
Chlorophycota (total) %									27									
Cerastoderma edule <10mm										6.25								
Cerastoderma edule 10 - 20mm	12.5	18.8	12.5				6.25	18.8		12.5	6.25			12.5		31.3		
Cerastoderma edule >20mm		6.25	18.8					18.8					6.25					
Ulva (tubular)															P		0.25	
Chlorophycota																	0.25	
Rhodophycota																		
Arenicola			1				1	1			1	1						
Lanice conchilega							1	1					1		P	P		P
Elminius modestus	P	0.25					P			P		0.25			P			P
Carcinus maenas			P				P			P								
Scrobicularia plana																		
Hydrobia ulvae	7500	8000	2000	1500		1200	3300	6500		1500	1500			800	80	800	200	1600
Hydrobia ulvae	P	P	P	P		P	P	P		P	P			P	P	P	P	P
Littorina littorea	4			4			9	3		8	6		P		P	P		P
Littorina obtusata														P		P		
Spionidae (tubes)																		
Semibalanus balanoides																		
Bacillariophyceae																		
Akera bullata																		
Littorina saxatilis	12	1				1	15			4	3	2		P		P		P
Crangon crangon																		
Polyplacophora															P			
Mytilus edulis																		
Polysiphonia fucoides															P			
Nephtys																		
Amphipoda																		
Osilinus lineatus																		
Idotea sp.																		
Lepidochitona cinereus	2						1			1								
Macoma baltica										1								

Appendix 5 Catalogue of photographs

Filename	Date / Time	Author	Station	Notes
20130918_CJ_Angle_Bay_878_B2.JPG	18/09/2013 10:50	Chloe Jennings	B2	
20130918_CJ_Angle_Bay_879_C2.JPG	18/09/2013 10:56	Chloe Jennings	C2	
20130918_CJ_Angle_Bay_880_B4.JPG	18/09/2013 10:59	Chloe Jennings	B4	
20130918_CJ_Angle_Bay_881_C4.JPG	18/09/2013 11:03	Chloe Jennings	C4	
20130918_CJ_Angle_Bay_881_C4.JPG	09/06/2014 16:07	Chloe Jennings	C4	
20130918_CJ_Angle_Bay_882_View_east.JPG	18/09/2013 11:09	Chloe Jennings		View
20130918_CJ_Angle_Bay_883_D4.JPG	18/09/2013 11:09	Chloe Jennings	D4	
20130918_CJ_Angle_Bay_884_E4.JPG	18/09/2013 11:14	Chloe Jennings	E4	
20130918_CJ_Angle_Bay_885_G6.JPG	18/09/2013 11:18	Chloe Jennings	G6	
20130918_CJ_Angle_Bay_886_F6.JPG	18/09/2013 11:25	Chloe Jennings	F6	
20130918_CJ_Angle_Bay_886_F6.JPG	09/06/2014 16:07	Chloe Jennings	F6	
20130918_CJ_Angle_Bay_887_E6.JPG	18/09/2013 11:28	Chloe Jennings	E6	
20130918_CJ_Angle_Bay_888_D6.JPG	18/09/2013 11:31	Chloe Jennings	D6	
20130918_CJ_Angle_Bay_889_C6.JPG	18/09/2013 11:35	Chloe Jennings	C6	
20130918_CJ_Angle_Bay_890_B6.JPG	18/09/2013 11:38	Chloe Jennings	B6	
20130918_CJ_Angle_Bay_891_C8.JPG	18/09/2013 11:47	Chloe Jennings	C8	
20130918_CJ_Angle_Bay_892_C8_core.JPG	18/09/2013 11:54	Chloe Jennings	C8	
20130918_CJ_Angle_Bay_892_C8_core.JPG	09/06/2014 16:07	Chloe Jennings	C8	
20130918_CJ_Angle_Bay_893_B10.JPG	18/09/2013 12:05	Chloe Jennings	B10	
20130918_CJ_Angle_Bay_893_B10.JPG	09/06/2014 16:07	Chloe Jennings	B10	
20130918_CJ_Angle_Bay_894_C10.JPG	18/09/2013 12:13	Chloe Jennings	C10	
20130918_CJ_Angle_Bay_895_D10.JPG	18/09/2013 12:26	Chloe Jennings	D10	
20130918_CJ_Angle_Bay_895_D10.JPG	09/06/2014 16:07	Chloe Jennings	D10	
20130918_CJ_Angle_Bay_896_E10.JPG	18/09/2013 12:32	Chloe Jennings	E10	
20130918_CJ_Angle_Bay_897_F10.JPG	18/09/2013 12:37	Chloe Jennings	F10	
20130918_CJ_Angle_Bay_898_G10.JPG	18/09/2013 12:41	Chloe Jennings	G10	
20130918_CJ_Angle_Bay_899_H10.JPG	18/09/2013 12:45	Chloe Jennings	H10	
20130918_CJ_Angle_Bay_900_WP8_bait_hole.JPG	18/09/2013 12:52	Chloe Jennings	WP8	
20130918_CJ_Angle_Bay_901_I10.JPG	18/09/2013 12:54	Chloe Jennings	I10	
20130918_CJ_Angle_Bay_902_J10.JPG	18/09/2013 12:58	Chloe Jennings	J10	
20130918_CJ_Angle_Bay_903_D14.JPG	18/09/2013 13:05	Chloe Jennings	D14	
20130918_CJ_Angle_Bay_904_WP11.JPG	18/09/2013 13:12	Chloe Jennings	WP11	
20130921_DPB_AngleBay_2980_bait_hole.JPG	21/09/2013 15:14	Paul Brazier		bait hole
20130921_DPB_AngleBay_2981_bait_hole.JPG	21/09/2013 15:14	Paul Brazier		bait hole
20130921_DPB_AngleBay_2982_bait_hole.JPG	21/09/2013 15:15	Paul Brazier		bait hole
20130921_DPB_AngleBay_2983_bait_hole.JPG	21/09/2013 15:16	Paul Brazier		bait hole
20130921_DPB_AngleBay_2984_bait_hole.JPG	21/09/2013 15:16	Paul Brazier		bait hole
20130921_DPB_AngleBay_2985_bait_hole.JPG	21/09/2013 15:17	Paul Brazier		bait hole
20130921_DPB_AngleBay_2986_bait_hole.JPG	21/09/2013 15:17	Paul Brazier		bait hole
20130921_DPB_AngleBay_2987_bait_hole.JPG	21/09/2013 15:18	Paul Brazier		bait hole
20130921_DPB_AngleBay_2988_bait_hole.JPG	21/09/2013 15:18	Paul Brazier		bait hole
20130921_DPB_AngleBay_2989_bait_hole.JPG	21/09/2013 15:18	Paul Brazier		bait hole

20130921_DPB_AngleBay_2990_bait_hole.JPG	21/09/2013 15:19	Paul Brazier		bait hole
20130921_DPB_AngleBay_2991_bait_hole.JPG	21/09/2013 15:19	Paul Brazier		bait hole
20130921_NL_Anglebay_2945_Paul_nav.JPG	21/09/2013 10:08	Natasha Lough		Paul navigating
20130921_NL_Anglebay_2946_I8.JPG	21/09/2013 10:15	Natasha Lough	I8	
20130921_NL_Anglebay_2947_I8.JPG	21/09/2013 10:19	Natasha Lough	I8	
20130921_NL_Anglebay_2947_I8.JPG	09/06/2014 16:07	Natasha Lough	I8	
20130921_NL_Anglebay_2948_H8.JPG	21/09/2013 10:25	Natasha Lough	H8	
20130921_NL_Anglebay_2949_H8.JPG	21/09/2013 10:32	Natasha Lough	H8	
20130921_NL_Anglebay_2950_H6.JPG	21/09/2013 10:38	Natasha Lough	H6	
20130921_NL_Anglebay_2950_H6.JPG	09/06/2014 16:07	Natasha Lough	H6	
20130921_NL_Anglebay_2951_G8.JPG	21/09/2013 10:54	Natasha Lough	G8	
20130921_NL_Anglebay_2952_G8.JPG	21/09/2013 10:54	Natasha Lough	G8	
20130921_NL_Anglebay_2953_F8.JPG	21/09/2013 11:05	Natasha Lough	F8	
20130921_NL_Anglebay_2954_F8.JPG	21/09/2013 11:05	Natasha Lough	F8	
20130921_NL_Anglebay_2955_E8.JPG	21/09/2013 11:10	Natasha Lough	E8	
20130921_NL_Anglebay_2956_E8.JPG	21/09/2013 11:15	Natasha Lough	E8	
20130921_NL_Anglebay_2957_D8.JPG	21/09/2013 11:19	Natasha Lough	D8	
20130921_NL_Anglebay_2958_D8.JPG	21/09/2013 11:24	Natasha Lough	D8	
20130921_NL_Anglebay_2960_D12.JPG	21/09/2013 11:38	Natasha Lough	D12	
20130921_NL_Anglebay_2961_D12.JPG	21/09/2013 11:38	Natasha Lough	D12	
20130921_NL_Anglebay_2962_E12.JPG	21/09/2013 11:45	Natasha Lough	E12	
20130921_NL_Anglebay_2963_E12.JPG	21/09/2013 11:45	Natasha Lough	E12	
20130921_NL_Anglebay_2964_F12.JPG	21/09/2013 11:52	Natasha Lough	F12	
20130921_NL_Anglebay_2964_F12.JPG	09/06/2014 16:07	Natasha Lough	F12	
20130921_NL_Anglebay_2965_bait_hole.JPG	21/09/2013 11:52	Natasha Lough		bait hole
20130921_NL_Anglebay_2966_F12.JPG	21/09/2013 11:59	Natasha Lough	F12	
20130921_NL_Anglebay_2992_G12.JPG	21/09/2013 15:20	Natasha Lough	G12	
20130921_NL_Anglebay_2993_G12.JPG	21/09/2013 15:21	Natasha Lough	G12	
20130921_NL_Anglebay_2993_G12.JPG	09/06/2014 16:07	Natasha Lough	G12	
20130921_NL_Anglebay_2994_H12.JPG	21/09/2013 15:32	Natasha Lough	H12	
20130921_NL_Anglebay_2994_H12.JPG	09/06/2014 16:07	Natasha Lough	H12	
20130921_NL_Anglebay_2995_H12.JPG	21/09/2013 15:32	Natasha Lough	H12	
20130921_NL_Anglebay_2995_H12.JPG	09/06/2014 16:07	Natasha Lough	H12	
20130921_NL_Anglebay_2996_C16.JPG	21/09/2013 15:45	Natasha Lough	C16	
20130921_NL_Anglebay_2997_C16.JPG	21/09/2013 15:45	Natasha Lough	C16	
20130921_NL_Anglebay_2998_slipper_limpet.JPG	21/09/2013 15:45	Natasha Lough		slipper limpet
20130921_NL_Anglebay_2999_D16.JPG	21/09/2013 15:52	Natasha Lough	D16	
20130921_NL_Anglebay_3000_D16.JPG	21/09/2013 15:53	Natasha Lough	D16	
20130921_NL_Anglebay_3001_E16.JPG	21/09/2013 15:58	Natasha Lough	E16	
20130921_NL_Anglebay_3002_E16.JPG	21/09/2013 15:58	Natasha Lough	E16	
20130921_NL_Anglebay_3003_F16.JPG	21/09/2013 16:06	Natasha Lough	F16	
20130921_NL_Anglebay_3003_F16.JPG	09/06/2014 16:07	Natasha Lough	F16	
20130921_NL_Anglebay_3004_F16.JPG	21/09/2013 16:06	Natasha Lough	F16	
20130921_NL_Anglebay_3004_F16.JPG	09/06/2014 16:07	Natasha Lough	F16	

20130921_NL_Anglebay_3005_G16.JPG	21/09/2013 16:13	Natasha Lough	G16	
20130921_NL_Anglebay_3005_G16.JPG	09/06/2014 16:07	Natasha Lough	G16	
20130921_NL_Anglebay_3006_G16.JPG	21/09/2013 16:15	Natasha Lough	G16	
20130921_NL_Anglebay_3007_H16.JPG	21/09/2013 16:21	Natasha Lough	H16	
20130921_NL_Anglebay_3008_H16.JPG	21/09/2013 16:21	Natasha Lough	H16	
20130921_NL_Anglebay_3009_I16.JPG	21/09/2013 16:30	Natasha Lough	I16	
20130921_NL_Anglebay_3010_I16.JPG	21/09/2013 16:30	Natasha Lough	I16	
20130921_NL_Anglebay_3011_J16.JPG	21/09/2013 16:38	Natasha Lough	I16	
20130921_NL_Anglebay_3012_J16.JPG	21/09/2013 16:38	Natasha Lough	I16	
20130921_NL_Anglebay_3013_K16.JPG	21/09/2013 16:47	Natasha Lough	K16	
20130921_NL_Anglebay_3014_K16.JPG	21/09/2013 16:47	Natasha Lough	K16	
20130922_DPB_Angle_Bay_Litsax_059.JPG	23/09/2013 08:17	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_060.JPG	23/09/2013 08:18	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_061.JPG	23/09/2013 08:19	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_063.JPG	23/09/2013 08:19	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_064.JPG	23/09/2013 08:20	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_065.JPG	23/09/2013 08:20	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_066.JPG	23/09/2013 08:21	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_066.JPG	09/06/2014 16:07	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_067.JPG	23/09/2013 08:22	Paul Brazier		Littorina saxatilis
20130922_DPB_Angle_Bay_Litsax_068.JPG	23/09/2013 08:23	Paul Brazier		Littorina saxatilis
20130922_KB_Angle_Bay_015_J12.JPG	22/09/2013 11:34	Kathryn Birch	J12	
20130922_KB_Angle_Bay_015_J12.JPG	09/06/2014 16:07	Kathryn Birch	J12	
20130922_KB_Angle_Bay_016_J12.JPG	22/09/2013 11:38	Kathryn Birch	J12	
20130922_KB_Angle_Bay_017_I12.JPG	22/09/2013 11:46	Kathryn Birch	I12	
20130922_KB_Angle_Bay_018_I12.JPG	22/09/2013 11:47	Kathryn Birch	I12	
20130922_KB_Angle_Bay_019_I14.JPG	22/09/2013 11:54	Kathryn Birch	I14	
20130922_KB_Angle_Bay_020_E14.JPG	22/09/2013 12:12	Kathryn Birch	E14	
20130922_KB_Angle_Bay_021_F14.JPG	22/09/2013 12:14	Kathryn Birch	F14	
20130922_KB_Angle_Bay_022_G14.JPG	22/09/2013 12:16	Kathryn Birch	G14	
20130922_KB_Angle_Bay_023_H14.JPG	22/09/2013 12:21	Kathryn Birch	H14	
20130922_KB_Angle_Bay_024_J14.JPG	22/09/2013 12:24	Kathryn Birch	J14	
20130922_KB_Angle_Bay_025_K14.JPG	22/09/2013 12:34	Kathryn Birch	K14	
20130922_KB_Angle_Bay_026_L14.JPG	22/09/2013 12:46	Kathryn Birch	L14	
20130922_KB_Angle_Bay_027_J18.JPG	22/09/2013 12:51	Kathryn Birch	J18	
20130922_KB_Angle_Bay_027_J18.JPG	09/06/2014 16:07	Kathryn Birch	J18	
20130922_KB_Angle_Bay_028_I18.JPG	22/09/2013 12:54	Kathryn Birch	I18	
20130922_KB_Angle_Bay_029_H18.JPG	22/09/2013 13:00	Kathryn Birch	H18	
20130922_KB_Angle_Bay_030_G18.JPG	22/09/2013 13:08	Kathryn Birch	G18	
20130922_KB_Angle_Bay_031_F18.JPG	22/09/2013 13:14	Kathryn Birch	F18	
20130922_KB_Angle_Bay_032_E18.JPG	22/09/2013 13:22	Kathryn Birch	E18	
20130922_KB_Angle_Bay_033_view_bait_hole.JPG	22/09/2013 13:23	Kathryn Birch		bait hole
20130922_KB_Angle_Bay_034_D18.JPG	22/09/2013 13:32	Kathryn Birch	D18	
20130922_KB_Angle_Bay_035_C18.JPG	22/09/2013 13:40	Kathryn Birch	C18	

20130922_KB_Angle_Bay_036_B18B.JPG	22/09/2013 13:50	Kathryn Birch	B18B	
20130922_KB_Angle_Bay_037_A18B.JPG	22/09/2013 14:02	Kathryn Birch	A18B	
20130922_KB_Angle_Bay_038_C20.JPG	22/09/2013 14:09	Kathryn Birch	C20	
20130922_KB_Angle_Bay_039_C20.JPG	22/09/2013 14:09	Kathryn Birch	C20	
20130922_KB_Angle_Bay_040_B20B.JPG	22/09/2013 14:20	Kathryn Birch	B20B	
20130922_KB_Angle_Bay_041_B20B.JPG	22/09/2013 14:21	Kathryn Birch	B20B	
20130922_KB_Angle_Bay_041_B20B.JPG	09/06/2014 16:07	Kathryn Birch	B20B	
20130922_KB_Angle_Bay_042_C22.JPG	22/09/2013 14:28	Kathryn Birch	C22	
20130922_KB_Angle_Bay_043_D24.JPG	22/09/2013 14:36	Kathryn Birch	D24	
20130922_KB_Angle_Bay_043_D24.JPG	09/06/2014 16:07	Kathryn Birch	D24	
20130922_KB_Angle_Bay_044_D22.JPG	22/09/2013 14:47	Kathryn Birch	D22	
20130922_KB_Angle_Bay_045_E22.JPG	22/09/2013 14:52	Kathryn Birch	E22	
20130922_KB_Angle_Bay_046_F22.JPG	22/09/2013 14:58	Kathryn Birch	F22	
20130922_KB_Angle_Bay_047_F20.JPG	22/09/2013 15:07	Kathryn Birch	F20	
20130922_KB_Angle_Bay_048_F20.JPG	22/09/2013 15:08	Kathryn Birch	F20	
20130922_KB_Angle_Bay_049_H20.JPG	22/09/2013 15:29	Kathryn Birch	H20	
20130922_KB_Angle_Bay_050_H20.JPG	22/09/2013 15:30	Kathryn Birch	H20	
20130922_KB_Angle_Bay_051_H22.JPG	22/09/2013 15:40	Kathryn Birch	H22	
20130922_KB_Angle_Bay_052_inf_G14.JPG	22/09/2013 16:02	Kathryn Birch	G14	Infaunal samples from this station
20130922_KB_Angle_Bay_053_inf_G14.JPG	22/09/2013 16:02	Kathryn Birch	G14	Infaunal samples from this station
20130922_KB_Angle_Bay_054_inf_G14.JPG	22/09/2013 16:03	Kathryn Birch	G14	Infaunal samples from this station
20130922_KB_Angle_Bay_055_inf_G14.JPG	22/09/2013 16:03	Kathryn Birch	G14	Infaunal samples from this station
20130922_KB_Angle_Bay_058_inf_G14_Paul.JPG	22/09/2013 16:10	Kathryn Birch	G14	Infaunal samples from this station

Appendix 6 ‘t-test’

The ‘t’ test was carried out on the whole data set (excluding peripheral zeroes, since these go beyond the seagrass bed) and also on data that was adjusted to account for duplication of some stations in 2008 and also only identifying those stations that were common to both survey events. This reduced the bias of the data as a result of differences in survey intensity.

Datasets used in calculating T test

Original full dataset (% *Zostera noltii*)

2008
0, 0, 2, 90, 25, 75, 75, 0, 0, 90, 30, 0, 80, 60, 0, 0, 60, 75, 0, 0, 70, 85, 40, 0, 85, 95, 98, 0, 70, 90, 0, 0, 60, 45, 80, 70, 40, 10, 30, 0, 0, 0, 25, 50, 15, 88, 35, 60, 0, 50, 85, 80, 85, 50, 0, 25, 80, 0, 85, 40, 45, 100, 90, 40, 35, 70, 0, 0, 20, 0, 0, 25, 0, 45, 4, 3, 0, 0, 0, 10, 1, 0, 0, 0, 0, 0, 15, 0, 0, 20, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 15, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0.5, 10, 4, 0, 0, 0, 5, 0
2013
0, 15, 60, 50, 75, 80, 80, 50, 40, 30, 0, 2, 0, 10, 4, 60, 75, 50, 50, 30, 0, 6, 75, 20, 40, 40, 7, 25, 33, 35, 75, 85, 2, 22, 18, 90, 80, 33, 40, 80, 70, 50, 0, 0, 0, 0, 0, 0, 30, 20, 80, 55, 60, 70, 60, 75, 75, 0, 85, 70, 80, 60, 75, 95, 3, 10, 0, 25, 20, 25, 2, 75, 70, 20, 4, 50, 6, 30, 40, 20, 50, 55, 40, 50, 55, 75, 25, 2, 40

	2008	**2013**
Average	20.85	37.85
Standard Deviation	31.52	29.89
t test statistic	**0.000619**	

Revised data set, accounting for duplicate and additional stations in 2008 (% *Zostera noltii*)

2008
42.5, 25, 75, 75, 56.5, 57.5, 92.5, 60, 60, 75, 95, 98, 60, 45, 80, 40, 10, 30, 15, 50, 85, 80, 80, 45, 45, 3, 10, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 10, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
2013
0, 15, 60, 50, 75, 80, 80, 50, 40, 30, 0, 2, 0, 10, 4, 60, 75, 50, 50, 30, 0, 6, 75, 20, 40, 40, 7, 33, 35, 75, 85, 2, 22, 18, 90, 80, 33, 40, 80, 70, 50, 0, 0, 0, 0, 0, 0, 30, 20, 80, 55, 60, 70, 60, 75, 75, 0, 85, 70, 80, 60, 75, 95, 3, 10, 0, 25, 20, 25, 2, 75, 70, 20, 4, 50, 6, 30, 40, 20, 50, 55, 0, 0, 40, 50, 55, 75, 0, 25, 2, 40

	2008	**2013**
Average	23.96	38.98
Standard Deviation	32.98	29.42
t test statistic	**0.000548**	

Appendix 7 Species names and habitat description

Species name	Habitat	Description
Anaitides mucosa	*A. mucosa* is abundant in the fine sand areas of the Dutch Continental Shelf. It is also reported from rnuddy sediment, mixed with sand, shell fragments and stones, and in mussel beds. Compared to *A. groenlandica*, this species inhabits the muddier types of sediment. It is suggested that one species forces the other into a different type of sediment by competition (Hartmann-Schröder, 1971; Wolff, 1973; Hayward & Ryland, 1990).	*A. mucosa* resembles *A. groenlandica*, but differs by the shape of the lamellae on the parapodia and its smaller dimensions. It can reach 50 mm in length and 250 segments. *A. mucosa* is whitish or yellowish in colour, with transverse dark brown bands or patches. The species shows a strong production of mucus (Hartmann-Schröder, 1971; Hayward & Ryland, 1990).
Nephtys hombergii	*N. hombergii* lives infaunally in muddy sand in the intertidal and shallow sublittoral. It may also be found amongst gravel, rocks, and occasionally in *Zostera* beds.	*N. hombergii* is a relatively thin, smooth, segmented (90-200) worm up to 10-20 cm in length. Its head is small with four small antennae. It has a prominent, papillated proboscis which it uses to dig into the sediment. Its body is rectangular when viewed in cross section but, may appear flattened (when viewed from above) owing to bristled lobes (parapods) that extend sidewards from the body. Typically it is a pearly white colour and chaetae (bristles on parapods) are golden. A long single tail-filament trails from its rear end. *Nephtys hombergii* is an active worm that demonstrates the characteristic swimming motion (a rapid lateral wriggling, starting from the rear and increasing in amplitude towards the head) of the *Nephtyidae*.
Scoloplos armiger	*S. armiger* occurs on the low shore and shallow sublittoral in fine, muddy sand, often amongst *Zostera* beds. It may be found in the lower reaches	*S. armiger* reaches lengths of 12 cm with 200 or more body segments. The front region of the body is swollen and sharply pointed, giving the head a cone-shaped appearance.

	of estuaries.	The eyes are not easily detectable. Gills occur dorsally from segments 9 to 17 onwards and the tip of the posterior has 2 long cirri. *Scoloplos armiger* is red or reddish brown in colour, and has prominent red blood vessels running down the length of the body.
Pygospio elegans	*P. elegans* is found on sandy shores and mud flats, and in mud that has collected in rock crevices, from mid shore to sublittoral.	*P. elegans* is a segmented tube worm up to 15 mm long. It is greenish or yellowish with a visible brown gut. The tube is long and flexible and covered with fine particles of sand or shell. There are two slender, mobile appendages from the head region.
Cirriforma tentaculata	*C. tentaculata* is found buried in sand or mud or between mussels.	Its body is semi cylindrical, flattened anteriorly and posteriorly. Prostomium bluntly conical, adult without eyes. Anterior three achaetous segments frequently fused to two segments. Many pairs of long filamentous palps in two groups on the 6-7th chaetiger, rarely at 4-5 chaetiger. Filamentous gills, starting at first chaetiger (C. tentaculata-anterior end). Chaetae capillary. In middle and posterior notopodia 4-5 additional thin hooks and on middle and posterior neuropodia 2-3 thicker and darker unidentate hooks.
Melitidae spp.	*Melitidae* spp. are stygobionts, restricted to subterranean waters, except *Melita plumulosa* which lives in the littoral areas of lentic waters.	Its body is laterally compressed. Antenna 1 subequal to, or longer than antenna 2. Antenna 2 flagellum 5- or more articulate pereopod. 5 coxa smaller than coxa 4, dactylus with a few subterminal setae. Uropod 1 peduncle with more than 1 basofacial robust setae rami foliaceous.
Idotea chelipes	*I. chelipes* is a brackish water species, among intertidal algae in sheltered estuaries or where streams flow over the shore, and also in sheltered brackish pools at or above high water mark.	Body slender. Antenna 1 extending well beyond article 3 of the peduncle of antenna 2; there is a single large aesthetasc, not a pair, at the distal end of the aesthetasc series on the antenna 1. Antenna 2 flagellum longer than the peduncle, about a quarter of the body length. Cephalon

		subquadrate, eyes dorsolateral, prominent. Coxal plates narrow, only those of pereion segments 5, 6 and 7 reaching the posterior border. Pereiopods all more or less alike. Pleon of two complete segments, and one partial suture in the pleotelson. Pleotelson with the sides subparallel, slightly keeled posteriorly in the mid-dorsal line; posterior border with a single, median tooth, hardly acute, and with obtuse lateral corners. Uropods uniramous. Males recognizable from about 5 mm body length, ranging to 15 mm; adult females from 6 to 10 mm. Colour mostly uniformly green or brown sometimes with white markings; females often darker than males.
Littorina spp.	*Littorina spp*. are widely distributed on rocky coasts, in all except the most exposed areas, from the upper shore into the sublittoral. In sheltered conditions they can also be found in sandy or muddy habitats such as estuaries and mud-flats. The species are fairly tolerant of brackish water.	Shells can reach a maximum height of 52 mm. Shells are sharply conical with a pointed apex and surface sculpturing. The spiral ridges which are marked in young animals tend to become obscured in older individuals, giving the shell a smooth appearance. The shell colours range from grey-black-brown-red but is generally black or dark grey-brown, often lighter towards the apex, and is usually patterned with spiral darker lines. The columella or central axis of the shell is typically white and the animal is recognizable in its juvenile stages by the transverse black barring of the tentacles which are rather flat and broad.
Peringia ulvae	*P.ulvae* is typically found on muddy sand, in estuaries and salt marshes. Sometimes also in lagoons and other areas of reduced salinity. Frequently associated with *Zostera* beds. Highest densities found mid-tidally but has been recorded down to 100 m depth.	*P.ulvae* is a small spiralling shell with six whorls. Up to 6 mm high but more typically around 4 mm. The shell is brown to yellow in colour. The body of the snail is a clear grey frequently with various pigment spots.
Cerastoderma	*C.edule* inhabits the surface of sediments, burrowing to a	The familiar edible cockle. The shell is solid, thick, equivalve, globular and

edule	depth of no more than 5 cm. Found on clean sand, muddy sand, mud or muddy gravel from the middle to lower intertidal, sometimes subtidally. Usually live at salinities between 15 -35 psu but can tolerate salinities as low as 10 psu. Often abundant in estuaries and sheltered bays, and population densities of 10,000 per m^2 have been recorded.	broadly oval in outline; up to 5 cm long but usually less. Shell with 22-28 radiating ribs, crossed by conspicuous concentric ridges and may bear short, flat spines. Outer surface off-white, yellowish or brownish. Growth lines are prominent. Inner surface dull white, with a brownish or light purple stain on or about the posterior adductor muscle scar. The pallial line lacks a sinus. Both valves bear two cardinal teeth. In addition the right bear two anterior and two posterior lateral teeth while the left valve bears a single anterior and posterior lateral. Shallow grooves on the inner surface run from the notched margin, fading before reaching the pallial line.
Abra tenuis	*A. tenuis* burrows in soft substrata, in estuaries and tidal flats subject to fluctuating salinity.	Shell thin and brittle, subtriangular; umbones prominent, with the hinge line sloping away evenly on each side. Sculpture of numerous fine concentric lines, growth stages visible with hand lens. Chondrophore slender, posteriorly directed. Right valve with two short cardinal teeth anterior to chondrophore and single, elongate anterior and posterior laterals; left valve with one small cardinal tooth and single, poorly developed, anterior and posterior laterals. Adductor scars and pallial line usually distinct; pallial sinus deep, its lower edge partly fused with pallial line. Cruciform muscle scars obscure.

Appendix 8 Data Archive Appendix

Data outputs associated with this project are archived as project 411 on server–based storage at Natural Resources Wales.

Recommended citation for this volume:

Duggan-Edwards, M. & Brazier, D.P. 2015. Intertidal SAC monitoring *Zostera noltii* in Angle Bay, Pembrokeshire Marine SAC 2013. NRW Evidence Report No: 55, 38pp + xi, Natural Resources Wales, Bangor.

The data archive contains:

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

[B] A series of GIS layers on which the maps in the report are based with a series of word documents detailing the data processing and structure of the GIS layers

[E] A spreadsheet of survey metadata and data from field survey.

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

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://libcat.naturalresources.wales (English), http://catllyfr.cyfoethnaturiol.cymru (Welsh), by searching 'Dataset Titles'. The metadata is held as record no 1525.

Published by: Natural Resources Wales
Maes y Ffynnon
Penrhosgarnedd
Bangor
LL57 2DW

0300 065 3000

Further copies of this report are available from the library

Email: library@cyfoethnaturiolcymru.gov.uk