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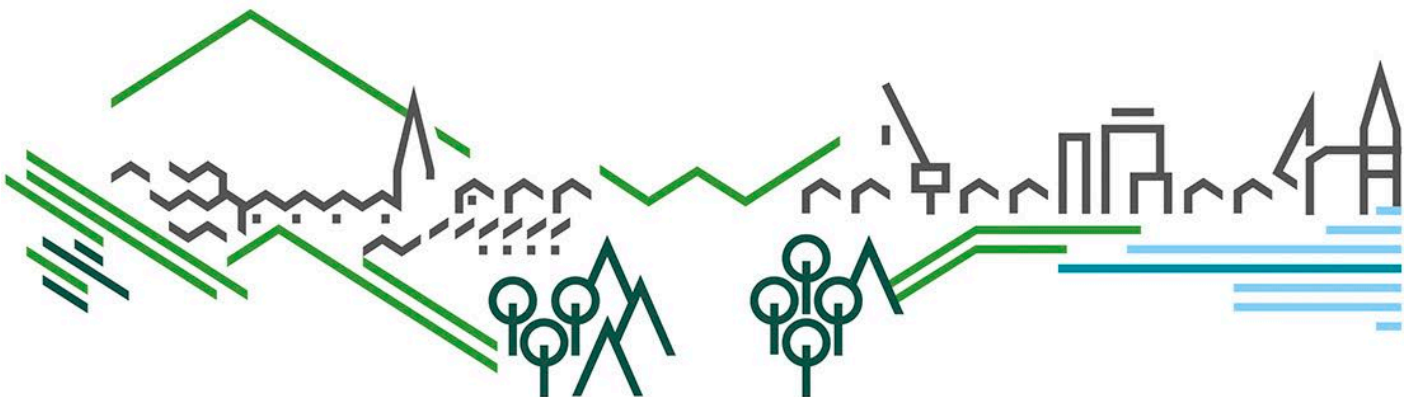
Cardigan Bay SAC, Intertidal *Sabellaria* reef monitoring, 2007-2019

Report No: 057

Date: December 2022

Jon Moore

Aquatic Survey & Monitoring Ltd.



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Crynodeb Gweithredol

Mae'r Gyfarwydddeb Cynefinoedd yn datgan y dylid rheoli Ardaloedd Cadwraeth Arbennig (ACAau) gan geisio sicrhau statws cadwraeth ffafriol y cynefinoedd a'r rhywogaethau a restrir o fewn Atodiad I ac Atodiad II yr ACA dan sylw. Yng nghyswllt ACAau yng Nghymru, gofynnir i Cyfoeth Naturiol Cymru (CNC) gyflwyno adroddiad yn rheolaidd ynghylch a oes gan y nodweddion statws cadwraeth ffafriol. Yn ACA Bae Ceredigion, mae rhaglenni o fonitro cyflwr nodweddion wedi eu datblygu gan CNC a'i gcontractwyr.

Mae riffiau yn un o'r nodweddion Atodiad I y mae'r ACA wedi'i dynodi ar eu cyfer. Mae meysydd o ddiddordeb penodol yn cynnwys riffiau biogenig rhynglanwol a ffurfiwyd o diwbiau'r llyngyren ddiliau *Sabellaria alveolata*, a all wella bioamrywiaeth leol y lan. Mae'r adroddiad hwn yn disgrifio rhaglen fonitro a gynhaliwyd ar gymunedau riffiau *Sabellaria* yn Aberaeron a Chei Bach, a ddechreuodd yn 2005, a gafodd ei hailgynllunio yn 2007, ac sydd wedi cael ei hailadrodd yn flynyddol. Mae adroddiadau blaenorol wedi disgrifio prif nodweddion y cymunedau; mae'r adroddiad hwn yn disgrifio canlyniadau dadansoddiadau amserol ar gyfer y cyfnod rhwng 2007 a 2019. Mae tair elfen i'r gwaith monitro:

- i) Mapio maint yr ardaloedd dethol o riffiau ar y ddau safle.
- ii) Cofnodi yn y man a'r lle bresenoldeb a helaethrwydd (% gorchudd) yr holl dacsonau amlwg o fewn cwadradau a osodwyd ar hap mewn gorsafoedd diffiniedig (chwe gorsaf yn Aberaeron, pedair gorsaf yng Nghei Bach). Hefyd, cwadradau ychwanegol wedi'u neilltuo ar gyfer recordio % gorchudd *Sabellaria*. Gweithredwyd gweithdrefnau sicrhau ansawdd a rheoli ansawdd i leihau anghysondeb wrth gofnodi, er bod rhai anghysondebau o hyd ac fe'u disgrifir yn yr adroddiad.
- iii) Arolygon asesu cyflym ar raddfa eang o gyflwr riffiau *Sabellaria* mewn safleoedd eraill yn yr ACA mewn rhai blynyddoedd (heb ei ddadansoddi yn yr adroddiad hwn).

Mae'r data monitro wedi cael eu dadansoddi gydag amryw o dechnegau unamryweb ac amlamryweb. Y canlyniadau mwyaf nodedig o'r dadansoddiadau amseryddol oedd:

- i) Amrywiadau o flwyddyn i flwyddyn ym maint y riffiau *Sabellaria* ar y ddau safle, ond heb unrhyw dueddiadau amserol amlwg.
- ii) Amrywiadau mawr yng nghanran gorchudd *Sabellaria*, ond gyda thuedd ar gyfer gostyngiad yn y gorchudd *Sabellaria* byw yn y blynyddoedd diweddaraf, yn enwedig yng Nghei Bach.
- iii) Peth tystiolaeth o newid amserol cynyddol yn y cymunedau epibiota, o 2007 i 2019, gyda gwahaniaeth ystadegol arwyddocaol rhwng y cyfnod cynnar a'r cyfnod diweddarach. Fodd bynnag, ychydig o rywogaethau sy'n cyfrannu at y gwahaniaeth hwnnw ac ychydig o gydamseru sydd rhwng y ddau safle. Felly, nid oes unrhyw dueddiadau clir.
- iv) Disgrifiwyd amrywiadau amserol yng nghanran y gorchudd ac amllder yr achosion ar gyfer nifer o rywogaethau unigol, gyda llawer o amrywiaeth – h.y. rhai achosion o gynnydd, rhai gostyngiadau, a rhai brigau ac absenoldebau nodedig – ond ychydig iawn o dystiolaeth o gydamseru.

v) Cynnydd mawr ymddangosiadol yn nifer yr achosion a chanran y gorchudd o ddiatomau cytrefol (rhywogaeth ffilamentaidd sy'n ffurfio matiau), a gofnodwyd yn anaml cyn 2014 ond a gofnodwyd wedyn yn helaeth bob blwyddyn yng Nghei Bach.

vi) Cynnydd nodedig yn helaethrwydd *Fucus serratus* yng Nghei Bach, er nad yw'n cael ei hystyried yn rhywogaeth drechol yn y cynefin hwn o hyd.

vii) Cynnydd nodedig yn helaethrwydd algâu gwyrdd deiliog yng Nghei Bach ers 2011, yn bennaf o *Ulva* (gwastad) ac *Ulva* (tiwbaid), er bod amrywiadau mawr yn dal i ddigwydd.

viii) Cynnydd nodedig yng nghyfoeth rhywogaethau yn ystod y blynyddoedd cyntaf yn Aberaeron, o bosibl oherwydd cynnydd anochel yng ngwybodaeth y rhai sy'n cynnal yr arolygon. Dim cynnydd tebyg yng Nghei Bach, o bosibl oherwydd bod y safle yn llai sefydlog.

Mae anghysondeb wrth gofnodi rhwng (ac o fewn) arolygwyr yn bryder parhaus ar gyfer arolygon monitro yn y man a'r lle. Fodd bynnag, mae'n eglur fod y fethodoleg yn ddigonol i nodi sawl newid amserol. Amlygir pwysigrwydd gweithrediad parhaus gweithdrefnau sicrhau ansawdd a rheoli ansawdd.

Mae cyflwr y safleoedd wedi cael ei asesu fel a ganlyn:

Aberaeron – Ffafriol – mae'n ymddangos bod newidiadau a gofnodwyd o ran maint, cyfoeth rhywogaethau, cyfansoddiad rhywogaethau a helaethrwydd o fewn yr ystod a gofnodir fel arfer o amrywiadau o'r fath. Mae newidiadau a thueddiadau nodedig hefyd yn cael eu hystyried yn naturiol.

Cei Bach – Ffafriol – er bod cymuned y riffiau yn llai amrywiol o'i chymharu ag Aberaeron ac yn dangos lefel uwch o amrywiad, o bosibl oherwydd ansefydlogrwydd yr is-haenau, nid yw'r newidiadau a gofnodwyd yng nghyfoeth y rhywogaethau a chyfansoddiad a helaethrwydd rhywogaethau yn dynodi unrhyw dueddiadau o bryder ac mae'n ymddangos eu bod o fewn yr ystod o amrywiadau o'r fath a gofnodir fel arfer. Mae newidiadau a thueddiadau nodedig hefyd yn cael eu hystyried yn naturiol.

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) is therefore required to report on a regular basis on whether features are in favourable conservation status. In Cardigan Bay SAC, programmes of feature condition monitoring have been developed by NRW and its contractors.

Reefs are one of the Annex I features for which the SAC is designated. Specific areas of interest include intertidal biogenic reefs formed from the tubes of the polychaete worm *Sabellaria alveolata*, which can enhance the local biodiversity of the shore. This report describes a monitoring programme carried out on *Sabellaria* reef communities at Aberaeron and Cei Bach, which began in 2005, was redesigned in 2007 and has been repeated annually. Previous reports have described the main characteristics of the communities; this report describes the results of temporal analyses for the period 2007 to 2019. There are three components to the monitoring:

- i) Mapping the extent of selected areas of reef at the two sites.
- ii) *In situ* recording of presence and abundance (%cover) of all conspicuous taxa within randomly placed quadrats at defined stations (6 stations at Aberaeron, 4 stations at Cei Bach). Plus, additional quadrats dedicated to the recording of the %cover of *Sabellaria*. Quality Assurance and Quality Control procedures were applied to minimise inconsistency of recording, though some inconsistencies remained and are described in the report.
- iii) Broadscale rapid assessment surveys of *Sabellaria* reef condition at other sites in the SAC in some years (not analysed in this report).

The monitoring data have been analysed with a variety of univariate and multivariate techniques. The most notable results of the temporal analyses were:

- i) Year to year fluctuations in the extent of the *Sabellaria* reef at both sites, but with no apparent temporal trends.
- ii) Large fluctuations in the percentage cover of *Sabellaria*, but with a trend of decreasing cover of live *Sabellaria* in the last few years, particularly at Cei Bach.
- iii) Some evidence of a progressive temporal change in the epibiota communities, from 2007 to 2019, with a statistically significant difference between early period and later period. However, few species contribute to that difference and there is little synchrony between the two sites. Thus, there are no clear trends.
- iv) Temporal fluctuations in percentage cover and frequency of occurrence have been described for numerous individual species, with much variability – i.e. some increases, some decreases and some notable peaks and absences – but little evidence of synchrony.

- v) An apparent large increase in the occurrence and percentage cover of colonial diatoms (a filamentous, mat forming, species) which were rarely recorded before 2014 but then recorded in large abundance every year at Cei Bach.
- vi) A notable increase in the abundance of *Fucus serratus* at Cei Bach, though it is still not considered a dominant species in this habitat.
- vii) A notable increase in the abundance of foliose green algae at Cei Bach since 2011, primarily of *Ulva* (flat) and *Ulva* (tubular), though large fluctuations still occurred.
- viii) A notable increase in species richness in the first few years at Aberaeron, possibly due to an inevitable increase in the knowledge of the surveyors. No similar increase at Cei Bach, possibly due to less stability of the site.

Inconsistency of recording between (and within) surveyors is a constant concern in *in situ* monitoring surveys. However, it is clear that the methodology is sufficient to detect many temporal changes. The importance of continued application of QA/QC procedures is highlighted.

The condition of the sites has been assessed as:

Aberaeron - Favourable - recorded changes in extent, species richness, species composition and abundance appear to be within the normally recorded range of such fluctuations. Notable changes and trends are also considered to be natural.

Cei Bach - Favourable – while the reef community is less diverse compared to Aberaeron and shows a greater level of variation, possibly due to instability of the substrata, the recorded changes in species richness, species composition and abundance do not indicate any trends of concern and appear to be within the normally recorded range of such fluctuations. Notable changes and trends are also considered to be natural.

1 Introduction

The Habitats Directive establishes that the management of Special Areas of Conservation (SACs) should aim to achieve favourable conservation status of habitat and species (*features*) listed within its Annex I and Annex II. Article 17 of the Directive requires reporting of the conservation status of those habitats and species every 6 years. For SACs in Wales, Natural Resources Wales (NRW) is responsible for that reporting. To do this NRW has developed programmes of feature condition monitoring, which include intertidal features of marine SACs. Aquatic Survey & Monitoring Ltd. (ASML) have been contracted by NRW to develop and manage the monitoring programme for these intertidal features for the period 2006 to 2023; working as a team with NRW staff.

Cardigan Bay Special Area of Conservation (SAC) is designated primarily for Bottlenose dolphins but is also designated for three Annex I habitats: *Sandbanks which are slightly covered by sea water all the time*, *Reefs* and *Submerged or partially submerged sea caves*. Conservation objectives for each feature are given in the Regulation 37 advice for the Cardigan Bay SAC (NRW 2018).

Intertidal *Reefs* within the SAC include areas of biogenic reef made from the sand grain tubes of the polychaete worm *Sabellaria alveolata*. *Sabellaria* reefs are often characterised by a high diversity of species. A programme to monitor an area of *Sabellaria* reef at Aberaeron was initiated in 2004 (Boyes *et al.* 2008). The monitoring methodology was developed further in 2007, both at Aberaeron and an additional site at Cei Bach (Moore 2009). Monitoring surveys have since been repeated every year at those sites to date (2019) (see table in Appendix 1). Figure 1 shows the locations of Aberaeron and Cei Bach in Cardigan Bay.

The program objectives are:

- To monitor the composition of communities of conspicuous epibiota present on the *Sabellaria* reef at Aberaeron and Cei Bach.
- To monitor the spatial area of *Sabellaria* reef at the two sites and the percentage cover of live and dead *Sabellaria* tubes within those areas.

This is relevant to the following Cardigan Bay SAC feature attributes (NRW 2018):

- Structure and Function: Species composition of reef biotopes in high energy locations
- Typical Species: Species composition of *Sabellaria* reef biotopes.

The overall aim of the program is to establish reference conditions for the interest features of the SAC and distinguish any deviations from those conditions, using established monitoring stations to describe natural and unnatural changes in the communities. This enables continued development of conservation objectives and informs appropriate management of those SAC features.

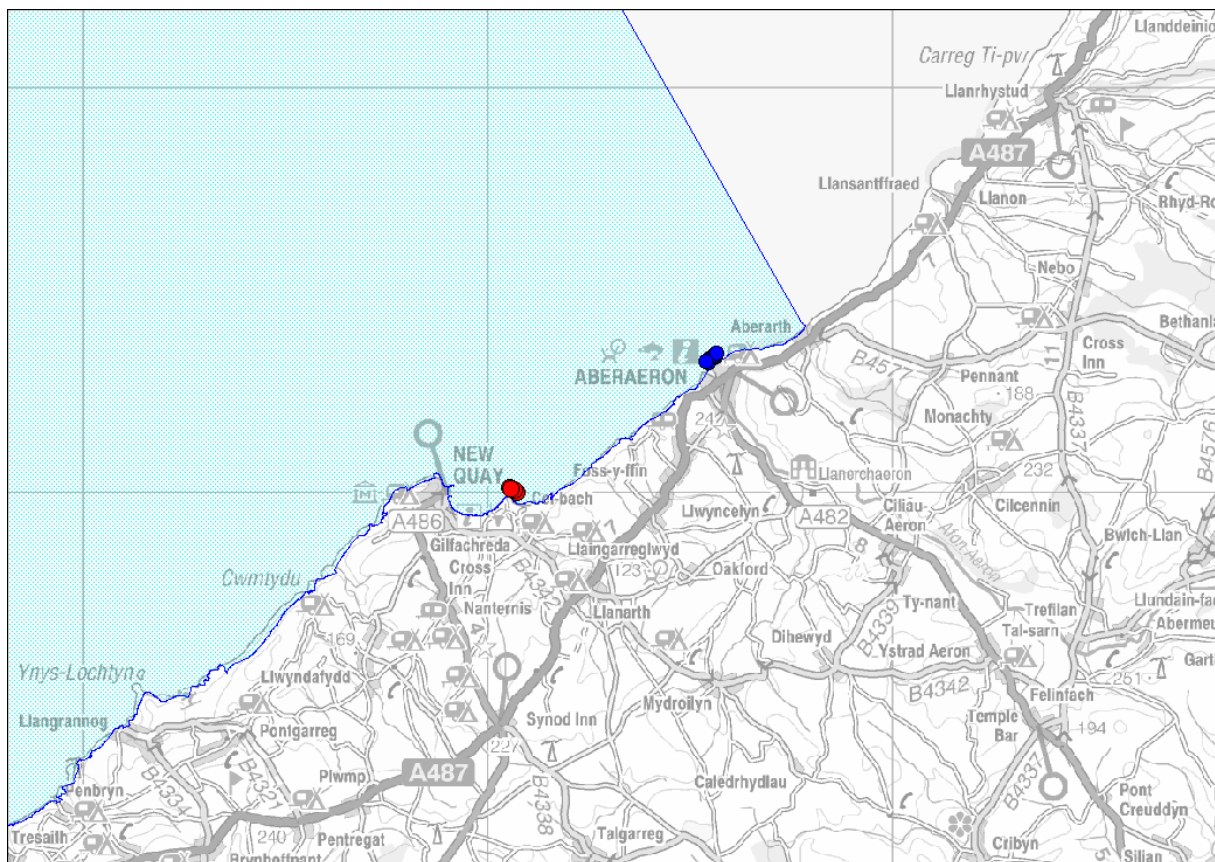
Previous reports (Moore 2009; 2010; 2016) have described the early years of the programme and the development of the monitoring methodology. This report describes the temporal changes up to 2019 and provides an assessment of the condition of the *Sabellaria* reef in May 2019.

Moore *et al.* (2017) assessed the condition of the *Sabellaria* reef communities at Aberaeron and Cei Bach and gave the following assessment (2017):

Aberaeron - recorded changes in species richness, species composition and abundance appear to be within the normally recorded range of such fluctuations. Notable changes and trends are also considered to be natural.

Cei Bach - recorded changes in species richness, species composition and abundance do not indicate any trends of concern and appear to be within the normally recorded range of such fluctuations. Notable changes and trends are also considered to be natural.

Figure 1 Location of *Sabellaria* reef monitoring sites. Aberaeron = blue dots; Cei Bach = red dots. Cardigan Bay SAC = light blue area. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 2022. Scale: 10 kilometre grid squares.



There are three components to the monitoring surveys – i) mapping the extent of selected areas of *Sabellaria* reef; ii) *in situ* recording of all conspicuous epibiota taxa at fixed stations within *Sabellaria* reef; iii) broadscale rapid assessment surveys of *Sabellaria* reef condition.

2 Methodology

2.1 Monitoring survey methods - summary

Detailed methodologies are given in Moore (2016), including rationales, procedures and protocols, equipment lists, survey forms and modifications made over the course of the programme (up to 2016). No significant modifications to the methodology or protocols have been made since then, though continuous additions to specimen collections, photographs and training does improve species identification, abundance reckoning and the overall quality of the data.

Figure 1 shows the locations of the monitoring sites (Aberaeron and Cei Bach). Figure 3 shows the locations of the monitoring stations within those sites. Station coordinates are given in Moore (2016). Survey field logs are held by NRW and ASML and are available on request. The photographs in Figure 2 show typical images of the habitat and dominant taxa and illustrate the quadrat methodology.

- Mapping the extent of selected areas of *Sabellaria* reef using the track function of handheld GPS units at low water on spring tides. Protocols are applied to aid decisions on inclusion and exclusion of marginal areas of reef.
- *In situ* recording of presence and abundance (%cover) of all conspicuous taxa in 5 randomly placed quadrats within defined areas of *Sabellaria* reef (Aberaeron, 6 stations; Cei Bach, 4 stations). Plus, recording of abundance (%cover) of *Sabellaria* only (live (i.e. occupied tubes) and total reef) in an additional 10 randomly placed quadrats at the same stations. The terms 'full quadrats' and '*Sabellaria* only quadrats' are used hereon.

Full quadrats: Most animal taxa were recorded as presence only. Algal taxa and *Sabellaria* were recorded as percentage cover. The following aggregate taxa were additionally recorded as percentage cover: *Sabellaria* reef (i.e. including both live and dead tubes), Cirripedia, Rhodophyta (dk enc), Rhodophyta (fil), Chlorophyta (non-enc).

- Broadscale rapid assessment surveys of *Sabellaria* reef condition: a transect methodology developed for the 2004 survey (Boyes *et al.* 2008). It was then used in the 2007 survey, as a precursor to the more detailed quadrat survey methodology. It was also used in 2015 for a repeat survey of reef condition at many of the 2004 sites. Further details and results of the 2007 transect surveys are included in Moore (2009), but the 2015 results are not included in this report.

Quality Assurance and Quality Control procedures (QA/QC), including training, identification and recording aids, purpose designed forms, verification procedures and validation procedures have been developed over the course of the monitoring survey programme to ensure the quality of the data for the monitoring objectives. Details of these procedures are given in Moore (2016).

Figure 2 Selected photographs to illustrate the *Sabellaria* reef habitat and communities at Aberaeron and Cei Bach; and the monitoring survey methodologies.



Note: one potential source of inconsistency is whether surveyors look under stones while surveying quadrats. The protocol states that stones are not turned over, but this was not rigorously applied for the earlier monitoring surveys.

2.2 Data management and analyses

The *in situ* quadrat survey data are stored in an Access database from which they are exported to Excel for selected analyses. The database includes detailed metadata to facilitate extraction of subsets and analyses. Appendix 2 provides a summary of the structure of the database and metadata.

The dataset contains quantitative and qualitative data which require different analytical approaches:

- Quantitative – 78% of the records are percentage cover, but more than a third of those are records of aggregate taxa (labelled T%) that sometimes need to be analysed separately to avoid double counting.
- Qualitative – approx. 22% of the records are presence/absence, and the percentage cover data can also be transformed to presence/absence. Multiple replicates (30 quadrats from Aberaeron and 20 quadrats from Cei Bach) of these data allows for calculation of frequency of occurrence as a surrogate quantitative measure of abundance.

In both datasets there are some taxa that are inconsistently recorded. For some taxa the confusing effects of this inconsistency has been reduced by aggregation to higher classifications (e.g. Genus, Family, or Class), using taxonomic classification information in the metadata. Metadata fields have also been applied to both datasets which allow simple selection of taxa that are relatively consistently recorded and suitable for temporal analysis. Appendix 3 lists the names of all taxa, as recorded and as analysed.

Data from repeated samples (collected for quality control checks in the *in situ* surveys) are discussed in Section 3.6.

Summary statistics and tabulation were prepared in the Access database and typically exported to Excel for further analysis and for preparation and formatting of graphs and tables for use in reports. Tabulated data in Excel formats ready for import into Marine Recorder and PRIMER were also exported from the database.

Multivariate analyses were carried out in PRIMER, primarily using the following routines and tools:

- Pre-treatment of data – square root transformation for percentage cover data.
- Resemblance matrices with Bray-Curtis similarity.
- MDS - non-metric Multi-Dimensional Scaling and bootstrap averaging.
- ANOSIM - Analysis of Similarity.
- SIMPER – contribution of each taxon to the dissimilarities between groups of samples.

Univariate analyses (including, parametric t-tests, non-parametric Mann-Whitney U-tests and Regression analysis) were carried out in Excel using tools from the Analysis ToolPak Add-in and the Real Statistics (www.real-statistics.com) Data Analysis Tools Add-in.

3 Results and discussion

3.1 *Sabellaria* reef extent

Figure 3 shows the surveyed extent of *Sabellaria* reef from every survey, suggesting a considerable amount of fluctuation. However, much of the apparent change is due to the height of the tide during the survey, so the lines along the lower edge of the reef cannot be relied upon. Also, at Aberaeron, *Sabellaria* reef continues along the shore to the north east, but routine mapping ends at a specific location (where a pipeline crosses the shore). However, some surveyors have continued beyond the pipeline in some years. Changes in the position of the upper edge of the reef are likely to be more useful as indicators of real change, and they indicate some year to year fluctuation but no clear trend over the period of the monitoring.

The area of reef along the east side of Cei Bach, which was only mapped in 2015 and 2016, may be a newly colonised area. However, it was characterised as a very thin sheet of *Sabellaria* tubes on fairly loose pebbles and small cobbles, so it may be relatively impermanent, and it was not mapped in 2017 or later.

The maximum extent along the upper edge of the reef in any one year was recorded in 2013 at Cei Bach (dark blue line) and in 2018 at Aberaeron (bright green line). The minimum extent was recorded in 2017 at Cei Bach (red line) and in 2010 at Aberaeron (red line). The most recent survey (2019) is shown by the black lines, which indicate a medium extent.

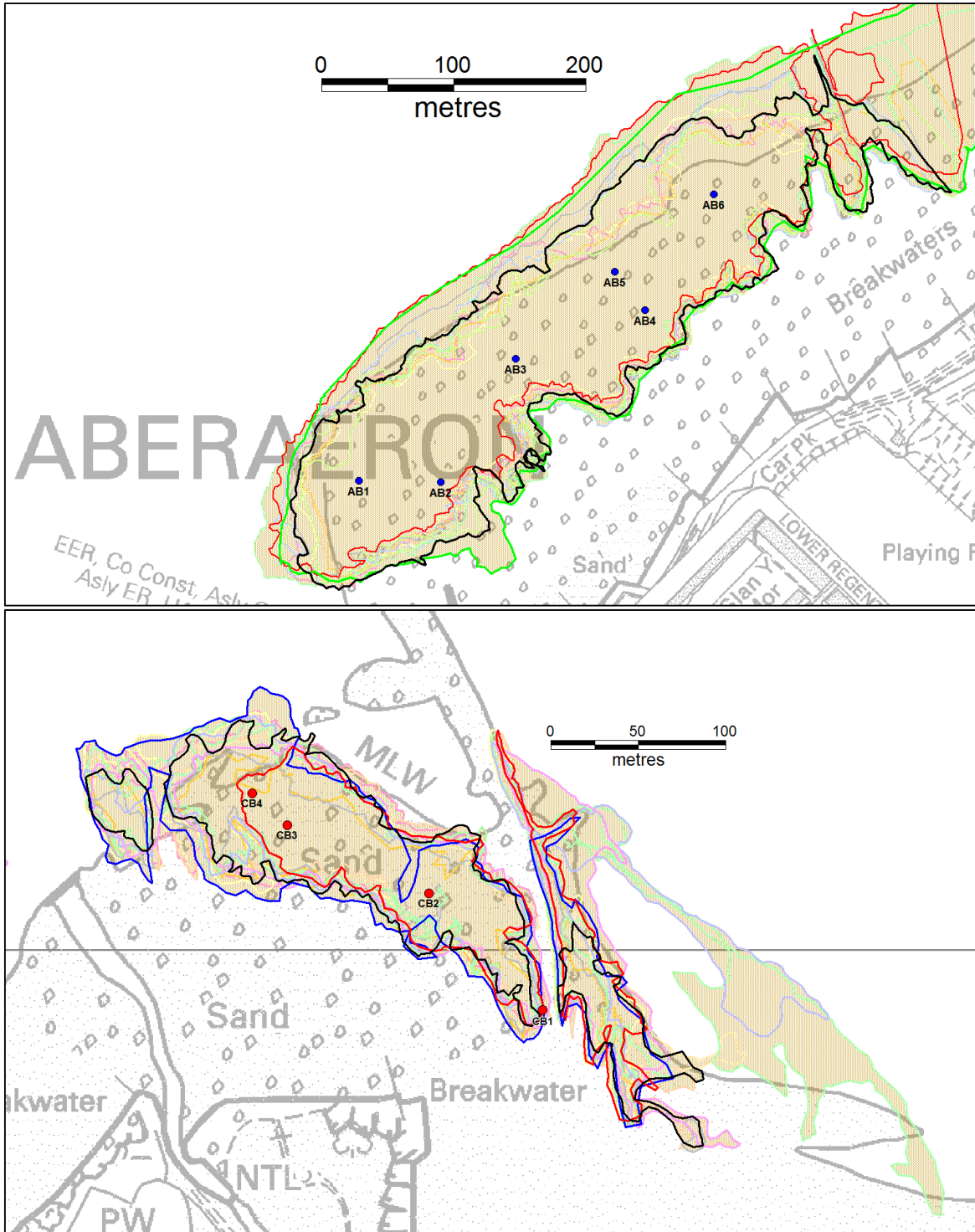
3.2 Epibiota community

3.2.1 General description

A general description of the *Sabellaria* reef habitat and communities at Aberaeron and Cei Bach is given in the report of the 2007 survey (Moore 2009). A complete list of all taxa recorded in each survey year is given in Appendix 3.

After *Sabellaria*, the most frequently occurring taxa were *Littorina littorea*, *Chondrus crispus*, encrusting coralline algae, *Fucus vesiculosus*, *Gibbula umbilicalis*, green algae, dark encrusting red algae, *Osmundea pinnatifida*, filamentous red algae, *Corallina officinalis* and *Osmundea hybrida*. Taxonomic richness per quadrat varied considerably, ranging from 0 to 27 taxa, but 85% of quadrats contained at least 10 individual taxa (not including aggregate taxa) and the mode was 16 taxa per quadrat.

Figure 3 Extent of *Sabellaria* reef at Aberaeron (top) and Cei Bach (bottom), 2007 to 2019. Light brown shading shows the combined maximum extent across all monitoring surveys. Coloured lines show boundaries from each year. Survey years: 2019 - Black; 2018 - Green; 2017 - Pale Green (inner); 2016 - Yellow; 2015 - Pale Green (outer); 2014 - Purple; 2013 - Pale Blue; 2012 - Grey; 2011 - Orange; 2010 - Red. Locations of the quadrat survey stations are also shown. Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 2022.



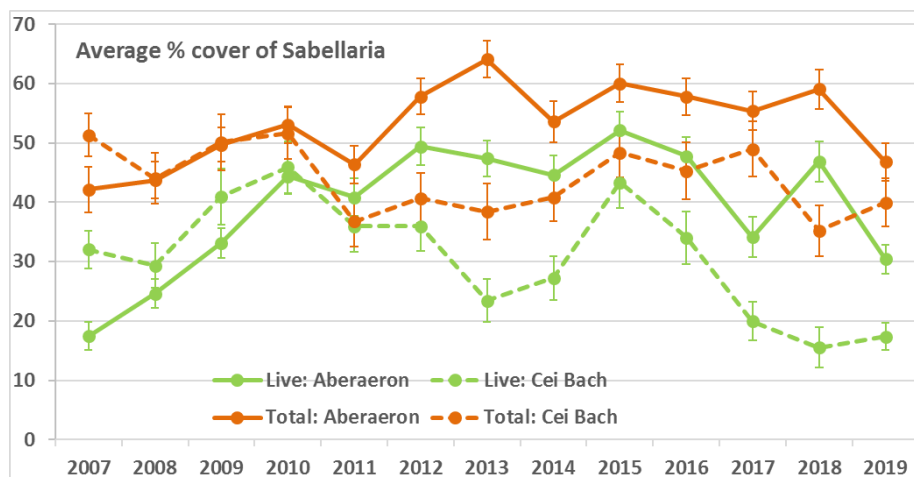
Initial analyses highlight the depauperate character of Station C1 at Cei Bach. The station lies at the sandy eastern edge of the *Sabellaria* reef, so many quadrats contained few species (sometimes none). Community data for this station are therefore very different from all other stations and have therefore been excluded from some of the multivariate analyses.

3.2.2 *Sabellaria* cover, all quadrats

This analysis uses the data from six stations at Aberaeron and 3 stations at Cei Bach (i.e. excluding station C1), with 15 quadrats per station (5 full quadrats and 10 *Sabellaria* only quadrats).

Figure 4 shows that the percentage cover of *Sabellaria* fluctuated considerably over the 13 years of monitoring; increasing at both sites between 2007 and 2010, showing various trends between 2011 and 2014, then decreasing at both sites from 2015. The cover of live *Sabellaria* since 2017 has been relatively low, particularly at Cei Bach.

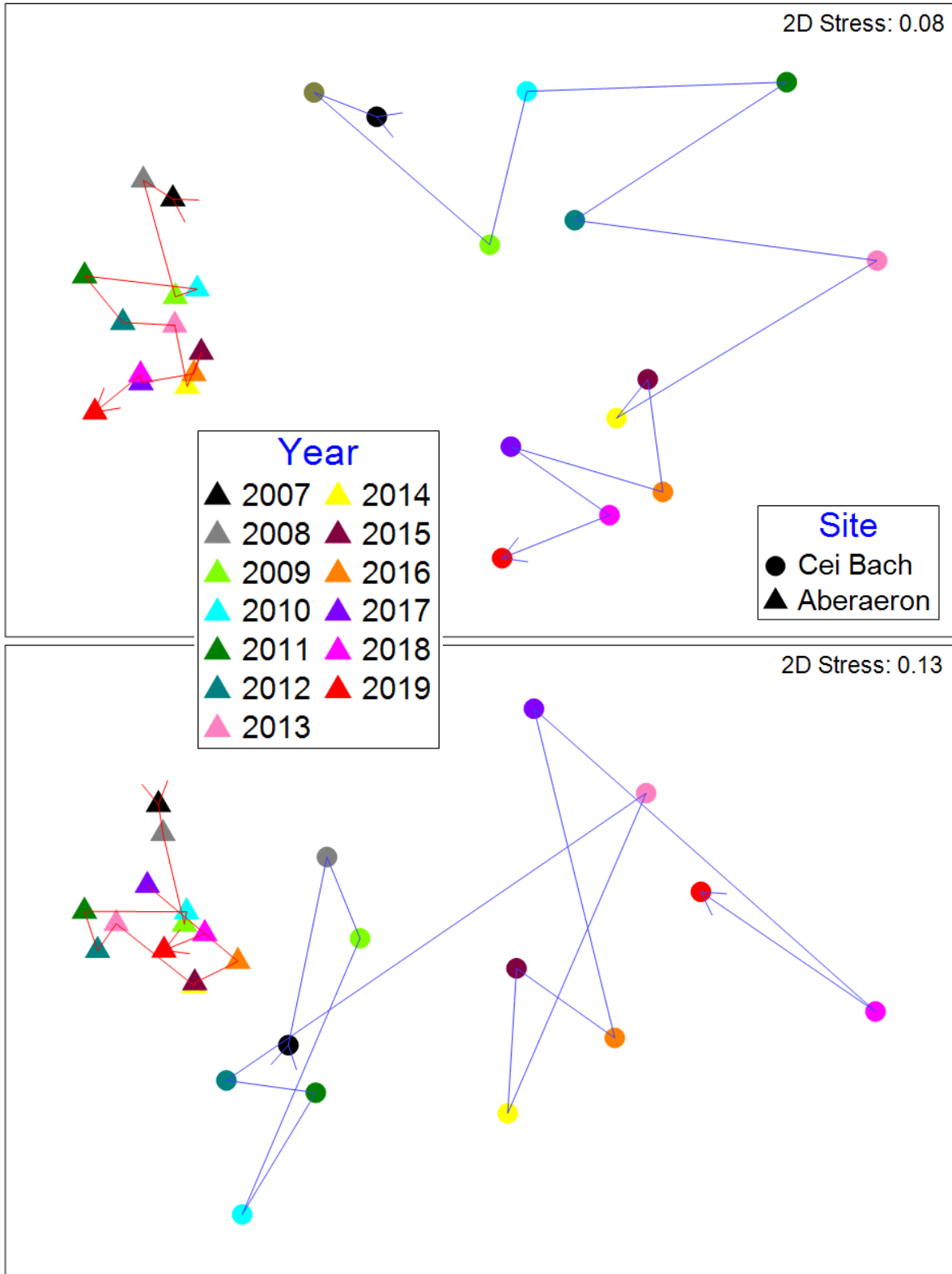
Figure 4 Percentage cover of *Sabellaria* (live and total) in quadrats at Aberaeron (6 stations) and Cei Bach (3 stations, excl. station C1), 2007 to 2019. Each value is average from at least 45 (Cei Bach) and 90 (Aberaeron) quadrats. Error bars are \pm Standard Error.



3.2.3 Community data

The MDS plots in Figure 5 clearly show that the reef communities at Aberaeron and Cei Bach have notable differences. ANOSIM results (see Appendix 4) show that the differences are statistically highly significant, in all periods (early 2007-2010, middle 2011-2015, late 2016-2019) and with either presence/absence data or percentage cover data. The year to year differences are greater at Cei Bach than Aberaeron, but that is at least partly due to the larger number of stations (and therefore quadrats) at Aberaeron, thereby reducing variability around the mean values. The plots also show a progressive temporal change from 2007 to 2019, though this is less convincing in the lower plot (percentage cover data). The upper plot (presence/absence data) suggests a similar trajectory in the progressive temporal change at the two sites, but the trajectories go in different directions in the lower plot.

Figure 5 MDS plots showing similarities (Bray Curtis) between epibiota communities in quadrats at Aberaeron and Cei Bach, 2007 to 2019. Overlain with trajectory lines from 2007 to 2019. Top plot: presence/absence data for 137 taxa. Bottom plot: percentage cover data (square root transformed) for 77 taxa.



SIMPER analysis (see Appendix 4) shows that many taxa contribute to the differences between the monitoring sites and to the temporal changes. Differences between the sites change from the early period to the late period, with relatively higher abundances of ephemeral green algae (*Ulva* spp.) and colonial diatoms at Cei Bach contributing much more to the later period. Other notable differences between the sites include higher abundances of live *Sabellaria*, *Fucus vesiculosus*, *Chondrus crispus* and coralline algae at Aberaeron while *Fucus serratus* and *Lanice conchilega* were more abundant at Cei Bach.

Taxa contributing most to the temporal changes include many of those listed above for the site differences, but the differences in abundance are more subtle and often show different trends. For example, *Fucus vesiculosus* was on average slightly more abundant in the later years at Cei Bach, while at Aberaeron it was slightly more abundant in the early years. Few species show any notable difference in abundance between the early year and the later years, apart from the live *Sabellaria*, *Ulva* and diatoms at Cei Bach, mentioned above. The only other notable difference is increased abundance of fucoid sporelings, at both sites.

3.3 Individual taxa

Inspection of data for individual taxa (Table 1, Table 2 and Figure 6) show that the main taxa responsible for the monitoring site differences and temporal changes described above are:

Lanice conchilega – generally more frequent at Cei Bach than at Aberaeron, except between 2011 and 2015 when there were fewer records (Appendix 3).

Barnacles – all three species (*Chthamalus montagui*, *Semibalanus balanoides* and *Austrominius modestus*) were generally much more frequent at Cei Bach than at Aberaeron (Appendix 3). Densities were generally low, but the frequency of both *S. balanoides* (Figure 6a) and *A. modestus* (Appendix 3) showed a marked rise and fall.

Polyplacophora – chitons are frequently found on stones, but usually underneath which is not supposed to be included in the survey (see Moore (2016)). The fluctuations in % occurrence (Appendix 3) may be explained by a lack of consistency in this protocol.

Patella vulgata – notable temporal changes, particularly at Aberaeron, where frequency of occurrence rose to a peak in 2010, descended to a low in 2015 and then rose again (Figure 6b). However, this pattern was not evident at Cei Bach.

Phorcus lineatus - generally more frequent at Cei Bach with a peak in 2010 and then dropping to 2017 (Appendix 3).

Sterromphala umbilicalis - generally more frequent at Aberaeron except in 2007 and 2019 when they were also very frequent at Cei Bach (Appendix 3).

Naviculales – a filamentous, mat forming, species; rarely recorded until 2014 at Cei Bach, where there was a very conspicuous growth present in some quadrats (Figure 6c). Notable patches were then recorded in every year at Cei Bach, particularly in 2018, but have remained rare at Aberaeron.

Dumontia contorta - generally more abundant at Aberaeron, with a peak in 2010 (Figure 6d). Less cover in recent years, but still recorded from more than 50% of quadrats.

Encrusting coralline algae – notably more abundant at Aberaeron (Figure 6e), where it was recorded from almost every quadrat. Abundance remained fairly stable over time.

Corallina – notably more abundant at Aberaeron, where it was recorded from almost every quadrat. Percentage cover increased gradually to a peak in 2013, then fell back to the original level before a steady climb and fall again (Figure 6f). The considerable reduction in 2014 is simultaneous to a drop in *Chondrus crispus*, both of which may relate to the 2011/12 winter storm event.

Chondrus crispus - generally more abundant at Aberaeron, where it was recorded from almost every quadrat. Percentage cover fluctuated at both sites, but with drop in frequency in Aberaeron in 2014 (Figure 6g).

Osmundea pinnatifida - generally more frequent at Aberaeron, and both frequency and percentage cover appear to have gradually dropped at Cei Bach (Figure 6h).

Fucoid sporelings – a large increase in the frequency of their occurrence occurred in 2014 and remained high in subsequent years (Table 2). A severe storm in winter 2013/14 caused some damage around and within the *Sabellaria* reef at both sites. This may have either removed older fucoids, making the sporelings more visible, or may have cleared space for recruitment of new fucoid plants. From 2015 onwards, an increase in *Fucus serratus* may also reflect this recruitment opportunity? It is also possible that the inclusion of fucoid sporelings on the recording form from 2015 onwards may have raised their profile during recording!

Fucus serratus – mostly very low abundance at both sites, until 2015 at Cei Bach when there was a notable rise (Figure 7i). Percentage cover at Cei Bach in the period 2015-19 was significantly higher than in the preceding 8 years (df=90, p<0.0001). The increase is even more striking in the frequency of occurrence data, where quadrats containing *F. serratus* were infrequent up to 2014 then increased to more than a third of quadrats from 2015.

Fucus vesiculosus – significantly more abundant at Aberaeron, but still a characterising species of the Cei Bach reef. Percentage cover has risen and fallen gradually over the years; showing remarkable synchrony between the sites (Figure 7j).

Cladostephus spongiosus - generally more frequent at Aberaeron, but frequency and percentage cover showed an apparent increase at both sites (Figure 7k). Regression

analysis of the Aberaeron percentage cover data found a highly significant increase to 2013, followed by a less significant decrease.

Green algae – a notable increase in frequency of occurrence and percentage cover of green algae (primarily *Ulva* (flat) and *Ulva* (tubular)) at Cei Bach since 2011 (Figure 7l & m). Regression analysis of the aggregated Chlorophyta turf percentage cover data shows that the increase is highly significant. Frequency of occurrence of *Chaetomorpha ligustica* (Figure 7n) also shows some interesting temporal fluctuations over the course of the monitoring but is not correlated with the *Ulva* records.

Table 1 Annual fluctuations in percentage cover of the most abundant algal taxa in *Sabellaria* reef quadrats at Aberaeron. Each value is an average from at least 30 quadrats.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Naviculales (fil. colonial diatoms)	0	0	0	0	0.1	0	0	0	0	0	0	0	0
Dumontia contorta	0.7	1.9	2.5	5.5	1.2	1.6	3.4	0.2	1	1.1	1.2	0.9	0.2
Hildenbrandia rubra	0	0	1.2	0.4	0.2	2.2	0.9	0.7	0.8	1.1	0.2	1	2
Corallinaceae (enc)	5	5.3	4.2	3	3.2	2.9	3.4	4.2	3.4	3.3	3.2	3.9	5.3
Corallina	4.3	5.2	6.8	7.4	10.1	7.5	12.4	3.6	4.2	6.2	6.5	7.2	4.1
Chondrus crispus	4.9	5.6	6	8.5	10.3	6.1	9	2.3	2.7	2.4	6.1	6.4	4.4
Ceramium	0	1.2	1.6	1.2	0.8	0.9	1.1	0	0.3	0.8	1.2	0.1	0.4
Osmundea hybrida	0.7	0.4	0.7	0.2	1.2	2.1	0.2	0.3	0.3	0.2	0.7	0.5	1.5
Osmundea pinnatifida	1.4	0.8	2.5	1.8	4.3	1.9	1.9	1.5	0.3	0.7	2.2	1.1	1.2
Vertebrata fucoides	0.9	0	0.9	0.4	0.9	1.4	0.6	0.3	0.4	0.2	0.8	1	0.8
Cladostephus spongiosus	0.1	0.4	0.5	1.1	1.1	1.2	2.1	1.4	1.3	1	1.4	0.8	0.8
Dictyota dichotoma	0.3	0	0.1	0	1.9	0.4	0	0	0	0	0.8	0.1	0.1
Fucaceae (sporeling)	0	0	0	0.9	0	0	0	1.2	3.6	1	7.7	1.9	1.7
Fucus serratus	1	0	0	0.9	0	0	0.7	0	0.1	0	0	0.4	0
Fucus vesiculosus	39.1	32.4	28.8	28	41.7	55.2	46.3	29.9	27.8	15.2	39.4	27.1	40.5
Ulva Agg	0	0.1	0	0.1	0.2	0	0	0	0	0	0.1	0	0.1
Cladophora	1	0.2	0.3	0.6	2.6	0.2	0.2	0.1	0.3	0	0.4	0.3	0.2
Verrucaria	2	2.3	1.2	2.6	1.3	1.1	0.7	0.1	0.8	0.3	0.1	0.3	0.4

Table 2 Annual fluctuations in percentage cover of the most abundant algal taxa in *Sabellaria* reef quadrats at Cei Bach. Each value is an average from at least 20 quadrats.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Naviculales (fil. colonial diatoms)	0	0	0	0	0	0.1	0	1.4	0.2	1.5	0.5	6.9	3
Dumontia contorta	0.4	2.3	0.3	0.6	0	0.1	0.6	0	0.2	0	0.3	0.2	0.1
Hildenbrandia rubra	0	0	1	0.2	0	1.4	0.7	3	0.4	1.2	0.2	0.6	3.7
Corallinaceae (enc)	1.5	2	1	1.4	0.1	0.6	0.3	0.4	1.1	0.6	0.6	0.8	0.5
Corallina	0.4	1.4	1.7	0.9	0.7	0.3	0.6	0.1	0.3	0.9	1.9	0.3	0.2
Chondrus crispus	1.2	3.6	5.3	2.6	2.7	0.7	2.7	0.6	2.7	2.7	5.3	1.7	2.5
Ceramium	0.2	1.3	3.1	0.5	0	0.2	1.5	0.1	2.8	1.4	2.2	0.5	2.6
Osmundea hybrida	2.5	1.2	0.6	0.6	0.4	2.2	0.2	0.1	0.1	0.1	0.4	0.2	0.3
Osmundea pinnatifida	1.7	2.1	2	1.1	1.1	2.1	0.8	0.2	0.3	0.3	0.8	0.1	0.2
Vertebrata fucoides	2.9	0.9	3.9	0.2	0.3	0	0.5	2.3	0.1	0.9	1	1.4	1.7
Cladostephus spongiosus	0	0.2	0.1	0.2	0.1	0.1	0.1	0.4	0.4	0.6	0.4	0.4	0.4
Dictyota dichotoma	0.1	0.1	0.1	0	0	0	0	0	0.1	0	0.7	0	0
Fucaceae (sporeling)	0	0	0	0.1	0	0	0	0.2	0.2	0.2	0.7	0.5	1.2
Fucus serratus	0.3	0.6	1	0	0	0	0.8	0.2	4.8	2.6	2.2	4.7	2.8
Fucus vesiculosus	20.7	18.4	8.1	3.5	22.3	30.2	22.9	15.6	16.5	10.2	23.7	9.6	17.6
Ulva Agg	1.3	0	0.5	0.1	0.7	0.4	12.8	0.6	11.2	3.5	7.2	7.2	14
Cladophora	0.6	0	0.2	0.1	1.6	0.2	0.1	0	0	0.1	1.6	0.2	0.1
Verrucaria	1.2	2.8	2.6	1.4	1.8	2.4	1.2	0.1	0.5	1.2	1	0.1	0.5

Figure 6 Graphs of temporal change in abundance (percentage cover or frequency of occurrence) for selected taxa. Graphs of average percentage cover (\pm standard error) are shown for selected algal taxa. Graphs of frequency of occurrence (calculated as a percentage of the number of quadrats surveyed) are shown for selected invertebrates and some algae that only occur with low cover. Each point represents at least 30 (Aberaeron) and 20 (Ceï Bach) quadrats.

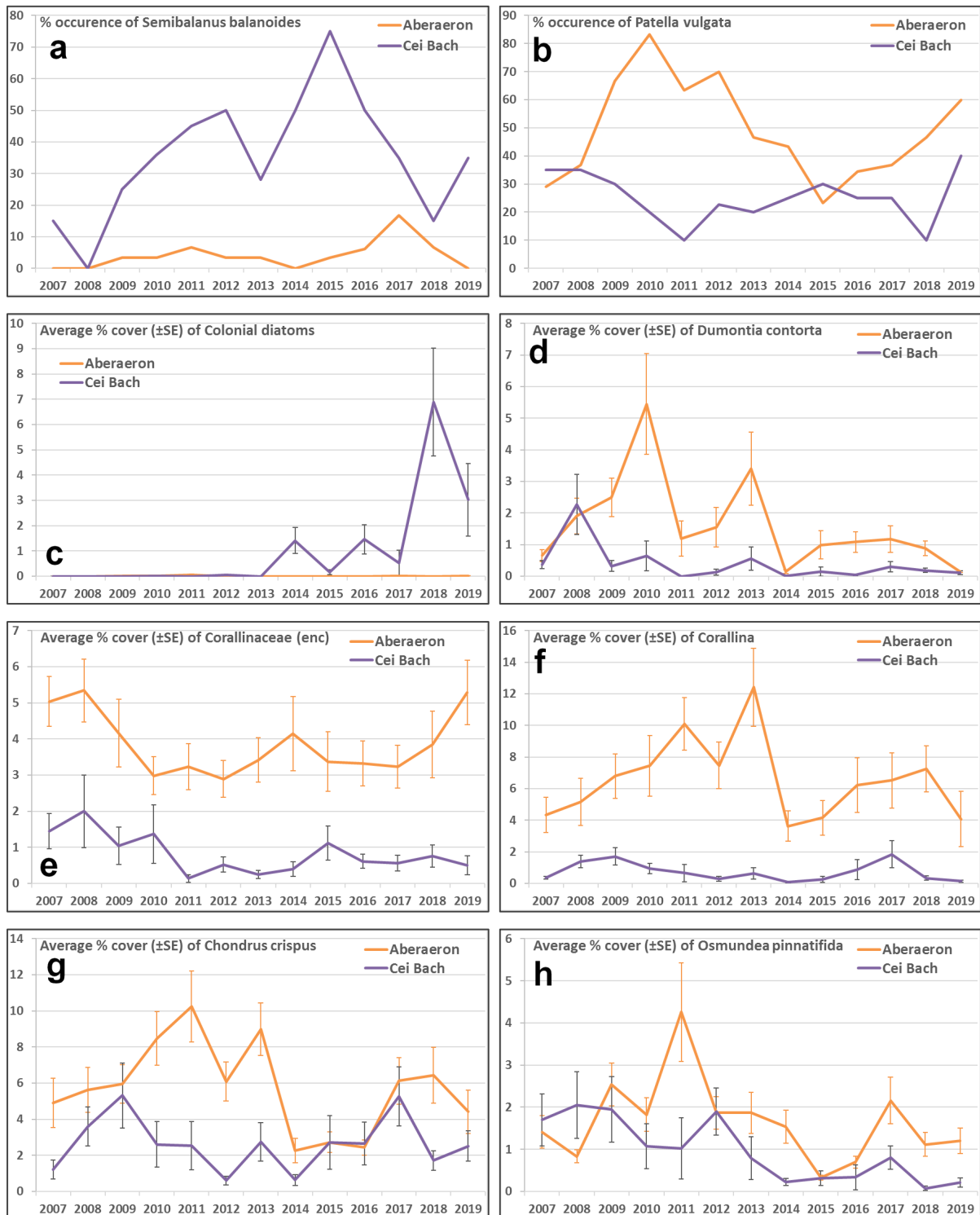
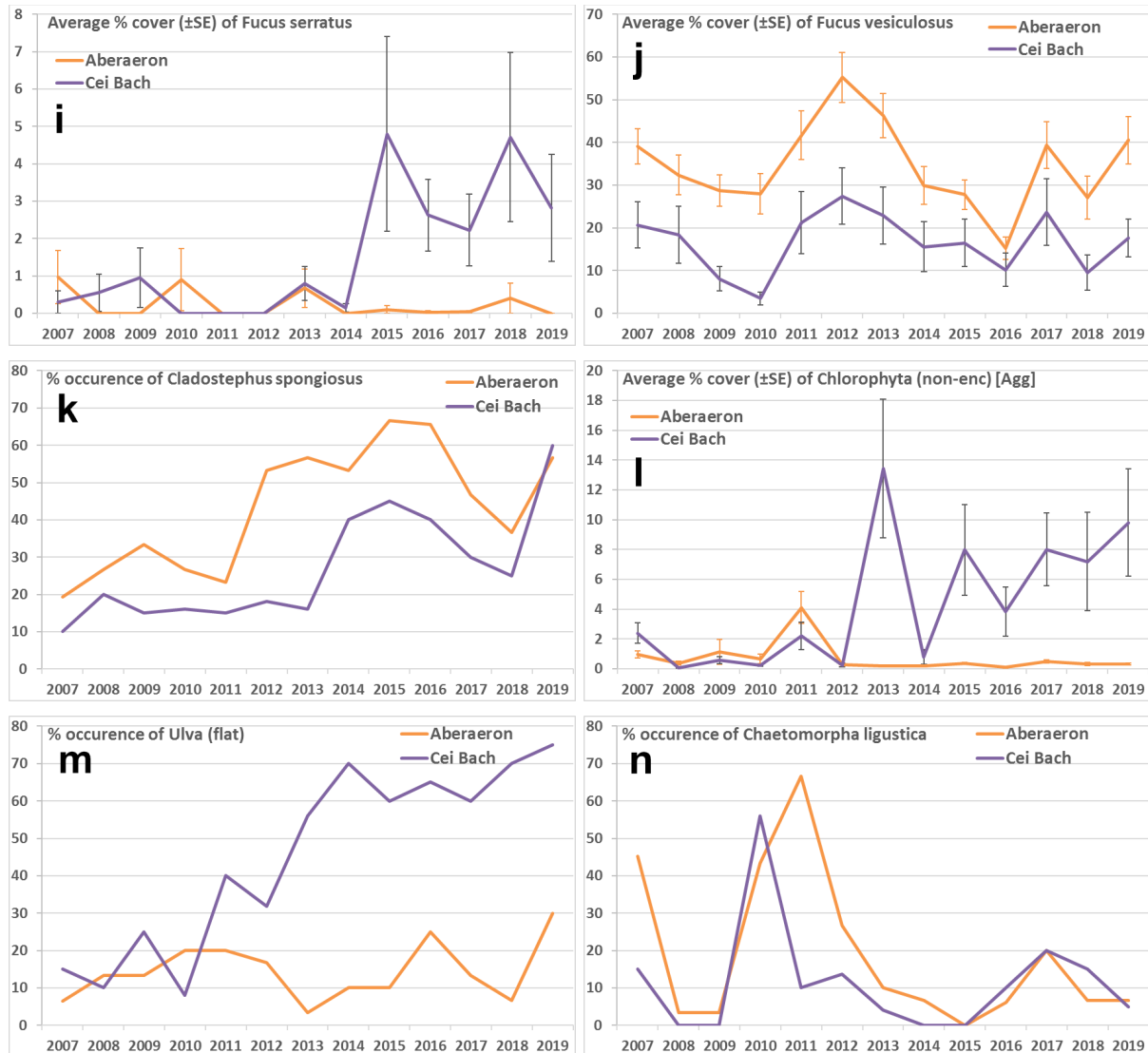


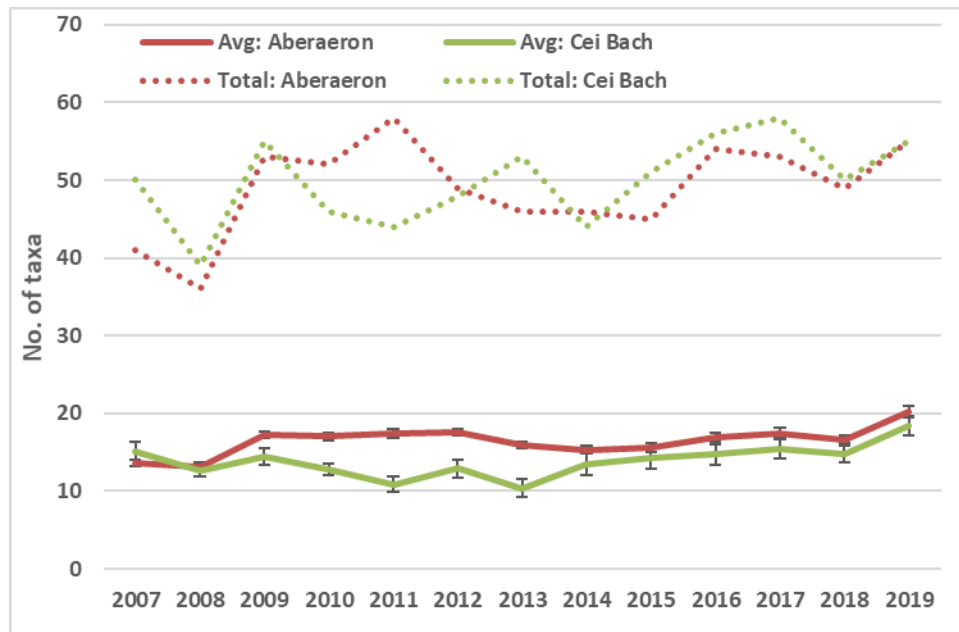
Figure 7 (continued from Figure 6). Graphs of temporal change in abundance (percentage cover or frequency of occurrence) for selected taxa. Graphs of average percentage cover (\pm standard error) are shown for selected algal taxa. Graphs of frequency of occurrence (calculated as a percentage of the number of quadrats surveyed) are shown for selected invertebrates and some algae that only occur with low cover. Each point represents at least 30 (Aberaeron) and 20 (Ceii Bach) quadrats



3.4 Species richness

Figure 8 shows average number of individual taxa (excluding aggregate taxa) recorded in the quadrats from the two monitoring sites. A notable increase is evident for Aberaeron, but not for Ceii Bach. A slight increase was expected, as the monitoring staff gain knowledge and familiarity with the taxa present at the sites, so the lack of an increase and the greater fluctuations at Ceii Bach suggest that this site is less stable.

Figure 8 Average number (per quadrat, with standard error bars) and total number of taxa recorded from *Sabellaria* reef stations at Aberaeron and Cei Bach, 2007 to 2019. Values exclude aggregate taxa.



3.5 Standing water

The percentage cover of standing water was recorded from all quadrats. Analyses of the data up to 2017 (Figure 9 and Figure 10) found no notable trends over time and no apparent relationships with species richness, sites, stations or surveyors.

Figure 9 Average percentage cover of standing water recorded in quadrats from *Sabellaria* reef stations at Aberaeron (A1 to A6) and Cei Bach (C1 to C4), 2007 to 2017.

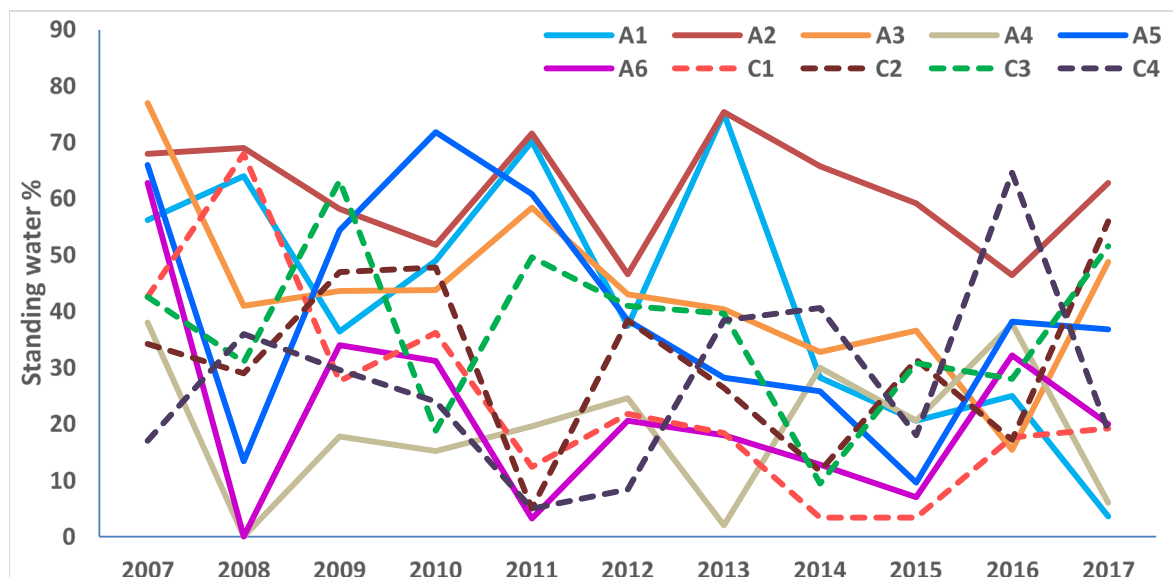
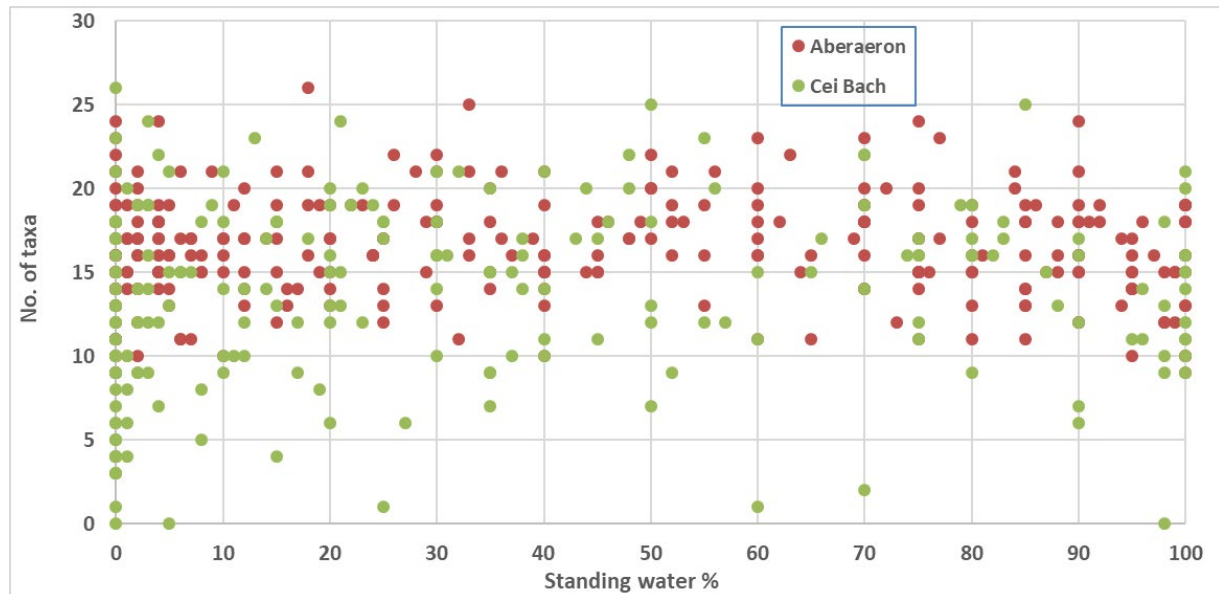


Figure 10 Scatter plot of percentage cover of standing water versus number of taxa, recorded *in situ* from quadrats (Aberaeron and Cei Bach, 2007 to 2017).



3.6 Quality Control – repeated samples

One of the quality control procedures (verification) in this programme has been to intermittently repeat surveys of some quadrats using a different pair of surveyors to provide data on the scale of inconsistencies in recording. Table 3 shows data from repeated surveys of the same quadrats on the same day in 2014. Numerous inconsistencies are apparent (114 discrepancies from 394 records; i.e. 29%), but only a small proportion (approx. 1%) are considered notable inconsistencies. Consistency of recording is therefore considered acceptable for describing notable changes in the population and community data and hence for the monitoring objectives.

Detailed inspection of the inconsistencies suggests that the majority were due to notable differences in estimates of percentage cover or where one surveyor recorded a species (usually in low abundance) and the other surveyor didn't see it. Only a small number of discrepancies were due to differences in identification.

4 Condition assessment

Aberaeron - Favourable - recorded changes in extent, species richness, species composition and abundance appear to be within the normally recorded range of such fluctuations. Notable changes and trends are also considered to be natural.

Cei Bach - Favourable – while the reef community is less diverse compared to Aberaeron and shows a greater level of variation, possibly due to instability of the substrata, the recorded changes in species richness, species composition and abundance do not indicate any trends of concern and appear to be within the

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Table 3 Records of the most frequently occurring taxa in repeated *Sabellaria* quadrat surveys from 2014. Each column represents a quadrat survey that has been repeated by different surveyors (green: first survey, pink: second survey). Abundances are estimates of percentage cover. P = present. T = Trace. Red font indicates a moderate but notable discrepancy in the repeated records. Red font with black border indicates a large discrepancy.

Station	A3-1	A3-1	A3-2	A3-2	A3-3	A3-3	A3-4	A3-4	A3-5	A3-5	A6-1	A6-1	A6-2	A6-2	A6-3	A6-3	A6-4	A6-4	A6-5	A6-5	C2-1	C2-1	C2-2	C2-2	C2-3	C2-3	C2-4	C2-4	C4-1	C4-1	C4-2	C4-2	C4-3	C4-3	C4-4	C4-4	
Sabellaria (live)	5	1	26	40	26	30	71	70	49	50	4	5	100	99	62	65	80	72	62	60	38	45	28	30	19	20	8	15	1	<1	<1	<1	<1	26	25	20	70
Sabellaria (total) [Agg]	14	5	36	40	35	40	75	80	92	95	12	10	100	99	86	90	85	82	82	80	43	50	34	35	31	35	61	50	2	<1	7	5	36	30	92	75	
Littorina littorea	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Rhodophyta (dk enc) [Agg]	1	<1	4	<1	<1	<1	<1	T	<1		4	3	-	-	<1	<1	1	2	2	<1	<1	1	T	<1	-	-	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Corallinaceae (enc)	5	15	5	20	6	15	1	3	1	1	2	5	-	T	3	5	3	3	<1	<1	1	2	T	<1	-	-	<1	<1	<1	<1	4	4	<1	<1	T	<1	
Chlorophyta (non enc) [Agg]	T	<1	T	<1	T	<1	T	<1	T	<1	-	-	-	<1	<1	-	-	T	T	-	<1	<1	T	<1	10	8	<1	<1	<1	<1	2	2	-	1	1	1	
Chondrus crispus	9	20	2	1	3	3	<1	<1	<1	<1	<1	1	-	<1	1	1	1	<1	<1	T	<1	1	-	-	-	-	-	1	1	<1	<1	1	1	1	2	2	
Hildenbrandia rubra	<1	-	4	T	<1	<1	<1	T	<1	-	4	3	-	-	<1	<1	1	2	2	<1	T	1	T	<1	-	-	1	<1	T	<1	<1	<1	T	<1	-	<1	
Gibbula umbilicalis	-	P	P	P	P	P	-	-	-	-	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Rhodophyta (fil) [Agg]	1	-	<1	<1	<1	<1	<1	<1	<1	<1	-	-	<1	<1	<1	-	-	<1	<1	1	-	-	-	-	-	-	-	2	-	-	-	-	-	T	T	1	<1
Fucaeae (sporeling)	T	<1	-	-	<1	-	<1	-	3	1	<1	<1	3	1	2	1	2	1	1	2	<1	<1	1	-	<1	1	-	<1	<1	-	<1	<1	-	<1	1	1	<1
Osmundea pinnatifida	<1	-	1	-	<1	<1	<1	1	1	1	2	<1	<1	<1	1	<1	<1	<1	<1	-	-	-	-	-	-	-	-	<1	<1	-	-	1	2	1	2		
Cladophora sericea	T	T	T	<1	T	<1	T	<1	T	<1	-	-	-	T	<1	<1	-	T	T	T	-	T	-	T	-	T	-	T	-	-	-	-	-	-	T	T	
Corallina officinalis	6	15	1	<1	4	2	1	<1	<1	<1	T	-	-	<1	<1	1	2	<1	-	-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	-
Lanice conchilega	P	T	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Cladostephus spongiosus	-	-	<1	<1	<1	<1	1	1	5	3	<1	T	<1	<1	5	5	<1	1	1	<1	<1	1	-	-	-	T	-	T	1	1	-	-	-	-	<1	<1	
Osmundea hybrida	<1	-	-	-	<1	-	<1	-	<1	<1	<1	-	-	<1	<1	-	T	<1	<1	-	<1	T	-	-	-	T	-	T	-	-	-	-	-	-	<1	<1	
Ceramium deslongchampsii	-	-	T	<1	-	T	-	<1	-	-	-	-	<1	-	-	-	-	-	-	-	T	T	-	-	-	-	-	-	-	-	-	-	-	-	-	T	<1
Ulva (flat)	-	-	-	-	-	-	-	-	-	-	-	-	T	T	-	-	-	-	-	-	<1	<1	T	<1	4	4	T	<1	<1	<1	-	-	<1	<1	-	1	
Spirobranchus	T	T	T	P	T	P	-	-	-	-	-	-	-	-	P	-	T	P	-	-	-	-	-	-	-	-	-	-	T	T	-	-	T	-	-	-	
Littorina obtusata (and/or L. fabalis)	-	-	P	-	-	-	-	-	-	-	-	-	P	P	P	T	P	P	-	-	P	P	T	-	-	P	P	P	-	-	-	-	-	P	-	-	
Naviculales (fil. colonial diatoms)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	T	<1	T	<1	2	-	<1	2	3	9	8	4	8	4	2	
Ulva (tubular)	-	-	-	-	-	-	-	T	T	-	-	-	-	-	-	-	-	-	-	-	-	-	T	-	4	4	T	<1	T	T	-	-	<1	<1	-	<1	
Dumontia contorta	1	<1	-	-	<1	<1	-	-	-	-	T	-	-	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	-	-	
Chaetomorpha linum	-	<1	T	<1	-	-	T	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	T	-	T	-	-	T	-	-	-	-	-	-	-	
Cirripedia [Agg]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1	-	-	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	-	
Semibalanus balanoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	P	-	-	-	-	-	-	P	P	P	P	P	P	-	
Verrucaria (green)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	<1	<1	-	-	T	-	T	-	-	-	T	-	T	<1	
Polysiphonia fucoides	<1	-	-	<1	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Carcinus maenas	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Mastocarpus stellatus	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	T	-	
Chlorophyta (fuzz)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	2	<1	<1	-	<1		
Hymeniacion perlevis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	P	-	P	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		

normally recorded range of such fluctuations. Notable changes and trends are also considered to be natural.

Confidence in this conclusion is high; based on the experience of the surveyors (both generally and specifically on this monitoring programme) and a lack of any other known / apparent stresses or mechanisms other than natural fluctuations.

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Appendix 1 *Sabellaria* reef monitoring surveys, Cardigan Bay, 2007-2019

Surveys of *Sabellaria* reef at Aberaeron and Cei Bach

Year	Start date	End date	Surveyors
2007	14 May	18 May	JJM, CMH, JJ, DPB
2008	5 May	6 May	JJM, CMH, JJ, GW, JH
2009	6 May	8 May	FDB, TSM, JJ, DPB, KSB, JH
2010	26 April	29 April	JJM, CMH, JJ, DPB, EH, BSa, ZO, JH
2011	13 June	16 June	DPB, GW, AB (CCW inhouse)
2012	7 May	10 May	DPB, BW, KSB, FP (CCW inhouse)
2013	25 April	28 April	CMH, JJM, JAT
2014	28 April	1 May	TSM, JJM, JAT, DPB, CJ, JMn
2015	17 April	18 April	TSM, CMH, JAT, DPB, JMn, JH
2016	5 May	8 May	JJM, TSM, DPB, JAT, NL, EJ
2017	25 May	27 May	JJM, FDB, JAT, BW, JD, TH, JH
2018	15 May	18 May	FDB, TSM, JAT, BW, LG
2019	3 May	6 May	JJM, TSM, DPB, JAT

More details are given in the survey field logs, which are available on request.

Appendix 2 Database structure

In situ survey data

The *in situ* survey data are stored in an Access database. A summary of the main data tables and fields is given below:

SabellariaData

Field name	Description
Entity	Accepted name for the taxon, based on WoRMS, plus qualifier
Year	Survey year: 2007 to 2019
SampleCode	Sample code. Year+Zone+Pool(+QArepeat), e.g. 17C4.10 = 2017, Cei Bach, Station 4, Quadrat 10.
Method	P (=Present), % (=Percentage) or T% (=Percentage of aggregate taxon). The actual method used for this entity in this sample. Not necessarily the default method given in the TaxaList table.
Abundance	A numeric value from 0.01 to 100. If Method = % then Abundance is percentage cover. If Method = P, then Abundance can only be 1 (=Present) or 0.01 (=Trace).

Taxa

Field name	Description
Entity	Accepted name for the taxon, based on WoRMS, plus qualifier
EntCode	Taxonomic code for each entity (=taxon + qualifier), based on Species Directory, e.g. Hymeniacion perlevis = C005230 and Corallinaceae (enc) = ZM03840.51
AnalysisEntity	Fairly reliable taxonomic entity for use in analyses where identification of Entity is not always reliable
AphiaID	Code for taxon name from WoRMS online database
Authority	Taxonomic authority from WoRMS online database
Kingdom -> Species	Multiple fields – taxonomic classification, from WoRMS online database
SabellariaChecklist	Tags entities that are listed on the recording form
Method	Default survey method: P (=Presence), % (=Percentage cover), T% (Percentage cover of aggregate taxa)
TemporalAnalysis	Tags entities to include in temporal analysis. Excluded taxa are those that are very inconsistently recorded.
Life form	e.g. Hydroid, Bryozoan turf, Green turf

Samples

Field name	Description
SampleCode	Sample code, as in SabellariaData table
Year	2007 to 2019
Site	Aberaeron or Cei Bach
Station	A1 to A6, C1 to C4
Quadrat	Between 1 and 15 (mainly), but up to 22 on occasions where extra quadrats have been surveyed
SurveyType	Full or Sabellaria; i.e. whether Full quadrat survey or Sabellaria only recorded
Date	Survey date
Surveyors	Initials of surveyors
Standing water	Percentage cover of the quadrat that is standing water
QA-repeat	1 or 2, where 2 is a repeated sample by another surveyor, for quality control

Quadrat Stns

Field name	Description
Site	Aberaeron or Cei Bach
SiteCode	AB or CB
Station	A1 to A6, C1 to C4
Transect	Integer, from 2 to 9, from 2007 survey when programme initiated. No longer used
Zone	Integer, from 2 to 5, from 2007 survey when programme initiated. No longer used
Old Stn Code	Alphanumeric code, from 2007 survey when programme initiated. Combines Transect and Zone numbers, e.g. A7.4 = Aberaeron transect 7 zone 4. No longer used.
Easting / Northing	Ordnance Survey grid reference location for pool
Longitude / Latitude	Pool location coordinates in decimal degrees, with WGS84 datum

Appendix 3 List of taxa

The following table lists all taxa recorded from all *Sabellaria* reef quadrats, with counts of records by year (out of 50 quadrats). Nomenclature is according to the WoRMS database (www.marinespecies.org), current in February 2020. Entity is the taxon and qualifier recorded. AnalysisEntity is that used during many of the statistical analyses described in the report, to merge data for taxa that may have been identified or recorded in different ways by different surveyors or in different years. Taxa have been sorted according to an alphanumeric code based on the Marine Species Directory (Howson & Picton, 1997).

Entity	AnalysisEntity	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Porifera	Porifera	4	0	0	0	0	0	0	0	0	0	0	1	0
Halichondria panicea	Halichondria panicea	0	1	2	0	0	2	0	0	0	0	2	0	1
Hymeniacion perlevis	Hymeniacion perlevis	3	6	4	3	1	3	1	5	2	4	1	3	3
Hydrozoa	Hydrozoa	0	0	0	0	2	0	0	1	0	1	0	0	1
Coryne muscoides	Anthoathecata (athecate hydroids)	0	0	0	0	2	0	0	0	0	0	0	0	0
Kirchenpaueria pinnata	Leptothecata (thecate hydroids)	0	0	0	0	1	0	0	0	0	0	0	0	0
Dynamena pumila	Leptothecata (thecate hydroids)	0	0	0	1	0	0	0	0	0	0	0	0	3
Campanulariidae	Campanulariidae	0	0	0	0	0	0	0	0	0	0	4	1	0
Laomedea flexuosa	Campanulariidae	2	0	4	0	0	0	1	0	0	1	2	0	0
Actinaria	Actinaria	0	0	0	0	0	0	0	0	0	0	0	1	0
Actinia equina	Actinia equina	0	4	5	4	1	7	3	5	5	3	3	2	4
Actinia fragacea	Actinia fragacea	0	0	0	1	0	0	0	1	0	1	0	0	0
Anemonia viridis	Anemonia viridis	0	0	0	0	0	0	0	0	1	0	0	1	0
Lineus	Lineus	0	0	0	0	1	0	0	0	0	1	0	0	0
Eulalia viridis	Eulalia viridis	5	0	6	2	3	6	3	2	0	2	1	2	3
Cirratulidae	Cirratulidae	0	0	2	1	0	0	0	0	0	0	0	0	0
Arenicola marina	Arenicola marina	3	3	7	2	4	6	8	6	3	1	1	3	1
Sabellaria (live)	Sabellaria (live)	48	48	48	53	45	48	46	64	46	59	47	46	47
Sabellaria (total) [Agg]	Sabellaria (total) [Agg]	50	49	48	53	46	48	47	64	46	59	47	48	47
Lanice conchilega	Lanice conchilega	29	31	38	36	17	20	21	33	24	37	27	31	25
Serpulidae	Serpulidae	0	0	2	0	0	2	0	0	0	0	0	0	0
Hydroides	Serpulidae	0	0	0	0	0	0	0	0	0	0	0	0	1
Spirobranchus	Spirobranchus	23	20	26	21	13	18	16	23	22	25	23	20	23
Spirorbinae	Spirorbinae	0	0	3	0	3	0	0	0	0	0	3	5	3
Spirorbis	Spirorbinae	0	0	0	0	0	6	0	0	0	0	0	0	0
Nymphon gracile	Nymphon gracile	0	0	0	0	0	0	0	0	1	0	0	0	0
Acari	Acari	0	0	0	0	0	0	0	0	0	0	1	0	0

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Cirripedia [Agg]	Cirripedia [Agg]	5	2	7	14	12	14	9	13	17	18	16	7	8
Chthamalus montagui	Chthamalus montagui	2	2	6	8	6	2	7	2	5	7	7	3	7
Chthamalus stellatus	Chthamalus stellatus	0	0	0	0	0	0	0	0	0	0	0	0	2
Semibalanus balanoides	Semibalanus balanoides	3	0	6	10	11	12	8	13	16	16	13	5	7
Balanus balanus	Balanus balanus	0	0	0	0	0	0	0	0	1	0	0	0	0
Austrominius modestus	Austrominius modestus	1	0	3	7	6	3	5	8	5	3	2	3	3
Amphipoda	Amphipoda	0	0	5	3	1	0	3	1	3	3	1	2	0
Idotea granulosa	Isopoda	0	0	0	0	0	0	0	3	2	3	2	0	0
Caridea	Caridea	0	0	0	0	0	0	0	0	0	1	0	0	0
Palaemonidae	Caridea	5	3	4	1	0	0	1	1	0	6	1	5	5
Palaemon elegans	Caridea	0	0	0	0	0	1	0	0	0	0	0	2	0
Crangon crangon	Caridea	0	0	1	2	0	0	0	0	1	0	1	0	0
Paguridae	Paguridae	5	1	2	0	5	1	0	0	0	1	3	4	1
Carcinus maenas	Carcinus maenas	5	3	12	4	13	3	2	9	5	14	18	16	8
Anurida maritima	Anurida maritima	0	0	0	0	0	0	0	0	1	1	0	0	3
Polyplacophora	Polyplacophora	0	0	1	0	0	0	0	0	0	0	0	0	0
Lepidochitona cinerea	Polyplacophora	1	12	6	13	9	1	7	7	13	3	3	0	2
Patella depressa	Patella depressa	0	0	2	3	2	0	0	0	2	4	1	0	0
Patella ulyssiponensis	Patella ulyssiponensis	0	0	0	0	0	0	0	0	0	1	1	2	0
Patella vulgata	Patella vulgata	16	18	26	30	21	26	19	25	13	21	16	16	26
Phorcus lineatus	Phorcus lineatus	9	9	12	24	6	4	9	3	5	5	2	8	9
Steromphala cineraria	Steromphala cineraria	0	14	1	6	2	1	10	2	1	6	3	2	2
Steromphala umbilicalis	Steromphala umbilicalis	46	39	39	38	36	40	37	42	36	49	43	41	49
Littorina littorea	Littorina littorea	47	49	49	54	48	49	46	65	48	57	49	45	45
Melarhaphe neritoides	Melarhaphe neritoides	0	0	0	0	0	0	0	0	1	0	0	0	0
Littorina obtusata / fabalis	Littorina obtusata/fabalis)	20	15	17	14	20	22	20	27	19	18	20	19	21
Littorina saxatilis	Littorina saxatilis	6	1	3	4	3	0	6	3	3	4	1	2	4
Epitonium clathrus	Epitonium clathrus	0	0	2	0	1	0	0	0	0	0	0	0	0
Nucella lapillus	Nucella lapillus	1	1	1	1	0	1	4	3	2	5	4	1	2
Ocenebra erinaceus	Ocenebra erinaceus	1	0	1	0	0	0	0	0	0	0	0	0	0
Buccinum undatum	Buccinum undatum	0	0	0	0	0	0	0	0	0	1	0	0	0
Mytilus edulis	Mytilus edulis	3	0	0	4	5	5	1	2	0	2	0	0	0
Venerupis corrugata	Venerupis corrugata	0	0	0	0	0	0	0	1	0	0	0	0	0
Bryozoa (enc)	Bryozoa (enc)	0	1	0	0	0	0	0	0	1	0	0	0	0
Alcyonidium (enc)	Alcyonidium (enc)	0	0	1	0	0	0	0	0	0	0	0	0	0
Membranipora membranacea	Membranipora membranacea	0	0	1	0	0	0	0	0	0	0	0	0	0
Electra pilosa	Electra pilosa	0	0	0	0	0	0	1	0	0	0	1	0	0
Molgula manhattensis	Molgula manhattensis	0	0	0	0	0	0	1	0	0	0	0	0	0
Actinopterygii (Fish!)	Actinopterygii (Fish!)	0	0	0	0	0	0	0	0	0	1	0	0	0
Cottidae (juv)	Cottidae (juv)	0	0	0	0	0	0	0	0	0	0	0	1	0
Lipophrys pholis	Lipophrys pholis	0	0	0	0	1	2	1	0	0	1	0	0	0
Pleuronectidae (juv)	Pleuronectidae (juv)	0	0	0	0	0	0	0	0	0	0	1	0	0

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Naviculales (colonial diatoms)	Naviculales (colonial diatoms)	0	0	1	2	3	4	0	21	6	17	5	14	17
Rhodophyta (dk enc) [Agg]	Rhodophyta (dk enc) [Agg]	38	25	27	37	27	31	35	59	45	57	39	43	44
Rhodophyta (fil) [Agg]	Rhodophyta (fil) [Agg]	26	30	33	29	36	31	37	41	41	49	36	36	36
Rhodophyta (sporeling)	Rhodophyta (sporeling)	0	0	0	0	0	0	0	0	0	0	0	1	0
Porphyra	Porphyra	0	0	0	0	0	0	0	0	0	0	0	0	1
Rhodothamniella floridula	Rhodothamniella floridula	3	0	0	0	0	1	0	0	0	3	0	0	0
Rhodochoorton purpureum	Rhodochoorton purpureum	0	0	0	0	0	0	0	0	0	0	0	0	1
Gelidium crinale	Gelidium	0	0	0	0	0	0	0	0	1	0	0	1	1
Gelidium pulchellum	Gelidium	2	0	1	0	0	1	1	3	0	1	0	0	0
Palmaria palmata	Palmaria palmata	0	0	2	0	0	0	1	0	0	0	0	0	1
Dumontia contorta	Dumontia contorta	31	31	27	40	17	24	23	17	15	30	25	32	26
Peyssonnelia	Peyssonnelia	0	0	0	0	0	0	0	0	0	0	0	8	0
Hildenbrandia rubra	Hildenbrandia rubra	0	0	29	21	4	36	28	55	26	49	36	39	44
Corallinaceae (enc)	Corallinaceae (enc)	44	41	45	43	33	37	36	60	43	53	42	45	43
Corallina	Corallina	40	44	42	40	37	37	35	40	32	40	37	39	35
Corallina caespitosa	Corallina caespitosa	0	0	0	0	0	0	0	0	0	0	0	0	20
Corallina officinalis	Corallina officinalis	0	0	0	0	0	0	0	0	0	0	0	0	12
Gracilaria gracilis	Gracilaria gracilis	1	0	0	0	1	0	1	0	0	1	0	0	0
Ahnfeltia plicata	Ahnfeltia plicata	0	1	0	0	0	0	0	0	1	0	0	0	0
Mastocarpus stellatus	Mastocarpus stellatus	3	6	2	3	1	3	4	8	1	9	5	3	1
Mastocarpus stellatus (Petrocelis cruenta)	Mastocarpus stellatus (Petrocelis cruenta)	0	2	0	0	2	0	0	0	0	5	0	0	2
Chondrus crispus	Chondrus crispus	39	43	45	45	39	40	41	55	38	51	43	42	43
Chondracanthus acicularis	Chondracanthus acicularis	0	0	0	0	0	0	0	0	0	0	0	0	2
Polyides rotunda	Polyides rotunda	0	0	0	0	1	0	0	0	0	0	0	0	0
Furcellaria lumbricalis	Furcellaria lumbricalis	1	0	0	0	1	0	0	0	0	0	0	1	0
Caulacanthus okamurae	Caulacanthus okamurae	0	0	0	0	0	0	0	0	0	0	1	0	0
Cystoclonium purpureum	Cystoclonium purpureum	1	0	0	0	0	0	0	0	0	0	1	0	0
Cordylecladia erecta (?)	Cordylecladia erecta (?)	0	0	0	0	0	0	0	2	0	1	0	0	0
Gaillona gallica	Aglaothamnion	0	0	0	0	0	1	0	0	0	0	0	0	0
Gaillona hookeri	Aglaothamnion	0	0	0	0	0	0	1	5	1	4	4	2	3
Ceramium	Ceramium	2	10	1	1	1	1	2	0	0	0	0	0	0
Ceramium botryocarpum	Ceramium	0	10	13	0	3	1	2	0	0	0	0	0	0
Ceramium deslongchampsii	Ceramium	1	2	9	19	6	13	22	11	28	43	24	13	20
Ceramium echinotum	Ceramium	0	0	0	0	0	3	0	0	0	0	0	0	0
Ceramium gaditanum	Ceramium	0	0	0	0	0	0	0	3	0	2	0	0	0
Ceramium virgatum	Ceramium	3	0	2	0	0	0	3	0	0	0	0	2	3
Ceramium pallidum	Ceramium	0	0	0	0	0	0	0	0	0	1	0	1	0
Ceramium secundatum	Ceramium	0	0	0	0	0	0	0	7	0	0	0	0	3
Halurus equisetifolius	Halurus equisetifolius	1	0	0	0	0	0	0	0	0	0	0	0	0
Apoglossum ruscifolium	Apoglossum ruscifolium	0	0	0	0	0	1	0	0	0	0	0	0	0
Cryptopleura ramosa	Cryptopleura ramosa	0	0	0	0	0	2	0	0	1	0	0	0	0

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Hypoglossum hypoglossoides	Hypoglossum hypoglossoides	0	0	0	1	0	0	0	0	0	0	0	0	0
Membranoptera alata	Membranoptera alata	0	0	0	1	0	0	0	0	0	0	0	0	0
Osmundea hybrida	Osmundea hybrida	28	24	30	31	33	31	20	30	25	33	34	27	38
Osmundea osmunda	Osmundea osmunda	0	0	0	2	0	1	0	0	2	0	0	0	5
Osmundea pinnatifida	Osmundea pinnatifida	33	36	39	35	27	39	33	47	32	42	38	26	36
Osmundea truncata	Osmundea truncata	0	0	2	2	0	0	0	0	0	0	0	0	0
Polysiphonia	Polysiphonia	0	11	0	0	0	3	0	0	0	0	0	0	0
Polysiphonia brodiei	Polysiphonia	0	0	0	0	0	0	2	0	0	0	0	0	0
Polysiphonia elongata	Polysiphonia	0	0	0	0	0	0	0	0	0	0	1	0	0
Melanothamnus harveyi	Polysiphonia	0	0	0	0	0	0	0	0	0	0	0	0	1
Vertebrata nigra	Polysiphonia	0	0	1	0	0	0	0	0	0	0	0	0	0
Vertebrata fucoides	Vertebrata fucoides	14	7	17	10	14	19	16	11	10	15	17	15	19
Phaeophyceae (enc)	Phaeophyceae (enc)	3	1	0	0	0	0	0	1	0	1	0	0	1
Phaeophyceae (fil)	Phaeophyceae (fil)	0	1	0	0	1	0	6	0	0	0	0	0	0
Phaeophyceae (sporeling)	Phaeophyceae (sporeling)	0	7	0	0	0	0	0	0	0	0	0	0	0
Ectocarpaceae	Ectocarpaceae	5	0	1	1	0	0	0	0	0	0	0	0	2
Ectocarpus fasciculatus	Ectocarpaceae	0	0	0	0	0	0	0	0	0	0	8	0	0
Ectocarpus siliculosus	Ectocarpaceae	0	0	0	0	2	0	0	0	0	0	2	0	0
Hincksia	Hincksia (Giffordia)	3	0	0	0	0	0	0	0	0	0	0	0	0
Pylaiella littoralis	Pylaiella littoralis	0	0	0	0	0	1	0	0	0	0	0	1	0
Ralfsia	Ralfsia	0	0	0	0	1	0	0	1	0	3	2	0	5
Elachista fucicola	Elachista fucicola	2	0	1	2	4	1	0	0	0	0	1	1	3
Leathesia marina	Leathesia marina	3	0	1	0	3	0	0	0	0	0	0	0	0
Eudesme	Eudesme	3	0	0	0	0	0	0	0	0	0	0	0	0
Sphacelaria	Sphacelaria	0	0	0	0	0	3	0	0	0	0	0	0	0
Halopteris filicina	Halopteris filicina	0	0	0	0	0	0	0	1	0	0	0	0	0
Cladostephus spongiosus	Cladostephus spongiosus	8	12	13	12	10	20	21	38	29	31	20	17	29
Dictyota dichotoma	Dictyota dichotoma	16	2	10	3	17	17	0	5	5	4	15	8	9
Punctaria tenuissima	Punctaria tenuissima	0	0	0	0	2	0	2	0	0	0	0	0	0
Dictyosiphon	Dictyosiphon	1	0	2	1	0	0	0	0	0	0	0	0	0
Dictyosiphon chordaria	Dictyosiphon chordaria	0	0	0	0	2	0	0	0	0	0	0	0	0
Colpomenia peregrina	Colpomenia peregrina	0	0	0	0	0	0	0	0	0	0	3	0	0
Scytosiphon lomentaria	Scytosiphon lomentaria	0	0	0	1	1	0	0	0	0	0	4	0	0
Chorda filum	Chorda filum	1	0	0	0	0	0	0	0	0	0	0	0	0
Laminaria (sporeling)	Laminaria (sporeling)	0	0	1	0	0	0	0	0	0	0	0	1	0
Laminaria digitata	Laminaria digitata	0	0	0	0	0	0	1	0	0	0	0	0	0
Fucaceae (sporeling)	Fucaceae (sporeling)	0	1	0	12	0	0	1	42	26	37	36	34	45
Fucus serratus	Fucus serratus	3	2	3	2	0	0	8	3	7	12	9	9	9
Fucus vesiculosus	Fucus vesiculosus	45	39	37	34	42	45	42	38	37	39	38	37	46
Bifurcaria bifurcata	Bifurcaria bifurcata	0	0	0	0	0	0	1	0	0	0	0	0	0
Chlorophyta (fil)	Chlorophyta (fil)	0	0	0	0	0	0	0	0	0	5	0	0	0
Chlorophyta (fuzz)	Chlorophyta (fuzz)	0	0	0	0	0	0	0	7	0	0	0	0	0

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Chlorophyta (turf) [Agg]	Chlorophyta (non-enc) [Agg]	43	20	34	45	44	29	35	52	36	46	45	39	43
Ulothrix flacca	Ulothrix flacca	0	0	0	0	0	0	3	0	0	0	0	0	0
Ulva (tubular)	Ulva (tubular)	19	0	5	9	12	4	3	20	11	14	9	14	20
Ulva clathrata	Ulva (tubular)	0	0	0	0	0	0	0	0	0	0	1	0	0
Ulva intestinalis	Ulva (tubular)	0	0	7	0	2	9	9	0	2	2	0	0	0
Ulva linza	Ulva (tubular)	0	0	0	0	1	0	0	0	0	0	1	0	5
Ulva prolifera	Ulva (tubular)	0	0	0	1	2	1	4	0	1	3	2	9	0
Ulva (flat)	Ulva (flat)	0	0	0	0	5	3	0	25	15	18	16	17	24
Ulva lactuca	Ulva (flat)	5	6	9	8	6	1	15	0	0	3	2	0	0
Ulva pseudocurvata	Ulva (flat)	0	0	0	0	8	8	2	0	2	5	0	0	1
Ulva rigida	Ulva (flat)	0	0	0	0	1	0	0	0	0	0	1	0	0
Monostroma grevillei	Monostroma grevillei	0	0	0	0	0	0	5	0	0	0	0	0	0
Chaetomorpha linum	Chaetomorpha linum	0	0	11	19	15	18	11	19	24	11	10	12	26
Chaetomorpha ligustica	Chaetomorpha ligustica	17	1	1	27	22	11	4	2	0	4	10	5	3
Chaetomorpha melagonium	Chaetomorpha melagonium	0	4	0	0	0	0	0	0	0	0	1	0	0
Cladophora	Cladophora	36	7	1	1	4	0	0	0	0	0	0	0	0
Cladophora albida	Cladophora	0	0	0	0	0	0	0	0	0	1	0	0	0
Cladophora laetevirens	Cladophora	0	0	7	1	0	0	1	1	0	0	0	0	0
Cladophora rupestris	Cladophora rupestris	0	0	0	0	0	0	0	0	0	1	1	0	2
Cladophora sericea	Cladophora	0	0	21	31	34	30	24	39	21	30	44	29	35
Bryopsis hypnoides	Bryopsis hypnoides	0	0	0	0	0	0	0	0	0	0	1	0	0
Bryopsis plumosa	Bryopsis plumosa	0	0	0	0	0	0	0	0	0	0	1	0	0
Verrucaria	Verrucaria	0	0	0	0	0	0	17	0	0	0	0	0	0
Verrucaria (green)	Verrucaria	19	18	21	21	15	24	0	13	17	19	6	10	19
Verrucaria (black)	Verrucaria	0	0	0	0	4	0	0	3	7	0	3	0	0
Pyrenocollema halodytes	Pyrenocollema halodytes	0	0	0	0	0	0	0	0	0	0	0	2	4

Appendix 4 Multivariate analyses results

More detailed results from multivariate analyses summarised in Section 3.2.3

ANOSIM: Site x Period (presence / absence data)

Analysis of Similarities (see Section 3.2.3)

Two-Way Analysis – Site x Period

Data – Bray-Curtis similarities derived from presence/absence data for 137 taxa. Excludes data for Station C1 (as unrepresentative of the *Sabellaria* reef).

Factors: Site (unordered): Aberaeron & Cei Bach x Period (unordered): Early (2007-10), Middle (2011-15) and Late (2016-19)

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.482

Significance level of sample statistic: 0.1%

Number of permutations: 999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Tests for differences between unordered Period groups

Global Test

Sample statistic (R): 0.127

Significance level of sample statistic: 0.1%

Number of permutations: 999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Early, Middle	0.096	0.1	Very large	999	0
Early, Late	0.243	0.1	Very large	999	0
Middle, Late	0.068	0.1	Very large	999	0

ANOSIM: Site x Period (%cover data)

Analysis of Similarities (see Section 3.2.3)

Two-Way Analysis – Site x Period

Data – Bray-Curtis similarities derived from square root transformed data for 77 taxa. Excludes data for Station C1 (as unrepresentative of the *Sabellaria* reef).

Factors: Site (unordered): Aberaeron & Cei Bach x Period (unordered): Early (2007-10), Middle (2011-15) and Late (2016-19)

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.38

Significance level of sample statistic: 0.1%

Number of permutations: 999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Tests for differences between unordered Period groups

Global Test

Sample statistic (R): 0.09

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Significance level of sample statistic: 0.1%

Number of permutations: 999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Early, Middle	0.007	0.1	Very large	999	0
Early, Late	0.141	0.1	Very large	999	0
Middle, Late	0.071	0.1	Very large	999	0

SIMPER: Site x Period (presence / absence data)

Similarity Percentages - species contributions (see Section 3.2.3)

Two-Way Analysis – Site (Aberaeron & Cei Bach) x Period (Early (2007-10), Middle (2011-15) and Late (2016-19))

Data – % cover data for 137 taxa. Excl. data for Station C1.

Analysis parameters: S17 Bray-Curtis similarity; Cut off for low contributions: 70.00%

Factor Groups: Site: Aberaeron & Cei Bach. Average dissimilarity = 49.94

Species	Group Aberaeron		Group Cei Bach		Contrib%	Cum.%
	Av.Abund	Av.Abund	Av.Diss	Diss/SD		
Ulva (tubular)	0.10	0.62	1.91	1.17	3.82	3.82
Corallina	0.92	0.48	1.87	0.99	3.73	7.55
Ulva (flat)	0.15	0.61	1.82	1.11	3.65	11.20
Lanice conchilega	0.43	0.74	1.74	1.00	3.49	14.69
Osmundea hybrida	0.66	0.50	1.73	0.97	3.47	18.16
Cladophora	0.67	0.48	1.71	0.96	3.43	21.59
Steromphala umbilicalis	0.92	0.52	1.71	0.91	3.43	25.02
Osmundea pinnatifida	0.85	0.54	1.69	0.90	3.38	28.40
Dumontia contorta	0.62	0.38	1.68	0.95	3.36	31.76
Patella vulgata	0.49	0.28	1.62	0.95	3.24	35.00
Ceramium	0.39	0.50	1.61	0.94	3.23	38.23
Spirobranchus	0.48	0.34	1.60	0.93	3.20	41.43
Littorina obtusata/fabalis	0.45	0.30	1.58	0.92	3.16	44.59
Cladostephus spongiosus	0.44	0.36	1.53	0.89	3.07	47.66
Hildenbrandia rubra	0.58	0.39	1.52	0.87	3.05	50.71
Vertebrata fucoides	0.29	0.32	1.40	0.84	2.80	53.51
Verrucaria	0.27	0.34	1.39	0.82	2.79	56.30
Corallinaceae (enc)	0.97	0.68	1.33	0.69	2.66	58.96
Chaetomorpha linum	0.37	0.10	1.28	0.78	2.56	61.52
Chondrus crispus	0.95	0.74	1.10	0.60	2.21	63.73
Fucus vesiculosus	0.91	0.73	1.09	0.64	2.19	65.92
Fucaceae (sporeling)	0.40	0.27	1.05	0.65	2.10	68.02
Naviculales (colonial diatoms)	0.02	0.34	1.02	0.70	2.04	70.07

Factor Groups: Period: Early & Middle. Average dissimilarity = 41.55

Species	Group Early		Group Middle		Contrib%	Cum.%
	Av.Abund	Av.Abund	Av.Diss	Diss/SD		
Hildenbrandia rubra	0.23	0.54	1.78	1.05	4.28	4.28
Dumontia contorta	0.68	0.40	1.74	0.99	4.19	8.47
Osmundea hybrida	0.58	0.58	1.67	0.94	4.01	12.49
Lanice conchilega	0.61	0.45	1.65	0.92	3.98	16.47
Cladophora	0.53	0.59	1.62	0.93	3.90	20.37

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Spirobranchus	0.47	0.38	1.62	0.96	3.90	24.27
Littorina obtusata/fabalis)	0.35	0.44	1.59	0.94	3.84	28.11
Patella vulgata	0.47	0.40	1.59	0.93	3.83	31.93
Cladostephus spongiosus	0.25	0.45	1.58	0.95	3.81	35.74
Ceramium	0.36	0.41	1.56	0.91	3.76	39.50
Verrucaria	0.33	0.34	1.45	0.82	3.49	42.99
Vertebrata fucoides	0.27	0.30	1.36	0.83	3.27	46.26
Chaetomorpha linum	0.16	0.36	1.33	0.83	3.20	49.46
Osmundea pinnatifida	0.78	0.73	1.17	0.67	2.81	52.27
Chaetomorpha ligustica	0.22	0.16	1.05	0.67	2.52	54.79
Ulva (flat)	0.15	0.32	1.01	0.63	2.43	57.22
Fucaceae (sporeling)	0.07	0.25	0.99	0.63	2.38	59.60
Dictyota dichotoma	0.17	0.18	0.97	0.66	2.34	61.94
Steromphala umbilicalis	0.78	0.72	0.92	0.57	2.22	64.16
Ulva (tubular)	0.22	0.29	0.90	0.57	2.16	66.32
Corallina	0.83	0.73	0.86	0.54	2.07	68.39
Polyplacophora	0.15	0.14	0.85	0.59	2.05	70.44

Factor Groups: Period: Early & Late. Average dissimilarity = 41.43

Species	Group Early		Group Late		Contrib%	Cum.%
	Av.Abund	Av.Abund	Av.Diss	Diss/SD		
Fucaceae (sporeling)	0.07	0.77	2.35	1.68	5.66	5.66
Hildenbrandia rubra	0.23	0.77	2.07	1.36	4.99	10.65
Cladostephus spongiosus	0.25	0.52	1.56	0.99	3.76	14.41
Spirobranchus	0.47	0.45	1.52	0.96	3.67	18.08
Osmundea hybrida	0.58	0.67	1.52	0.94	3.67	21.75
Patella vulgata	0.47	0.40	1.52	0.96	3.67	25.42
Ceramium	0.36	0.52	1.52	0.95	3.66	29.08
Cladophora	0.53	0.70	1.51	0.93	3.64	32.72
Dumontia contorta	0.68	0.58	1.45	0.90	3.50	36.22
Littorina obtusata/fabalis)	0.35	0.40	1.45	0.93	3.50	39.72
Lanice conchilega	0.61	0.57	1.38	0.87	3.32	43.04
Vertebrata fucoides	0.27	0.34	1.22	0.80	2.95	45.99
Verrucaria	0.33	0.20	1.22	0.79	2.94	48.92
Ulva (flat)	0.15	0.42	1.12	0.74	2.69	51.62
Chaetomorpha linum	0.16	0.30	1.11	0.77	2.69	54.31
Carcinus maenas	0.12	0.29	1.05	0.72	2.54	56.84
Osmundea pinnatifida	0.78	0.73	1.03	0.67	2.48	59.33
Dictyota dichotoma	0.17	0.19	0.93	0.67	2.25	61.57
Chaetomorpha ligustica	0.22	0.12	0.87	0.62	2.09	63.66
Corallina	0.83	0.76	0.80	0.55	1.93	65.59
Ulva (tubular)	0.22	0.30	0.71	0.54	1.72	67.31
Phorcus lineatus	0.20	0.08	0.68	0.52	1.65	68.96
Fucus vesiculosus	0.86	0.83	0.68	0.50	1.64	70.60

Factor Groups: Period: Middle & Late. Average dissimilarity = 39.35

Species	Group Middle		Group Late		Contrib%	Cum.%
	Av.Abund	Av.Abund	Av.Diss	Diss/SD		
Fucaceae (sporeling)	0.25	0.77	1.92	1.26	4.88	4.88
Cladostephus spongiosus	0.45	0.52	1.53	0.97	3.90	8.78
Ceramium	0.41	0.52	1.53	0.95	3.90	12.68
Lanice conchilega	0.45	0.57	1.50	0.93	3.81	16.48
Spirobranchus	0.38	0.45	1.47	0.95	3.75	20.23

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Littorina obtusata/fabalis)	0.44	0.40	1.47	0.94	3.73	23.96
Dumontia contorta	0.40	0.58	1.46	0.92	3.71	27.67
Patella vulgata	0.40	0.40	1.44	0.93	3.65	31.32
Hildenbrandia rubra	0.54	0.77	1.37	0.84	3.47	34.79
Cladophora	0.59	0.70	1.36	0.85	3.47	38.26
Osmundea hybrida	0.58	0.67	1.36	0.85	3.46	41.72
Vertebrata fucoides	0.30	0.34	1.35	0.86	3.44	45.15
Chaetomorpha linum	0.36	0.30	1.31	0.87	3.34	48.49
Verrucaria	0.34	0.20	1.14	0.77	2.90	51.40
Carcinus maenas	0.12	0.29	1.04	0.72	2.64	54.04
Dictyota dichotoma	0.18	0.19	0.94	0.68	2.39	56.42
Osmundea pinnatifida	0.73	0.73	0.90	0.62	2.29	58.72
Ulva (flat)	0.32	0.42	0.88	0.60	2.24	60.95
Fucus vesiculosus	0.86	0.83	0.76	0.53	1.94	62.89
Chaetomorpha ligustica	0.16	0.12	0.75	0.58	1.90	64.79
Steromphala umbilicalis	0.72	0.87	0.72	0.51	1.82	66.61
Corallina	0.73	0.76	0.69	0.49	1.76	68.37
Ulva (tubular)	0.29	0.30	0.69	0.51	1.74	70.11

SIMPER: Site x Period (% cover data)

Similarity Percentages - species contributions (see Section 3.2.3)

Two-Way Analysis – Site (Aberaeron & Cei Bach) x Period (Early (2007-10), Middle (2011-15) and Late (2016-19))

Data – % cover data for 77 taxa. Excl. data for Station C1.

Analysis parameters: S17 Bray-Curtis similarity; Cut off for low contributions: 70.00%

Factor Groups: Site: Aberaeron & Cei Bach. Average dissimilarity = 56.39

Species	Group Aberaeron		Group Cei Bach		Contrib%	Cum.%
	Av.Abund	Av.Abund	Av.Diss	Diss/SD		
Fucus vesiculosus	5.18	3.56	9.20	1.32	16.31	16.31
Sabellaria (live)	5.79	4.77	8.47	1.18	15.02	31.34
Corallina	1.97	0.50	4.34	1.10	7.69	39.03
Chondrus crispus	1.96	1.27	3.92	1.20	6.94	45.97
Corallinaceae (enc)	1.69	0.60	3.27	1.22	5.80	51.77
Ulva (flat)	0.07	1.13	2.49	0.65	4.41	56.19
Osmundea pinnatifida	0.98	0.69	2.31	1.14	4.10	60.29
Ceramium	0.42	0.75	1.93	0.86	3.43	63.71
Dumontia contorta	0.76	0.32	1.84	0.77	3.27	66.98
Vertebrata fucoides	0.36	0.55	1.76	0.66	3.12	70.11

Factor Groups: Period: Early & Middle. Average dissimilarity = 46.69

Species	Group Early		Group Middle		Contrib%	Cum.%
	Av.Abund	Av.Abund	Av.Diss	Diss/SD		
Sabellaria (live)	5.21	5.99	7.69	1.14	16.47	16.47
Fucus vesiculosus	4.40	5.14	7.61	1.20	16.29	32.76
Corallina	1.49	1.54	3.60	1.17	7.71	40.48
Chondrus crispus	1.88	1.67	3.51	1.21	7.53	48.00
Corallinaceae (enc)	1.48	1.18	2.42	1.10	5.17	53.18
Dumontia contorta	0.93	0.47	2.32	0.92	4.97	58.15
Osmundea pinnatifida	1.04	0.89	2.22	1.09	4.75	62.90
Verrucaria	0.62	0.40	1.97	0.65	4.22	67.12
Ceramium	0.56	0.44	1.64	0.75	3.51	70.63

Factor Groups: Period: Early & Late. Average dissimilarity = 49.06

Species	Group		Av.Diss	Diss/SD	Contrib%	Cum.%
	Early	Late				
Sabellaria (live)	5.21	4.99	7.60	1.24	15.49	15.49
Fucus vesiculosus	4.40	4.23	7.53	1.31	15.35	30.84
Corallina	1.49	1.38	3.65	1.13	7.45	38.29
Chondrus crispus	1.88	1.65	3.56	1.21	7.27	45.55
Fucaceae (sporeling)	0.09	1.06	2.60	1.04	5.30	50.85
Corallinaceae (enc)	1.48	1.34	2.52	1.18	5.14	55.99
Dumontia contorta	0.93	0.48	2.21	0.92	4.50	60.49
Osmundea pinnatifida	1.04	0.71	2.05	1.12	4.19	64.67
Ceramium	0.56	0.60	1.77	0.81	3.60	68.27
Verrucaria	0.62	0.19	1.75	0.61	3.57	71.85

Factor Groups: Period: Middle & Late. Average dissimilarity = 46.97

Species	Group		Av.Diss	Diss/SD	Contrib%	Cum.%
	Middle	Late				
Fucus vesiculosus	5.14	4.23	8.00	1.28	17.03	17.03
Sabellaria (live)	5.99	4.99	7.16	1.22	15.25	32.28
Corallina	1.54	1.38	3.55	1.08	7.56	39.85
Chondrus crispus	1.67	1.65	3.32	1.14	7.07	46.92
Fucaceae (sporeling)	0.33	1.06	2.46	1.06	5.23	52.15
Corallinaceae (enc)	1.18	1.34	2.35	1.17	5.01	57.16
Osmundea pinnatifida	0.89	0.71	1.82	1.04	3.88	61.03
Cladostephus spongiosus	0.54	0.55	1.73	0.93	3.69	64.73
Hildenbrandia rubra	0.53	0.68	1.62	0.93	3.46	68.18
Dumontia contorta	0.47	0.48	1.56	0.84	3.32	71.50

Appendix 5 Data archive

Data outputs associated with this project are archived in the NRW Document Management System on server-based storage at Natural Resources Wales.

The data archive contains:

- [A] The final report in Microsoft Word and Adobe PDF formats.
- [B] Excel spreadsheets of data, including validation data, verification data and metadata.
- [C] A NBN data file containing the relevant survey details.
- [D] A Marine Recorder snapshot of the survey for NRW validation purposes.
- [E] A full set of images from the survey, in jpg format,

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue <http://libcat.naturalresources.wales/webview/> (English Version) and <http://libcat.naturalresources.wales/cnc/> (Welsh Version) by searching 'Dataset Titles'. The metadata is held as record within [Intertidal Monitoring](#).



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