Cyfoeth Naturiol Cymru
Natural Resources Wales

Menai Strait and Conwy Bay SAC intertidal monitoring of tide-swept *Fucus serratus* epibiota, 2009-2019

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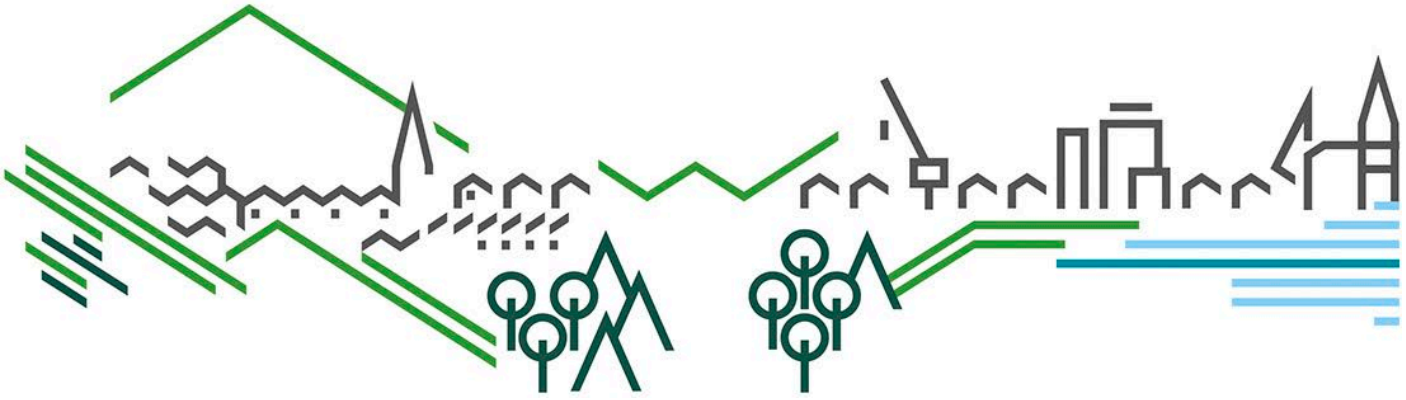
Jon Moore

Aquatic Survey & Monitoring Ltd.



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Contents

List of Figures

List of Tables

Crynodeb Gweithredol

Yng Nghymru, mae'n ofynnol i Cyfoeth Naturiol Cymru (CNC) roi adroddiadau rheolaidd sy'n nodi a yw nodweddion Ardaloedd Cadwraeth Arbennig (ACA) mewn statws cadwraeth ffafriol. Yn ACA Afon Menai a Bae Conwy, mae CNC a'i gontractwyr wedi datblygu rhaglenni i fonitro cyflwr nodweddion.

Ymhlith y meysydd penodol sydd o ddiddordeb mae gwastadeddau llaid a gwastadeddau tywod a riffiau a ysgubir gan y llanw (gan gynnwys clogfeini) o fewn Afon Menai, lle ceir amrywiaeth uchel o rywogaethau mewn rhai nodweddion. Mae'r adroddiad hwn yn disgrifio rhaglen fonitro a gynhaliwyd ar gymunedau o epibiota sy'n glynu at forwiail danheddog *Fucus serratus* a ysgubir gan y llanw ac sy'n tyfu ar glogfeini a choblau. Dechreuodd y rhaglen yn 2009 ac mae wedi cael ei hailadrodd bron bob blwyddyn. Mae adroddiadau blaenorol wedi disgrifio prif nodweddion y cymunedau; mae'r adroddiad hwn yn disgrifio canlyniadau dadansoddiadau amserol ar gyfer y cyfnod 2009 i 2019.

Defnyddiwyd planhigion unigol (thali) *Fucus serratus* ar safleoedd ar y lan isaf ger Brynsiencyn fel unedau samplu ar gyfer cofnodi rhywogaethau epibiota amlwg. Mae'r cymunedau hyn yn agored i newidiadau mewn amodau hydrodynamig ac ansawdd dŵr. Arolygwyd thali lluosog mewn tri safle monitro i fonitro cyflwr y cymunedau. Defnyddiwyd gweithdrefnau Sicrhau Ansawdd a Rheoli Ansawdd i leihau anghysondebau wrth gofnodi; serch hynny, roedd rhai anghysondebau o hyd ac fe'u disgrifir yn yr adroddiad.

Dyma ganlyniadau mwyaf nodedig y dadansoddiadau amserol:

i) Roedd canran gorchudd *Fucus serratus* yn yr ardaloedd a arolygwyd yn amrywio ond heb unrhyw dueddiadau amlwg. Yn yr un modd, ni welwyd unrhyw dueddiadau yn yr amrywiadau yn hyd y thali.

ii) Mae canran gorchudd yr epibiota ar thali *F. serratus* yn awgrymu amrywiadau tymhorol mawr a thueddiad o ostyngiad mewn gorchudd ar ddau safle. Fodd bynnag, mae hyder yng nghywirdeb y fethodoleg yn isel a gallai fod llawer o ffactorau dryslyd eraill. Awgrymir y dylid adolygu'r fethodoleg.

iii) Roedd cydberthynas gadarnhaol rhwng cyfoeth tacsonomaidd a hyd y thalws (nid yw hyn yn syndod), ond roedd cryn amrywiaeth a gwahaniaethau rhwng y safleoedd.

iv) Dengys dadansoddiad amserol o gyfoeth rhywogaethol rai amrywiadau ond canfuodd hefyd duedd ystadegol arwyddocaol o leihad mewn cyfoeth yn y ddau safle yn Llanidan. Awgrymir y dylid cynnal astudiaethau pellach i asesu dilysrwydd y canlyniad hwnnw.

v) Mae dadansoddiadau aml-amrywedd yn dangos y gwahaniaethau rhwng y tri safle ond ni chanfuwyd unrhyw dueddiadau amserol clir.

vi) Disgrifiwyd amrywiadau amserol o ran amlder presenoldeb ar gyfer nifer o rywogaethau unigol, gyda llawer o amrywiaeth – h.y. cynnydd weithiau, gostyngiad weithiau gyda rhai clystyrau dwys ac absenoldebau nodedig – ond ychydig iawn o dystiolaeth o gydamseroldeb.

vii) Mae tuedd ymddangosiadol o ddirywiad yn nhoreithrwydd y bryosoad *Flustrellidra hispida* yn nodedig, yn bennaf oherwydd iddo gael ei adrodd gan eraill fel dangosydd posibl o ansawdd dŵr. Awgrymir y dylid cynnal astudiaethau pellach i asesu dilysrwydd y canlyniad hwnnw.

Mae anghysondeb o ran cofnodi rhwng (ac o fewn) syrfewyr yn bryder cyson yn y math hwn o fonitro. Mae'n amlwg bod y fethodoleg yn ddigonol i ganfod llawer o newidiadau amserol ond awgrymir y dylid ystyried adolygu'r fethodoleg. Amlygir pwysigrwydd parhau i ddefnyddio gweithdrefnau Sicrhau Ansawdd/Rheoli Ansawdd.

Aseswyd cyflwr y safleoedd fel a ganlyn:

Ansicr - mae nifer o newidiadau wedi digwydd yn y cymunedau sy'n cael eu monitro ers i'r rhaglen ddechrau yn 2009 ac mae'r rhan fwyaf yn cael eu hystyried yn amrywiadau naturiol. Fodd bynnag, nodwyd gostyngiad bach ond ystadegol arwyddocaol yn y cyfoeth rhywogaethol a gofnodwyd ar safleoedd Llanidan.

Executive Summary

In Wales, Natural Resources Wales (NRW) is required to report on a regular basis on whether features of Special Areas of Conservation (SACs) are in favourable conservation status. In Menai Strait and Conwy Bay SAC, programmes of feature condition monitoring have been developed by NRW and its contractors.

Specific areas of interest include mudflats and sandflats and tide-swept reefs (including boulders) within the Menai Strait, where some features are characterised by a high diversity of species. This report describes a monitoring programme carried out on communities of epibiota attached to tide-swept serrated wrack *Fucus serratus,* growing on boulders and cobbles. The programme began in 2009 and has been repeated almost annually. Previous reports have described the main characteristics of the communities; this report describes the results of temporal analyses for the period 2009 to 2019.

Individual plants (thalli) of *Fucus serratus* on lower shore sites near Brynsiencyn were used as sampling units for recording conspicuous species of epibiota. These communities are vulnerable to changes in hydrodynamic conditions and water quality. Multiple thalli within a defined area of the lower shore were surveyed at three monitoring sites to monitor the condition of the communities. Quality Assurance and Quality Control procedures were applied to minimise inconsistency of recording, though some inconsistencies remained and are described in the report.

The most notable results of the temporal analyses were:

viii) Percentage cover of *Fucus serratus* within the surveyed areas fluctuated but with no apparent trends. Similarly, fluctuations in lengths of thalli showed no trends.

ix) Percentage cover of epibiota on *F. serratus* thalli suggest large temporal fluctuations and an apparent trend of decreasing cover at two sites. However, confidence in the accuracy of the methodology is low and many other confounding factors may be involved. A review of the methodology is suggested.

x) Taxonomic richness was positively correlated with length of thallus (not surprisingly), but there was considerable variability and differences between the sites.

xi) Temporal analysis of species richness shows some fluctuations but also found a statistically significant trend of decreasing richness at both of the Llanidan sites. It is suggested that further studies are carried out to assess the validity of that result.

xii) Multivariate analyses show the differences between the three sites but found no clear temporal trends.

xiii) Temporal fluctuations in 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.

xiv) An apparent trend of decline in abundance of the bryozoan *Flustrellidra hispida* is notable, mainly because it has been reported elsewhere as a possible indicator of water quality. It is suggested that further studies are carried out to assess the validity of that result.

Inconsistency of recording between (and within) surveyors is a constant concern in this type of monitoring. It is clear that the methodology is sufficient to detect many temporal changes but it is suggested that a review of the methodology is considered. The importance of continued application of QA/QC procedures is highlighted.

The condition of the sites has been assessed as:

Uncertain - a number of changes have occurred in the monitored communities since the programme began in 2009 and most are considered to be natural fluctuations. However, a subtle but statistically significant decrease in recorded species richness at the Llanidan sites has been noted.

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. Regulation 9a of the Habitats Regulations (formerly Article 17 of the Birds and Habitats 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.

Menai Strait and Conwy Bay Special Area of Conservation (SAC) is designated for five Annex I habitats: *Sandbanks which are slightly covered by sea water all the time*, *Mudflats and sandflats not covered by seawater at low tide*, *Reefs*, *Large shallow inlets and bays* and *Submerged or partially submerged sea caves*. Conservation objectives for each feature are given in the Regulation 37 advice for the Menai Strait and Conwy Bay SAC (NRW 2018).

Fucus serratus dominates lower shore hard substrata in many areas of the SAC. In some areas of the Menai Strait, the *F. serratus* thalli are strongly tide-swept and characterised by a high diversity and abundance of epibiota (Seed 1985; Wood and Seed 1980). The epibiota typically comprise species from a wide variety of taxonomic groups, including bryozoa, ascidians, hydroids, barnacles, snails, spirorbid worms, red algae and green algae (see photos in Figure 1). The diversity and abundance of these species is dependent on environmental factors including the water quality and tidal regime. For example, it has recently been suggested that the sensitivity of the bryozoan *Flustrellidra hispida* to water quality could make it a useful indicator species (Little et al. 2018). Sites were selected for this monitoring programme in areas that were known to have good examples of the tide-swept *Fucus serratus* biotope (Phase 1 intertidal survey, (Brazier et al. 2007)) and which could be vulnerable to potentially significant changes in use (for example a proposed extension of the mussel fishery in the Menai Strait).

Figure 1 Examples of epibiota on tides-wept *Fucus serratus* in the Menai Strait.

The overall aim of the program is to establish reference conditions for the interest features of the SAC and to 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.

A programme to monitor these epibiota communities at sites near Brynsiencyn was initiated in 2009. Two monitoring sites were initially defined, at Castell Gwylan and Llanidan East and surveys were carried out. An additional monitoring site, Llanidan West, was added in 2010. Surveys were repeated at all three monitoring sites in 2011 and then annually from 2013 to 2019, with dates ranging from late June to early August. This report describes the results from all monitoring surveys up to June 2019. Monitoring survey protocols and species identification have developed and improved over the course of the programme, but not enough to compromise interpretation of the main temporal changes in the data.

The program objectives are:

- To monitor the composition of communities of epibiota present on tide-swept *Fucus serratus* at three locations in the Menai Strait.
- To assess the condition of those communities

This is relevant to the following Menai Strait and Conwy Bay SAC attributes (NRW 2018):

- Structure & Function: Species composition of reef biotopes in high energy tide-swept wave sheltered locations,
- Typical Species: Typical epiphytic species (variety and frequency of occurrence).

Other previous reports on this programme include Moore et al. (2010), Moore et al. (2017) and Moore (2018).

Moore et al. (2017) assessed the condition of the tide-swept *Fucus serratus* epibiota communities at these monitoring sites and gave the following assessment:

> **Condition (2017)** - Recorded changes in species richness, species composition and frequencies do not indicate any trends of concern and appear to be within normal range of natural fluctuations.

2 Methods

2.1 Data collection

A summary of the methodology is given below. Detailed methodologies and protocols are given in Moore and Brazier (2016) (common procedures) and Moore 2016 (*Fucus serratus* epibiota). They include rationale, site details, methods, protocols, proformas, equipment lists, quality assurance and quality control procedures and modifications that have been made to the methods over the course of the programme up to and including 2016.

Figure 2 shows the locations of the monitoring sites. Monitoring surveys were normally carried out in June or July each year, during a five day survey period in which surveys of various other sites and features in the SAC were also carried out. Field logs for each annual survey (available from NRW or ASML on request) describe the work carried out, including dates, times and surveyors. A summary is given in Appendix 1.

A handheld GPS was used to find the previously surveyed monitoring site during a period of low spring tide and an area of 5m x 5m was marked out with a tape measure. The percentage cover of *Fucus serratus* in this area was estimated and recorded. A quadrat (0.25 m^2) was randomly placed within the 5 m x 5 m survey box, using tape measure distance and paces. Estimates of the percentage cover of *Fucus serratus* and the thickness of silt on rocks in the quadrat were recorded. Up to five *Fucus serratus* thalli that had their holdfasts attached within the quadrat were randomly selected. The percentage cover of epibiota on each thallus was estimated and all conspicuous epibiota taxa present were identified and recorded (presence only). This was then repeated for as many quadrats as could be done before the tide covered the survey box (see Figure 3).

The quality of the data from these monitoring surveys is reliant on the surveyors' experience, *in situ* identification skills and thoroughness. Quality assurance (QA) procedures have included pre-survey training and familiarisation. The same experienced individuals have carried out most of the surveys. Quality control (QC) procedures have included some (limited) repeated recording of selected *Fucus serratus* thalli by different surveyors (see Section 2.3 and Appendix 4). However, significant inconsistencies between surveyors, and by the same surveyors between surveys, are possible.

Figure 2 Locations of the monitoring sites: ● Castell Gwylan, ■ Llanidan East, ▲ Llanidan West. Maps based upon Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2023].

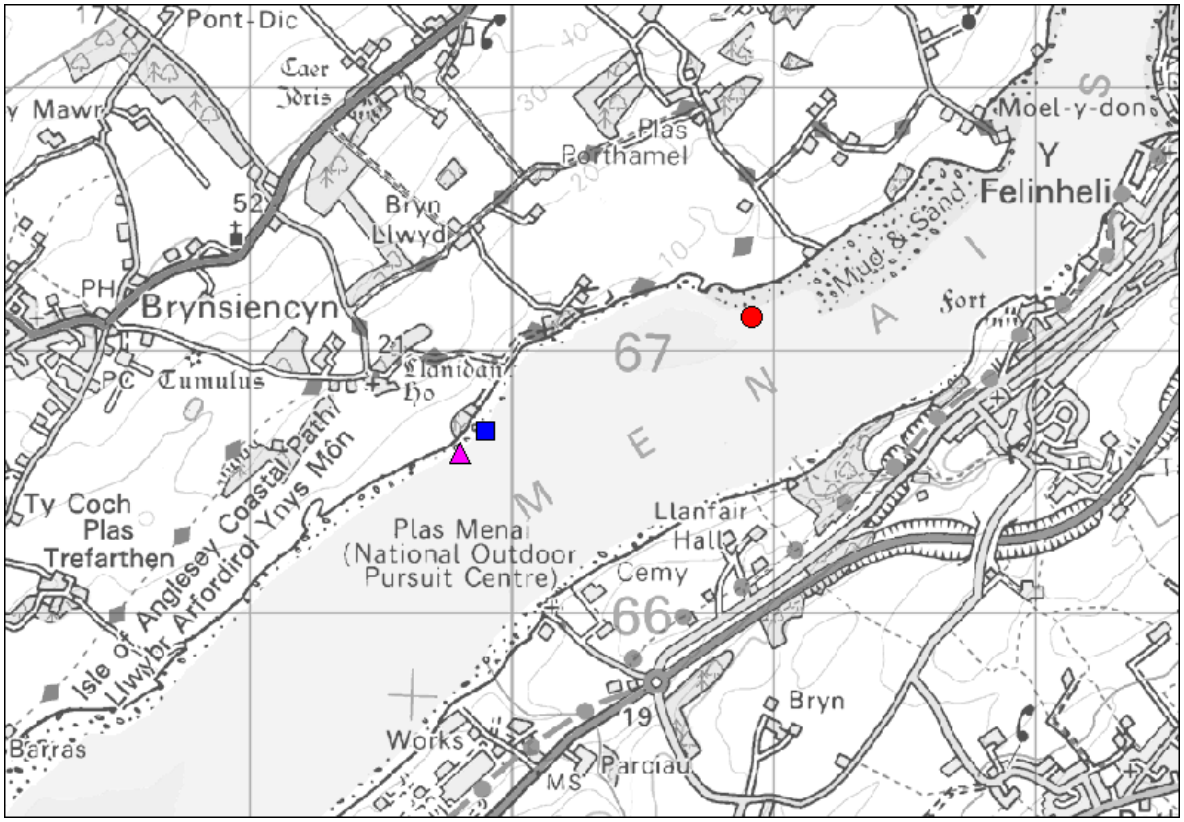


Figure 3 Surveying *Fucus serratus* epibiota at Llanidan.

2.2 Data management and analysis

2.2.1 Data structure

Taxon abundance data and all associated metadata are stored in a bespoke Microsoft Access relational database allowing flexible manipulation, querying, summarisation and export in required formats. A summary of the data structure is given in Appendix 3, including various metadata (attributes) that have been applied in the analyses.

The following key attribute data are linked to each taxon abundance record: Year, Site (CG, LE or LW), Quadrat (1 to 14), Thallus (1 to 6). Additional attribute data that have been used in analyses include: thallus length and estimated percentage cover of epibiota on each thallus.

The list of recorded taxa (*entities*) is carefully managed to provide a level of standardisation appropriate for long-term monitoring. Each *entity* is defined as a taxon (using the agreed taxonomic nomenclature provided by the WoRMS website) and any qualifiers (e.g. encrusting, juvenile, orange) that are typically recorded. A few new entities are routinely added to the list after each survey, but only if they are clearly different from those already on the list. Attribute data linked to each entity includes the AphiaID, taxonomic authority and classification details available from the WoRMS website, a taxon code based on the UK Marine Species Directory (used for sorting in a conventional taxonomic order), and tags for entities that are listed on the recording form and entities that are appropriate for temporal analysis. As some taxa are inconsistently recorded, each entity is also linked to a standardised higher entity that is more reliably recorded, allowing straightforward aggregation of abundance data for analysis.

2.2.2 Data analysis

Summary statistics and tabulation are 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 are also exported from the database. Multivariate analyses are carried out in PRIMER, primarily using the following routines and tools:

- Resemblance matrices with Bray-Curtis similarity
- MDS - non-metric Multi-Dimensional Scaling
- ANOSIM - Analysis of Similarity
- SIMPER – contribution of each taxon to the dissimilarities between groups of samples

Univariate analyses (including significance tests and Spearman rank correlation) were carried out in Excel.

The majority of the analyses are carried out on frequency of occurrence data (or % frequency of occurrence data to take account of the variable numbers of thalli surveyed). They are often presented as percentage occurrence – for example, in 2009 the sponge *Halisarca dujardini* was recorded from 26 of the 38 thalli surveyed = **68% occurrence**. Not to be confused with **percentage cover!**

2.3 Inconsistencies and confounding factors

Interpretation of the results must take account of various sources of potential error, including some that are inherent within the methodology, some improvements in recording protocols and also the increasing familiarity and recognition of the species present. The following considerations are particularly important:

- Recording in the early years of the programme was relatively less consistent, particularly for some species, e.g. distinguishing between *Alcyonidium* species , which some surveyors were not initially familiar with. Familiarity and routine training sessions greatly improved the recording of this and other such species as the programme progressed. These inconsistencies are, to a large extent, recognised and taken into consideration in this report; but significant errors are still possible.
- Limiting the number of thalli surveyed in each quadrat to a maximum of 5 could potentially result in some selection bias if more than 5 thalli are present in the quadrat. Thus, while surveyors attempted to select thalli in an unbiased way this could be difficult to apply. It is possible that some bias for or against large / small thalli or dense / light covering of epibiota may be present in some situations (e.g. when the tide is coming in!). This could affect average length and epibiota cover data and also the species record data. The extent of any such biases are unknown but it is assumed that they even out across all of the records within each year. The methodology states that the thallus should be at least 20 cm long, for recording. Some indication of the presence of other, undersized thalli in the recording may be useful in the future.
- Thallus size has an inevitable relationship with the thoroughness of recording and therefore on the consistency of recording. Some thalli are enormous, with many levels of branching, so that the surface area for potential epibiota attachment can be much more than a surveyor can effectively study in a reasonable length of time. Furthermore, thallus surface area is not necessarily well correlated with thallus length.

Section 2.1 mentions the QA/QC procedures, including training, which have been applied to improve consistency, but it is clear that inconsistency of recording between (and within) surveyors can still be high. Appendix 4 gives the results of a small exercise to measure consistency of recording by different surveyors on the same 2 thalli. While this is a concern, it should be appreciated that by surveying large numbers of thalli from each monitoring site the measure of abundance (frequency of occurrence) will be more robust, assuming that there is no bias in the surveyors recording.

3 Results

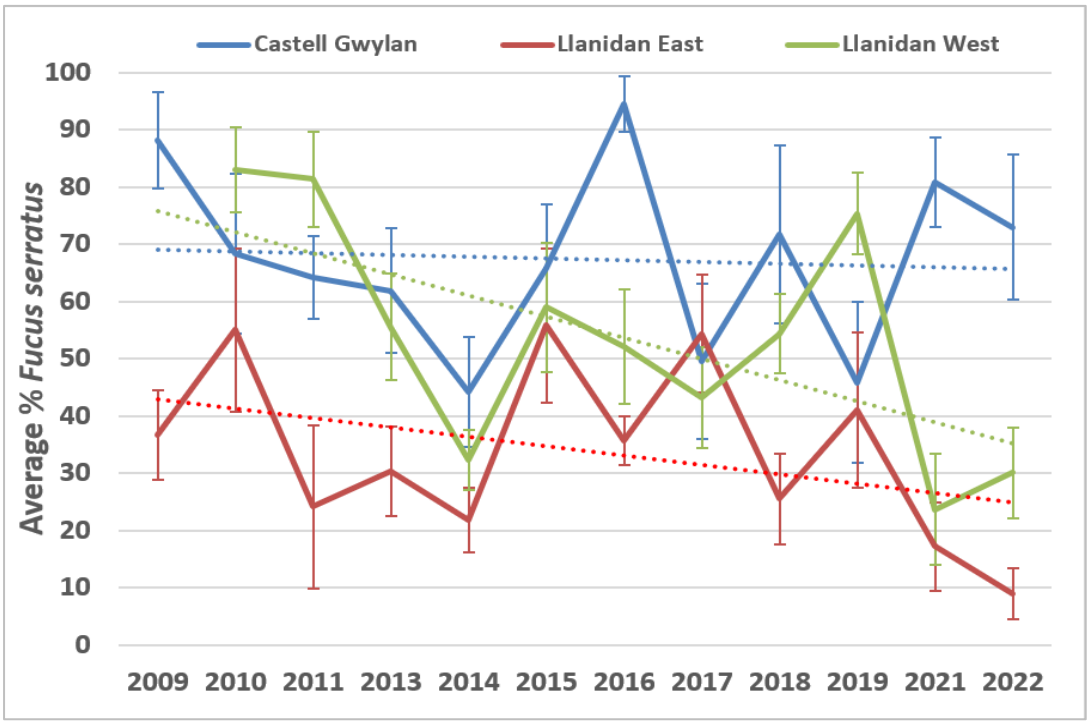
3.1 General description

Epibiota cover on the *Fucus serratus* thalli typically varies from thallus to thallus, with some thalli sparsely covered and others heavily covered. Size and age are factors, but the relationship is not always predictable. The most frequently occurring colonisers are Spirorbinae worms, encrusting bryozoans (particularly *Flustrellidra hispida*, *Alcyonidium hirsutum*, *Alcyonidium polyoum* / *gelatinosum* and *Electra pilosa*), snails (particularly flat winkles *Littorina obtusata* / *fabalis*), small barnacles *Balanus crenatus*, slimy brown sponge *Halisarca dujardinii*, star seasquirt *Botryllus schlosseri*, erect bryozoan *Amathia imbricata*, hydroid *Dynamena pumila*, flat green alga *Ulva*, various red algae (particularly *Osmundea oederi*, *Cystoclonium purpureum*, *Melanothamnus harveyi* and *Lomentaria articulata*) and brown algae (particularly *Elachista fucicola* and *Dictyota dichotoma*). There are some notable differences between the monitoring sites, with more *Alcyonidium polyoum* / *gelatinosum*, *Halisarca dujardinii* and *Amathia imbricata* at Castell Gwylan, and more red algae at the Llanidan sites (see Table 2. Species richness was generally higher at the Llanidan sites. Average thallus length was generally higher at Castell Gwylan.

3.2 *Fucus serratus* cover

The fluctuations in average percentage cover of *Fucus serratus* recorded from quadrats at each monitoring site is shown in Figure 4. The *F. serratus* cover was typically patchy at these sites and the number of quadrats surveyed was rarely enough to provide a good estimate of the actual mean, so the error bars are fairly large. Although there was a consistent decline up to 2014 at each site, with a subsequent increase, there are no significant temporal trends in the overall abundance of *F. serratus*.

Figure 4 Annual fluctuations in average percentage cover (± standard error) of *Fucus serratus* (recorded in quadrats) with trendlines, at the three monitoring sites.

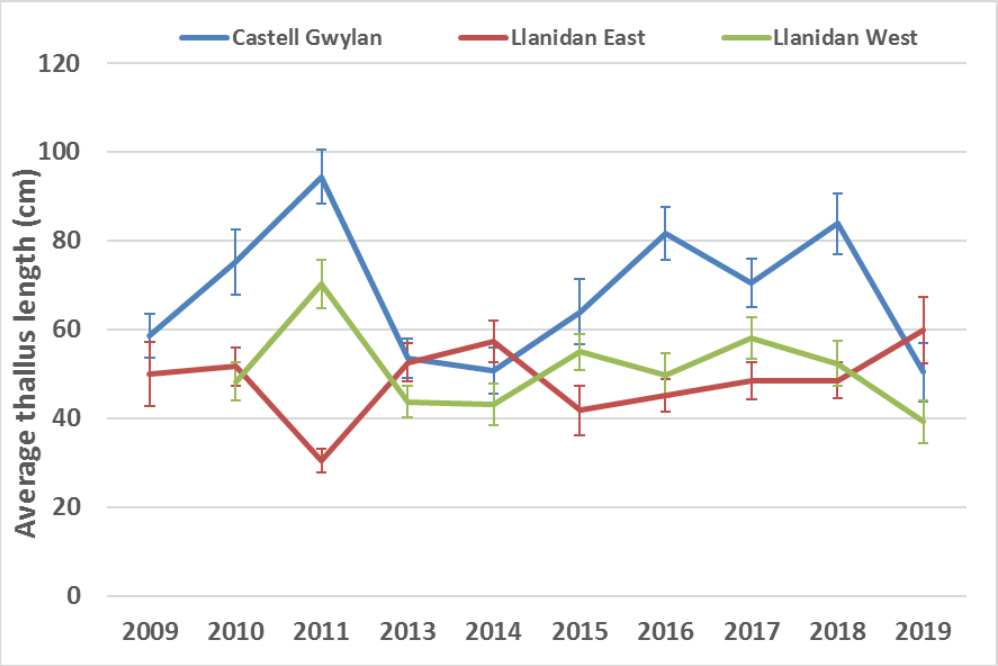


3.3 Thallus length and epibiota cover

Figure 5 shows the fluctuations in thallus length and differences between the three monitoring sites but none that can be considered a notable trend. As noted in Section 2.3, it is likely that the selection of thalli contained some elements of bias, so the apparent changes and differences are not reliable.

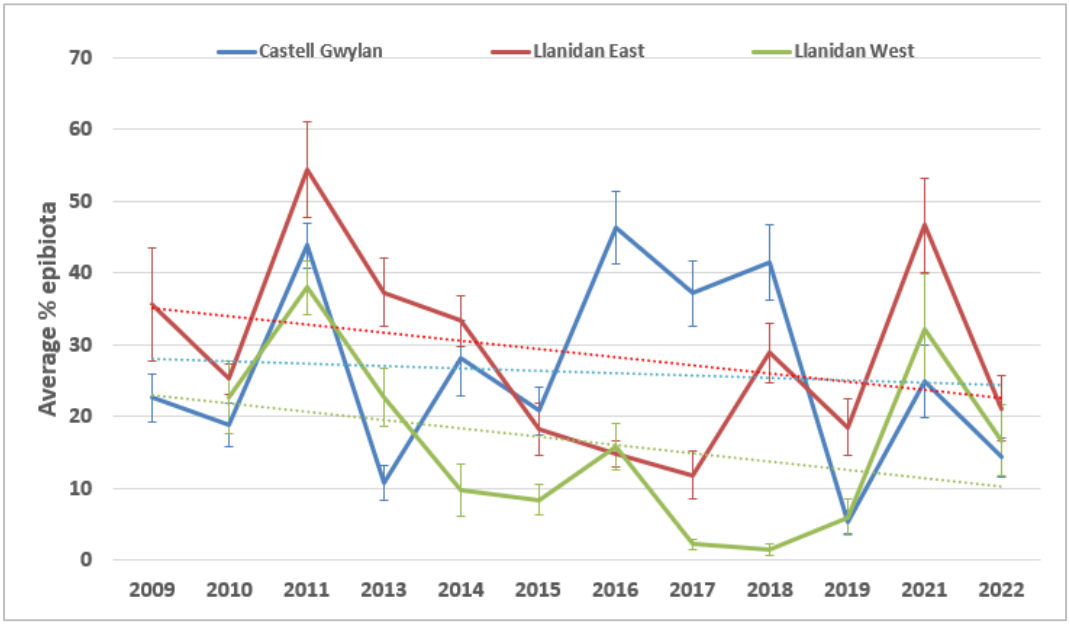
The estimation of percentage cover of epibiota on the thalli is difficult and also liable to recorder bias, so errors are likely. The results in Figure 6 must therefore be treated with caution. The graph suggests considerable temporal variability, particularly at Castell Gwylan, but also suggests a trend of decreasing cover at the Llanidan sites. Unfortunately, no supporting evidence is available (i.e. the available photographs cannot provide useful data), so it is not possible to confirm this trend. The variability is very high, with epibiota percentage cover consistently varying between near zero to over 60% on the same sampling occasion. The number of thalli recorded seems therefore to be insufficient to accurately represent the epibiota cover consistently.

Figure 5 Annual fluctuations in average thallus length (± standard error) at the three sites.



The relationship between percentage cover of epibiota and thallus length (which will be somewhat related to thallus age) has also been studied (graph not included here). It shows a very weak, but statistically significant, positive correlation between them (Adjusted R^2 = 0.027, N = 576, P <0.0001). The poor relationship is due to many factors which throw further doubt on the value of the percentage cover estimates for condition monitoring. This is discussed in Section 4.2.

Figure 6 Annual fluctuations in average percentage cover (± standard error) of epibiota on *Fucus serratus* thalli at the three monitoring sites.



3.4 Species richness

A total of 210 individual taxa (*entities*) have been recorded as epibiota on *Fucus serratus* in these monitoring surveys (2007 to 2019); 101 at Castell Gwylan, 152 at Llanidan East, 142 at Llanidan West. A full list of these taxa is given in Appendix 2. Note: analyses of species richness in this section have used data for the full list of recorded entities, not the aggregated list of more consistently recorded taxa.

Temporal analysis of species richness has considered both the total number of taxa recorded (by year and site) and the average number of taxa per thallus (by year and site).

Figure 7 shows that taxonomic richness is correlated with length of thallus and a least squares regression analysis finds that the correlation is statistically significant ($R^2 = 0.803$). However, it is also evident that there is considerable variability, with some small thalli colonised by more than 10 taxa while some long thalli have less than 10 taxa. The graph also shows some differences between the sites, with Llanidan East characterised by relatively more thalli with a high ratio of taxa to length, while Llanidan West appear to have relatively more long thalli with a low ratio. Note: as mentioned in Section 3.1, average thallus length was generally greatest at Castell Gwylan, but annual fluctuations occurred at all three sites, though there were no obvious temporal trends. The methodology does carry some potential for selection bias by the surveyors, when more than 5 thalli are attached within a quadrat, so some of the apparent differences between sites may not be real.

Temporal analysis of species richness has considered both the total number of taxa recorded (by year and site) and the average number of taxa per thallus (by year and site).

Figure 7 Relationship between thallus length and number of taxa recorded from it, categorised by site, including line of best fit (across all monitoring sites).

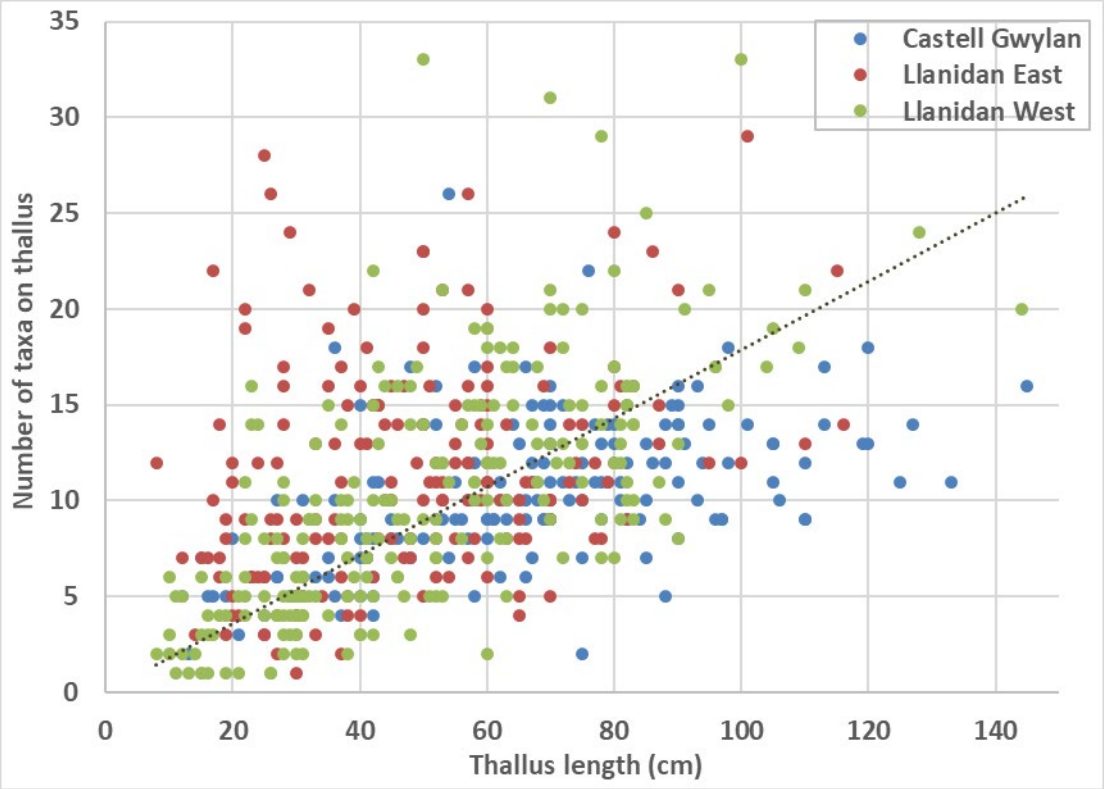


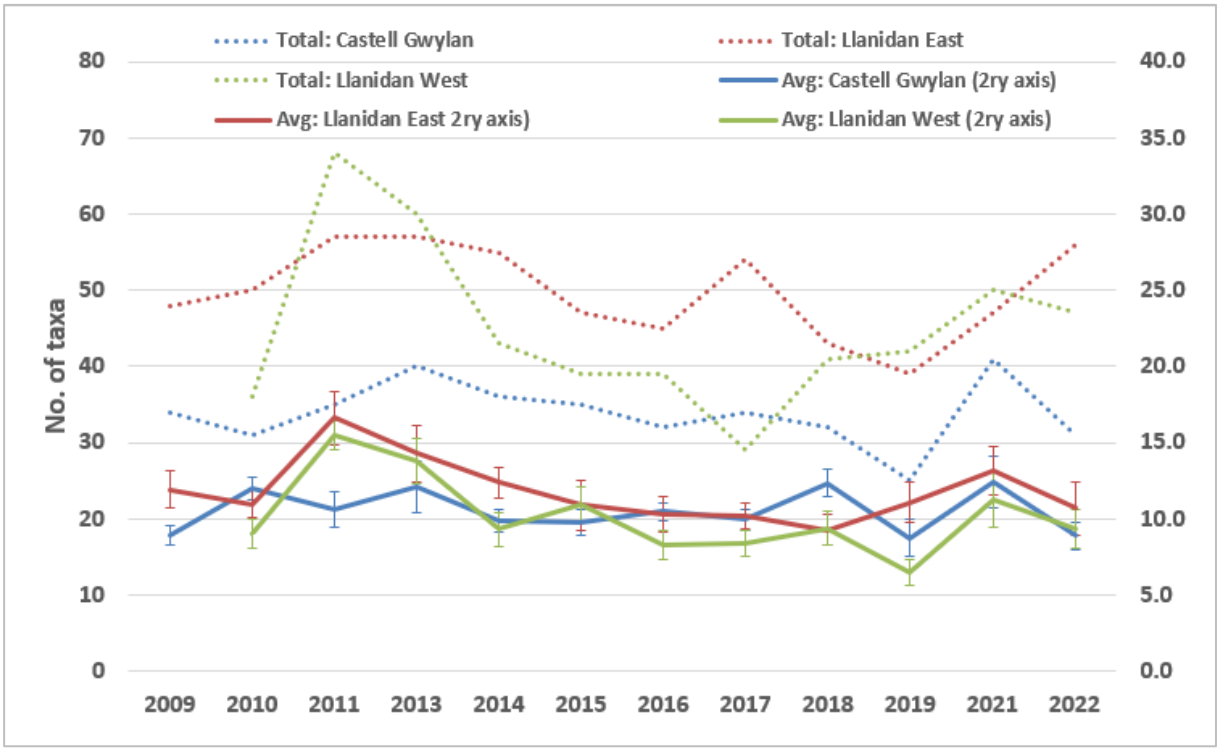
Figure 8 shows some fluctuations in average and total species richness over the ten years of the monitoring, particularly at Llanidan West. It also shows some slight trends of decreasing richness and regression analyses find that there is a statistically significant decrease in the average number of taxa recorded at both of the Llanidan sites, but not at Castell Gwylan.

Table 1 Regression analysis of average number of species over time (years)

	Adj R2	*N*	*Coef.*	*SE*	*P*
Castell Gwylan	-0.0063	160	0.009	0.096	0.928026
Llanidan East	0.0376	186	-0.363	0.127	0.004591
Llanidan West	0.0879	230	-0.643	0.134	0.000003

It would be interesting to look for any relationships with environmental variables, particularly various weather, climate and water quality variables to evaluate potential causal or correlated relationships.

Figure 8 Annual fluctuations in species richness at the three monitoring sites. Solid lines: average number of taxa per thallus (± standard error). Dashed lines: total number of taxa recorded across all thalli.

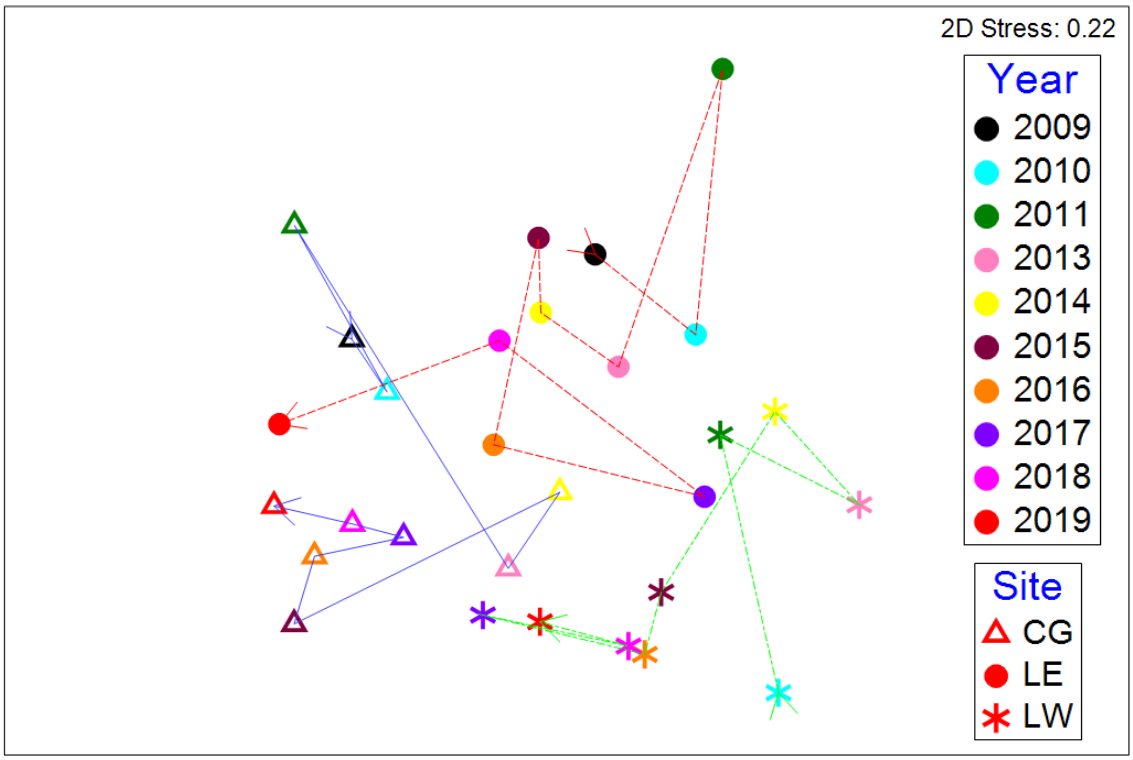


3.5 Community composition

Multivariate analysis of whole community data from the *Fucus serratus* epibiota (Figure 9) show that the three monitoring sites are distinctly different from each other (Note: stress is high in a 2D plot, but this is more clearly shown in a 3D plot). ANOSIM analyses show that the differences are statistically significant (One-way analysis on *Site*, Global R = 0.488, P=0.1%, pairwise tests between sites all give P=0.1%, more details in Appendix 5). The MDS plot also shows some apparent progressive changes over time, but there is no apparent pattern to these temporal changes.

SIMPER analyses (Appendix 5) show that the taxa contributing most to the differences between the sites include the encrusting bryozoans *Flustrellidra hispida*, *Alcyonidium hirsutum*, *Alcyonidium* (*polyoum* / *gelatinosum*), *Electra pilosa* and *Celleporella hyalina*, the erect bryozoan *Amathia imbricata*, the sponge *Halisarca dujardinii*, Campanulariidae hydroids, the barnacle *Balanus crenatus* and red alga *Osmundea* (flat). These species are discussed further in Section 3.6.

Figure 9 MDS plot of *Fucus serratus* epibiota data from Castell Gwylan (CG), Llanidan East (LE) and Llanidan West (LW), 2007 to 2019. Each dot represents between 11 and 32 thalli, with similarities calculated from proportional occurrence data for 154 taxa. Lines link consecutive years to show progressive change over time.



3.6 Individual taxa

The annual abundance of the most frequently occurring taxa are tabulated in Table 2. Graphs in Figure 10 show how abundances in selected taxa have fluctuated. Notable temporal fluctuations or between site differences in species abundance include:

- Sponge *Halisarca dujardinii* – fewer records at Llanidan West since 2015 compared to the early years, but no such trend shown at Llanidan East (Figure 10a).
- Hydroids Campanulariidae (multiple species, aggregated to improve consistency) – very large fluctuations in frequency of occurrence, but many more records in recent years compared to the first three years (Figure 10b). However, many records from the early years were assigned to the higher taxon Hydrozoa.
- Barnacle *Austrominius modestus* – records peaked in 2014 and 2017 at all sites, but were otherwise infrequent (Figure 10c).
- Polychaetes Spirorbinae – usually present on the majority of thalli at all sites, but less frequent in 2014 and 2015 (Figure 10d). The almost complete absence at Castell Gwylan in 2015 is very striking – critical inspection of the field data finds no evidence that this was a recording error. Detailed close-up study of the quadrat

photographs confirms a relative lack of Spirorbinae compared to photographs from other years.

- Gastropod *Steromphala cineraria* – synchronised decline to 2014 followed by more variable and poorly synchronised increase (Figure 10e).
- Gastropod *Steromphala umbilicalis* – few records up to 2015, then a notable rise, particularly at Llanidan West (Figure 10f).
- Bryozoan *Alcyonidium polyoum* / *gelatinosum* – notable differences between sites, but generally lower frequency up to 2013/14 and then increasing (Figure 10g).
- Bryozoan *Alcyonidium hirsutum* – notable difference between Castell Gwylan and the Llanidan sites – the former fluctuating dramatically from year to year, while the Llanidan sites showed a synchronised fall, rise and fall (Figure 10h).
- Bryozoan *Flustrellidra hispida* – another notable difference between sites, but Llanidan East being the odd one. However, there was very low abundance at all three sites in 2019 (Figure 11i).
- Bryozoan *Electra pilosa* – an overall trend of increasing frequency at all three sites (Figure 11j).
- Seasquirt *Botryllus schlosseri* – a notable rise and then fall, fairly well synchronised between all three sites (Figure 11k).
- Seasquirt Didemnidae – moderately large fluctuations from year to year, but fairly well synchronised between all three sites (Figure 11l).
- Encrusting coralline red algae – generally infrequent, but a notable rise in occurrence at Llanidan East from 2016 to 2019 (Figure 11m).
- Red alga *Lomentaria articulata* - generally infrequent, but a notable rise in occurrence at the Llanidan sites in 2011-13 (Figure 11n).
- Red alga *Osmundea* (flat) - notable difference in frequency and trends between the sites (Figure 11o).
- Filamentous red algae *Polysiphonia* (type) – including a number of closely related taxa that can be difficult to identify in the field. Much more frequent at Llanidan East, but with a trend of reduction (Figure 11p). No records at any site in 2019.
- Filamentous brown alga *Elachista fucicola* - generally infrequent at Llanidan West and Castell Gwylan, but at Llanidan East there was a notable rise to 2015 then decrease (Figure 11q).
- Brown alga *Dictyota dichotoma* – Not recorded from Castell Gwylan and infrequent at Llanidan West, but was very frequent at Llanidan East, then gradually decreased to complete absence in 2019 (Figure 11r).

Table 2 Percentage occurrence of selected taxa, across all sites. Each value is calculated from presence / absence data from at least 38 thalli (max: 71 in 2017). Coloured data bars (using conditional formatting feature from Excel) have been added to aid visualisation of changes. Example: in 2009 the sponge *Halisarca dujardinii* was recorded as present on 68% (26) of the 38 surveyed thalli, but only 37% (21) of the 57 surveyed thalli in 2010.

Entity	2009	2010	2011	2013	2014	2015	2016	2017	2018	2019
Halisarca dujardinii	68	37	59	41	52	30	18	35	30	22
Anthoathecata		30	9	13	7	2	8	9	16	18
Dynamena pumila		23	36	49	15	36	31	14	13	6
Campanulariidae	5	5	2	39	12	41	74	47	56	82
Spirorbinae	100	100	93	97	77	55	97	94	100	93
Balanus crenatus	71	54	25	49	56	34	67	48	64	51
Austrominius modestus	3	5		21	62	13	16	42	20	15
Steromphala cineraria	18	19	8	2		9	10	16	12	15
Steromphala umbilicalis	8	2	2		3		13	30	13	11
Lacuna pallidula		19		20			30	18	25	16
Littorina littorea	11	5	11	10	29	13	12	16	21	13
Littorina (obtusata / fabalis)	47	63	68	75	44	48	33	49	38	27
Alcyonidium (polyoum / gelatinosum)	24	21	53	44	66	77	79	69	69	53
Alcyonidium hirsutum	58	88	53	87	24	27	67	37	38	18
Flustrellidra hispida	13	72	60	87	34	23	31	18	33	18
Amathia imbricata	66	16	13	12	22	32	20	31	26	22
Celleporella hyalina	8	12	8				23	37	31	40
Electra pilosa	40	21	17	16	18	39	36	51	49	36
Polyclinidae (stalked)	37	19	57	12	32	5	10		3	6
Polyclinidae (not stalked)		12	23	7		13	2	3	3	6
Didemnidae	21		64	33	7	4	23	1	15	26
Corella eumyota	3	11	23	18	21	16	2	7		
Botryllus schlosseri	24	47	76	38	38	46	5	18	12	15
Palmaria palmata		11	4	15	4	14	8	1	2	
Dumontia contorta		2		16	4	2		20	15	13
Corallinaceae (enc)	3		11	2	3	2	5	17	13	16
Cystoclonium purpureum	11	19	6	31	7	21	3		15	
Lomentaria articulata	3	5	28	28	15	16	3	7	3	2
Ceramium	3	23	32	18	6		2	3	2	2
Ceramium deslongchampsii	3		15	20	13	14	3	3	10	4
Ceramium virgatum	3		25	3	24	21	5	18	7	11
Hypoglossum hypoglossoides	18	4	17	26		9		1		2
Membranoptera alata	3	7	19	7	2	11		3	7	2
Osmundea (flat)	24	26	40	38	32	46	25	39	28	20
Polysiphonia (type)	21	12	34	20	16	4	2	4	7	
Elachista fucicola	3	9	13	30	25	30	21	17	10	16
Dictyota dichotoma	29	9	25	3	4	11	2	7	8	
Fucaceae (sporelings)		7	19	8		13	10	1	20	6
Ulva (tubular)		4	8	5	28	7	2	3	15	7
Ulva (flat)	13	28	28	33	46	38	20	14	15	2
Cladophora		4	17	15	4	7	3	4	5	6

Figure 10 Graphs of temporal change in abundance (frequency of occurrence) for selected taxa. Frequency of occurrence calculated as a percentage of the number of thalli surveyed. Each point represents between 11 and 32 thalli.

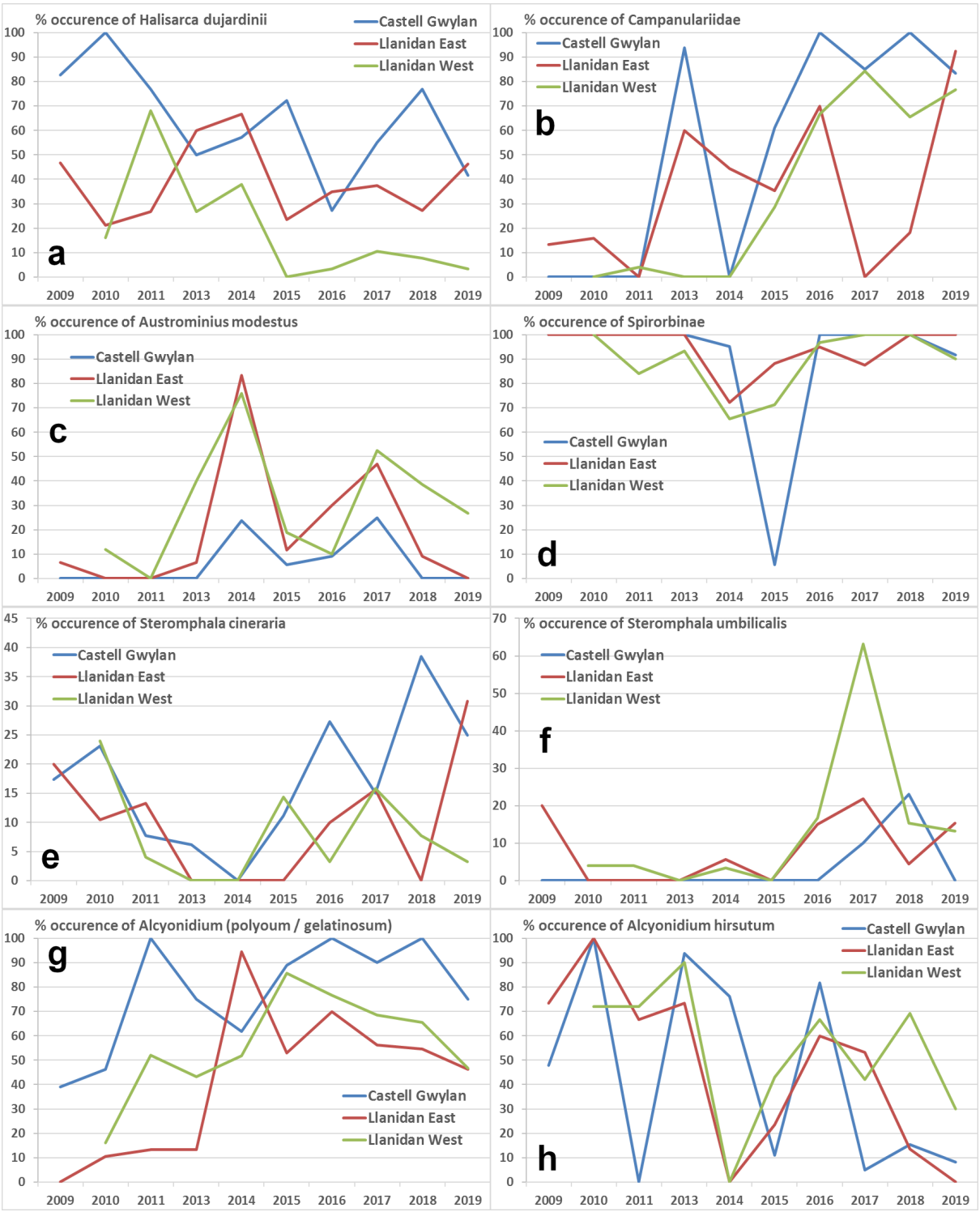
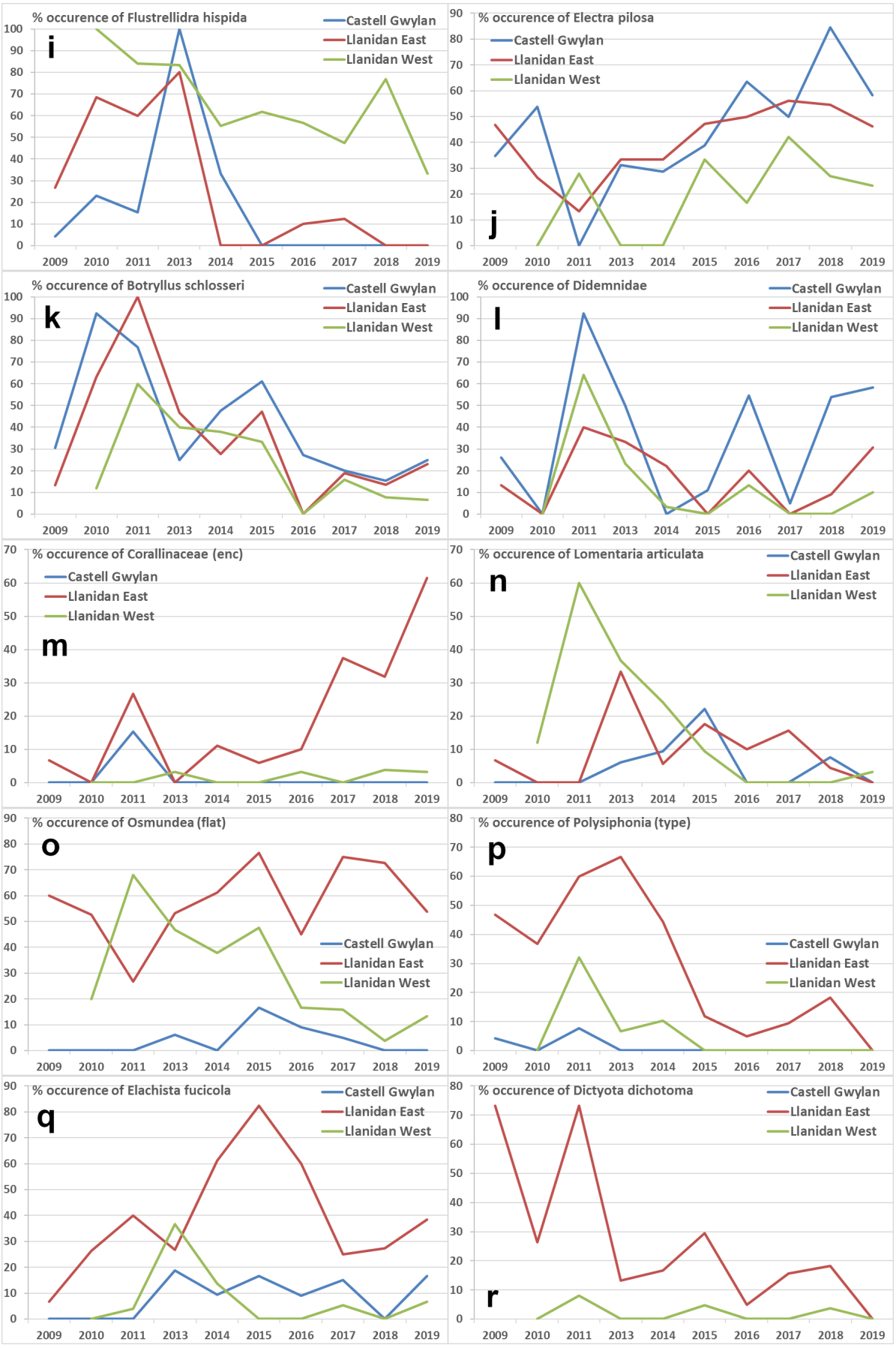


Figure 11 Continuation from Figure 10.



4 Discussion and conclusions

4.1 Temporal changes and differences between monitoring sites

The main conclusion from the results is that the composition of the epibiota assemblage is very variable, in both space and time. With that level of variability, it is difficult to identify any notable trends in the condition of the habitat, but overall the fluctuations are considered natural and the habitat is generally considered to be in favourable condition.

However, species richness at the Llanidan sites does appear to have reduced over the course of the programme. The trend is subtle, but it is statistically significant. While the levels of potential error make it difficult to be confident in this apparent trend the possibility that it is real should be noted. The lack of any such trend at Castell Gwylan suggests the effect is localised, but evidence of species richness decline has been described from other sites in the Menai Strait. Results from the associated programme of monitoring lower eulittoral boulder communities (Moore 2021) have described significant reductions at Felinheli over a similar period of years.

One feature of the variability in epibiota that is particularly striking is the lack of synchrony in species abundance changes between the three sites. The Llanidan sites are only 130 m apart, but there are many examples of species increasing in abundance at one site, but decreasing at the other. Examples include *Flustrellidra hispida*, *Osmundea* and *Elachista fucicola*. (Figure 11). Differences with Castell Gwylan are even greater, for example the almost complete lack of Spirorbinae at Castell Gwylan in 2015 while at least 70% of thalli were colonised at the Llanidan sites (Figure 10).

Lastly, it is notable that while changes in abundance of *Flustrellidra hispida* were not synchronised between the sites, the overall trend from 2014 to 2019 was downwards. Little et al. (2018) have suggested that *F. hispida* may be a useful indicator of water quality, so it would be useful to focus some attention on any other available recent data for this bryozoan in the Menai Strait.

It would also be interesting to look for relationships between any of the variables discussed in this report with various environmental parameters, particularly those associated with weather, climate and water quality, to evaluate potential causal or correlated relationships.

4.2 Methods and protocols

Inconsistency of recording between (and within) surveyors is a constant concern in this type of monitoring and inevitably limits the ability to detect real change and can result in apparent changes that are not real. In this programme, inconsistency of

species recording is part of the concern, but a greater concern is the effects of non-random selection of thalli and the poor quality estimates of percentage cover of epibiota. For the latter, the accuracy of the rapid *in situ* methodology used is very low, but it is also clear that many factors that affect epibiota cover are not being controlled. Wood and Seed (1981) and Seed (1985) describe some of the ecological and environmental factors that affect settlement and growth of various epifauna on fucoids, and they are complex. For example, our surveyors have observed that thallus age and length are often poorly correlated as old thalli can break, particularly if grazed. These old partially broken thalli are often densely covered by epibiota, likely due to a number of factors (including lack of new growth of the thallus frond, and because the epibiota may be subject to reduced flexing and abrasion on a short frond). In conclusion, estimates of percentage cover of epibiota on thalli using the current methodology may have limited value for monitoring. Improvements may be achieved by developing stricter criteria for thallus selection, based on size range or other characteristics.

A review of the methodology to assess possible ways to reduce variability and improve consistency of recording should be considered. This should include more trials to test recording consistency, primarily as a quality control check to assess potential bias between surveyors. This in turn will inform the need for any additional training.

5 Condition assessment

Uncertain - a number of changes have occurred in the monitored communities since the programme began in 2009 and most are considered to be natural fluctuations. However, a subtle but statistically significant decrease in recorded species richness at the Llanidan sites has been noted.

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Appendix 1 Monitoring surveys of lower eulittoral tide-swept *Fucus serratus* epibiota in the Menai Strait

CG = Castell Gwylan, LE = Llanidan East, LW = Llanidan West. 8 (23) = No. of quadrats (and thalli) surveyed

Year	CG	LE	LW	Dates	Surveyors
2009	8 (23)	9 (15)		26 Jun	JJM, GW, FDB, JMJ
2010	9 (13)	5 (19)	7 (25)	15 Jul	JJM, DH, RS, FDB, EH, DPB, JMJ
2011	13 (13)	7 (15)	9 (25)	3 & 4 Aug	JJM, LK, GA, DPB, FDB, CD
2013	8 (16)	12 (15)	7 (30)	27 Jun	JJM, NL, FDB, RS, DPB, JMJ
2014	12 (21)	8 (18)	13 (29)	16 Jul	JJM, RS, FDB, JMJ, DPB, MD
2015	6 (18)	6 (17)	8 (21)	05 Jul	JJM, BW, FDB, EWJ, JMJ, LK
2016	4 (11)	7 (20)	9 (30)	07 Jun	JJM, LK, FDB, JMJ, DPB, EWJ
2017	9 (20)	10 (32)	12 (19)	26 & 27 Jun	JJM, KG, DPB, JMJ, TSM , JJM, LK
2018	6 (13)	14 (22)	8 (26)	16 Jun	JJM, FDB, JMJ, DPB, SE
2019	6 (12)	5 (13)	13 (30)	04 Jun	JJM, FDB, JAT, DPB, KSB

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

Appendix 2 Full list of taxa recorded

Taxonomic names are according to the World Register of Marine Species (WoRMS, http://www.marinespecies.org), updated for this report in April 2020. Qualifiers, for some taxa, are given in brackets after the name. Total number of records from all thalli at each monitoring site (2007 to 2019) is given in brackets: CG = Castell Gwylan, LE = Llanidan East, LW = Llanidan West. Taxa are sorted in a taxonomic order based on the Species Directory codes of Howson & Picton (1997).

SPONGES
Leucosolenia CG 7 LE 5 LW 1
Sycon ciliatum CG 1
Grantia compressa CG 1 LE 1
Halichondria (Halichondria) panicea LE 2 LW 1
Hymeniacidon perlevis LE 2 LW 1
Amphilectus fucorum LE 1
Dysidea fragilis CG 4
Halisarca dujardinii CG 104 LE 71 LW 47
HYDROIDS & ANEMONES
Hydrozoa LE 4 LW 26
Anthoathecata LW 16
Clava multicornis CG 14 LE 3 LW 38
Plumularia setacea LE 3
Dynamena pumila CG 17 LE 23 LW 94
Campanulariidae CG 50 LE 39 LW 6
Gonothyraea loveni CG 23 LW 76
Obelia LE 13 LW 1
Obelia dichotoma CG 15 LE 6
Actiniaria (juv) CG 2
Actinia equina CG 1
FLAT WORMS
Fecampia erythrocephala (egg flask) LE 1
RIBBON WORMS
Nemertea LW 1
POLYCHAETE WORMS
Polychaeta CG 1 LE 2 LW 1
Polychaeta (soft sand tube) LE 10 LW 1
Polynoidae CG 2
Spionidae (tubes) LE 3
Sabellidae CG 1
Serpulidae LW 2
Spirobranchus CG 1 LE 2 LW 2
Spirorbinae CG 141 LE 174 LW 211
SEA SPIDERS AND MITES
Pycnogonida CG 7 LW 2
Nymphon brevirostre CG 1
Nymphon gracile LE 1 LW 9
Phoxichilidium femoratum LW 1
Pycnogonidae LW 3
CRUSTACEA
Cirripedia CG 3 LW 12
Cirripedia (juv) CG 22 LE 5 LW 2
Semibalanus balanoides CG 3 LE 1 LW 19
Balanus crenatus CG 88 LE 103 LW 111
Austrominius modestus CG 12 LE 42 LW 72
Amphipoda CG 35 LE 8 LW 22
Jassa LE 1
Isopoda LW 2
Dynamene bidentata CG 1 LW 1
Sphaeroma LW 1
Brachyura (juv crabs) LW 8
Carcinus maenas (juv) CG 3 LE 5 LW 19
MOLLUSCA
Gastropoda (eggs) CG 13 LE 19 LW 23
Phorcus lineatus LW 1
Steromphala cineraria CG 25 LE 18 LW 17
Steromphala umbilicalis CG 5 LE 17 LW 28
Tricolia pullus LE 1
Lacuna pallidula LE 13 LW 65
Lacuna (eggs) CG 5
Littorina (eggs) CG 3 LW 15
Littorina littorea CG 9 LE 29 LW 47
Littorina (obtusata / fabalis) CG 79 LE 80 LW 129
Peringia ulvae LE 2
Epitonium LW 1
Trivia monacha LE 1
Lamellaria perspicua LE 2 LW 1
Nucella lapillus LW 2
Nucella lapillus (eggs) LW 3
Ocenebra (eggs) LW 4
Buccinum undatum LW 3
Tritia (eggs) LE 3 LW 7
Pleurobranchus LW 1
Nudibranchia (eggs) CG 4 LW 1
Goniodoris nodosa LE 1
Acanthodoris pilosa CG 15 LE 3 LW 5
Onchidoris bilamellata CG 1 LE 2 LW 2
Onchidoris muricata CG 1 LW 1
Mytilus edulis LW 1
Musculus subpictus CG 4
Ostrea chilensis LE 5 LW 1
Anomiidae CG 5 LE 3
BRYOZOA
Bryozoa (enc) CG 2 LE 4 LW 3

Cyclostomatida LW 2
Alcyonidium (polyoum / gelatinosum) CG 120 LE 82 LW 130
Alcyonidium diaphanum LW 1
Alcyonidium hirsutum CG 70 LE 87 LW 129
Flustrellidra hispida CG 29 LE 44 LW 158
Amathia imbricata CG 115 LE 20 LW 8
Cryptosula pallasiana CG 1 LE 8
Celleporella hyalina CG 36 LE 49 LW 10
Membranipora membranacea CG 1 LE 2 LW 13
Electra pilosa CG 68 LE 79 LW 43
Callopora lineata LE 11

ECHINODERMS

Asterias rubens CG 2 LE 1
Ophiothrix fragilis CG 8 LE 2 LW 3

SEA SQUIRTS

Ascidiacea LE 3 LW 1
Ascidiacea (sandy colonial) LE 5
Clavelina lepadiformis LE 2
Polyclinidae CG 1 LE 2
Polyclinum aurantium CG 4 LE 4 LW 14
Morchellium argus LE 1
Aplidium turbinatum CG 34 LE 39 LW 27
Aplidium densum LE 2 LW 2
Aplidium nordmanni CG 6 LE 8 LW 1
Aplidium punctum LE 1
Didemnidae CG 6 LE 2
Didemnidae (transparent) CG 12 LE 3 LW 18
Didemnidae (white) CG 13 LE 5 LW 5
Didemnidae (cream) CG 8
Didemnidae (yellow) LE 1
Didemnidae (orange) LW 3
Didemnidae (purple) LE 1 LW 2
Didemnidae (brown) CG 2
Didemnidae (black) LW 2
Didemnidae (grey) CG 2 LW 1
Trididemnum tenerum CG 7 LE 1
Didemnum LW 1
Didemnum (white) LE 9 LW 7
Didemnum maculosum LE 7 LW 1
Diplosoma CG 2 LE 14 LW 1
Diplosoma listerianum LE 3
Perophora listeri LE 1
Corella eumyota CG 32 LE 14 LW 15
Ascidiella scabra CG 10 LE 4 LW 2
Polycarpa scuba LE 3
Dendrodoa grossularia CG 6 LE 13 LW 2
Botryllus schlosseri CG 66 LE 61 LW 57
Botrylloides violaceus LE 3
Botrylloides leachii CG 1 LE 12 LW 2
Pyura microcosmus LE 1
Molgulidae (sandy) LE 2
Molgula LE 2

DIATOMS

Naviculales (fil. colonial diatoms) LW 2

RED ALGAE

Rhodophyta CG 1
Rhodophyta (fil) CG 12 LE 3 LW 6
Rhodophyta (flat) CG 2 LE 1 LW 2
Porphyra LW 2
Pyropia leucosticta LW 3
Porphyra umbilicalis LW 1
Acrochaetiaceae LE 2
Palmaria palmata CG 5 LE 14 LW 17
Dumontia contorta CG 1 LE 42 LW 2
Corallinaceae (enc) CG 2 LE 37 LW 4
Gracilariaceae LE 5
Chondrus crispus CG 4 LE 8 LW 8
Cystoclonium purpureum CG 27 LE 14 LW 26
Botryocladia wrightii LE 2
Lomentaria articulata CG 8 LE 18 LW 40
Lomentaria clavellosa LE 10 LW 2
Aglaothamnion CG 1
Aglaothamnion bipinnatum LE 1
Aglaothamnion tenuissimum LE 9 LW 1
Callithamnion corymbosum LE 1
Ceramium CG 7 LE 13 LW 11
Ceramium botryocarpum CG 1 LE 1 LW 2
Ceramium deslongchampsii CG 34 LE 6 LW 10
Ceramium echionotum LE 2
Gayliella flaccida LW 2
Ceramium virgatum CG 38 LE 20 LW 12
Ceramium pallidum CG 1 LE 1 LW 4
Ceramium secundatum CG 4 LE 7
Griffithsia corallinoides LE 15
Halurus flosculosus LE 9
Pterothamnion plumula LE 3 LW 1
Apoglossum ruscifolium LE 1
Cryptopleura ramosa CG 3 LE 1 LW 5
Hypoglossum hypoglossoides LE 26 LW 15
Membranoptera alata CG 16 LE 5 LW 13
Haraldiophyllum bonnemaisonii LE 12 LW 1
Nitophyllum punctatum LE 3
Phycodrys rubens LW 1
Dasysiphonia japonica LE 6 LW 1
Chondria dasyphylla LE 10
Osmundea hybrida LE 7 LW 8
Osmundea oederi CG 5 LE 66 LW 57
Osmundea pinnatifida LE 2 LW 6
Osmundea truncata CG 1 LE 44 LW 14
Polysiphonia CG 1
Carradoriella elongata LE 13
Melanothamnus harveyi CG 1 LE 38 LW 14
Vertebrata nigra LE 2
Vertebrata fucoides LE 6 LW 2
Polysiphonia stricta LE 3

Rhodomela confervoides LE 3
BROWN ALGAE
Phaeophyceae (fil) CG 6 LW 2
Ectocarpaceae CG 15 LE 3 LW 1
Ectocarpus fasciculatus LE 5 LW 3
Hincksia granulosa LE 15 LW 8
Pylaiella littoralis LE 10
Elachista fucicola CG 14 LE 72 LW 19
Sphacelaria cirrosa LE 2 LW 1
Cladostephus spongiosus LE 1 LW 1
Dictyota dichotoma LE 47 LW 6
Dictyota spiralis LE 7 LW 1
Asperococcus LW 1
Punctaria LW 6
Scytosiphon lomentaria LE 4
Chorda filum CG 1
Laminaria (sporelings) CG 1 LE 23
Saccharina latissima LE 7
Fucaceae (sporelings) CG 5 LE 1 LW 42
Fucus serratus LW 3
GREEN ALGAE
Ulva (tubular) CG 3 LE 30 LW 11
Ulva clathrata LE 1
Ulva compressa LE 2 LW 3
Ulva (flat) CG 37 LE 32 LW 56
Ulva lactuca LW 1
Ulva pseudocurvata LW 22
Chaetomorpha LW 2
Chaetomorpha linum LE 7 LW 1
Cladophora CG 1 LE 9 LW 9
Cladophora albida LW 3
Cladophora hutchinsiae LE 1
Cladophora rupestris CG 3 LE 1 LW 2
Cladophora sericea CG 1 LE 10
Bryopsis plumosa LE 8 LW 7

Appendix 3 Database structure

The boulder data are stored in an Access database, A summary of the main data tables and fields is given below:

Records

Field name	Description
Entity	Accepted name for the taxon, based on WoRMS online database, plus qualifier
SampleID	Integer: from 1 to the maximum number of samples (581 after 2019 survey)
Abundance	Integer: normally 1 (as survey records are simply presence), but some 0 value records are included as dummy values

TaxaList

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. *Hymeniacidon perlevis* = C005230 and Corallinaceae (enc) = ZM03840.51
Form	Only for entities that are listed on the recording form: integer value, giving the order that they are listed on the form
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

Thalli

Field name	Description
SampleID	Integer, as in Records table
SampleCode	Unique sample identifier: Year+Site+Quadrat+Thallus(+repeat), e.g. 11LW5.4R = 2011, Llanidan West, Quadrat 5, Thallus 4, repeat
Year	2009 to 2019
Site	CG, LE or LW, as in Sites table
Quadrat	Integer: 1 to 14
Thallus	Integer, 1 to 6
Length	Length (in cm) of the thallus, from base to tip
Epibiota	Estimated percentage cover of epibiota on the thallus
Records	Integer: the number of records (i.e. taxa) recorded from the thallus
Repeat	1 or 2, where 2 is a repeated sample by another surveyor, for quality control

Quadrats

Field name	Description
Year	2009 to 2019
Site	CG, LE or LW, as in Sites table
Quadrat	Integer: 1 to 14
Thalli	Number of thalli surveyed in the quadrat
Fser%	Estimated percentage cover of *Fucus serratus* in the quadrat
Silt	Average thickness of silt (in mm) on top of the hard substrata in the quadrat that have *Fucus serratus* holdfasts attached

Events

Field name	Description
Year	2009 to 2019
Site	CG, LE or LW, as in Sites table
Date	Date survey carried out
Surveyors	Initials of surveyors
Conditions	Environmental conditions during survey
Time start	Time survey started on site
Time end	Time survey ended on site
Fser%	Estimated percentage cover of *Fucus serratus* in the defined 5m x 5m box
Quadrat	Number of quadrats surveyed
Thalli	Number of thalli surveyed

Sites

Field name	Description
Site name	Castell Gwylan, Llanidan East, Llanidan West
Site	Two letter code: CG (Castell Gwylan), LE (Llanidan East), LW (Llanidan West)
Easting	OS grid reference (6 figure) for the centre of 5m x 5m box.
Northing	OS grid reference (6 figure) for the centre of 5m x 5m box.
Longitude	Longitude coordinates (digital degrees) for the centre of 5m x 5m box.
Latitude	Latitude coordinates (digital degrees) for the centre of 5m x 5m box.

Appendix 4 Results of an exercise to assess consistency of recording

To date, there has been very limited testing of the consistency of recording epibiota by the surveyors during this monitoring programme. However, Table 2 shows the results from surveys of two thalli at Llanidan West in 2011, carried out independently by two pairs of surveyors. In both cases the thalli were surveyed by one pair while the second pair was out of hearing; the thalli were then marked and then re-surveyed by the second pair with an interval of no more than 20 minutes. The table excludes mobile taxa that could have fallen off during the first survey.

It should be noted that both thalli were large, making it difficult for the surveyors to study every surface in a reasonable length of time. However, the number of inconsistencies is very high. Most will have been species that were present in low abundance, while a few will have been due to differences in identification.

Table 3 Repeat surveys: species occurrence records from two large thalli at Llanidan West in August 2011. Orig = records by first pair of surveyors. Rep = records from second pair of surveyors. Inconsistencies highlighted in **bold**.

Thallus	**1**	**1**	**2**	**2**
Record	**Orig**	**Rep**	**Orig**	**Rep**
Thallus length (cm)	**91**	**85**	**128**	**110**
Epibiota % cover	**60**	**30**	**70**	**60**
Halisarca dujardinii	**P**	-	P	P
Clava multicornis	**P**	-	**P**	-
Dynamena pumila	P	P	P	P
Polychaeta	-	**P**	-	-
Spirorbinae	P	P	P	P
Semibalanus balanoides	-	-	**P**	-
Balanus crenatus	P	P	P	P
Nucella lapillus (eggs)	-	**P**	-	-
Bryozoa (enc)	-	-	**P**	-
Alcyonidium (*polyoum / gelatinosum*)	**P**	-	**P**	-
Alcyonidium hirsutum	-	**P**	-	**P**
Flustrellidra hispida	P	P	P	P
Electra pilosa	-	**P**	P	P
Polyclinum aurantium	-	**P**	P	P
Aplidium turbinatum	P	P	P	P
Aplidium densum	**P**	-	**P**	-
Didemnidae (transparent)	-	**P**	P	P
Corella eumyota	P	P	P	P
Dendrodoa grossularia	**P**	-	-	-
Botryllus schlosseri	P	P	P	P
Palmaria palmata	-	**P**	-	-
Chondrus crispus	**P**	-	-	-
Cystoclonium purpureum	-	**P**	-	**P**
Lomentaria articulata	**P**	-	**P**	**P**
Lomentaria clavellosa	-	**P**	-	-

Ceramium	**P**	-	-	-
Ceramium deslongchampsii	**P**	-	-	-
Ceramium virgatum	-	-	**P**	-
Pterothamnion plumula	-	-	-	**P**
Membranoptera alata	P	P	**P**	-
Haraldiophyllum bonnemaisonii	-	-	-	**P**
Osmundea oederi	**P**	-	P	P
Melanothamnus harveyi	-	**P**	P	P
Hincksia granulosa	-	**P**	-	-
Dictyota dichotoma	-	**P**	-	**P**
Fucaceae (sporelings)	**P**	-	**P**	-
Ulva (flat)	-	**P**	P	P
No. of records	19	21	23	20
No. found by both pairs	-	8	15	-
No. found by only one pair	-	**24**	**13**	-

Appendix 5 Multivariate analyses results

More detailed results from multivariate analyses summarised in Section 3.5.

ANOSIM: Site

Analysis of Similarities (see Section 3.5)
One-Way – Site
Data – Bray-Curtis similarities derived from presence/absence data for 154 taxa.
Factors: Site (unordered): LE, LW, CG

Tests for differences between unordered Site groups
Global Test
Sample statistic (R): 0.488
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
LW, LE	0.552	0.1	Very large	999	0
LW, CG	0.462	0.1	Very large	999	0
LE, CG	0.433	0.1	Very large	999	0

SIMPER: Site

Similarity Percentages - species contributions (see Section 3.5)
One-Way Analysis - Site
Data – presence/absence data for 154 taxa
Analysis parameters: S17 Bray-Curtis similarity; Cut off for low contributions: 70.00%

Factor Groups: Site: LW & LE. Average dissimilarity = 73.52

Species	Group LW Av.Abund	Group LE Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Flustrellidra hispida	0.77	0.00	4.26	1.35	5.79	5.79
Osmundea (flat)	0.04	0.73	4.23	1.13	5.76	11.55
Alcyonidium hirsutum	0.69	0.14	3.45	1.14	4.69	16.23
Balanus crenatus	0.69	0.41	3.35	0.90	4.56	20.80
Alcyonidium (polyoum / gelatinosum)	0.65	0.55	3.30	0.74	4.48	25.28
Littorina (obtusata / fabalis)	0.23	0.50	3.28	0.71	4.46	29.74
Campanulariidae	0.65	0.18	3.27	1.04	4.45	34.18
Celleporella hyalina	0.08	0.59	3.17	1.01	4.31	38.49
Lacuna pallidula	0.58	0.00	2.99	0.98	4.06	42.55
Electra pilosa	0.27	0.55	2.97	0.91	4.04	46.60
Pylaiella littoralis	0.00	0.45	2.76	0.74	3.75	50.35
Austrominius modestus	0.38	0.09	2.21	0.73	3.00	53.35
Fucaceae (sporelings)	0.38	0.00	1.96	0.71	2.67	56.02
Ulva (tubular)	0.04	0.36	1.93	0.70	2.62	58.65
Dumontia contorta	0.04	0.36	1.83	0.71	2.49	61.13
Littorina littorea	0.23	0.18	1.76	0.63	2.39	63.52
Elachista fucicola	0.00	0.27	1.70	0.50	2.32	65.84
Corallinaceae (enc)	0.04	0.32	1.59	0.65	2.16	68.00
Dynamena pumila	0.15	0.18	1.54	0.57	2.09	70.10

Factor Groups: Site: LW & CG. Average dissimilarity = 65.22

	Group LW	Group CG				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Amathia imbricata	0.00	0.92	4.71	2.22	7.23	7.23
Electra pilosa	0.27	0.85	3.69	1.20	5.66	12.89
Halisarca dujardinii	0.08	0.77	3.66	1.41	5.61	18.50
Flustrellidra hispida	0.77	0.00	3.54	1.58	5.43	23.93
Alcyonidium hirsutum	0.69	0.15	2.89	1.21	4.43	28.36
Didemnidae	0.00	0.54	2.64	0.97	4.05	32.41
Lacuna pallidula	0.58	0.00	2.52	1.08	3.86	36.27
Littorina (obtusata / fabalis)	0.23	0.46	2.39	0.86	3.67	39.94
Campanulariidae	0.65	1.00	2.37	0.69	3.63	43.57
Alcyonidium (polyoum / gelatinosum)	0.65	1.00	2.29	0.68	3.51	47.08
Amphipoda	0.12	0.46	2.25	0.87	3.44	50.53
Balanus crenatus	0.69	0.92	2.13	0.67	3.27	53.80
Steromphala cineraria	0.08	0.38	2.11	0.74	3.23	57.03
Fucaceae (sporelings)	0.38	0.15	1.92	0.80	2.95	59.98
Ceramium deslongchampsii	0.00	0.38	1.81	0.73	2.78	62.76
Celleporella hyalina	0.08	0.31	1.74	0.65	2.67	65.43
Austrominius modestus	0.38	0.00	1.68	0.75	2.58	68.01
Littorina littorea	0.23	0.23	1.67	0.68	2.56	70.57

Factor Groups: Site: LE & CG. Average dissimilarity = 66.81

	Group LE	Group CG				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Campanulariidae	0.18	1.00	4.28	1.75	6.41	6.41
Amathia imbricata	0.18	0.92	3.99	1.59	5.98	12.39
Osmundea (flat)	0.73	0.00	3.46	1.47	5.18	17.57
Halisarca dujardinii	0.27	0.77	3.19	1.19	4.77	22.34
Balanus crenatus	0.41	0.92	3.18	1.08	4.77	27.10
Electra pilosa	0.55	0.85	2.65	0.87	3.97	31.07
Celleporella hyalina	0.59	0.31	2.59	0.99	3.87	34.94
Didemnidae	0.09	0.54	2.58	0.99	3.86	38.81
Littorina (obtusata / fabalis)	0.50	0.46	2.54	0.92	3.80	42.60
Alcyonidium (polyoum / gelatinosum)	0.55	1.00	2.25	0.84	3.37	45.98
Pylaiella littoralis	0.45	0.00	2.19	0.86	3.28	49.25
Amphipoda	0.00	0.46	2.14	0.87	3.21	52.46
Steromphala cineraria	0.00	0.38	2.00	0.74	2.99	55.45
Ceramium deslongchampsii	0.05	0.38	1.83	0.76	2.73	58.19
Ulva (tubular)	0.36	0.00	1.57	0.73	2.35	60.54
Littorina littorea	0.18	0.23	1.52	0.66	2.28	62.81
Dumontia contorta	0.36	0.00	1.50	0.73	2.24	65.06
Membranoptera alata	0.00	0.31	1.39	0.64	2.08	67.14
Elachista fucicola	0.27	0.00	1.33	0.58	1.99	69.13
Ceramium virgatum	0.00	0.31	1.30	0.65	1.94	71.08

Appendix 6 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 boulder physical parameters and species data, including validation data, verification data and metadata.

[C] A Marine Recorder NBNdata file containing the relevant survey details.

[D] A Marine Recorder snapshot of the survey for NRW validation purposes.

[F] A full set of images from the survey, in jpg format.

[G] A full set of GIS files of any spatial data.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue by searching 'Dataset Titles'.

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