Cyfoeth Naturiol Cymru
Natural Resources Wales

Carmarthen Bay and estuaries - rocky shore monitoring at Monkstone Point 2015 to 2021

Report no: 784

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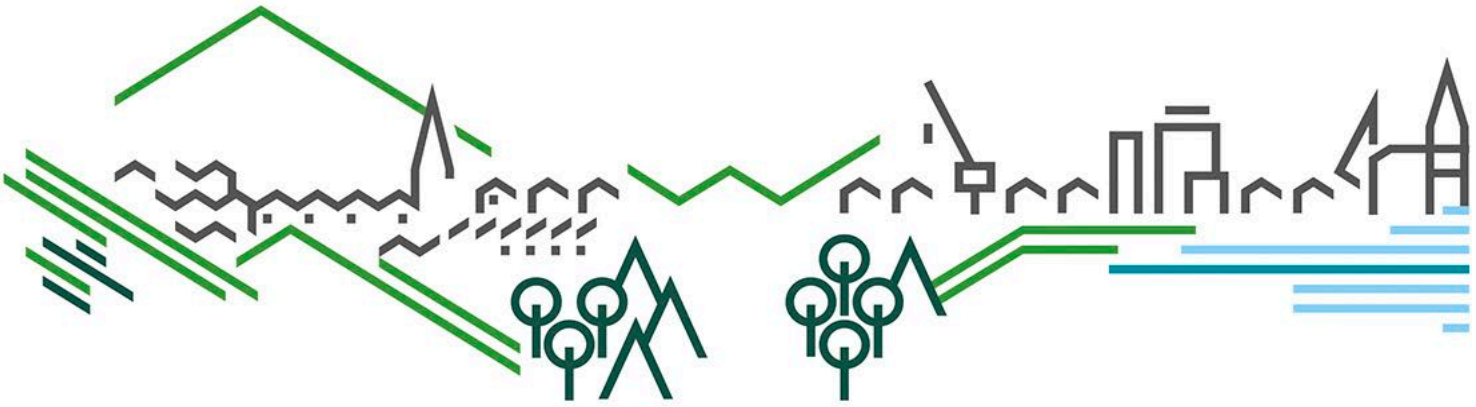

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Crynodeb gweithredol

Mae'r Gyfarwyddeb Cynefinoedd yn sefydlu y dylai'r gwaith o reoli Ardaloedd Cadwraeth Arbennig (ACAau) anelu at gyflawni statws cadwraeth ffafriol cynefinoedd a rhywogaethau (nodweddion) a restrir yn ei Atodiad I ac Atodiad II. Mae Rheoliad 9a o'r Rheoliadau Cynefinoedd (Erthygl 17 gynt o'r Gyfarwyddeb Adar a Chynefinoedd) yn ei gwneud yn ofynnol i adrodd ar statws cadwraeth y cynefinoedd a'r rhywogaethau hynny bob 6 blynedd. Yn achos ACAau yng Nghymru, Cyfoeth Naturiol Cymru (CNC) sy'n gyfrifol am y gwaith adrodd hwnnw. Er mwyn gwneud hyn, mae CNC wedi datblygu rhaglenni monitro cyflwr nodweddion, sy'n cynnwys nodweddion rhynglanwol ACAau morol.

Aquatic Survey & Monitoring Ltd. Mae CCGC, a CNC yn ddiweddarach, wedi contractio (ASML) i barhau i ddatblygu'r gwaith o reoli'r rhaglen monitro rhynglanwol ar gyfer pob ACA morol ers 2007, gan weithio fel tîm gyda staff CCGC/CNC.

Mae'r adroddiad hwn yn cyflwyno dadansoddiad o fonitro'r glannau creigiog yn Nhrwyn Monkstone, Sir Benfro, o fewn ACA Bae Caerfyrddin a'r Aberoedd.

- Mae riffiau rhynglanwol yn ffurfio cynefin nodweddiadol Cilfachau a Baeau Mawr Bas ACA Bae Caerfyrddin a'r Aberoedd.
- Mae monitro ac adrodd ar gyflwr nodweddion yr ACA yn ddyletswydd statudol ar Cyfoeth Naturiol Cymru.
- Arolygwyd ardaloedd wedi'u marcio o'r lan Uchaf, Canol ac Isaf yn Nhrwyn Monkstone yn ystod hydref bob blwyddyn o 2015 i 2021. Mae canlyniadau'r arolygon hyn wedi'u dadansoddi ac fe'u cyflwynir yn yr adroddiad hwn.
- Ni nodwyd unrhyw newidiadau ar raddfa fawr mewn unrhyw barth glan môr, ar wahân i gynnydd o ran y cregyn gleision *Mytilus edulis* yn y lan ganol.
- Mae bywyd morol ar y riffiau rhynglanwol hyn yn amrywiol ac yn ddiddorol.
- Gellir defnyddio canlyniadau'r astudiaeth hon fel dangosydd o gyflwr nodwedd y Baeau a Chilfachau Bas Mawr.

Executive summary

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 and formerly CCW, to continue development and management of the intertidal monitoring programme for each marine SAC since 2007, working as a team with CCW/NRW staff.

This report presents an analysis of rocky shore monitoring at Monkstone Point, Pembrokeshire, within the Carmarthen Bay and Estuaries SAC.

- Intertidal reefs make up typical habitat of the Large Shallow Inlet and Bay feature of the Carmarthen Bay and Estuaries SAC.
- The monitoring and reporting of the condition of the features of the SAC is a statutory duty of Natural Resources Wales.
- Marked areas of the Upper, Middle and Lower shore at Monkstone Point were surveyed in the autumn of each year from 2015 to 2021. The results of these surveys have been analysed and are presented in this report.
- No large-scale changes were noted in any shore zone apart from an increase in the mussel *Mytilus edulis* in the middle shore.
- Marine life on these intertidal reefs is diverse and interesting.
- The results of this study can be used as an indicator of the condition of the Large Shallow Inlet and Bay feature.

1. Introduction

The following description of the Carmarthen Bay and Estuaries SAC is taken from (NRW, 2018).

“The Carmarthen Bay and Estuaries SAC is a large site encompassing the estuaries of the Rivers Loughor, Tâf and Tywi (coastal plain estuaries) and the Gwendraeth (a bar-built estuary). There are extensive areas of intertidal mudflats and sandflats with large areas of these flats dominated by bivalves.

Carmarthen Bay is an extensive shallow bay with a wide variety of seabed types, including mud, sand and rock, although the majority of the seabed is sandy. The SAC includes Helwick Bank, a linear shallow subtidal sandbank that is unusual in being highly exposed to wave and tidal action. The Burry Inlet and Three Rivers system provides a migratory route for salmonids, lampreys and shad.

The Carmarthen Bay and Estuaries SAC is a multiple interest site which has been selected for the presence of ten marine features. For the qualifying habitats and species, the SAC is considered to be one of the best areas in the UK for:

- Estuaries
- Mudflats and sandflats not covered by seawater at low tide
- Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
- *Salicornia* and other annuals colonising mud and sand
- Large shallow inlets and bays
- Sandbanks which are slightly covered by sea water all the time
- Allis shad (Alosa alosa)
- Twaite shad *(Alosa fallax*)
- and to support a significant presence of: River lamprey *(Lampetra fluviatilis),* Sea lamprey *(Petromyzon marinus)* and Otter *(Lutra lutra)*

The features are distributed throughout the SAC with no single feature occupying the entire SAC and with features overlapping in some locations. The SAC boundary and the general location of the Annex I habitat features are shown in the feature map1 on the NRW website (and in this report). These are indicative maps as the extent of most features is not known precisely and some, such as sandbanks, are dynamic and can be highly mobile.

More information on the site and its features can be found in NRW’s conservation advice for the site on the NRW website.

Figure 1 Map to show location and boundaries of the Carmarthen Bay and Estuaries SAC

Figure 2 Aerial picture showing Monkstone Point and the location of monitoring stations. US = Upper Shore, MS = Middle Shore, LS = Lower Shore

2. Methods

The survey methodology employed is based upon recommendations provided to the Countryside Council for Wales by the Institute of Estuarine and Coastal Studies (IECS) in 2005 (Hull et al., 2006). Refinements to this methodology have been adopted (Bunker and Brazier, 2013) and (Bunker, 2015) and recording protocols have been honed over the years in order to improve consistency. Site specific relocation sheets, recording forms and protocols have been developed and are given in the Appendices 0, 0 and 0.

Four fixed quadrat positions have been selected in each of three zones: the Upper Shore (US), Middle Shore (MS) and Lower Shore (LS). The shore heights are defined as follows:

- Upper shore (US): Quadrats located at the top of the barnacle zone or the *Pelvetia canaliculata* zone.
- Middle shore (MS): Quadrats located in the middle of the barnacle zone or *Ascophyllum nodosum* zone.
- Lower shore (LS): Quadrats located at the lower edge of barnacle zone or middle of the *Fucus serratus* zone.

In each zone, four 1 m x 1 m square quadrats are located at the same height in homogeneous areas of inclined rock, where possible avoiding rock pools and large fissures. These quadrats are marked using screws and (where appropriate[1]) plastic discs in at least two corners. Quadrats are placed over the markers and recording of organisms present and abundances are taken *in situ*. Photographs are taken of all quadrats within each zone.

2.1. The survey team, briefings and data collection

At the beginning of each survey, the survey leader shows the team a PowerPoint presentation outlining the common shore species, common identification problems, and reports on new non-native species which may be encountered. The basic methodology is also explained.

Field surveys are ideally carried out by one or more team of three persons; two with identification expertise and one recorder.

Prior to a field outing the survey teams are given a briefing on the sites to be surveyed (including things that are unique to each site) and protocols for recording at those sites are discussed (see Appendix 0)

Personnel in teams should be familiar with the sites, the species and the methods used. A core team of marine biologists has undertaken this monitoring program and this has been a great asset to helping achieve recording consistency. The familiarity of the sites and development of protocols by the team over the years has all helped in this regard.

1 Some of the plastic discs are lost over time and not always replaced, especially at sites where they would be conspicuous to the public.

2.2. Site relocation

Detailed site relocation sheets have been prepared. These include photographs and diagrams illustrating the location of the quadrats and the bolts drilled into the rock on which they are placed. Photographs showing the locations of the Upper Shore (US), Middle Shore (MS) and Lower Shore on aerial photographs are given in Appendix 0.

2.3. Quadrat recording

Data is recorded onto prepared recording sheets which are bespoke for every zone on each shore and these have been developed over the course of the surveys (see Appendix 0). Recording protocols have also been produced for each shore and are taken into the field as a reminder for recorders (see example in Appendix 0).

1 m^2 quadrats are placed over the rock markers prior to recording and the quadrat is photographed. The quadrats are gridded into 25 cells (each 20 cm x 20 cm) and frequency scores (out of 25) are recorded for most species. Where an organism cannot reliably be identified to species it is identified to genus or a higher taxon. Examples of this include Corallinaceae (crusts) and *Patella*. In some cases (like *Patella*) individual species may be recognised and where this is so, a record is made of the species being 'present' in the whole 1 m^2 quadrat.

Barnacles are counted as Cirripedia (apart from the large *Perforatus perforatus*) as it has proved very difficult (and time consuming) to look for the presence of each species in each one of the 25 cells (Bunker, 2015). Instead, individual barnacle species are recorded as being 'present' in the whole 1 m^2. The proportion of the different species of barnacle is calculated from a series of (at least 5) randomly placed 25 cm^2 photographic quadrats in each zone, which are analysed after the fieldwork. (This has been done by NRW and by other consultants, but the results are not available for this report).

Some other species have proved problematical to count consistently for different reasons. One example are small snails living in crevices and empty barnacle shells. These include rough periwinkles (*Littorina saxatilis* and related species), *Melarhaphe neritoides* and other small or juvenile snails. Often, the frequency of each species present proves difficult if not impossible to count with accuracy, so they have been recorded as the group 'small Gastropods in crevices'. Records of the individual species are recorded as 'present'. Other species recorded as 'present' include highly mobile species such as gammarids, amphipods and crabs.

Only algae whose holdfasts are within the quadrat are counted. Epiphytes on macroalgae are recorded to be from the quadrat cells where the macroalgae they are epiphytic on are attached. Care is taken to minimise disturbance of mobile invertebrates when macroalgal species are moved.

2.4. Photography

Photographs of each quadrat are taken together with general 'contextual' shots of the shore and each zone. These photographs are an essential visual record to supplement the data records from the quadrats. The photographs are labelled and catalogued during each survey and a set is held by NRW.

2.5. Limpet counts

Limpet abundance (all species aggregated) is recorded from 5 random 20 cm x 20 cm cells within each quadrat to allow the estimation of mean limpet abundance for all zones at each monitoring site. The recording form for limpet counts is given in Appendix 0. The limpet data is not considered in this report.

2.6. Limpet measurements

Approximately 200 limpets (minimum 100) are selected at random within the middle zone at each site. The longest shell length at the base is measured in millimetres using Vernier callipers. Recorders are instructed to record limpets within the same zone and habitat as the fixed monitoring quadrats (but not necessarily within the quadrats). The recorders work systematically measuring all the limpets of different sizes within an area. Once measured, the limpet shells are marked with chalk to prevent repeated measuring of the same limpet. The data collected are used to construct population profiles for each site. The recording form for limpet measurements is given in Appendix 0. The limpet data is not considered in this report.

2.7. Cirripedia (barnacle) abundance

Percentage cover of barnacles (all species aggregated) are recorded from 5 random 20 cm x 20 cm cells within each quadrat to allow the estimation of mean barnacle abundance for all zones at each survey site. The recording form for barnacle abundance is given in Appendix 0. The barnacle abundance data is not considered in this report.

2.8. Other contextual information

Contextual information on the amount of cover of common shore species in each zone on each shore, together with records of non-native species encountered which were present (e.g. in the lower shore) but not necessarily in the quadrats, is recorded. An example of the recording form is given in Appendix 0. The information from these forms, as well as photographs, has been used to help interpret the data analysed in this report.

2.9. Data management and analysis

2.9.1 Compiling the data

The quadrat data has been entered into an Access database with species names based on the World Register of Marine Species taxonomic database (WoRMS). The database is a bespoke Microsoft Access relational database called Shore Survey Data, created by James Perrins and modified by Jon Moore.

Data has been exported from the database to Excel and following this, a certain amount of ‘data cleaning’ is required to remove inconsistencies of recording.

2.9.2 Quality assurance and quality control

Inconsistencies in recording are minimised by a series of quality assurance (QA) procedures. The site-specific protocols for Monkstone Point are given in Appendix 0. The

bespoke recording sheets for each shore level (Appendix 0) are a great help in ensuring that species are recorded consistently.

QA procedures continue with data entry. The field surveyors enter their data directly into the database. The entered data is then checked by another field team against the recording sheets and inconsistencies are resolved with the recorders.

Quality control (QC) is carried out on the data set when it is exported at the end of the survey. Once inconsistencies have been ironed out the data then goes forward for analysis and storage into Marine Recorder. All original field data sheets are kept in case further reference to them is needed in subsequent years.

Prior to any analyses further QC is undertaken to ensure consistency in recording and nomenclature between years.

2.9.3 Analysis of data

This report focuses on the analysis of the quantitative frequency data collected at each site and each zone. Those species for which only presence / absence data is recorded from whole quadrats are not considered here.

Tabulated data in Excel formats were exported from the Shore Survey Data in a form ready for import into Marine Recorder[2] and PRIMER 7 (Clarke K. R. et al., 2014, Clarke K.R. and R.N., 2015) where multivariate analyses were carried out. Within PRIMER 7, the data were handled as follows:

- Prior to analysis, the frequency data were square root transformed,
- Resemblance matrices were created by employing Bray-Curtis similarity,
- MDS - non-metric Multi-Dimensional Scaling was carried out,
- Where data required further analyses to explain trends, Cluster Analysis and SIMPER with SIMPROF groups were undertaken.

2.9.4 Analysis of photographs

The photographic archive has been catalogued in Adobe Lightroom and can be searched using keywords allotted to each image.

Sets of images for each site, zone and individual quadrat have been prepared and examined to look for visual changes over time. Observations from the sets of photographs are described in the results and related (where possible) to the data analyses.

2.9.5 Data storage

Details of data storage and archiving are given in Appendix 4.

[2] Marine Recorder is a Microsoft Access database used by the Countryside Agencies and JNCC to store survey data.

3. Results

3.1. Monkstone Point upper shore

The results of data analyses for Monkstone Point US are summarised below. The monitoring area and position of the quadrats within it are shown in Figure 3.

Figure 3 Photograph to show locations of quadrats in the US at Monkstone Point.

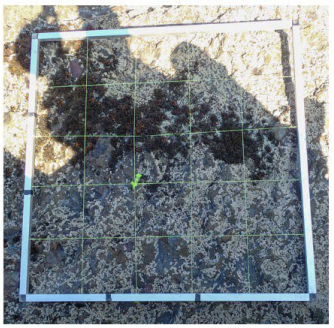
3.1.1 Visual change

The US quadrats are barnacle dominated and showed little variation over the years apart from in the abundance of *Pelvetia canaliculata* (see Figure 4). The photographs of US Q1 have been selected to illustrate the decline in cover of *P. canaliculata* cover between 2015 and 2021.

The average frequency data recorded for *P. canaliculata* each year was plotted graphically (Figure 5). The graph shows variation in the abundance of *P. canaliculata* between years but the standard deviation bars on the graph indicates that these changes were not significant.

These results indicated that although the percentage cover of *P. canaliculata* has declined between 2015 and 2021, there are many small plants which have been picked up in the frequency counts and that this frequency has not changed significantly.

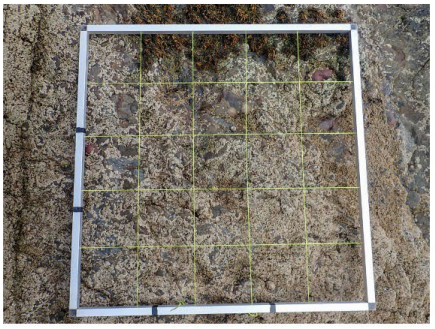
Figure 4 US Q1 at Monkstone Point showing a decrease in *Pelvetia canaliculata* between 2015 and 2021.



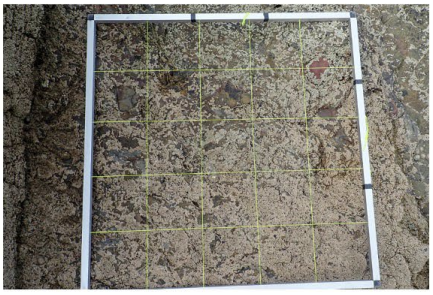
US Q1 2015

US Q1 2016

US Q1 2017



US Q1 2018



US Q1 2019

US Q1 2020

US Q1 2021

Figure 5 Graph to show the mean abundance (frequency) of *Pelvetia canaliculata* in the US of Monkstone Point fixed monitoring quadrats, with standard deviation bars.

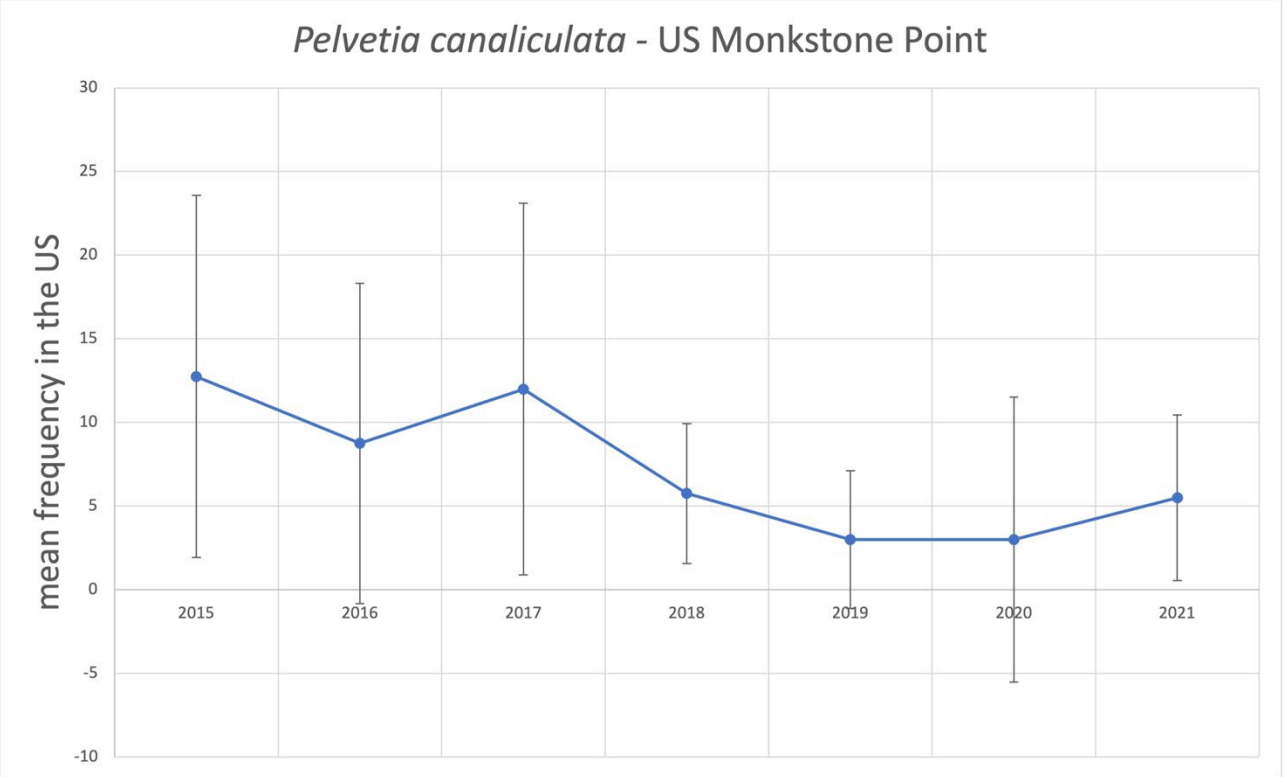


Table 1 Table to show the mean abundance (frequency) of *Pelvetia canaliculata* in the US of Monkstone Point fixed monitoring quadrats.

Year	Mean abundance	Standard deviation
2015	12.6	10.8
2016	8.6	9.6
2017	12	11
2018	5.6	4
2019	3	4
2020	3	8.5
2021	5.5	5

A better idea of cover is shown in the photographs of the Monkstone Point US quadrats (Figure 4).

3.1.2 Multidimensional scaling (MDS)

MDS plots presenting the data for all taxa recorded in the US quadrats are shown in Figure 6 and Figure 7. The stress is low (below 0.2) suggesting there is a good fit of the data to the two-dimensional plots generated.

Figure 6 shows a general pattern where quadrats for specific years are grouped together. Figure 7 shows the trend shown by the US quadrat data, where frequencies of each

species have been averaged for all four quadrats (each year). There are no obvious trends shown in the data.

Figure 6 Non-metric MDS plot showing the data for all taxa (for which frequency was recorded) in all quadrats in Monkstone Point US between 2015 and 2021.

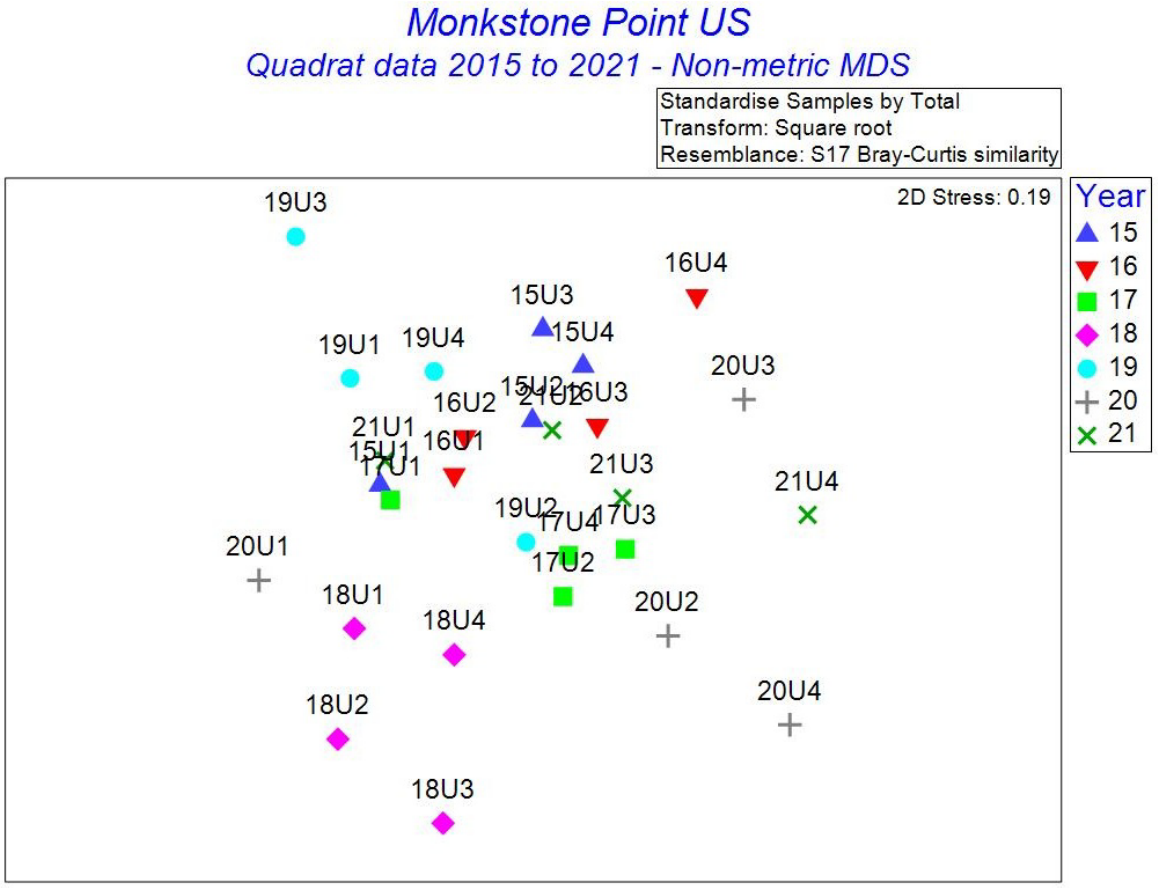
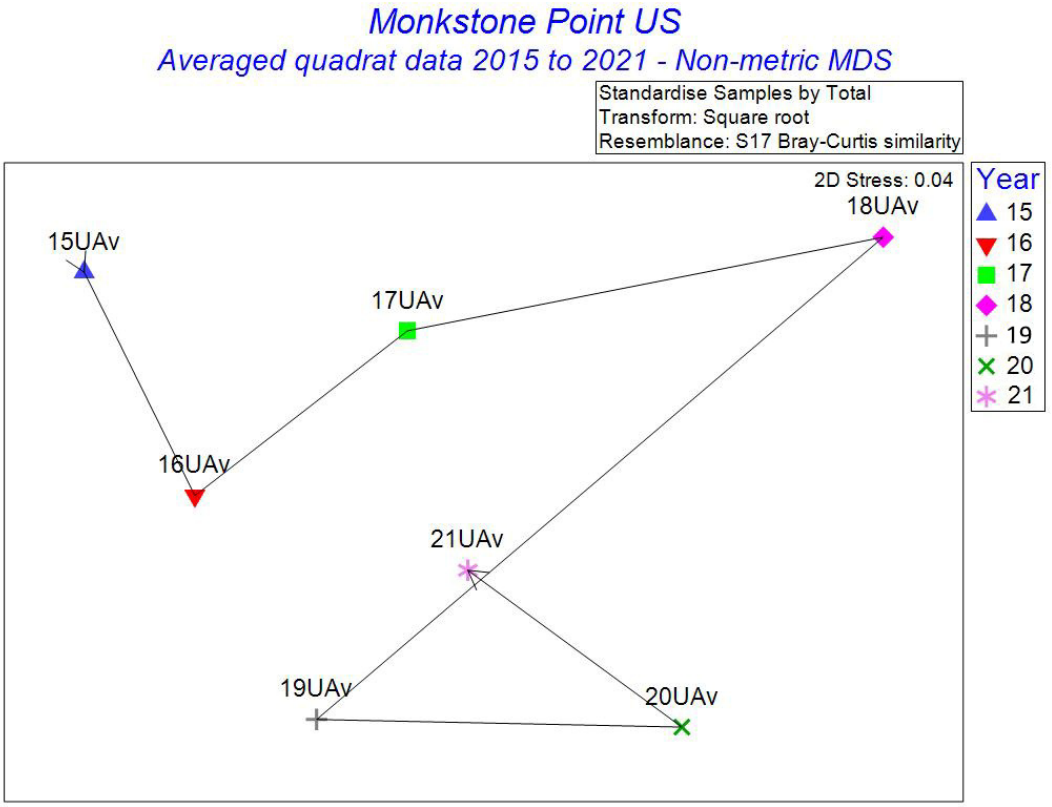


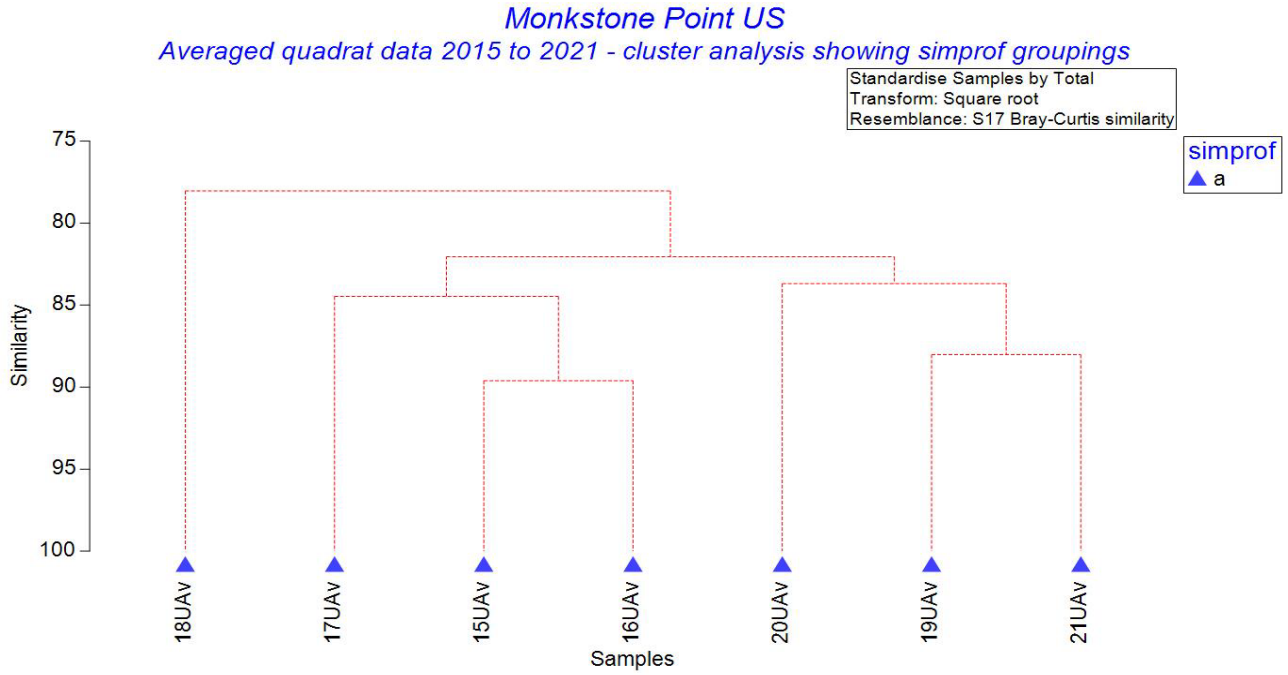
Figure 7 Non-metric MDS plot showing trends in the mean frequency data from US quadrats (for all taxa for which frequency was recorded) at Monkstone Point between 2015 and 2021.



3.1.3 Cluster analysis with SIMPROF (similarity profile tests)

In order to look for significant differences between years or year groups, cluster analysis with SIMPROF tests were undertaken using the **average quadrat** data. The result is shown in Figure 8. Only one SIMPROF group was detected so there was no significant difference between years.

Figure 8 Cluster analysis dendrogram showing the data from each year between 2015 and 2021 labelled according to SIMPROF group (no significant differences between years).



When cluster analysis with SIMPROF was undertaken with the data for **individual quadrats**, three SIMPROF groups were detected (**Error! Not a valid bookmark self-reference.**).

A SIMPER analysis of the three SIMPROF groups was undertaken. The similarity of the quadrat data within groups b and c were high (over 75%) but there was only one sample (quadrat) in **group a**, so a similarity test was not possible. The dissimilarity between the groups was in all cases less than 40%. The three SIMPROF groups all had a similar conspicuous species but the abundance of the species varied between groups (Table 2).

In summary, there was a high degree of similarity in the species present in the US and their abundances between 2015 and 2021.

Figure 9 Cluster analysis dendrogram showing the data from Upper shore individual quadrats between 2015 and 2021 labelled according to SIMPROF group.

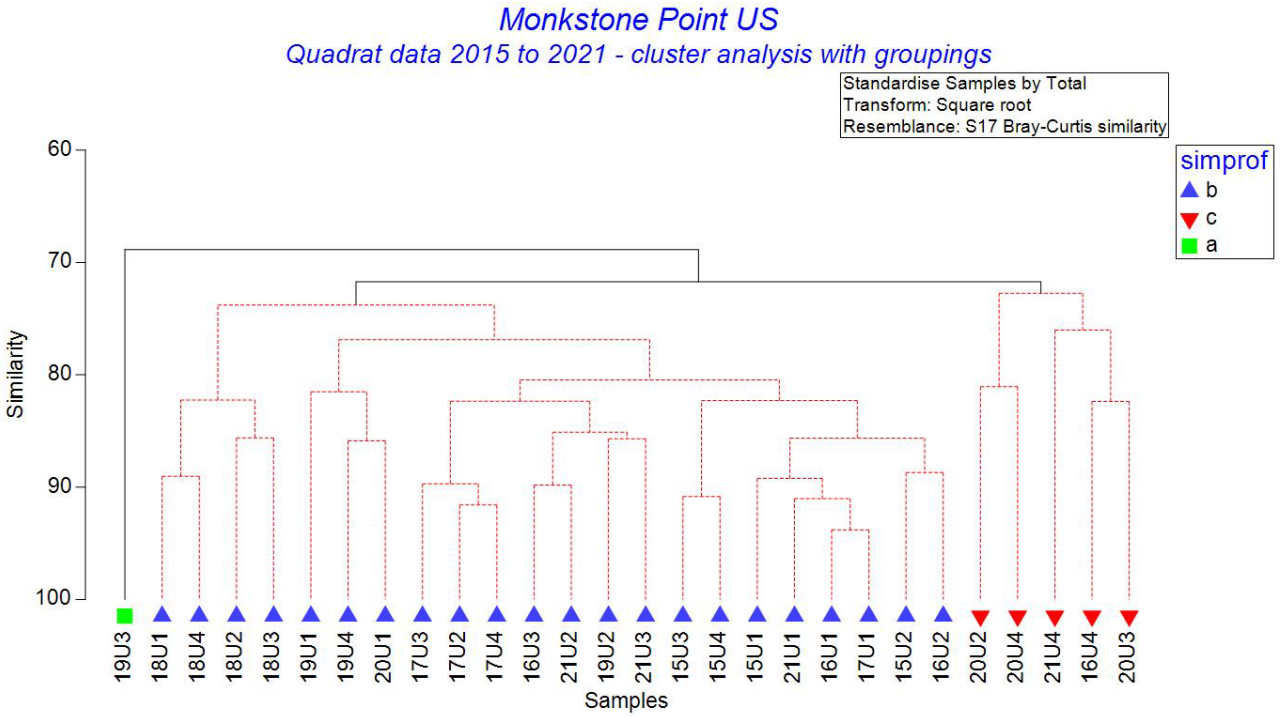


Table 2 Group b results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the US Monkstone Point data from 2015 to 2021. Average similarity: 78.79.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cirripedia all except *P. perforatus*	4.77	17.18	10.28	21.81	21.81
Gastropoda (small in crevices)	4.77	17.18	10.28	21.81	43.61
Hildenbrandia all species	3.76	12.86	6.80	16.33	59.94
Verrucaria (black)	3.91	12.79	3.43	16.23	76.17

Table 3 Group c results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the US Monkstone Point data from 2015 to 2021. Average similarity: 75.20.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cirripedia all except *P. perforatus*	5.37	20.34	10.75	27.05	27.05
Gastropoda (small in crevices)	5.37	20.34	10.75	27.05	54.11
Hildenbrandia all species	3.86	12.17	3.12	16.19	70.30

Group a results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the US Monkstone Point data from 2015 to 2021: Less than 2 samples in group.

Table 4 Groups b & c results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the US Monkstone Point data from 2015 to 2021. Average dissimilarity = 28.28.

Species	Group b Av.Abund	Group c Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Verrucaria (black)	3.91	1.63	4.50	1.84	15.90	15.90
Pelvetia canaliculata	2.51	1.53	3.03	1.45	10.72	26.62
Chlorophyta film, fuzz or threads	0.81	0.77	2.31	0.87	8.18	34.79
Lichina pygmaea	0.33	1.29	2.27	1.66	8.02	42.81
Catenella caespitosa	0.69	1.08	2.12	1.18	7.49	50.30
Hildenbrandia all species	3.76	3.86	2.08	1.74	7.37	57.67
Verrucaria (green)	1.07	0.00	2.02	0.86	7.13	64.80
Patella	2.29	2.95	1.95	1.20	6.88	71.68

Table 5 Groups b & a results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the US Monkstone Point data from 2015 to 2021. Average dissimilarity =29.78.

Species	Group b Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hildenbrandia all species	3.76	0.00	7.15	6.27	23.99	23.99
Lichina pygmaea	0.33	3.26	5.58	3.89	18.74	42.74
Verrucaria (green)	1.07	3.26	4.38	2.09	14.70	57.44
Pelvetia canaliculata	2.51	1.33	2.72	1.85	9.12	66.55
Patella	2.29	3.12	1.69	1.19	5.68	72.23

Table 6 Groups c & a results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the US Monkstone Point data from 2015 to 2021. Average dissimilarity = 37.14.

Species	Group c Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hildenbrandia all species	3.86	0.00	7.49	3.14	20.15	20.15
Verrucaria (green)	0.00	3.26	6.34	19.61	17.06	37.21
Verrucaria (black)	1.63	4.70	5.94	2.81	15.98	53.19
Lichina pygmaea	1.29	3.26	3.87	2.30	10.43	63.62
Catenella caespitosa	1.08	0.00	2.01	0.95	5.42	69.04
Pelvetia canaliculata	1.53	1.33	1.82	1.25	4.91	73.96

3.2. Monkstone Point mid shore

3.2.1 Visual change

The results of data analyses for Monkstone Point MS are summarised below. The monitoring area and position of the quadrats within it are shown in Figure 10.

Since the start of the survey, the MS quadrats have changed from barnacle dominated to mussel dominated with cover of each species changing over time. This is illustrated in Figure 11 where the photographs of MS Q1 show an increase in cover by *Mytilus edulis* between 2015 and 2017 which has been maintained up to 2021.

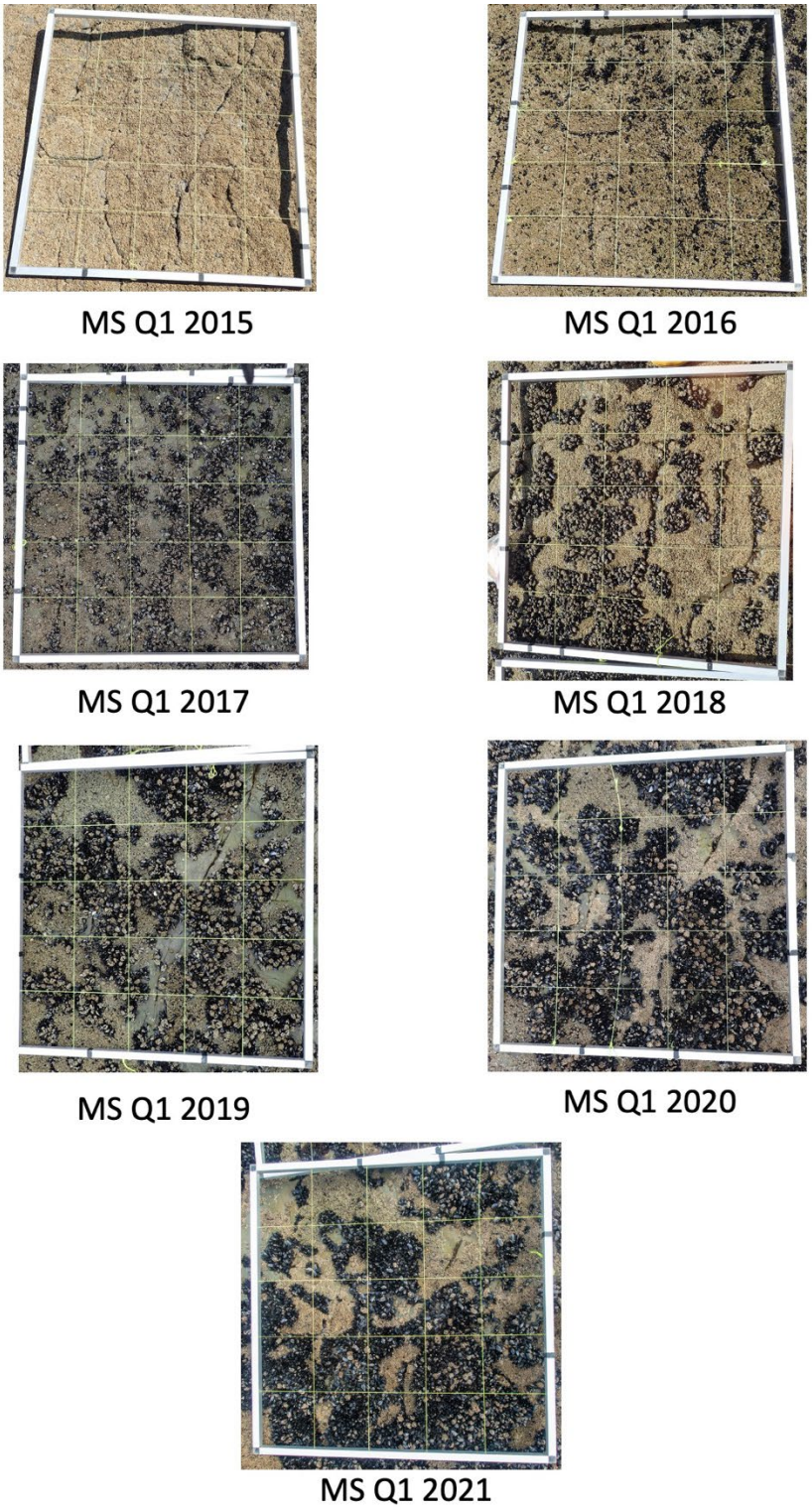
Figure 10 Views of the middle shore monitoring area in 2015, 2017 and 2021.

Monkstone Point MS monitoring area 2015

Monkstone Point MS monitoring area 2017

Monkstone Point MS monitoring area 2021

Figure 11 MS Q1 at Monkstone Point showing the establishment of the *Mytilus edulis* population between 2015 and 2021.



3.2.2 Multidimensional scaling (MDS)

MDS plots presenting the data for all taxa recorded in the MS quadrats are shown in Figure 12 and Figure 13. The stress is low (below 0.2) suggesting there is a good fit of the data to the two-dimensional plots generated. Individual quadrats for each year tend to group visually (Figure 12) in the MDS plot, but there are no significant differences between years, from the SIMPROF test.

Figure 12 Non-metric MDS plot showing the data for all taxa (for which frequency was recorded) in all quadrats in Monkstone Point MS between 2015 and 2021.

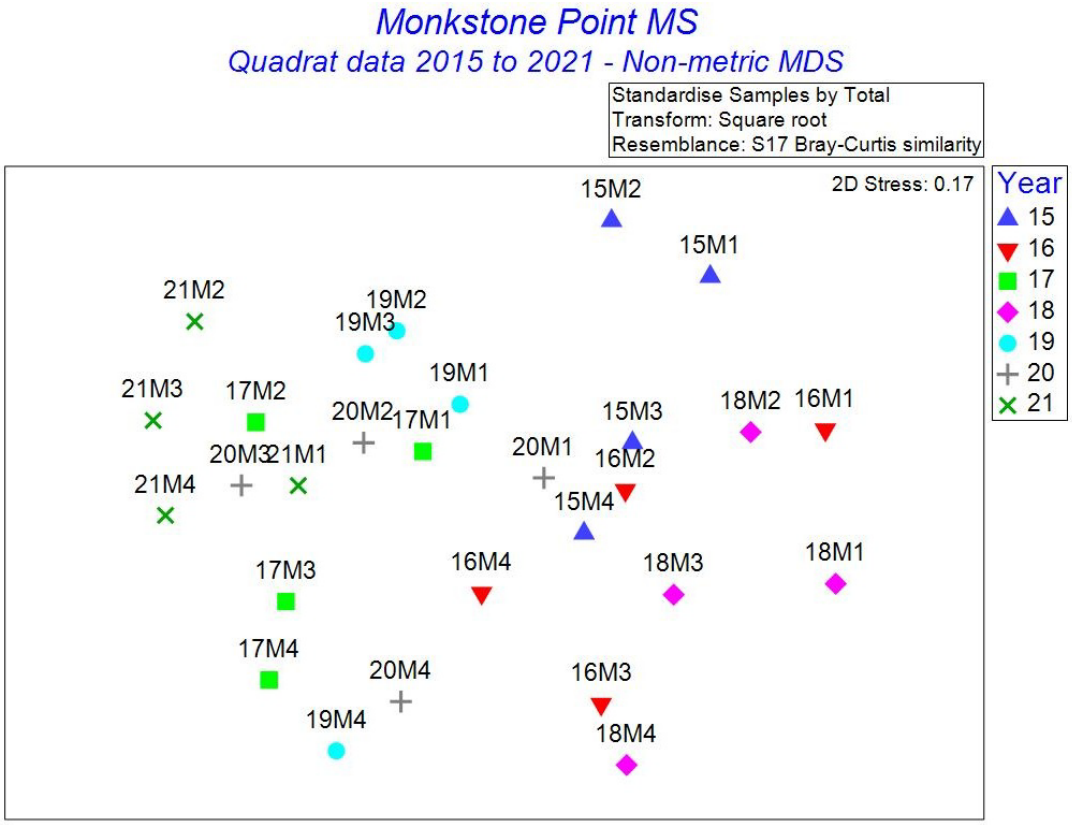


Figure 13 shows the similarity pattern for the MS quadrat data, where frequencies of each species has been averaged for all four quadrats (each year). There are no obvious trends shown in the data.

3.2.1 Cluster analysis with SIMPROF (similarity profile tests)

In order to look for significant differences between years or year groups, cluster analysis with SIMPROF tests were undertaken using the **average quadrat** data. The result is shown in Figure 14. Only one SIMPROF group was detected indicating that there was no significant change between years.

When cluster analysis with SIMPROF was undertaken with the data for **individual quadrats**, three SIMPROF groups were detected (Figure 15). Each of the quadrats move between the SIMPROF groups over time but with no obvious pattern detected.

Figure 13 Non-metric MDS plot showing trends in the mean frequency data from MS quadrats (for all taxa for which frequency was recorded) at Monkstone Point between 2015 and 2021.

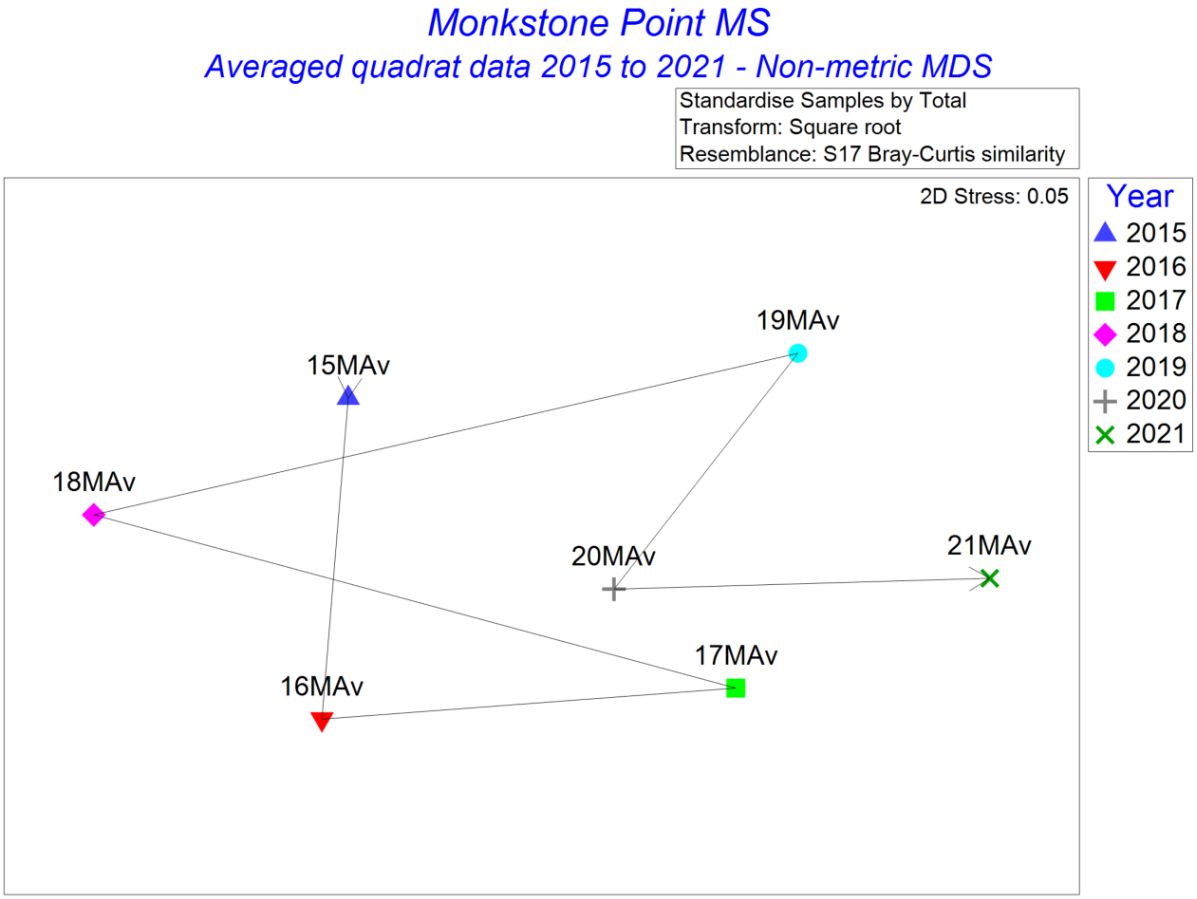


Table 7 Distribution of each SIMPROF group across years and quadrats.

Quadrat No	1	2	3	4
2015	c	c	c	c
2016	c	c	c	c
2017	a	a	b	b
2018	c	c	c	c
2019	a	a	a	b
2020	c	a	a	b
2021	a	a	a	a

A SIMPER analysis of the three SIMPROF groups was undertaken (Table 8). The similarity of the quadrat data within each group was high (over 75%). The dissimilarity between the groups was in all cases low and less than 33%. The three SIMPROF groups all had similar conspicuous species, but the abundance of the species varied between groups (Table 8). The main species contributing to the dissimilarity between the groups included *Hildenbrandia* (all species), gastropods and black *Verrucaria*.

In summary, there was a high degree of similarity in the species present in the MS and their abundances between 2015 and 2021.

Figure 14 Cluster analysis dendrogram showing the averaged data from MS quadrats each year between 2015 and 2021 labelled according to SIMPROF group.

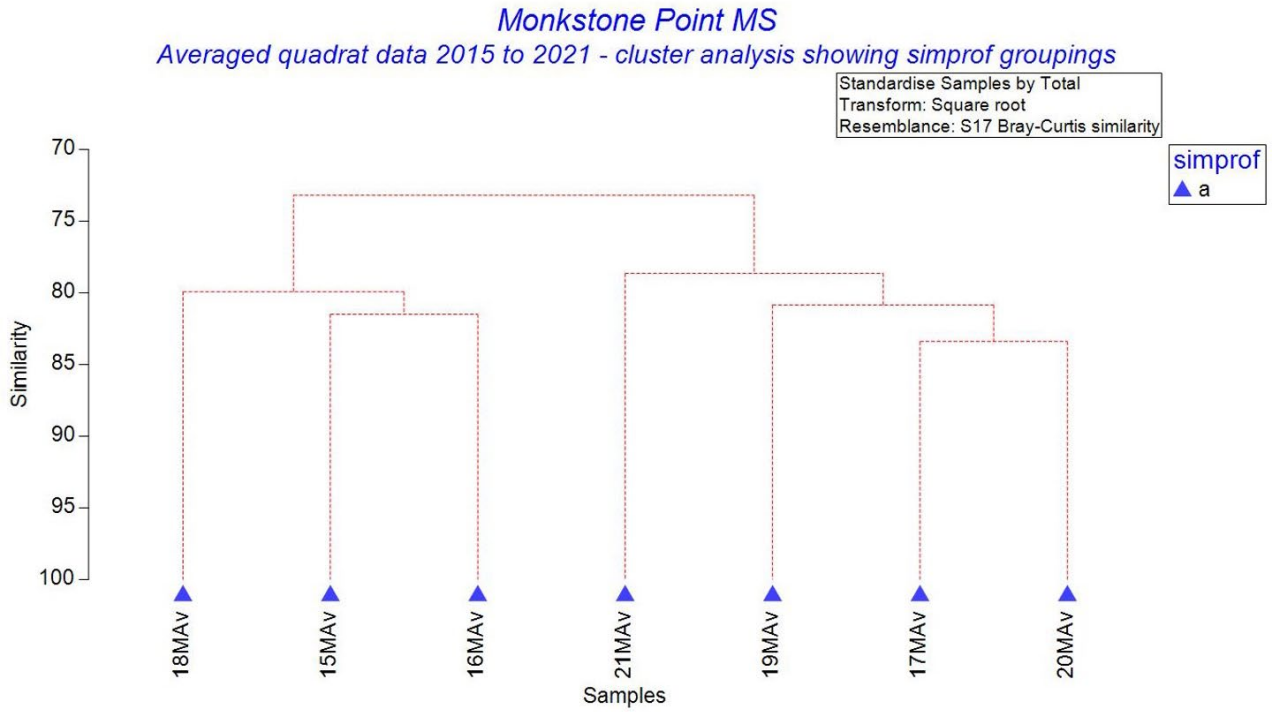


Figure 15 Cluster analysis dendrogram showing the data from individual quadrats each year between 2015 and 2021 labelled according to SIMPROF group.

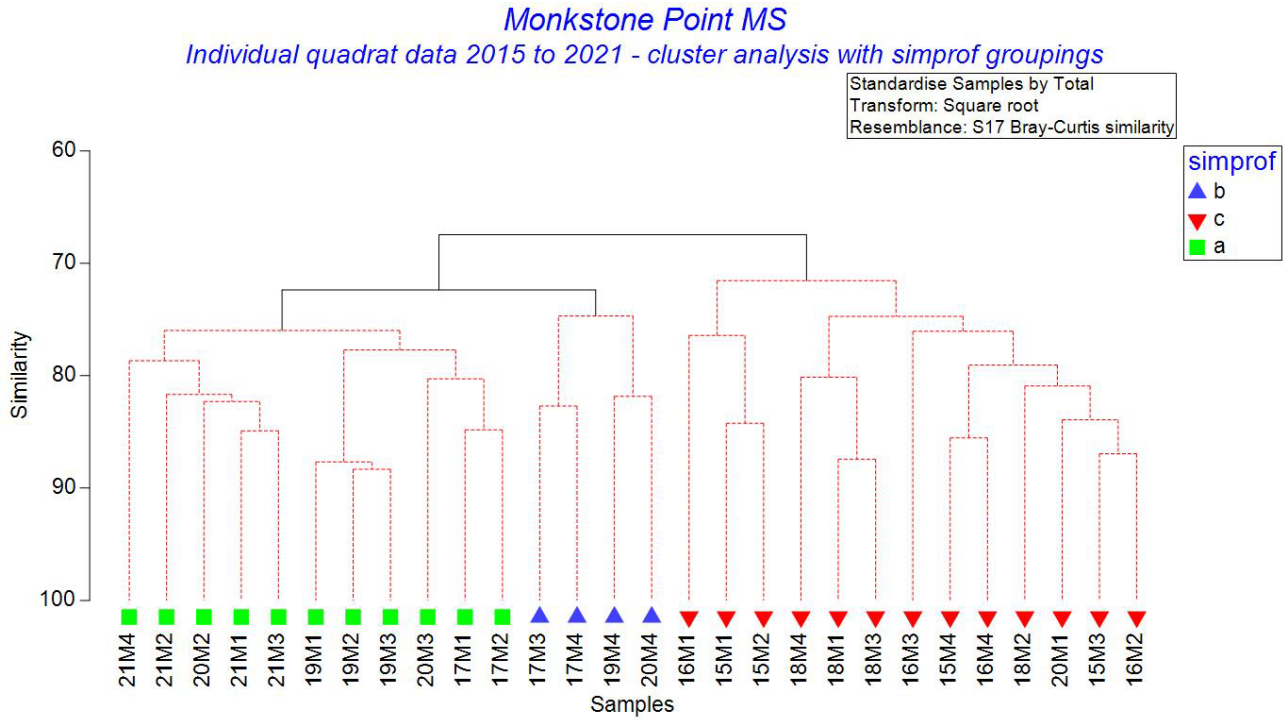


Table 8 Group c results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the MS Monkstone Point data from 2015 to 2021 (continued over page). Average similarity: 75.29.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cirripedia all except *P. perforatus*	4.45	15.23	8.95	20.23	20.23
Mytilus edulis	4.42	15.07	9.03	20.02	40.25
Gastropoda (small in crevices)	4.00	13.03	6.48	17.31	57.56
Patella	3.99	12.78	4.19	16.97	74.54

Table 9 Group a results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the MS Monkstone Point data from 2015 to 2021 (continued over page). Average similarity: 78.13.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cirripedia all except *P. perforatus*	3.79	10.50	9.23	13.44	13.44
Mytilus edulis	3.79	10.50	9.23	13.44	26.89
Patella	3.55	9.86	8.38	12.62	39.50
*Gastropoda (*small in crevices)	3.55	9.70	8.20	12.42	51.92
Hildenbrandia all species	3.17	8.42	4.84	10.77	62.69
Nucella lapillus	3.18	8.40	5.09	10.75	73.44

Table 10 Group b results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the MS Monkstone Point data from 2015 to 2021. Average similarity: 77.22.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cirripedia all except *P. perforatus*	4.32	12.32	41.54	15.95	15.95
Mytilus edulis	4.32	12.32	41.54	15.95	31.90
Nucella lapillus	3.44	9.30	7.02	12.05	43.95
Patella	3.28	9.14	55.45	11.84	55.79
Littorina littorea	2.78	7.13	20.90	9.23	65.03
Hildenbrandia all species	3.04	7.12	3.03	9.22	74.24

Table 11 Group c & a results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the MS Monkstone Point data from 2015 to 2021. Average dissimilarity = 32.31.

Species	Group c Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hildenbrandia all species	1.33	3.17	3.10	1.59	9.59	9.59
Nucella lapillus	1.83	3.18	2.32	1.35	7.16	16.76
Verrucaria (black)	0.22	1.55	2.31	1.30	7.15	23.91
Littorina littorea	3.10	2.93	2.18	1.27	6.75	30.66
*Fucaceae (*sporelings)	1.26	0.07	1.94	1.03	5.99	36.66
Steromphala umbilicalis	0.43	1.50	1.83	1.80	5.67	42.32
Ceramium shuttleworthianum	0.00	0.93	1.47	1.80	4.55	46.88
Corallinaceae crusts	0.32	1.04	1.46	1.28	4.50	51.38
Osmundea pinnatifida	0.72	0.93	1.19	1.29	3.69	55.07
Patella	3.99	3.55	1.19	1.72	3.69	58.76
*Ulva (*flat)	0.00	0.71	1.08	1.02	3.34	62.10

Cirripedia all except *P. perforatus*	4.45	3.79	1.07	1.86	3.30	65.39
Bangiales bladed	0.68	0.00	1.06	0.71	3.29	68.69
*Gastropoda (*small in crevices)	4.00	3.55	1.05	1.56	3.25	71.94

Table 12 Groups c & b results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the MS Monkstone Point data from 2015 to 2021. Average dissimilarity = 33.13.

Species	Group c Av.Abund	Group b Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hildenbrandia all species	1.33	3.04	3.15	1.53	9.51	9.51
Gastropoda (small in crevices)	4.00	2.23	2.87	2.16	8.66	18.17
Steromphala umbilicalis	0.43	2.06	2.82	1.54	8.50	26.67
Verrucaria (black)	0.22	1.92	2.77	2.83	8.37	35.05
Nucella lapillus	1.83	3.44	2.69	1.48	8.11	43.15
Littorina littorea	3.10	2.78	2.33	1.64	7.05	50.20
Fucaceae (sporelings)	1.26	0.22	1.91	1.05	5.77	55.97
Patella	3.99	3.28	1.46	1.55	4.41	60.39
Bangiales bladed	0.68	0.75	1.41	1.44	4.25	64.64
Hymeniacidon perlevis	0.20	0.96	1.38	1.43	4.18	68.81
Osmundea pinnatifida	0.72	0.22	1.08	1.14	3.27	72.09

Table 13 Groups a & b results of SIMPER analysis of the SIMPROF groups obtained from cluster analysis of the MS Monkstone Point data from 2015 to 2021 (continued over page). Average dissimilarity =27.62.

Species	Group a Av.Abund	Group b Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Gastropoda (small in crevices)	3.55	2.23	1.95	1.94	7.07	7.07
Verrucaria (black)	1.55	1.92	1.63	1.43	5.91	12.97
Steromphala umbilicalis	1.50	2.06	1.49	1.35	5.39	18.36
Ceramium shuttleworthianum	0.93	0.00	1.35	1.79	4.89	23.25
Hymeniacidon perlevis	0.13	0.96	1.34	1.47	4.85	28.10
Hildenbrandia all species	3.17	3.04	1.28	1.70	4.64	32.75
Corallinaceae crusts	1.04	0.64	1.28	1.31	4.63	37.37
Littorina littorea	2.93	2.78	1.25	1.64	4.54	41.91
Osmundea pinnatifida	0.93	0.22	1.23	1.31	4.45	46.36
Bangiales bladed	0.00	0.75	1.08	1.61	3.93	50.28
Ulva (flat)	0.71	0.00	0.99	1.01	3.60	53.88
Actinia equina	0.26	0.75	0.94	1.37	3.41	57.29
Ralfsia verrucosa	0.39	0.52	0.93	1.10	3.36	60.65
Nucella lapillus	3.18	3.44	0.80	1.32	2.90	63.55
Cirripedia all except *P. perforatus*	3.79	4.32	0.78	1.81	2.82	66.37
Mytilus edulis	3.79	4.32	0.78	1.81	2.82	69.19
Cladophora all except *C. rupestris*	0.49	0.00	0.69	0.74	2.48	71.68

Group c consists largely of quadrats from 2015, 2016 and 2018, where the frequency of fucoid sporelings is higher and frequency of *Nucella lapillus* and *Steromphala umbilicalis* are lower. Latter years (2017-2021) show much fewer fucoid sporelings and less

gastropods such as *N. lapillus* and *S. umbilicalis*, which might benefit from some canopy cover.

3.3. Monkstone Point lower shore

3.3.1 Visual change

The results of data analyses for Monkstone Point LS are summarised below. The monitoring area and position of the quadrats within it are shown in Figure 16.

Figure 16 Lower shore monitoring site at Monkstone Point in 2015 and 2020.

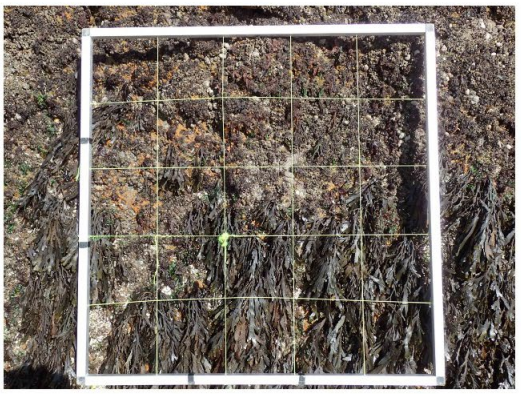
Monkstone Point LS monitoring area 2015

Monkstone Point LS monitoring area 2020

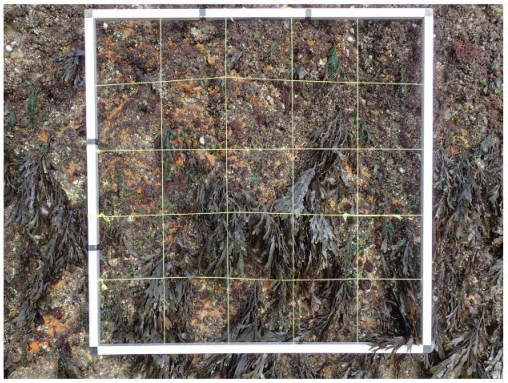
Since the start of the survey, cover by *Fucus serratus* has increased in the LS quadrats. This is illustrated in Figure 17 in the photographs of LS Q1. This pattern is similar in the other LS quadrats.

Figure 17 LS Q1 at Monkstone Point showing the increase in cover of *Fucus serratus* between 2015 and 2020 (n.b. the 2021 photos were not clear so have been omitted).

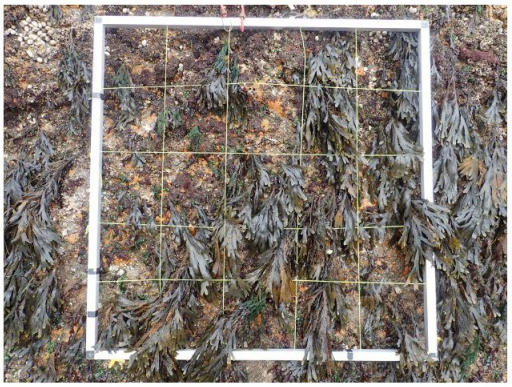
LS Q1 2015



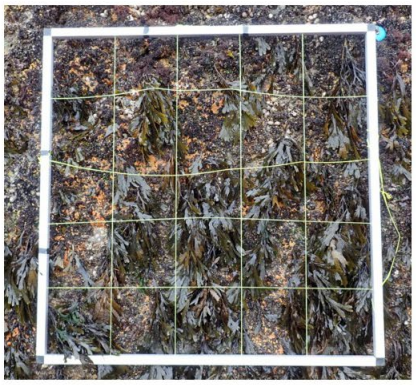
LS Q1 2016



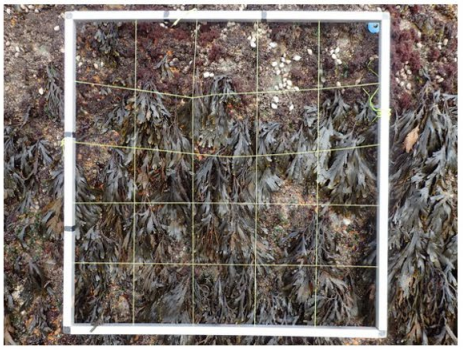
LS Q1 2017



LS Q1 2018



LS Q1 2019



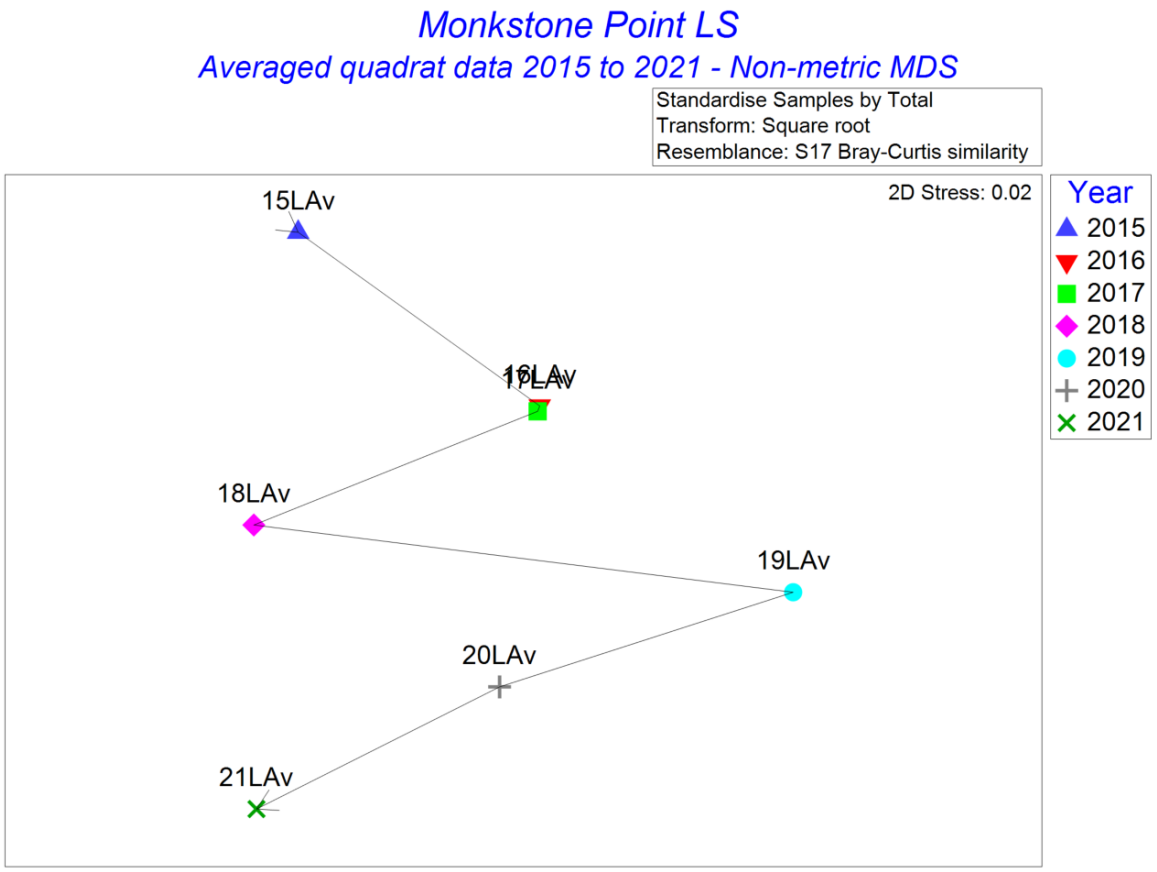
LS Q1 2020

3.3.2 Multidimensional scaling (MDS)

MDS plots presenting the data for all taxa recorded in the LS quadrats are shown in Figure 18 and Figure 20. The stress is low (below 0.2) suggesting there is a good fit of the data to the two-dimensional plots generated.

Figure 18 shows the trend shown by the LS quadrat data, where frequencies of each species has been averaged for all four quadrats (each year). A definite trend through the years is apparent.

Figure 18 Non-metric MDS plot showing trends in the mean frequency data from LS quadrats (for all taxa for which frequency was recorded) at Monkstone Point between 2015 and 2021

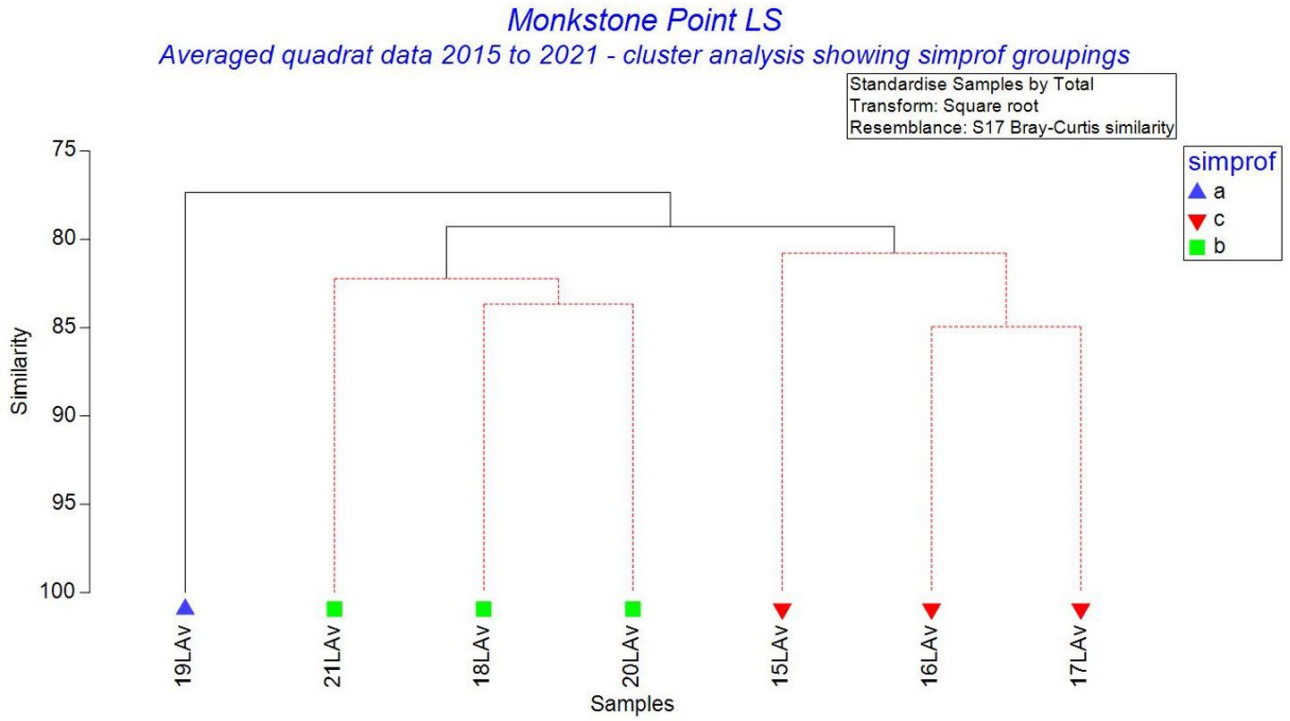


3.3.3 Cluster analysis with SIMPROF (similarity profile tests)

To determine whether there were significant differences between years or year groups, cluster analysis with SIMPROF tests were undertaken using the average quadrat data and the data for individual quadrats.

The result of the averaged quadrat data is depicted graphically in Figure 19. Three SIMPROF groups were detected with a pattern, illustrated with the MDS plot pattern seen in Figure 18. Years 2015 to 2017 are in one group (c), 2019 in another (a) and 2018, 2020 and 2021 in another (b).

Figure 19 Cluster analysis dendrogram showing the averaged data from LS quadrats each year between 2015 and 2021 labelled according to SIMPROF group.



A SIMPER analysis was undertaken to determine the species responsible for the differences between the SIMPROF groups. The species responsible for the dissimilarity between the SIMPROF groups are shown in the results of the SIMPER analysis in Table 14, Table 15 and Table 16. Note that the average dissimilarity between groups is low (< or = 22.66%).

A similar suite of species is found in each group but each group differs slightly in the species recorded and abundances and it is this that accounts for the differences between SIMPROF groups. There are no single species or particularly obvious groups of species that stand out as accounting for the dissimilarities.

Table 14 Results of SIMPER analysis of SIMPROF groups obtained from cluster analysis of the LS Monkstone Point averaged quadrat data for years 2015 to 2021; **group a** = 2019, **group b** = 2018, 2020 and 2021. Groups b & a: Average dissimilarity= 22.66.

Species	Group b Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contri b%	Cum%
Chlorophyta film, fuzz or threads	0	2.32	1.9	49.58	8.4	8.4
Mytilus edulis	0.7	2.49	1.47	2.44	6.51	14.91
Gelidium pusillum	2.2	1.14	0.87	7.23	3.84	18.74
Alcyonidium hirsutum	0	1.06	0.87	49.58	3.82	22.57
Serpulidae	1.16	2.02	0.71	65.29	3.12	25.68
Flustrellidra hispida	1.8	1	0.66	4.75	2.92	28.61
Osmundea osmunda	0.81	0	0.66	1.13	2.92	31.53
Ceramium deslongchampsii	0.8	0	0.65	3.39	2.89	34.42
Ulva (tubular)	1.46	0.9	0.51	1.22	2.25	36.66

Species	Group b Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Sphenia binghami	0.24	0.83	0.48	2.67	2.13	38.8
Hildenbrandia all species	0.29	0.86	0.47	2.08	2.08	40.88
Nucella lapillus	1.56	2.13	0.47	2.12	2.06	42.94
Steromphala umbilicalis	0.47	1	0.43	3.92	1.9	44.85
Osmundea pinnatifida	1.78	1.29	0.4	1.77	1.75	46.6
Dynamena pumila	2.39	1.91	0.39	3.71	1.72	48.33
Fucaceae (sporelings)	1.64	1.2	0.37	4.3	1.62	49.95
Hiatella arctica	0.44	0	0.37	1.75	1.62	51.56
Gelidium pulchellum	1.79	1.83	0.36	1.77	1.61	53.17
Bangiales bladed	1.19	0.75	0.36	8.14	1.6	54.77
Corallinaceae crusts	1.97	2.42	0.36	1.31	1.59	56.37
Didemnidae	0.42	0	0.35	2.7	1.54	57.91
Lomentaria articulata	1.79	1.37	0.35	4.06	1.53	59.44

Table 15 Results of SIMPER analysis of SIMPROF groups obtained from cluster analysis of the LS Monkstone Point averaged quadrat data for years 2015 to 2021; **group b** = 2018, 2020 and 2021 and **group c** = 2015, 2016 and 2017. Groups c & b: Average dissimilarity = 20.72.

Species	Group c Av.Abund	Group b Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Alcyonidium (incl. A. gelatinosum, A. mytili, A. polyoum)	1.07	0.39	0.75	2.08	3.63	3.63
Mytilus edulis	1.4	0.7	0.73	1.33	3.52	7.14
Alcyonidium diaphanum	0.88	0	0.71	9.31	3.43	10.57
Caulacanthus okamurae	0.28	1.16	0.71	2.07	3.41	13.98
Ceramium virgatum	1.1	0.35	0.6	2.64	2.89	16.87
Osmundea osmunda	0.24	0.81	0.57	1.3	2.77	19.64
Fucaceae (sporelings)	1.15	1.64	0.53	0.88	2.56	22.2
Sabellaria	0.9	1.41	0.47	1.59	2.25	24.45
Ulva (tubular)	1.82	1.46	0.4	1.18	1.92	26.37
Cirripedia all except P. perforatus	1.51	1.27	0.4	3.05	1.91	28.27
Gelidium pulchellum	1.87	1.79	0.37	1.11	1.8	30.07
Patella	1.49	1.08	0.36	1.82	1.72	31.79
Didemnidae	0	0.42	0.34	3.11	1.66	33.45
Hildenbrandia all species	0.69	0.29	0.34	1.53	1.63	35.08
Electra pilosa	1.69	1.81	0.33	1.91	1.61	36.69
Rhodophyta (non-calcareous red enc)	0.38	0.56	0.32	2.68	1.56	38.25
Bangiales bladed	0.89	1.19	0.32	1.88	1.55	39.79

Table 16 Results of SIMPER analysis of SIMPROF groups obtained from cluster analysis of the LS Monkstone Point averaged quadrat data for years 2015 to 2021; **group a** = 2019, **group c** = 2015, 2016 and 2017. Groups c & a: Average dissimilarity = 22.64.

Species	**Group c Av.Abund**	**Group a Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum%**
Chlorophyta film, fuzz or threads	0	2.32	1.87	196.42	8.28	8.28
Ceramium virgatum	1.1	0	0.89	8.96	3.91	12.19
Mytilus edulis	1.4	2.49	0.88	1.47	3.87	16.06
Caulacanthus okamurae	0.28	1.32	0.84	3.47	3.72	19.78
Alcyonidium hirsutum	0.09	1.06	0.78	6.73	3.46	23.24
Ulva (tubular)	1.82	0.9	0.74	3.34	3.28	26.52
Flustrellidra hispida	1.91	1	0.74	9.01	3.26	29.78
Alcyonidium diaphanum	0.88	0	0.71	8.17	3.14	32.92
Sabellaria	0.9	1.76	0.7	1.95	3.08	36
Gelidium pusillum	1.99	1.14	0.68	2.17	3.01	39.01
Osmundea pinnatifida	2.14	1.29	0.68	10.06	2.99	42.01
Alcyonidium (incl. *A. gelatinosum, A. mytili, A. polyoum)*	1.07	0.7	0.67	7.59	2.96	44.96
Ceramium deslongchampsii	0.78	0	0.63	4.65	2.77	47.74
Fucaceae (sporelings)	1.15	1.2	0.61	1.8	2.67	50.41
Serpulidae	1.37	2.02	0.53	1.27	2.32	52.73
Nucella lapillus	1.61	2.13	0.42	2.14	1.86	54.59
Rhodophyta (non-calcareous red enc)	0.38	0.83	0.39	1.27	1.74	56.33
Cirripedia all except *P. perforatus*	1.51	1.32	0.38	3.56	1.68	58.02
Morchellium argus	0.46	0	0.37	3.66	1.63	59.64
Corallinaceae crusts	1.99	2.42	0.35	46.94	1.53	61.17

Figure 20 Non-metric MDS plot showing the data for all taxa (for which frequency was recorded) in all quadrats in Monkstone Point LS between 2015 and 2021.

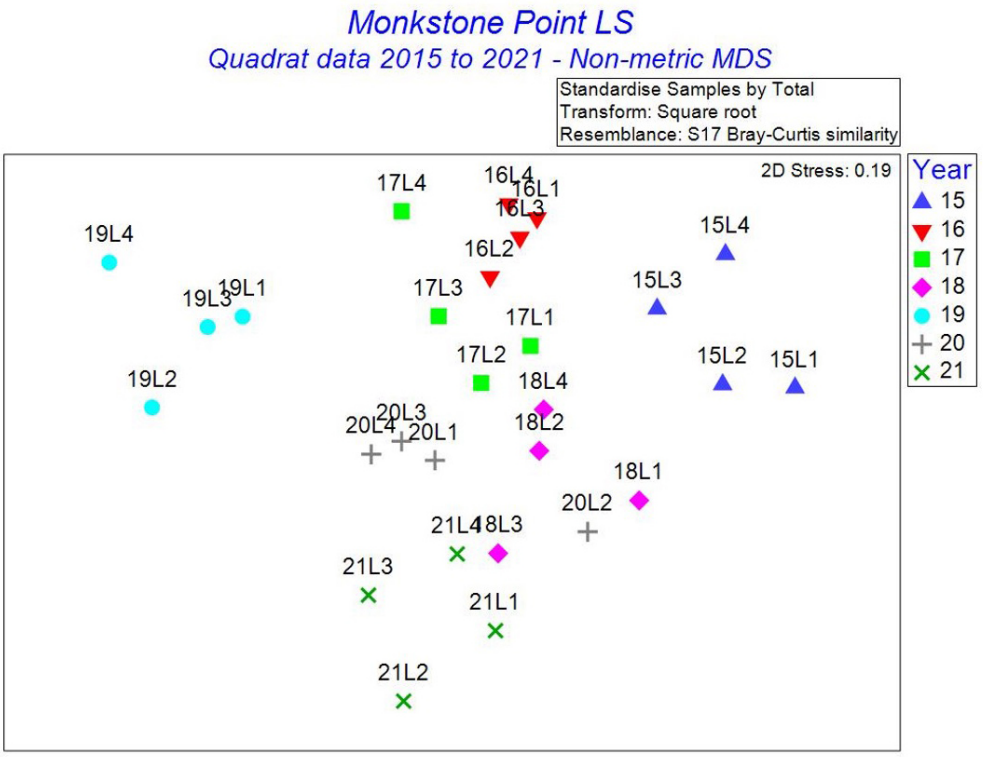


Figure 21 Cluster analysis dendrogram showing the data from individual quadrats each year between 2015 and 2021 labelled according to SIMPROF group.

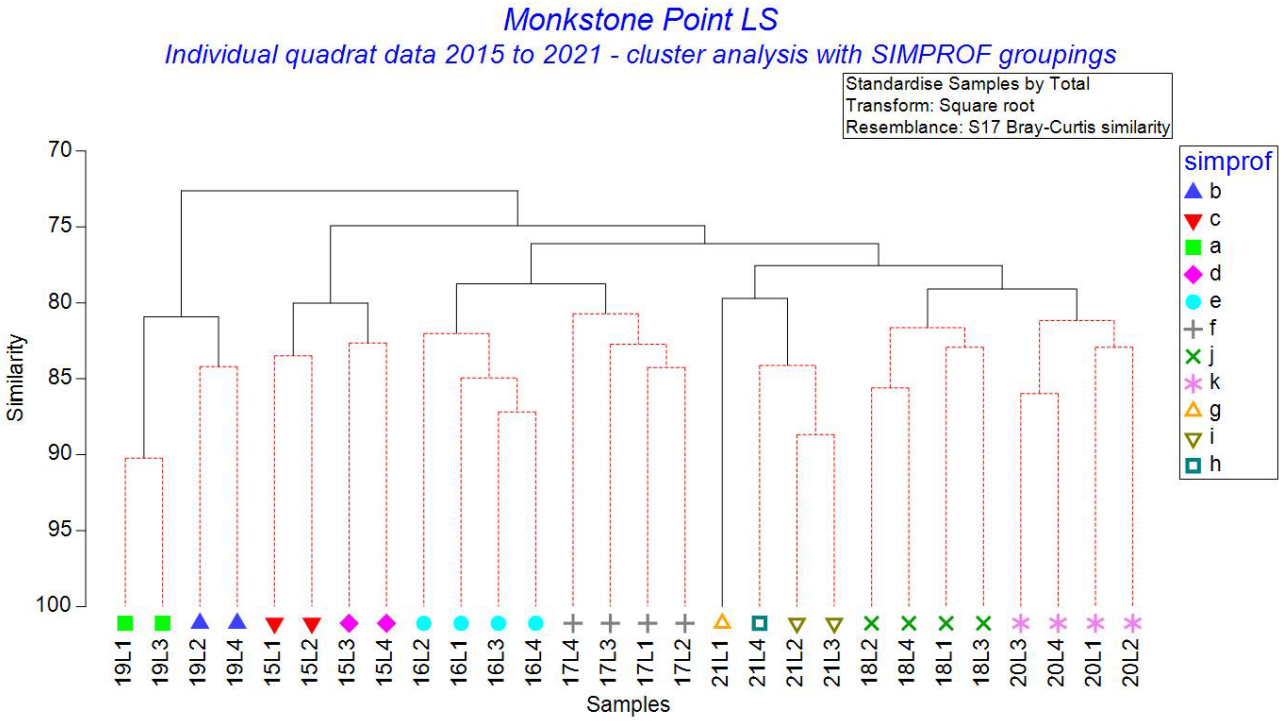


Figure 20 shows that there is a pattern for all the quadrats for each year to be grouped together but there are no obvious groupings of years or individual quadrats.

When cluster analysis with SIMPROF was undertaken with the data for individual quadrats (Figure 21), the general picture is of quadrats for each year clustering together. There were separate SIMPROF groups for each year, apart from 2015, 2019 and 2021.

In 2015, LS Q1 and LS Q2 were in a different SIMPROF group (**group c**) to LS Q3 and LS Q4 (**group d**). The data showing the species responsible for the difference between the SIMPROF groups is shown in Table 17. In summary, the data shows that the main differences between **groups c** and **d** are in the recording of several common species. Apart from this, the same basic suit of species was present in all both quadrat groups in 2015.

Table 17 Results of SIMPER analysis of two SIMPROF groups obtained from cluster analysis of the LS Monkstone Point individual quadrat data for 2015. **Group c** = quadrats 1 and 2 and **Group d** = quadrats 3 and 4. Groups c & d: Average dissimilarity=19.98.

Species	Group c Av.Abund	Group d Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Serpulidae	0.63	1.63	0.88	9.26	4.43	4.43
Steromphala umbilicalis	0.35	1.19	0.73	1.57	3.66	8.09
Bangiales bladed	0.82	0	0.72	17.82	3.62	11.71
Gelidium pulchellum	0.98	1.67	0.61	4.77	3.08	14.79
Corella eumyota	0	0.69	0.6	3.8	3	17.79
Cladostephus spongiosus	1.8	1.27	0.6	1.43	2.99	20.78
Dynamena pumila	2.58	1.95	0.55	2.31	2.75	23.53
Polyclinum aurantium	0	0.61	0.53	6.64	2.66	26.19
Flustrellidra hispida	2.29	1.75	0.48	3.69	2.42	28.61
Osmundea osmunda	0.39	0.81	0.48	1.51	2.41	31.02
Electra pilosa	1.86	1.33	0.47	4.39	2.33	33.35
Sabellaria	0.25	0.5	0.43	1.22	2.16	35.51
Ceramium virgatum	1.44	0.98	0.4	1.46	1.99	37.5
Chondrus crispus	0.98	1.28	0.39	1.24	1.93	39.42
Morchellium argus	0.43	0	0.38	0.87	1.89	41.31
Cladophora all except *C. rupestris*	0.43	0	0.38	0.87	1.89	43.2
Verrucaria (black)	0	0.43	0.37	0.87	1.84	45.04
Hildenbrandia all species	0	0.43	0.37	0.87	1.84	46.88
Corallinaceae crusts	1.92	2.05	0.36	2.71	1.82	48.71
Littorina littorea	0.64	1.05	0.36	1.73	1.79	50.5
Alcyonidium diaphanum	1.12	0.71	0.36	2.92	1.78	52.28
Hiatella arctica	0.64	0.25	0.35	1.17	1.76	54.04
Ceramium deslongchampsii	0.63	0.91	0.35	1.19	1.73	55.77
Lomentaria articulata	1.49	1.38	0.34	1.77	1.7	57.47
Patella	1.44	1.83	0.34	1.45	1.7	59.17
Fucus serratus	2.12	2.28	0.34	1.34	1.7	60.86
Mytilus edulis	1.44	1.24	0.33	1.44	1.66	62.52
Cirripedia all except *P. perforatus*	1.82	2.05	0.32	1.36	1.61	64.13

Species	Group c Av.Abund	Group d Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Polychaeta (sandy tube)	0.53	0.35	0.31	1.65	1.57	65.69
Palio nothus	0.35	0	0.31	0.87	1.54	67.23
Clathria (Microciona) atrasanguinea	0.35	0	0.31	0.87	1.54	68.77
Mastocarpus stellatus	0	0.35	0.3	0.87	1.51	70.28

In 2019, LS Q1 and LS Q3 were in a different SIMPROF group (**group a**) to LS Q2 and LS Q4 (**group b**). The data showing the species responsible for the difference between the SIMPROF groups is shown in Table 18. In summary, the data shows that the main differences between **groups a** and **b** are in the recording of several common species e.g. in **group a** Fucaceae (sporelings) were recorded whereas in **group b**, they were not. Apart from a few anomalies, the same basic suite of species was present in both quadrat groups in 2019.

Table 18 Results of SIMPER analysis of two SIMPROF groups obtained from cluster analysis of the LS Monkstone Point individual quadrat data for 2016. **Group a** = quadrats 1 and 3 and **Group b** = quadrats 2 and 4. Groups a & b: Average dissimilarity = 19.07.

Species	Group a Av.Abund	Group b Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Fucaceae (sporelings)	1.68	0	1.47	27.47	7.73	7.73
Alcyonidium hirsutum	0	1.51	1.33	46.92	6.95	14.68
Gelidium pusillum	0.61	0.98	0.87	1.18	4.54	19.22
Trivia monacha	0	0.87	0.77	46.92	4.01	23.23
Molgula	0	0.86	0.76	2.13	3.97	27.2
Serpulidae	2.4	1.55	0.75	8.12	3.91	31.11
Osmundea pinnatifida	1.17	1.19	0.6	1.87	3.13	34.23
Alcyonidium (incl. *A. gelatinosum, A. mytili, A. polyoum)*	0.92	0.25	0.59	2.24	3.11	37.34
Rhodophyta (non-calcareous red enc)	0.35	1.02	0.59	1.25	3.08	40.43
Hildenbrandia all species	0.43	1.02	0.58	1.32	3.04	43.47
Ralfsia verrucosa	0.25	0.86	0.54	1.85	2.81	46.28
Mastocarpus stellatus	0.86	0.25	0.54	2.08	2.81	49.09
Botryllus schlosseri	0	0.61	0.53	4.62	2.8	51.9
Didemnum maculosum	0	0.61	0.53	4.62	2.8	54.7
Nucella lapillus	2.4	1.81	0.52	3.03	2.7	57.4
Palmaria palmata	1.48	2.03	0.48	2.4	2.5	59.9
Botrylloides leachii	0	0.5	0.44	46.92	2.32	62.22
Cirripedia all except *P. perforatus*	1.52	1.05	0.41	1.94	2.17	64.39
Sabellaria	1.51	1.96	0.4	1.35	2.09	66.48
Cliona celata	0	0.43	0.38	0.87	1.97	68.45
Dynamena pumila	1.76	2.02	0.37	1.46	1.95	70.4

In 2021, the LS Q1 was in a SIMPROF group of its own (**group g**) as was LS Q4 (**group h**) and LS Q2 and LS Q3 were together in their own SIMPROF group (**group i**). The data

showing the species responsible for the difference between the SIMPROF groups is shown in Table 19, Table 20 and Table 21. As with previous years, a similar suite of species was recorded in each quadrat.

Table 19 Results of SIMPER analysis of two SIMPROF groups obtained from cluster analysis of the LS Monkstone Point individual quadrat data for 2021. **Group g** = quadrat 1 and **Group i** = quadrats 2 and 3. Groups g & i: Average dissimilarity = 21.86.

Species	Group g Av.Abund	Group i Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Molgula	0	1.34	1.16	10.29	5.33	5.33
Bangiales bladed	0.54	1.48	0.82	14.16	3.75	9.08
Botrylloides leachii	0.93	0	0.81	397.71	3.69	12.77
Ceramium deslongchampsii	0	0.88	0.76	230.83	3.5	16.26
Osmundea osmunda	1.2	2.02	0.72	4.76	3.29	19.55
Fucaceae (sporelings)	1.93	1.13	0.7	4.97	3.19	22.75
Polychaeta (sandy tube)	0.76	0	0.66	397.71	3.01	25.76
Cliona celata	0.76	0	0.66	397.71	3.01	28.77
Chondrus crispus	0	0.72	0.62	230.83	2.85	31.63
Palmaria palmata	1.07	1.76	0.6	139.47	2.73	34.36
Osmundea pinnatifida	1.85	1.19	0.58	8.77	2.65	37.01
Halisarca dujardinii	0	0.61	0.53	4.05	2.44	39.45
Hildenbrandia all species	0	0.61	0.53	4.05	2.44	41.89
Rhodophyta (non-calcareous red enc)	0	0.61	0.53	4.05	2.44	44.32
Corallinaceae crusts	1.93	1.33	0.52	2.19	2.4	46.72
Ralfsia verrucosa	0	0.57	0.49	0.71	2.26	48.98
Alcyonidium (incl. A. gelatinosum, A. mytili, A. polyoum)	0.54	0	0.47	397.71	2.13	51.11
Hiatella arctica	0.54	0	0.47	397.71	2.13	53.25
Grantia compressa	0.54	0	0.47	397.71	2.13	55.38
Didemnidae	0.54	0	0.47	397.71	2.13	57.51
Aglaothamnion hookeri	0.54	0	0.47	397.71	2.13	59.64
Actinia equina	0	0.51	0.44	230.83	2.02	61.66
Aulactinia verrucosa	0	0.51	0.44	230.83	2.02	63.68
Steromphala umbilicalis	0	0.51	0.44	230.83	2.02	65.69
Botrylloides violaceus	0	0.51	0.44	230.83	2.02	67.71
Trivia monacha	0.76	0.25	0.44	1.4	2.01	69.72
Sabellaria	0.76	1.2	0.38	0.98	1.76	71.48

Table 20 Results of SIMPER analysis of two SIMPROF groups obtained from cluster analysis of the LS Monkstone Point individual quadrat data for 2021. **Group h** = quadrat 4 and **Group i** = quadrats 2 and 3. Groups i & h: Average dissimilarity = 15.87.

Species	Group i Av.Abund	Group h Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Osmundea osmunda	2.02	0.92	0.97	6.39	6.09	6.09

Species	Group i Av.Abund	Group h Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Didemnidae	0	0.92	0.8	395.91	5.06	11.15
Molgula	1.34	0.53	0.71	6.15	4.45	15.6
Botryllus schlosseri	0.72	0	0.63	230.22	3.95	19.55
Chondrus crispus	0.72	0	0.63	230.22	3.95	23.5
Fucaceae (sporelings)	1.13	1.84	0.62	4.38	3.9	27.39
Ulva (flat)	1.86	2.54	0.59	14.41	3.74	31.14
Halisarca dujardinii	0.61	0	0.54	4.05	3.37	34.51
Didemnum maculosum	0.61	0	0.53	4.19	3.37	37.88
Cirripedia all except P. perforatus	1.32	0.75	0.5	0.91	3.13	41.01
Ralfsia verrucosa	0.57	0.75	0.5	2.22	3.12	44.14
Hiatella arctica	0	0.53	0.46	395.91	2.92	47.06
Elachista fucicola	0	0.53	0.46	395.91	2.92	49.98
Actinia equina	0.51	0	0.44	230.22	2.79	52.77
Aulactinia verrucosa	0.51	0	0.44	230.22	2.79	55.56
Nucella lapillus	1.86	1.4	0.4	3.03	2.52	58.08
Clathria (Microciona) atrasanguinea	0.44	0	0.38	0.71	2.41	60.5
Bangiales bladed	1.48	1.06	0.37	6.4	2.3	62.8
Osmundea pinnatifida	1.19	1.59	0.35	5.34	2.22	65.01
Sphenia binghami	0.36	0	0.31	0.71	1.98	66.99
Mastocarpus stellatus	0.36	0.53	0.31	1.49	1.98	68.97
Actiniaria	0.36	0	0.31	0.71	1.97	70.94

Table 21 Results of SIMPER analysis of two SIMPROF groups obtained from cluster analysis of the LS Monkstone Point individual quadrat data for 2021. **Group g** = quadrat 1 and **Group h** = quadrat 4. Groups g & h: Average dissimilarity = 17.13.

Species	Group g Av.Abund	Group h Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Botrylloides leachii	0.93	0	0.84	Undefined	4.89	4.89
Palmaria palmata	1.07	1.98	0.82	Undefined	4.81	9.7
Trivia monacha	0.76	0	0.68	Undefined	3.99	13.69
Polychaeta (sandy tube)	0.76	0	0.68	Undefined	3.99	17.69
Cliona celata	0.76	0	0.68	Undefined	3.99	21.68
Botryllus schlosseri	0.76	0	0.68	Undefined	3.99	25.67
Ralfsia verrucosa	0	0.75	0.68	Undefined	3.95	29.62
Alcyonidium (incl. A. gelatinosum, A. mytili, A. polyoum)	0.54	0	0.48	Undefined	2.82	35.41
Grantia compressa	0.54	0	0.48	Undefined	2.82	38.23
Didemnum maculosum	0.54	0	0.48	Undefined	2.82	41.05
Aglaothamnion hookeri	0.54	0	0.48	Undefined	2.82	43.88
Steromphala umbilicalis	0	0.53	0.48	Undefined	2.8	46.67
Botrylloides violaceus	0	0.53	0.48	Undefined	2.8	49.47
Molgula	0	0.53	0.48	Undefined	2.8	52.26

Species	Group g Av.Abund	Group h Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Elachista fucicola	0	0.53	0.48	Undefined	2.8	55.06
Hildenbrandia all species	0	0.53	0.48	Undefined	2.8	57.85
Mastocarpus stellatus	0	0.53	0.48	Undefined	2.8	60.65
Rhodophyta (non-calcareous red enc)	0	0.53	0.48	Undefined	2.8	63.44
Ceramium deslongchampsii	0	0.53	0.48	Undefined	2.8	66.24
Ulva (tubular)	1.31	1.84	0.47	Undefined	2.77	69.01
Bangiales bladed	0.54	1.06	0.47	Undefined	2.77	71.77

4. Discussion

The steep environmental gradient that occurs from the top to the bottom of the shore allows for different communities to develop in the each of the upper, middle and lower zones (see Lewis 1964). The marked separation between the zones, within a single shore, makes it sensible to consider the data for each shore level separately. This report concentrates on the frequency data collected and observations from examining the photographs.

Only basic multivariate tests using PRIMER have been used here and further analyses are possible. However, it is believed that the current suite of tests used here is sufficient to tease out long term changes and trends to be able to assess the site condition. The photographs have assisted with data interpretation and have been particularly useful in highlighting visual change that is not obvious from the frequency data, particularly regarding cover of conspicuous species.

Some data has not been considered here. The species 'presence / absence' (mobile species) data from the quadrats was not analysed but in future could give an indication of change in species composition and / or diversity over time.

The limpet counts and measurements are not considered here, nor the barnacle percentage cover data, nor the proportion of the different barnacle species (obtained from photographs). Limpets and barnacles are some of the most numerous and important species on rocky shores and how they change over time is of fundamental importance to the communities. This data should be analysed and reported in a future document.

In both the upper and mid shores, the cell frequency methodology is poor at differentiating percent cover of those species that have high abundance such as *M. edulis* and Cirripedia, due to the maximum cell count of 25 being easily reached at quite low abundance levels (c. 10% when not clumped).

4.1. Upper shore

The most notable change in the upper shore is a decline in *Pelvetia canaliculata* cover over time. Whereas cover of *Pelvetia* has visually decreased, the cell frequency counts have not declined significantly (see Figure 5). When studying quadrats close to, tiny individual thalli can be seen growing between clumps of barnacles and in crevices, too small to be seen in the photographs. It could be that the thalli are kept small by the grazing of littorinids and limpets. The thalli of *P. canaliculata* are known to live between two and five years (White, 2008) so it will be interesting to monitor how the percent cover changes over time at this site.

An Interesting feature of the upper shore community includes the presence of an unidentified black beetle, seen almost every year but never captured for identification. Also of interest are clumps of the bivalve *Lasaea adansoni*. This species is listed as commonly occurring around the UK coastline (Tyler-Walters, 2005), however the author has rarely encountered *L. adansoni* around Pembrokeshire.

4.2. Middle shore

Fluctuations in mussel and barnacle abundances are the most noticeable changes over time observed between 2015 and 2021. The interaction of these two species on rocky shores is poorly understood. A South African study looking at barnacle settlement on different surfaces found that *Chthamalus dentatus* showed a distinct preference for settling on rock surfaces rather than mussel shell (Bell et al., 2015). It could be that a similar mechanism is at work at Monkstone point and once mussels became established in the MS, they have deterred barnacle settlement.

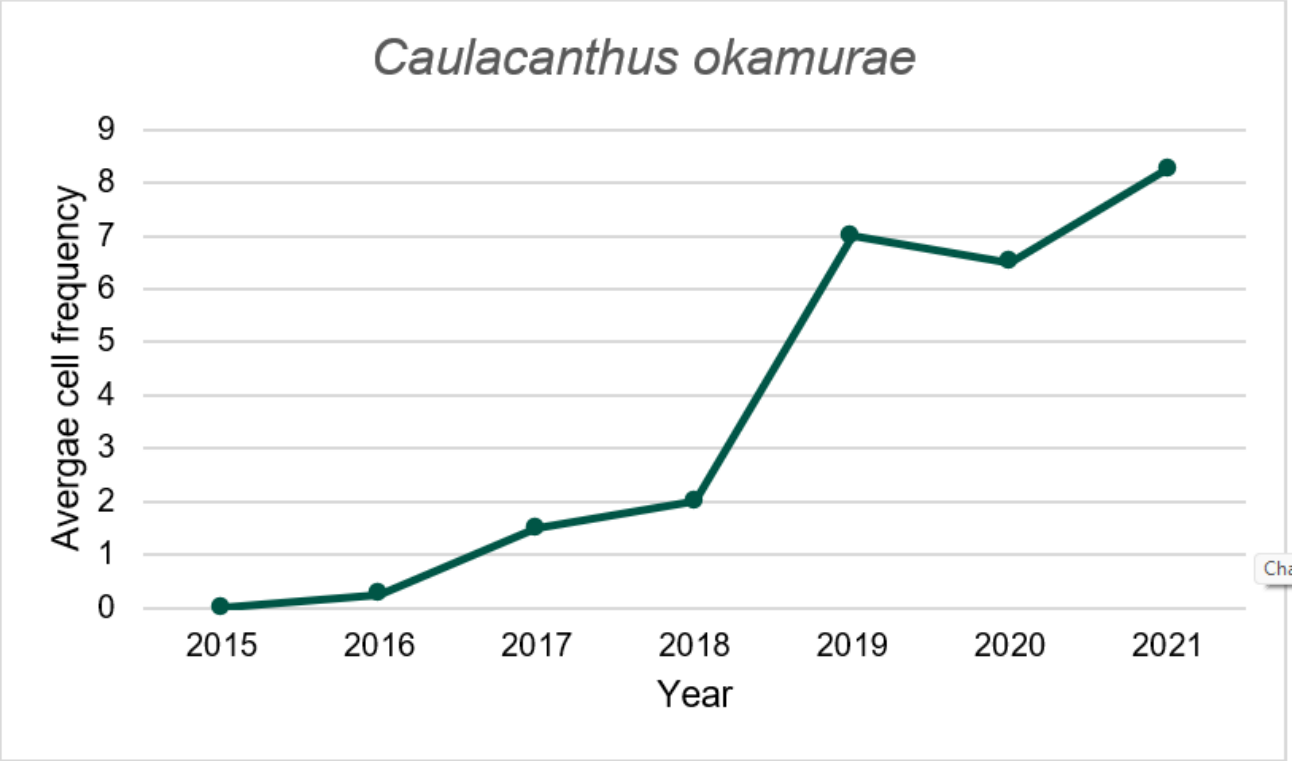
Despite the marked visual change that occurred over time, the community analyses undertaken (see section 3.2.1) did not show any very distinct patterns of significant change over time.

In the field it was more difficult to view species such as encrusting algae and small gastropods when mussel cover was dense which probably accounted for any dissimilarity between groups that were noticed.

4.3. Lower shore

The lower shore communities at Monkstone Point are rich in species as is characteristic of the lower shore limestone communities of the Carmarthen Bay and Estuaries SAC (Brazier and Bunker, 2008; Ryland and De Putron, 1998). The data analyses showed shifts in abundances of species over time but no clear trend of community change. 2019 stood out as an anomalous year, mainly due to a dense settlement of *Mytilus edulis* spat and an abundance of Serpulidae worms. The majority of the mussels had gone by 2020. It is probable that this dense settlement of mussels either prevented or masked the presence of several species e.g. *Ceramium deslongchampsii*. The only notable change in species population change is of the non-native pom-pom weed *Caulacanthus okamurae*, which has shown a steady increase since 2015.

Figure 22 Average cell frequency for the non-native alga *Caulacanthus okumarae* for each year.



4.4. Condition assessment

Other than the non-native alga density increase, there are no large scale changes within the monitoring stations and so the reef features at Monkstone Point are considered to be in good condition.

5. References

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Appendices

Appendix 1 Site-specific relocation sheet

Figure 23 Aerial photograph to show the general location of the Monkstone Point rocky shore monitoring stations (and the Trevayne monitoring rockpools)

Appendix 2 Site-specific recording forms

Figure 24 Upper shore field recording form for Monkstone Point

Monkstone Point 2022 US Recorders: Date:

Conditions:

			2022MPUS1	2022MPUS2	2022MPUS3	2022MPUS4
	Time start					
	Time finish					
	Photo Nos.					
ScientificName	**Species Qualifier**	**f / p**				
Acarina		p				
Anurida maritima		p				
Coleoptera	balck beetle	p				
Austrominius modestus		f				
Chthamalus montagui		f				
Chthamalus stellatus		f				
Semibalanus balanoides		f				
Cirripedia	all except P. perforatus	f				
Gastropoda	small in crevices	f				
Littorina saxatilis		p				
Melarhaphe neritoides		p				
Littorina littorea						
Patella	spp	f				
Lasaea adansoni		f				
Hildenbrandia		f				
Collemopsidium		p				
Verrucariaceae	all	f				
Verrucaria	black	f				
Verrucaria	green	f				

QA Date: FDB for ASML

QA by: Specimen taken? Shade to right hand corner of cell 2022

Figure 25 Middle shore field recording form for Monkstone Point

Monkstone Point 2022 MS Recorders: Date:
Conditions:

			2022MPMS1	2022MPMS2	2022MPMS3	2022MPMS4
	Time start					
	Time finish					
	Photo Nos.					
ScientificName	**Species Qualifier**	***f*** **/ p**				
Hymeniacidon perlevis		*f*				
Acarina	mites	p				
Actinia equina		*f*				
Cylista	inc. C elegans	*f*				
Urticina felina		*f*				
Anurida maritima		p				
Austrominius modestus		*f*				
Chthamalus montagui		*f*				
Chthamalus stellatus		*f*				
Semibalanus balanoides		*f*				
Cirripedia	all except P. perforatus	*f*				
Carcinus maenas		p				
Polychaeta	Polychaeta Spongy worm holes, Polydora?	*f*				
Gastropoda	small in crevices	*f*				
Littorina obtusata/fabalis	obtusata/mariae	*f*				
Littorina saxatilis		p				
Melaraphe neritoides		p				
Mytilus edulis		*f*				
Sphenia binghami		*f*				
Nucella lapillus		*f*				
Patella	spp	*f*				
Steromphala umbilicalis		*f*				
Bangiales	bladed	*f*				
Ceramium shuttleworthianum		*f*				
Cladophora	all except C. rupestris	*f*				
Corallina	all species	*f*				
Corallinaceae	crusts	*f*				
Elachista fucicola		*f*				
Fucaceae	sporelings	*f*				
Fucus vesiculosus	var linearis	*f*				
Hildenbrandia	all species	*f*				
Pseudoralphsia verrucosa		*f*				
Ulva	flat	*f*				
Ulva	tubular	*f*				
Collemopsidium		p				
Verrucariaceae	all	*f*				
Verrucaria	black	*f*				
Verrucaria	green	*f*				

QA Date: FDB for ASML
QA by: Specimen taken? Shade to right hand corner of cell 2022

Figure 26 Lower shore seaweeds field recording form for Monkstone Point

Monkstone Point 2022 LS Plants Recorders: Date:
Conditions:

			2022MPLS1	2022MPLS2	2022MPLS3	2022MPLS4	
	Time start						
	Time finish						
	Photo Nos.						
ScientificName	**Species Qualifier**	***f*** **/ p**					
Aglaothamnion hookeri		*f*					
Bladed Bangiales		*f*					
Bryopsis hypnoides		*f*					
Caulacanthus okamurae		*f*					
Ceramium deslongchampsii		*f*					
Ceramium virgatum		*f*					
Chaetomorpha ligustica		*f*					
Chlorophyta	film, fuzz or threads	*f*					
Chondrus crispus		*f*					
Cladophora	all except C. rupestris	*f*					
Cladostephus spongiosus		*f*					
Corallina	all species	*f*					
Corallina officinalis		p					
Corallinaceae	crusts	*f*					
Dumontia contorta		*f*					
Elachista fucicola		*f*					
Fucaceae	sporelings	*f*					
Fucus serratus		*f*					
Gelidium pussilum		*f*					
Gelidium pulchelum		*f*					
Gelidium spinosum		*f*					
Hildenbrandia		*f*					
Jania rubens		*f*					
Lomentaria articulata		*f*					
Mastocarpus stellatus		*f*					
Osmundea hybrida		*f*					
Osmundea osmunda		*f*					
Osmundea pinnatifida		*f*					
Palmaria palmata		*f*					
Phaeophyceae	encrusting	*f*					
Pseudoralphsia verrucosa		*f*					
Rhodophycota	non calcareous red crusts	*f*					
Ulva	flat	*f*					
Ulva	tubular	*f*					
Vertebrata fucoides		*f*					
Collemopsidium		p					
Verrucariaceae	all	*f*					
Verrucaria	black	*f*					

QA Date: FDB for ASML
QA by: Specimen taken? Shade to right hand corner of cell 2022

Figure 27 Lower shore animals field recording form for Monkstone Point

Monkstone Point 2022 LS Animals Recorders: Date:
Conditions:

Sheet 1 of 2			2022MPLS1	2022MPLS2	2022MPLS3	2022MPLS4
	Time start					
	Time finish					
	Photo Nos.					
ScientificName	Species Qualifier	f / p				
Halichondria panicea		f				
Hymeniacidon perlevis		f				
Clathria atrasanguinea		f				
Cliona celata		f				
Dynamena pumila		f				
Actinia equina		f				
Gammaridae		p				
Austrominius modestus		f				
Semibalanus balanoides		f				
Cirripedia	all except P. perforatus	f				
Perforatus perforatus		f				
Eulalia viridis		p				
Polychaeta	sandy tube	f				
Sabellaria		f				
Serpulidae	round aperture					
Spirobranchus		f				
Lanice conchilega		f				
Gastopoda	small in crevices	f				
Trivia monacha		f				
Littorina littorea		f				
Littorina saxatilis		f				
Steromphala umbilicalis		f				
Nucella lapillus		f				
Patella	spp	f				
Mytilus edulis		f				
Sphenia binghami		f				
Bryozoa	indet. crusts	f				
Alcyonidium	Includes A. gelatinosum, A. mytili and A. polyoum	f				
Alcyonidiium diaphanum		f				
Alcyonidium hirsuitum		f				
Aplidium punctum		f				
Electra pilosa		f				
Flustrellidra hispida		f				
Steromphala umbilicalis		f				
Botryllus schlosseri		f				
Botrylloides leachii		f				
Corella eumyota		f				

QA Date: FDB for ASML
QA by: Specimen taken? Shade to right hand corner of cell 2022

Monkstone Point 2022 LS Animals Recorders: Date:
Conditions:

Sheet 2 of 2			**2022MPLS1**	**2022MPLS2**	**2022MPLS3**	**2022MPLS4**
Didemnidae		*f*				
Didemnum maculosum		*f*				
Molgula		*f*				
Morchellium argus		*f*				

QA Date: FDB for ASML
QA by: Specimen taken? Shade to right hand corner of cell 2022

Appendix 3 Site-specific protocols for Monkstone Point

General notes on taking barnacle photographs

Quality of the photographs is key to be able to later identify the species. Use a good quality camera, hold camera steady when taking the photograph and check results afterwards. If image quality is poor and barnacles cannot be correctly identified, then re-take. The macro mode photo-stacking in the Olympus TG cameras is ideal for this work.

Take at least 5 good quality photographs at each zone.

Make 5 cm x 5 cm barnacle photo quadrats out of grey waterproof paper. (This can be achieved via a laser printer). Don't use white paper as this tends to under expose the barnacles and flare the photograph.

Avoid putting the quadrat on a very 3D-ish surface if possible as the camera will blur a section of barnacles in a different field.

Avoid crevices and rock that isn't level as this can blur parts of the photo making identification of species impossible.

Make sure camera is set to macro mode and adequate lighting is available (an LED ring light is ideal).

Wet barnacles are tricky to identify, if possible dry the patches which will be photographed by dabbing with a towel.

In some lower shore sites, the barnacles have merged into a form of barnacle "cement" and none of the plates are visible. Endeavour to take photographs in non-cemented areas if possible.

If camera has a photo-stacking option, then use this to get a good depth of field.

Rocky shore field data recording

General

The recorder should always read though the check list once the quadrat is finished. It's easy to miss common species e.g. *Patella* spp., Corallinaceae (crusts), Littorinids (small in crevices and dead barnacles) and Cirripedia.

When recording each species, check the proforma to ensure whether frequency or presence / absence should be recorded.

Bring kneeling pads, gloves and bungees.

Use a torch to scrutinise cracks and crevices.

Take limpet measurements at the same beach level as the monitoring quadrats. There are localised variabilities in limpet size, ensure that the habitat chosen is defined precisely.

Take general contextual photos of each zone (including the quadrat area) and use the example photo sheet to make sure they are being taken from the same place each time.

Black *Verrucaria* and green *Verrucaria* can easily be mistaken for each other, particularly when the rock is wet. Note if this is a problem during the survey. Record Verrucariaceae (as a combination of both black and brown as well as both types).

Lichens boring into barnacles and limpets are counted as the same: *Collemopsidium halodytes*.

Brown encrusting algae on limpets is recorded as *Pseudoralfsia* but it is recognised that other species may be present.

Specific

Upper shore quadrats can be reached 3 hours before LW. Limited time on LS so move down as soon as possible (depends on weather conditions).

MS, look carefully for *Chthamalus montagui*.

Calcareous worm tubes, typically with circular openings are recorded as Serpulidae.

Check carefully that the *Perforatus perforatus* barnacles are live as there are often empty shells present.

When dry, *M. neritoides* can be very hard to see in US quadrats. Although there are some larger *L. saxatilis*, there are many smaller ones also, so record both species as 'P' and the frequency of 'Gastropoda - small in crevices'.

Record *Littorina saxatilis* when there are individuals large enough to identify. Record as frequency.

LS, look carefully for cryptic bivalves *Hiatella arctica, Hiatella rugosa* and *Sphenia binghami*.

LS *Gelidium* includes *Gelidium pusillum* (small) and *G. pulchellum* and occasional plants of *G. spinosum*.

Try and collect specimens of red filamentous algae (from outside the quadrat) to confirm.

LS, Q2 look out for the nudibranch *Palio nothus*.

Brush up on field ID of the following:

Tunicates:

Polyclinum aurantium
Synoicum incrustatum
Morchellium argus
Aplidium punctum
Didemnum maculosum
Corella eumyota
Botryllus schlosseri
Botrylloides leachii
Molgula

And seaweeds:
Porphyra umbilicalis vs *P. purpurea*
Cordylecladia erecta

Caulacanthus okamurae

Limpet and barnacle recording

Figure 28 Limpet and barnacle field recording proforma

Site …… Surveyors:…… Date:…….. Conditions?..... .....

	U1	U2	U3	U4	M1	M2	M3	M4	L1	L2	L3	L4
Limpet counts	21	8	6	16	15	16	16	23	15	2	5	1
(5 of 20 x 20 cm)	24	12	9	11	5	5	2	2	20	7	19	3
Random nos. in grey	22	5	24	4	12	12	8	19	23	3	24	16
	3	14	4	25	16	19	3	1	9	17	14	2
	13	16	18	9	19	11	4	22	8	14	2	5
Barnacle photos (5 x 25 cm^2) (✓ when done)												
Barnacle %	16	1	11	8	16	2	1	3	7	8	21	8
(5 x 400 cm^2)	22	4	7	18	19	13	2	4	23	17	25	20
Random nos. in grey	14	13	2	23	10	11	4	12	5	3	17	17
	11	10	9	12	12	5	19	14	18	12	11	10
	9	14	22	21	18	24	24	22	12	18	7	21

Limpet measurements	**8**						**25**					
100-200 individuals	**9**						**26**					
Mid shore quadrats only	**10**						**27**					
	11						**28**					
Use tally method to count	**12**						**29**					
each size category (mm)	**13**						**30**					
	14						**31**					
	15						**32**					
	16						**33**					
	17											
	18											
	19											
	20											
	21											
	22											
	23											
	24											

Figure 29 Recording form for contextual species information

Zone & Species	% Cover	Photo taken? (tick)
US		
Pelvetia canaliculata		
Fucus spiralis		
Cirripedia		
MS		
Ascophyllum nodosum		
Fucus vesiculosus		
Cirripedia		
Mytilus edulis		
LS		
Fucus serratus		
Caulacanthus okamurae		
Chondrus crispus		
Corallina spp.		
Mastocarpus stellata		
Cirripedia		
Mytilus		

Surveyors to estimate % cover of the species / species groups mentioned above in a 10 m horizontal strip of the zone in which the monitoring quadrats occur, including above or below the quadrats if appropriate (e.g. if quadrats are positioned high in the zone, make sure these observations include the whole zone). Estimate rapidly by eye. Make a record of all non-native species seen.

Appendix 4 Data Archive Appendix

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

[C] A set of images from the surveys, in jpg format.

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