Cyfoeth Naturiol Cymru
Natural Resources Wales

Across-Wales intertidal SAC monitoring, Pen Llŷn a'r Sarnau SAC 2015 - 2019

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Aquatic Survey and Monitoring Ltd

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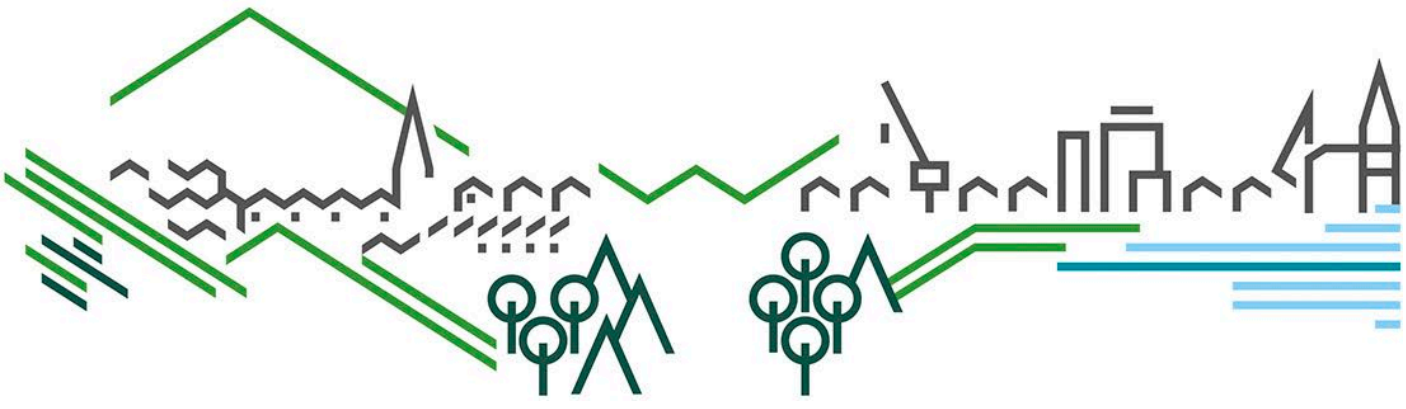

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We work to support Wales' economy by enabling the sustainable use of natural resources to support jobs and enterprise. We help businesses and developers to understand and consider environmental limits when they make important decisions.

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

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- Having a well-resourced proactive programme of evidence work;
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Mae ACA Pen Llŷn a'r Sarnau yn safle o ddiddordeb amrywiol a ddewiswyd ar sail presenoldeb naw math o gynefin morol a bywyd gwyllt cysylltiedig (cynefinoedd Atodiad I y Gyfarwyddeb Cynefinoedd) a thair o rywogaethau mamaliaid (rhywogaethau Atodiad II y Gyfarwyddeb Cynefinoedd). O ran y cynefinoedd cymhwysol, ystyrir bod ACA Pen Llŷn a'r Sarnau yn un o'r ardaloedd gorau yn y DU ar gyfer:

- Riffiau
- Cilfachau a baeau bas mawr
- Banciau tywod a orchuddir yn rhannol gan y môr drwy'r adeg
- Aberoedd
- Morlyn arfordirol

a bod y safle yn cynnal presenoldeb arwyddocaol o'r canlynol:

- Gwastadeddau llaid a gwastadeddau tywod nad ydynt dan ddŵr môr adeg llanw isel
- Dolydd heli Iwerydd (Glauco-Puccinellietalia maritimae)
- *Salicornia* a phlanhigion unflwydd eraill ar laid a thywod
- Ogofâu môr sydd dan ddŵr neu'n rhannol dan ddŵr

Mae'r adroddiad hwn yn ystyried y nodweddion pwysig sydd o ddiddordeb rhynglanwol: Yr aberoedd a'r gwastadeddau llaid, y gwastadeddau tywod a'r riffiau sydd o'u hamgylch, Cilfachau a baeau bas mawr gyda gwelyau *Zostera* rhynglanwol, poblogaethau o'r deudroediad *Pectenogammarus* sy'n byw mewn graean, pidogau mewn clai a chymunedau clogfeini ar y traeth is, a Riffiau, yn arbennig y riffiau biogenig *Sabellaria alveolata*. Yr elfennau sydd o ddiddordeb penodol i'r adroddiad hwn yw'r gwaddodion rhynglanwol a'r ardaloedd creigiog a'r poblogaethau o *Pectenogammarus* ym Mhwllheli.

Mae'r adroddiad hwn yn crynhoi'r arolygon a gynhaliwyd rhwng 2015 a 2019. Dyma'r nodweddion yr ymdrinnir â nhw:

I. Riff biogenig y mwydyn crwybr a adeiladwyd gan y mwydyn gwrychog *Sabellaria alveolate* ar lannau creigiog. Caiff arolygon llawn o gwmpas y riff *Sabellaria* a strwythur y gymuned, lle defnyddir arolygon cwadratau, eu cwblhau'n flynyddol mewn dau leoliad, sef Llandanwg ac i'r 'Gorllewin o Afon Dwyfor'. Cyflwynir dadansoddiadau unamryweb ac amlamryweb (trwy ddefnyddio PRIMER).

II. Caiff traeth graean ym Marian y De, Pwllheli ei arolygu'n flynyddol er mwyn cadarnhau cwmpas a helaethrwydd *Pectenogammarus planicrurus*.

III. Caiff cynefinoedd gwaddodion aberoedd Dwyryd/Glaslyn, Mawddach a Dyfi eu harolygu mewn cylch treigl o dair blynedd fel y gellir pennu newidiadau a thueddiadau mewn cymunedau rhywogaethau isfilodol a biotopau yn yr aberoedd.

IV. Caiff cynefinoedd gwaddodion y cynefinoedd arfordirol agored yng Nghricieth, Traeth y Greigddu, Morfa Harlech a Morfa Dyffryn (a leolir i gyd ym Mae Tremadog) eu harolygu bob tair blynedd fel y gellir pennu newidiadau a thueddiadau mewn cymunedau rhywogaethau isfilodol a biotopau.

V. Mae arolwg cwadratau ar draethau creigiog ym Mhorth Oer yn cynnwys gorsafoedd ar rannau uchaf, canol ac isaf y traeth. Mae pob un â chwadratau $1m^2$ yr un fath â'i gilydd, a chynhelir yr arolygon yn flynyddol. Cofnodir yr holl rywogaethau o fewn y cwadratau, a cheir rhifiad ychwanegol mewn perthynas â brennig a chregyn llong, gan esgor ar ddata ar gyfer asesu newidiadau a thueddiadau yn y gymuned fiolegol.

Cafodd data'r gwaith monitro ei ddadansoddi trwy ddefnyddio amrywiaeth o dechnegau unamryweb ac amlamryweb. Dyma'r canlyniadau mwyaf trawiadol yn y dadansoddiadau tymhorol:

I. Mae tywod yn effeithio ar y riff *Sabellaria* yn Llandanwg, yn y pen deheuol, oherwydd lefelau tywod sy'n amrywio'n naturiol. Arweiniodd stormydd 2018 at erydu rhywfaint ar y riff, ond ymddengys mai byrhoedlog fu'r effaith ac mae'r riff wedi adfer ers hynny.

II. Mae'r riff *Sabellaria* i'r Gorllewin o Afon Dwyfor yn amrywiol iawn, yn rhannol oherwydd yr anhawster o ran mapio'r riff darniog, ond hefyd oherwydd peth dirywiad amlwg ac adferiad dilynol mewn rhai rhannau o'r riff.

III. Ar y ddau safle lle cofnodir riff *Sabellaria*, mae'r prif organebau gorchuddio yn amrywio, ond ni ddangosir unrhyw dueddiadau parhaol arbennig.

IV. Mae'r poblogaethau *Pectenogammarus* yn ddigyfnewid ym Mhwllheli.

V. Mae'r dosbarthiad maint gronynnau yn Aber Dyfi wedi aros yr un fath fwy neu lai rhwng y cyfnodau samplu, tra gwelir lleihad amlwg ym mhresenoldeb llaid yng Nglaslyn/Dwyryd (2014, 2017) a'r safleoedd arfordirol agored. Cynigiwyd bod llaid gweddillol i'w gael yn y mannau hyn yn 2014 yn sgil y stormydd a gafwyd yn ystod gaeafau 2013/2014, sef llaid a ddeilliodd o lifwaddod a dyddodion clai clogfeini morol.

VI. Mae'r cymunedau isfilodol i gyd yn wahanol oherwydd lefelau newidiol y tywod a symudiadau sianel yr afon; er, gellir gweld cymunedau ailadroddadwy, amlwg mewn a). gwaddodion sefydlog a b). gwaddodion tywodlyd mwy symudol. Ceir anhawster wrth gymharu gorsafoedd a barwyd ar draws y blynyddoedd oherwydd natur ddynamig sianeli'r afonydd yn yr aberoedd.

VII. Yn 2017, câi cymunedau isfilodol y traeth is ar yr arfordir agored eu nodweddu gan fwy o *Macomangulus tenuis* nag yn 2014.

VIII. Mae cofnodion brennig a chregyn llong yn amrywio o un flwyddyn i'r llall, a cheir rhyw gymaint o ddiffyg cysondeb o du'r arolygwyr, ond gwelwyd lleihad trawiadol yn y gorchudd cregyn llong ar y traeth is yn 2019.

Mae diffyg cysondeb o ran cofnodi rhwng (ac o fewn) arolygwyr yn bryder cyson ym mhob arolwg monitro *in situ*. Fodd bynnag, mae'n amlwg bod y fethodoleg yn ddigonol i ganfod newidiadau yn y gymuned fiolegol.

Awgryma'r data sydd wedi deillio o fonitro ACA Pen Llŷn a'r Sarnau yn ystod y pum mlynedd diwethaf nad yw amcanion cadwraeth y safle wedi'u tanseilio a bod y nodweddion a gafodd eu monitro mewn cyflwr cadwraethol ffafriol.

Executive Summary

The Habitats Directive establishes that the management of Special Areas of Conservation (SACs) should aim to achieve the favourable conservation status of habitat and species features listed within its Annex I and Annex II. For SACs in Wales, Natural Resources Wales (NRW) is therefore required to report on a regular basis on whether features are in favourable conservation status. In Pen Llŷn a'r Sarnau SAC, programmes of feature condition monitoring have been developed by NRW and its contractors.

Pen Llŷn a'r Sarnau SAC is a multiple interest site that has been selected for the presence of 9 marine habitat types and associated wildlife (Habitats Directive Annex I habitat types) and 3 mammal species (Habitats Directive Annex II species). For the qualifying habitats, the Pen Llŷn a'r Sarnau SAC is considered to be one of the best areas in the UK for:

- Reefs
- Large shallow inlets and bays
- Sandbanks which are slightly covered by seawater all the time
- Estuaries
- Coastal lagoon

and to support a significant presence of:

- Mudflats and sandflats not covered by seawater at low tide
- Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
- *Salicornia* and other annuals colonising mud and sand
- Submerged or partially submerged sea caves

This report considers the major features of intertidal interest: Estuaries and the encompassed mudflats, sandflats and reefs, Large shallow inlets and bays with intertidal *Zostera* beds, populations of the shingle-dwelling amphipod *Pectenogammarus*, piddocks in clay and lower shore boulder communities and Reefs, particularly biogenic reefs of *Sabellaria alveolata*. Specific areas of interest for this report are the intertidal sediments and rocky areas and the populations of *Pectenogammarus* at Pwllheli.

This report summarises the surveys carried out from 2015 to 2019. The features covered are:

I. The biogenic honeycomb reef constructed by the polychaete worm *Sabellaria alveolata* on rocky shore. Full surveys of extent of *Sabellaria* reef and community structure, based on quadrat surveys are completed annually at two locations Llandanwg and 'West of Afon Dwyfor'. Uni and multi-variate analyses (using PRIMER) are presented.

II. A single shingle beach at Marian-y-De, Pwllheli is surveyed annually, to confirm the extent and abundance of *Pectenogammarus planicrurus*.

III. The sediment habitats of the Dwyryd/Glaslyn, Mawddach and Dyfi estuaries are surveyed on a rolling 3 year cycle, to identify changes and trends in infaunal species communities and biotopes in the estuaries.

IV. The sediment habitats of open coast habitats at Criccieth, Black Rock Sands, Morfa Harlech and Morfa Dyffryn, all in Tremadog Bay, are surveyed every 3

years, to identify changes and trends in infaunal species communities and biotopes.

V. A rocky shore quadrat survey at Porth Oer consists of upper, mid and low shore stations, each with 4 replicate 1 m^2 quadrats and is surveyed annually. Full species recording is carried out within the quadrats, with additional limpet and barnacle enumeration, providing data to assess changes and trends in the biological community.

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

I. *Sabellaria* reef at Llandanwg is affected by sand inundation at the southern end, due to naturally fluctuating sand levels. 2018 storms caused some erosion of the reef, but this appears to have been short lived and subsequently recovered.

II. *Sabellaria* reef at West of Afon Dwyfor is highly variable, in part due to the difficulty in mapping the patchy reef, but also due to some clear declines and subsequent recovery in certain parts of the reef.

III. At both *Sabellaria* reef recording sites, the main cover organisms fluctuate, but show no particular lasting trends.

IV. *Pectenogammarus* populations are consistent at Pwllheli.

V. The sediment granulometry in the Dyfi estuary has largely stayed the same between sampling episodes, whilst in the Glaslyn/Dwyryd (2014, 2017) and the open coast sites (2014, 2017), a distinct reduction in the presence of mud is evident. It has been proposed that in 2014, there may have been residual mud from the 2013/14 winter storms, derived from flood alluvium and marine boulder clay deposits.

VI. Infaunal communities all vary, due to changing sand levels and river channel movements, although distinct, repeatable communities can be identified from a). stable sediments and b). those more mobile sandy sediments. There are difficulties in comparing paired stations across years, due to the dynamic nature of the river channels in the estuaries.

VII. Low shore infaunal communities on the open coast in 2017 were characterised by the presence of more *Macomangulus tenuis* than in 2014.

VIII. Limpet and barnacle records vary year on year, with a certain degree of surveyor variability evident, but a notable reduction of barnacle cover was noted on the lower shore in 2019.

Inconsistency of recording between (and within) surveyors is a constant concern in all *in situ* monitoring surveys. However, it is clear that the methodology is sufficient to detect changes in biological community.

The data from the 5 years of monitoring in the PLAS SAC suggests that the conservation objectives for the site have not been undermined and therefore that the features monitored are in favourable conservation condition.

1 Introduction

1.1 Background

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

Natural Resources Wales (NRW) has a statutory duty to produce advice under Regulation 33 of the Habitats Regulations 1994, which states:

"As soon as possible after a site becomes a European marine site, [NRW/EN] shall advise other relevant authorities as to – the conservation objectives for that site, and any operations which may cause deterioration of natural habitats or ... disturbance of species, for which the site has been designated."

Conservation objectives for each feature are given in the Regulation 37 advice for the Pen Llŷn a'r Sarnau SAC (NRW 2018).

NRW developed an initial programme of intertidal monitoring work across Wales during 2004 and 2005. These surveys were managed and implemented for CCW by the Institute of Estuarine and Coastal Studies (IECS, University of Hull). These projects focused on a wide range of sensitive habitats such as *Zostera*, muddy gravels, caves, rockpools, algal dominated rocky shores, *Sabellaria* reefs, under-boulder habitats and various rare habitats and species.

Aquatic Survey & Monitoring Ltd. (ASML) have been contracted by CCW and later NRW to continue development and management of the intertidal monitoring programme for each marine SAC for the period 2007 to 2023, working as a team with CCW/NRW staff. This report continues on from previous, annual monitoring reports, and in particular, the most recent Mercer (2016).

2 Pen Llŷn a'r Sarnau SAC

Pen Llŷn a'r Sarnau SAC (Figure 1) contains nine Annex 1 habitats.

Annex I habitats that are a primary reason for selection of this site

- Sandbanks which are slightly covered by sea water all the time
- Coastal lagoons
- Large shallow inlets and bays
- Reefs
- Estuaries

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site

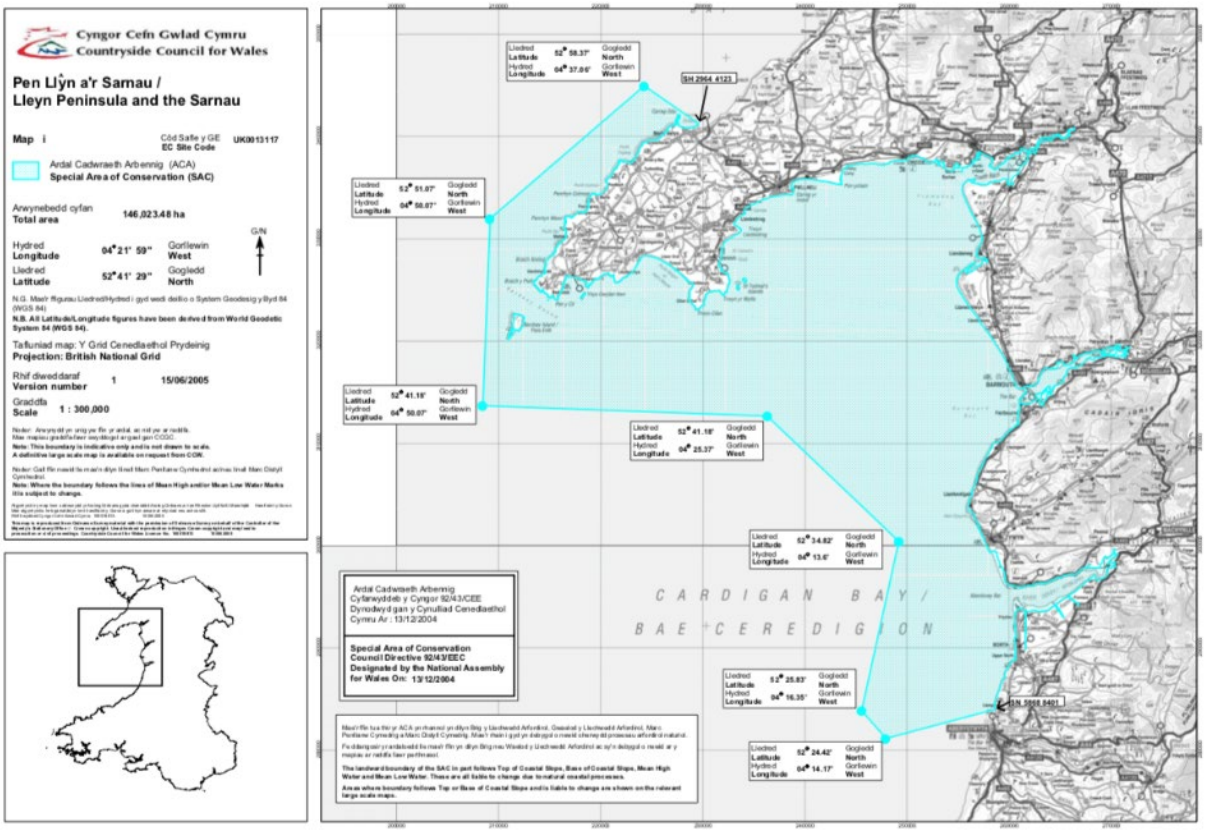
- Mudflats and sandflats not covered by seawater at low tide
- Salicornia and other annuals colonising mud and sand
- Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)
- Submerged or partially submerged sea caves

Of these, Estuaries and their constituent Mudflats and sandflats and Reefs, Large shallow inlets and bays with intertidal *Zostera* beds, populations of the shingle-dwelling amphipod *Pectenogammarus*, piddocks in clay and lower shore boulder communities and Reefs, particularly biogenic reefs of *Sabellaria alveolata* are the main habitats of interest within the intertidal areas of the SAC. Conservation Objectives for features of the SAC are given in the Regulation 37 advice for Pen Llŷn a'r Sarnau SAC (NRW 2018).

Phase 1 surveys of intertidal habitats in the SAC were carried out between 1999 and 2003 (Brazier *et al*. 2007), providing detailed mapping of the intertidal biotopes with some information on characterising species. Previous data exists on the intertidal habitats and communities present at many sites in the SAC, particularly the Mawddach Estuary where monitoring trials as part of the LIFE programme were carried out in 1999 and 2000 (Mercer 1999; Sanderson *et al.* 2001).

The present report deals with features within Tremadog Bay, on the Llŷn peninsula and the continued presence of a gravel-dwelling amphipod (*Pectenogammarus planicrurus*) at Pwllheli.

Figure 1 Pen Llŷn a'r Sarnau SAC and work area



2.1 Estuaries

Pen Llŷn a'r Sarnau SAC has representative examples of bar-built estuaries in north-west Wales, and includes the Glaslyn/Dwyryd, Mawddach and Dyfi estuaries. There is a continuous gradient between the clean mobile sands near the entrance to the sea and the consolidated mud or muddy sands in the sheltered extremes of the estuaries. The intertidal sandflats support communities of burrowing invertebrates, including dense populations of polychaete worms, crustaceans, bivalve molluscs and gastropod

molluscs. Saltmarsh fringing the shores of the estuaries, and the saltmarsh creeks and pools, are important habitat features for juvenile fish (JNCC website).

All three estuarine systems in the SAC were visited by CCW staff during September 2006 to evaluate the likely impacts of the opening of the cockle fishery. Major channel changes in the Glaslyn/Dwyryd estuary, apparently due to natural processes, meant that the main cockle bed had gone. The saltmarsh boundaries were broadly similar to those recorded by the 1997 intertidal survey (Brazier *et al*. 2007) in the area surveyed on the south side of the estuary (Morfa Harlech). NNR photo monitoring points were used to assess this. There was little change noted in the channel positions in the Mawddach and the cockle bed was still evident. There had however been an expansion of the *Salicornia* spp. boundary onto the mudflats by as much as 200 m in the area surveyed (G. Wyn, NRW pers. comm.). The coverage of *Spartina sp.* remained similar to the 1997 boundary in the area surveyed. The cockle bed was in poor condition with few large cockles and extensive growths of algae. It was thought that this could be due to the hot summer. The boundaries of the higher saltmarsh in the Dyfi were broadly similar to those in 1997. *Salicornia* spp. encroachment in the area surveyed was up to 500 m in places (G. Wyn, NRW pers. comm.). The cockle bed was in poor condition with banks of cockle shells mixed in with live cockles.

It was concluded that there had been major changes in all three estuaries since the 1997 survey, with major changes in channel morphology in the Glaslyn/Dwyryd estuary and encroachment of pioneer saltmarsh onto the mudflats in the Mawddach and Dyfi estuaries. The reasons for these changes were not known but in the absence of any other evidence appeared to be due to natural fluctuations in sediment levels, water flow and temperature.

2.2 Reefs

Intertidal reefs in Pen Llŷn a'r Sarnau SAC include areas of bedrock and boulder/ cobble habitats and many areas are characterised by biogenic reef formed by the honeycomb reef worm *Sabellaria alveolata*.

Surveys of intertidal habitats in the SAC in 1996 and 2003 (Brazier *et al.* 2007) provided detailed maps of the intertidal biotopes with some information on the characterising species.

Sabellaria reefs are a Section 7 habitat (Environment Act (Wales) 2016) (having previously been designated as a Biodiversity Action Plan Habitat (c.f. www.ukbap.org.uk)) and Nationally Important Biotopes (JNCC 1996). Surveys of *Sabellaria* reefs in the SAC were carried out for NRW in 2004 and 2005 (Boyes & Allen 2008) and in 2008, 2009, 2010, 2012, 2013, 2014, 2015, 2016, 2017, 2018 and 2019 (Mercer 2010a, b, Mercer 2011, Mercer 2013, Mercer 2016).

Rocky shore monitoring at Porth Oer has been carried out every year since 2012.

2.3 Presence of *Pectenogammarus planicrurus* at Pwllheli

Pectenogammarus planicrurus is the only amphipod which is a permanent resident of shingle beaches. It is found on the steep sand/shingle beach fronting the Promenade at Pwllheli (Marian y De) (LGS.Pec biotope) as discovered during the CCW Phase 1 surveys, June 1996 (Brazier *et al*. 2007). IECS was commissioned in 2004 to identify and map the presence and extent of *P. planicrurus* along the beach, establishing

whether the amphipod was restricted to a localised habitat or was present along the entire length of Pwllheli beach. In addition, they estimated its abundance and took core samples for Particle Size Analysis (PSA) across the full extent of the biotope (Hemingway *et al*. 2004). 61 stations were sampled and the amphipods were found to be present at 53 of these and abundant (SACFOR scale) at 21 of the 53 stations. The animals can be observed in the shingle in the lower half of the beach in the vicinity of the surf zone, when a small scrape reveals standing water. Dense aggregations can usually be found under any of the larger embedded cobbles, where they are presumably more secure. Further surveillance of the amphipod has been undertaken by ASML since 2007 on an annual basis.

2.4 Survey objectives

Table 1 Tasks selected by NRW for study by ASML in the SAC in 2015 - 2019

Feature / attribute	Site(s)	Task
Pectenogammarus populations (LGS.Pec) - presence	Marian-y-de at Pwllheli	To observe the population of this scarce 'shingle beach specific' amphipod species on an annual basis.
Sabellaria alveolata - distribution, quality and associated species	Llandanwg and West of Afon Dwyfor rocky shores.	To re-map the boundary of a section of the *Sabellaria* reef and to re-survey, with quadrats, the locations already established and surveyed in 2009–2014 on an annual basis.
Intertidal Reef – quality	Porth Oer rocky shore	To re-survey the fixed monitoring quadrats established in 2012 in the upper, mid and lower shore stations at Porth Oer on an annual basis.
Estuaries	Dyfi, Mawddach & Glaslyn/Dwyryd estuaries	To re-survey some of the estuary "grid sites" *in situ* and the quantitative coring sites previously established, on a rolling programme, to include each estuary at least once every three years.
Open coast	East Criccieth, Black Rock sands, Morfa Harlech and Morfa Dyffryn	To quantitatively sample the infauna of the middle and lower shore sediment biotopes on these 'open coast' beaches at least once every three years.

The surveys of the *Pectenogammarus* population (LGS.Pec) intends primarily to confirm the continued presence of the species at Pwllheli whilst repeating, to a greater or lesser degree, work carried out by IECS in 2004 (Hemingway *et al*. 2004). ASML conduct a brief annual survey/observation exercise to confirm the presence of and to a greater or lesser extent the approximate distribution and abundance of this amphipod. The extent of the spatial aspect of the survey generally depends on the human resources available during the annual field work week.

The *Sabellaria alveolata* work planned annually, repeated the 2009, 2010, 2012, 2013, and 2014 surveys. In 2015, 2016, 2017, 2018 and 2019 quadrat work was carried out by CCW/NRW and ASML at the two main monitoring sites within the SAC (Llandanwg and West of Afon Dwyfor). This occurred on an annual basis and included mapping the extent of the beds in a locally defined area in the vicinity of the quadrat survey sites.

The intertidal reef work at Porth Oer aimed to re-survey 12 fixed quadrats on this rocky shore at the western end of the Llŷn peninsula. This has occurred on an annual basis since 2012 when the quadrats were established. This survey utilises the methods developed for the existing rocky shore monitoring sites in the Pembrokeshire Coast SAC (Hull *et al.* 2008) and in the Skomer Marine Conservation Zone. Four fixed quadrats are located in each of the upper, middle and lower shores, whilst species-specific surveys are also conducted for limpets and barnacles.

Sediment sampling in the estuaries has evolved into a rolling programme of surveillance of the infaunal communities, visiting each estuary at least once every three years. The Mawddach quantitative sediment sampling transects established in 1999 (Mercer 1999) were revisited in 2014, 2016 and 2019; the Dwyryd in 2013, 2014 and 2017 and the Dyfi in 2013, 2015 and 2018. On each occasion the work repeated a previous quantitative infaunal coring exercise, whilst in the Dwyryd and the Dyfi a limited number of *in situ* observations were also made. These observations were planned to use a pre-existing grid of sampling points which were established across each of the estuaries. This exercise helps to continually re-map the channel positions and the locations of the broad littoral sediment biotopes found within these estuaries.

The open coast sediment-shore monitoring programme encompasses a quantitative set of infaunal cores being taken from both mid-shore and lower shore on each of four beaches; Morfa Dyffryn, Morfa Harlech, East Criccieth and Black Rock Sands. The sediment is sieved over a 0.5 mm mesh *in situ* and the retained residues are later fixed at the field base and then processed by an independent analytical laboratory for the presence and abundance of all taxa. The data are then analysed for their univariate and multivariate infaunal community characteristics.

3 Methods

3.1 Survey planning, logistics and risk assessment

Development of a survey strategy and methodology for all the tasks has been carried out continually by ASML and NRW. Logistical planning for the annual surveys is carried out by ASML and each year a draft Survey Plan and Risk Assessment is prepared and distributed to all the surveyors in advance of the survey. This plan once finalised includes information on the survey location, personnel involved, work scope and plan, logistics, tide tables, potential hazards, assessment of risk from those hazards, actions/measures to minimise risk, contact details for emergency services, personnel and next of kin. The team is always based in holiday cottages and/or B&B accommodation. The houses are generally located in the vicinity of Harlech or Porthmadog to enable efficient work across the Pen Llŷn a'r Sarnau SAC from south to the Dyfi and north and west to Porth Dinllaen and Porth Oer on the Llŷn peninsula. Wi-Fi, off-road parking, with spacious inside and outside accommodation are always high on the list of pre-requisites for a suitable fieldwork base.

Field survey equipment is provided by both ASML and NRW; this includes handheld GPS receivers (various makes and models), digital cameras (various makes and models, all set to high resolution and local time), gridded quadrats (various sizes), tape measures, first aid kits. Microscopes, identification guides, laptop computers, laser printer and other field laboratory equipment are also provided by both ASML and NRW. GIS mapping software (MapInfo, ArcMap and QGIS), Microsoft Office software and

various other utilities are used for daily survey planning, data entry, downloading GPS data and digital photographs and cataloguing files.

All field work throughout the five years described in this report was carried out during five days of spring tides, between the 1st July and 6th August. The field teams have been comprised of up to nine marine biological surveyors (see field logs, Appendix 1). Weather conditions have been generally workable for all five weeks of survey encompassed in this report. During the five surveys only one day has been lost to bad weather. On August 3rd, 2016, a westerly gale prevented the tide from falling sufficiently to allow *Zostera marina* seagrass beds to be surveyed at Porth Dinllaen on the north coast of the Llŷn Peninsula. Only the upper edge of the *Zostera* bed was exposed on that day as the tide receded. The storm surge held the water in the bay, resulting in an abandonment of the survey.

3.2 *Sabellaria* reef surveys

The modified quadrat methodology for *Sabellaria* monitoring (Boyes & Allen 2008) has been used in the Pen Llŷn a'r Sarnau SAC survey since 2009. A rationale for the modified methodology is given below. The proforma recording form used in the field is presented in Appendix 2.

3.2.1 Rationale

Extent and distribution of *Sabellaria* reef in Wales has clearly been increasing in recent years and this may be related to climate change (Welsh Government 2020). Monitoring both extent and overall condition at selected sites is therefore very relevant to SAC condition. The quadrat survey methodology developed for Pen Llŷn a'r Sarnau SAC (Boyes & Allen 2008) and adapted by ASML on the surveys of 2007, 2008 and 2009 provide good quality, repeatable data in a relatively short timescale. Hence these methods have been considered appropriate since 2009 (Mercer 2010a, b, Mercer 2011, Mercer 2013, Mercer 2016).

Good condition of *Sabellaria* reef is listed as a Conservation Objective of the Pen Llŷn a'r Sarnau SAC. The summary results shown in section 4 focus on the value that the *Sabellaria* reef provides to the biological condition of the communities of fauna and flora. Monitoring work to date suggests that the most useful attributes to measure to give the best indication of conservation status are species diversity and percentage cover of *Sabellaria*. Mature *Sabellaria* reef tends to increase sub-habitat diversity (including abundance of overhangs, crevices, pools etc.) and consequently can increase species diversity on the shore. However, there is no simple correlation with age and condition of the reef. Measures of sub-habitat diversity and/or species diversity may therefore provide information on the biological condition, but measures of the condition of the reef itself may only provide information on its viability.

Many of the measures described in Boyes & Allen (2008) to record attributes in a 4 m^2 quadrat are very difficult to estimate with any accuracy or repeatability. Photographs are likely to provide better comparative information. Quadrats provide the simplest repeatable recording unit, but fixed quadrats were not thought to be feasible, especially as much of the underlying boulder substratum, on both selected shores, is potentially mobile during rough weather and the biotope is of course very fragile, so repeated surveys in one place would almost certainly be destructive. The best quadrat size for rapid deployment and recording, limiting the effects of small scale heterogeneity (in the typical large boulder/cobble habitats present) and for practical use in the field, is

considered to be 0.25 m^2 (0.5 m x 0.5 m). A larger size quadrat is cumbersome in the large boulder habitat and they are also known to be inefficiently searched.

The methodology of Boyes & Allen (2008) provided data for only eight quadrats spaced over a large area of shore, which provides an inadequate amount of data for monitoring change in this habitat due to its high natural spatial and temporal variability (high risk of both type I and type II errors[1]). Greater replication of quadrat data can be achieved by reducing the number of attributes recorded and using measures that are simpler and quicker to collect. In particular, recording abundance of all conspicuous species with cell frequencies in a $1m^2$ quadrat can take too long. For many species in this habitat it also provides more precision than is necessary, because of the high natural spatial and temporal variability in their abundance. Rapid estimates of percentage cover are much quicker to record for algae and other ground covering taxa, whereas 'presence' only is adequate for mobile faunal species. If presence of a species is recorded in a large number of random quadrats, this provides a robust and ecologically relevant measure of its abundance at a site. Some saving in survey time can be achieved by concentrating the quadrats on just a few (e.g. 7-9) selected stations within each site. It remains a challenge to fully take account of the habitat heterogeneity, when, at a quadrat scale, percent cover of *Sabellaria* reef can frequently range from zero to 100%.

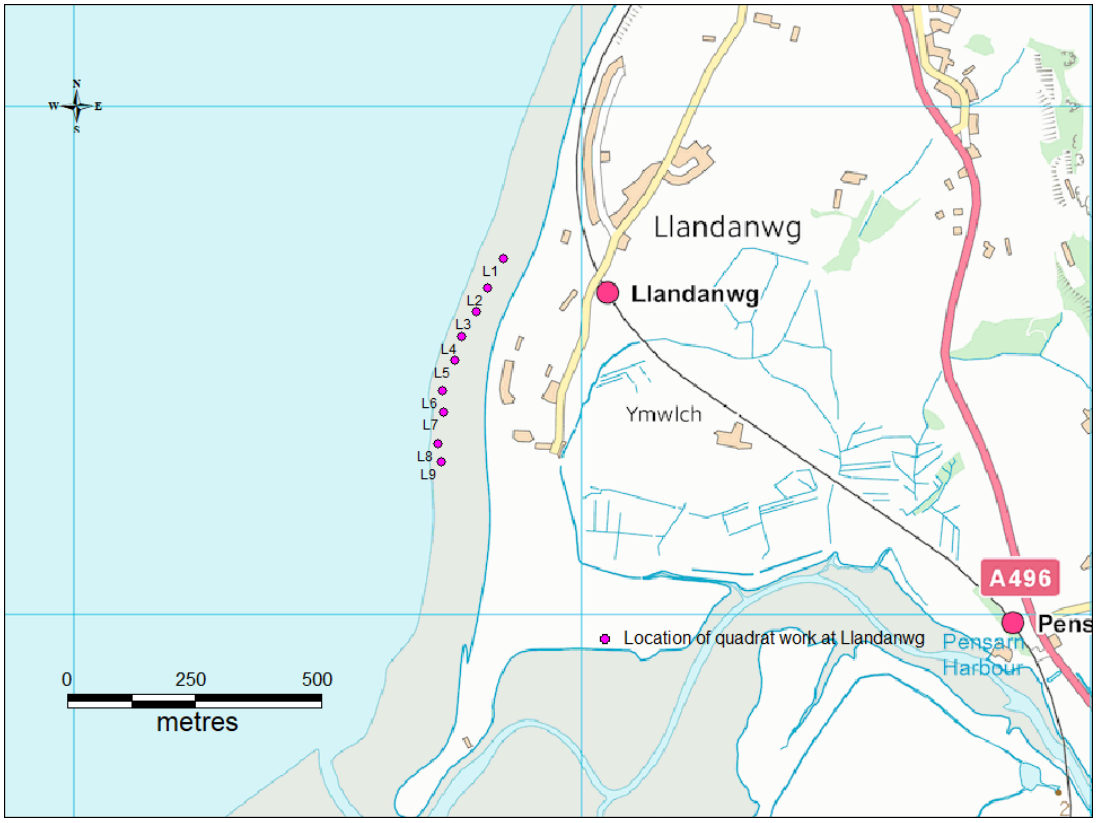
It is vitally important that the condition of the fragile *S. alveolata* reefs is not degraded by the act of monitoring itself, an issue that can occur in fragile biotopes due to localised trampling.

3.2.2 Site and transect locations

The Llandanwg and West Afon Dwyfor *Sabellaria* reef stations were re-surveyed in 2015, 2016, 2017, 2018 and 2019 (every year covered by this report), having been surveyed by ASML in each of the five previous years (2009, 2010, 2012, 2013 and 2014).

[1] If a null hypothesis is incorrectly rejected, when it should be accepted, it is called a **Type I error** (also known as a false positive). A **Type II error** (also known as a false negative), occurs when a null hypothesis is incorrectly accepted when it should be rejected.

Figure 2 Location of the *Sabellaria alveolata* reef quadrat assessment sites at Llandanwg. © Crown Copyright and database right 2022. Ordnance Survey. Licence number 100019741.

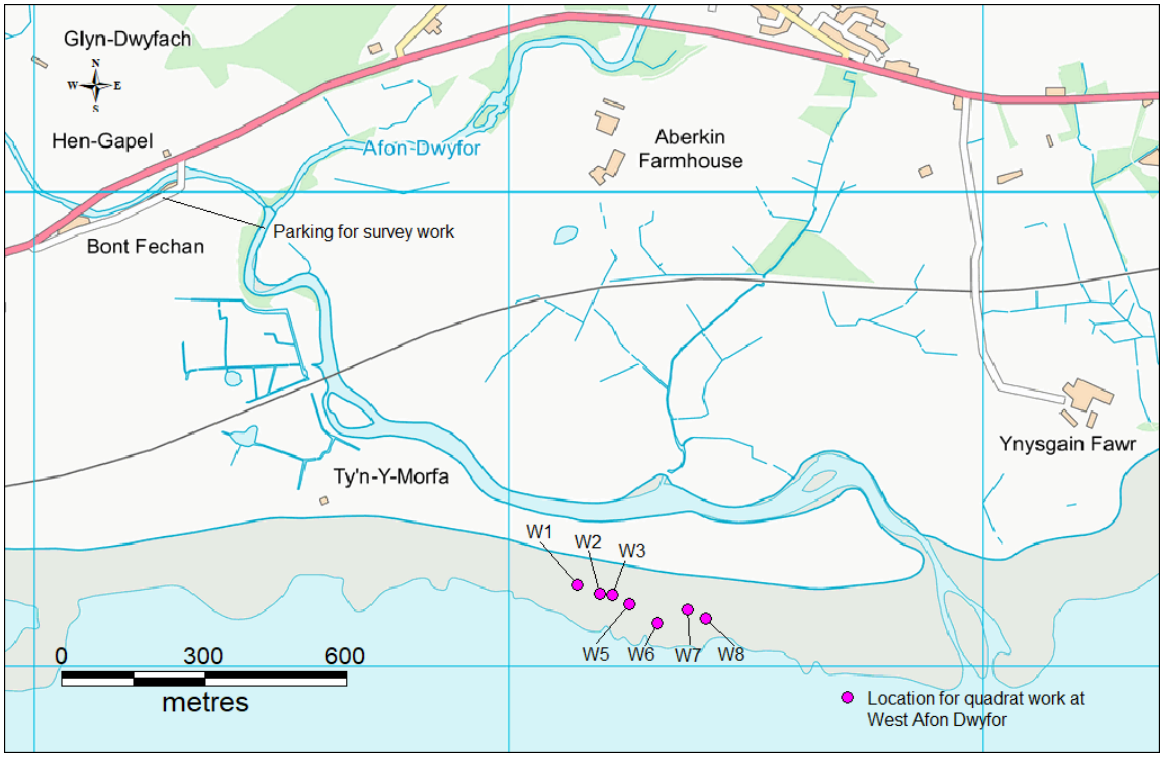


At both Llandanwg and West of Afon Dwyfor, the annual survey task is to re-survey the areas in the vicinity of the quadrat survey area. The extent of the *Sabellaria* reef area that can be mapped varies from year to year, as it depends on the amount of labour and experience available on the survey as well as the tidal heights and survey itinerary. However, a minimum comparable area that is local to the quadrat recording site, is always covered. The *Sabellaria* beds are mapped by GPS from their upper limit on the shore, to the lower limit of access on the shore, as dictated by the height of the low tide. GPS receivers were also used by the survey teams to navigate to the correct, central position of each monitoring station, within the original area of *Sabellaria* reef, as described in 2009 (Mercer 2011). The mapped *Sabellaria* reefs and quadrat stations at Llandanwg and West of Afon Dwyfor are shown in Figure 2 and Figure 3. Quadrat station positions for the *Sabellaria* reef surveys are presented in Table 2. The original transect locations (from 2009) are found in Mercer (2011).

Table 2 Quadrat stations on the transects at Llandanwg and West of Afon Dwyfor

Site	Station Code	Transect	Zone	Easting	Northing	Main Quadrats	Extra Quadrats
Llandanwg	L1	L1	B	256845	328703	5	10
Llandanwg	L2	L2	B	256813	328644	5	10
Llandanwg	L3	L3	B	256791	328597	5	10
Llandanwg	L4	L4	B	256763	328548	5	10
Llandanwg	L5	L5	C	256748	328501	5	10
Llandanwg	L6	L6	B	256725	328441	5	10
Llandanwg	L7	L7	B	256726	328400	5	10
Llandanwg	L8	L8	B	256718	328338	5	10
W Afon Dwyfor	WAD1	C3	B	247143	337174	5	10
W Afon Dwyfor	WAD2	C4	A	247191	337155	5	10
W Afon Dwyfor	WAD3	C5	B	247217	337153	5	10
W Afon Dwyfor	WAD5	C6B	A	247252	337134	5	10
W Afon Dwyfor	WAD6	C7	D	247312	337093	5	10
W Afon Dwyfor	WAD7	C8	A	247376	337120	5	10
W Afon Dwyfor	WAD8	C9	B	247414	337103	5	10

Figure 3 Location of the *Sabellaria alveolata* reef quadrat assessment sites at West of Afon Dwyfor. © Crown Copyright and database right 2022. Ordnance Survey. Licence number 100019741.



3.2.3 Quadrat survey methods

At each station, surveyors establish an origin, with their rucksacks, at the centre of an imaginary 20 m x 20 m grid i.e. at co-ordinate location (10 m,10 m) (x,y) and then the surveyors proceeded to survey 15 random quadrats. 5 of these quadrats were surveyed in detail, recording some biotope properties and all taxa present. In the other 10 quadrats just the abundance of total *Sabellaria* reef and total live *Sabellaria* reef were recorded. To minimise trampling, the 15 random positions, generated by

assigning a random x-value and random y-value were plotted on a map of the grid and then surveyed within the 20 m x 20 m field grid travelling from one to the other by following the map and not returning to the origin each time. Estimates were made of the percentage cover of standing water, total *Sabellaria*, live *Sabellaria* and a small selection of known key species/taxa in each quadrat. Other typical fauna and flora (listed on the proforma) were then searched for and recorded. No estimation of abundance was required for these species (to speed up the recording), but rapid estimates of algal cover and some other major cover organisms such as *Mytilus edulis* were made. The presence of any other species that were seen and could be reliably identified *in situ* was then recorded in the blank rows available on the proforma (Appendix 2). Specimens of notable species that could not be reliably identified *in situ* were taken for laboratory identification (a field laboratory and taxonomic keys were available in the survey accommodation). The taking of a specimen is always recorded on the data sheet at the time, so that the data integrity is maintained. At each quadrat position, a gridded 0.25 m^2 quadrat (0.5 m x 0.5 m) was placed on the point of the surveyor's toe without them looking at the substratum. Digital photographs were taken of each detailed quadrat to illustrate habitat and condition of *Sabellaria* reef at that point. The photographs were taken in plan-view, so that the quadrat filled the frame and the photograph number was recorded against quadrat number.

3.2.4 *Sabellaria alveolata* reef extent

The extent of the *Sabellaria* reef at Llandanwg and at West of Afon Dwyfor were mapped in the 2015 -19 surveys using the track function of the handheld GPS units. In each case the methodology was standardised as described below. In 2015-19 the areas covered by the mapping exercise varied for the reasons given above.

The surveyor walked along the edge of the area with the GPS automatically recording a track fix at least every 5 seconds.

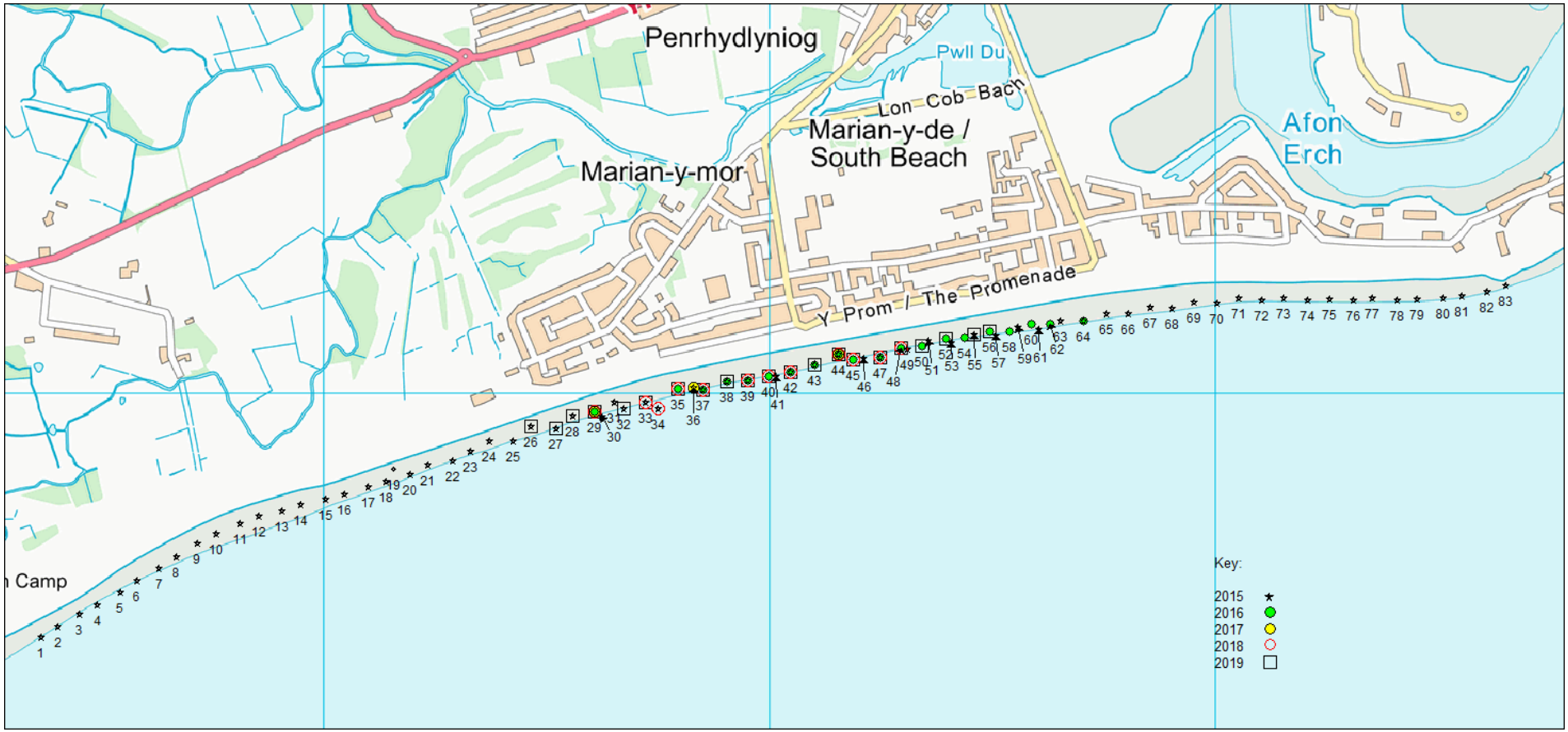
A '5 m rule' is applied – i.e. if a loop in the margin of the reef was more than 5 m across, it was walked around; but if it is less than 5 m it was ignored. It was also sometimes necessary to cross small gaps in the reef in order to include notable outlying patches. In places, quite large gaps were crossed, but the surveyor would then return to the main reef via the same access route and make a note with a waypoint to back up this observation.

Full results of the *Sabellaria alveolata* surveys are presented in the appropriate accompanying Excel file.

3.3 *Pectenogammarus* surveys

Populations of the amphipod *Pectenogammarus planicrurus* are present in the intertidal shingle at Marian-y-de, Pwllheli. Visits were made in all years to the site within 2-3 hours of low water to determine if populations of the amphipod were still thriving. The amphipods are found by making a small scrape in the shingle, with a bare hand as a wave retreated from the top of the surf zone. The resulting temporary pool should briefly contain swimming amphipods if they are present. This process was repeated at least ten times at each of the stations surveyed. A variable suite of survey stations along the shore were visited during the five years. These are shown in Figure 4 and the mean result for each station is presented in section 4.2.

Figure 4 *Pectenogammarus planicrurus* sampling locations in the years 2015 to 2019. © Crown Copyright and database right 2022. Ordnance Survey. Licence number 100019741.



3.4 Sampling of the sediment shores within the estuaries of Pen Llŷn a'r Sarnau SAC

Maps of the estuaries and the survey type and locations are shown in Figure 5a-c.

***In situ* surveys**: these are shown by numerous □ on the figures below. In each case the station numbers represent a reduced tranche of an original suite of sites (approximately 100 within each estuary). On each occasion, survey teams navigated to the selection of stations and carried out an *in situ* assessment of the sediment biotope.

Records of conspicuous species and surface sediment features were made from each station within a circle of 10m radius around the central core sample position. Some key features recorded were:

- Sediment description, with the aid of a grain size comparator and magnifying glass (e.g. well sorted medium Sand, muddy very fine Sand, gravelly medium Sand, fine Sand / very fine Sand).
- Sediment softness - on a scale of 1 to 5 (1 = very hard / rock, 5 = soft – sink to ankle depth or more).
- Depth (cm) of black layer (redox potential discontinuity layer).
- Abundance of common epifaunal and floral taxa e.g. *Arenicola marina* casts and Green algal mats.
- Abundance of common yet visible infaunal taxa e.g. cockles, ragworm, spionids and amphipod shrimps, etc.

These assessments were made in part from the single 0.01 m^2 core sample that was taken at each survey station unless the station happened to lie on a rocky outcrop, in a drainage channel or in a pool greater than ~5 cm deep.

The core sample was sieved through a 0.5 mm mesh sieve in a nearby pool or channel and the sieve contents were inspected closely with the aid of a hand lens. As far as possible all visible animals were identified and counted by the surveyor with the most infaunal taxonomic experience in the pair. A simple photographic guide to the most common species/taxa present was carried by each pair of surveyors as an *aide memoire*. Specimens of animals that a surveyor could not recognise, but which were frequent and were distinctly marked or shaped, were collected for later identification with microscopes and keys at the survey base. The names and counts of all conspicuous species/taxa were recorded on a waterproof recording form. A copy of this form is presented in Appendix 2, whilst the full quantitative core sites' results are also found in the appropriate Excel files accompanying this report.

The quality and thoroughness of the species records and counts appear generally high, but they are unavoidably reduced when large amounts of coarse sediment, such as bivalve shell material, or allochthonous organic material is also present within the sediment.

Quantitative infauna sampling: either 3x or 5x 0.01 m^2 infaunal core samples were taken from each of a selection of sites represented by a ○ in Figure 5. At each site the cores were all taken within a radius of approximately 5 m from the central grid point; the corer was randomly placed without reference to the surface features (with eyes closed). Each core was then sieved *in situ* over a 0.5 mm mesh and the residual sieve contents were transferred to a suitably labelled pot or *ziploc* plastic bag. These

samples were returned to the survey base and fixed in 10% formalin solution prior to later laboratory analysis.

One sample of the sediment was also taken (approx. 200g) from each of these stations for Particle Size Analysis (PSA). The sediment sample was taken from the side of one of the corer holes, to a depth of at least 5 cm. This sediment sample was labelled and double bagged prior to later laboratory analysis.

Figure 5a – c: Coring stations and *in situ* assessments sampled on the Dyfi, Mawddach and Glaslyn /Dwyryd estuaries in 2015 - 2019. © Crown Copyright and database right 2022. Ordnance Survey. Licence number 100019741.

Figure 5a Dyfi sediment sampling locations 2015 & 2018

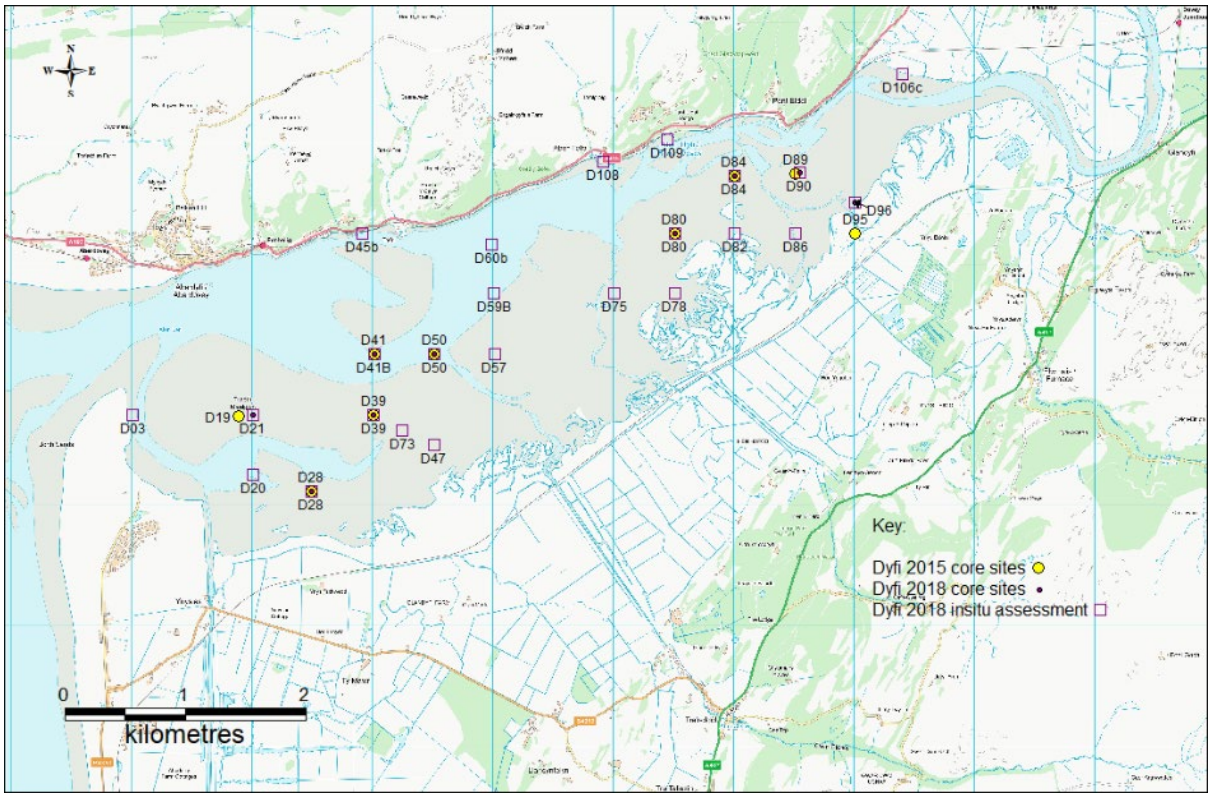


Figure 5b Mawddach sediment sampling locations 2016 and 2019

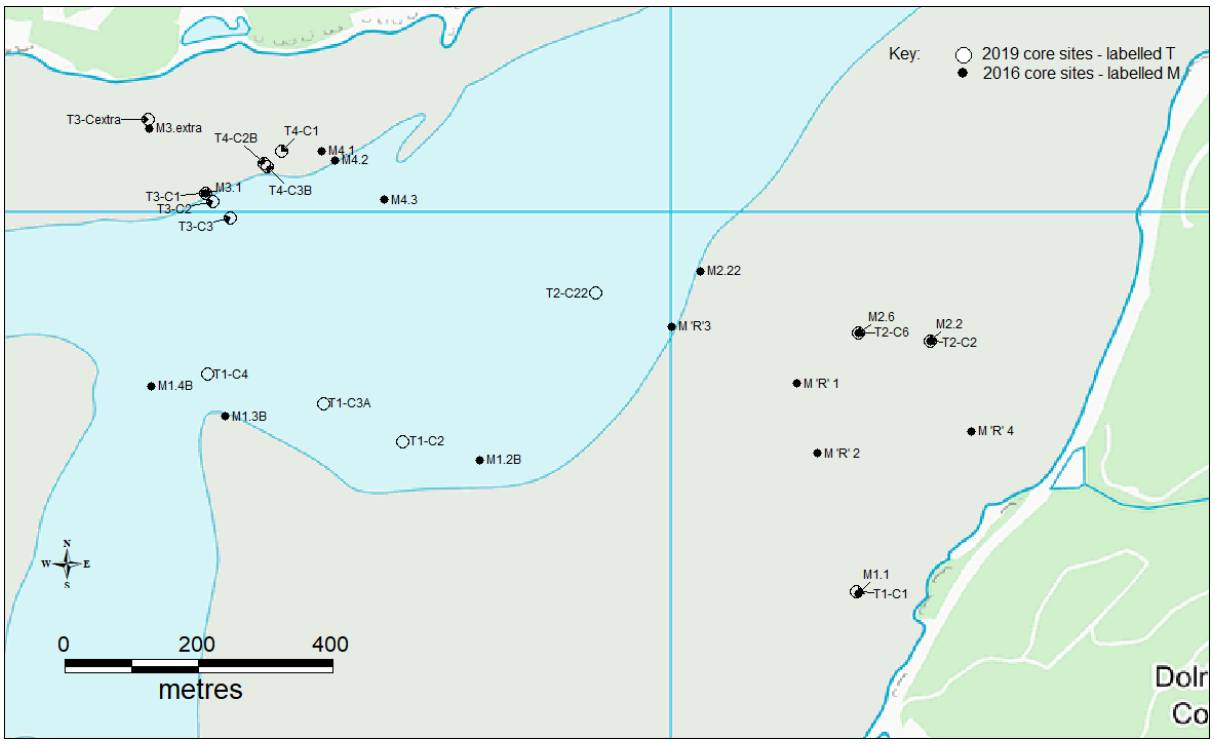
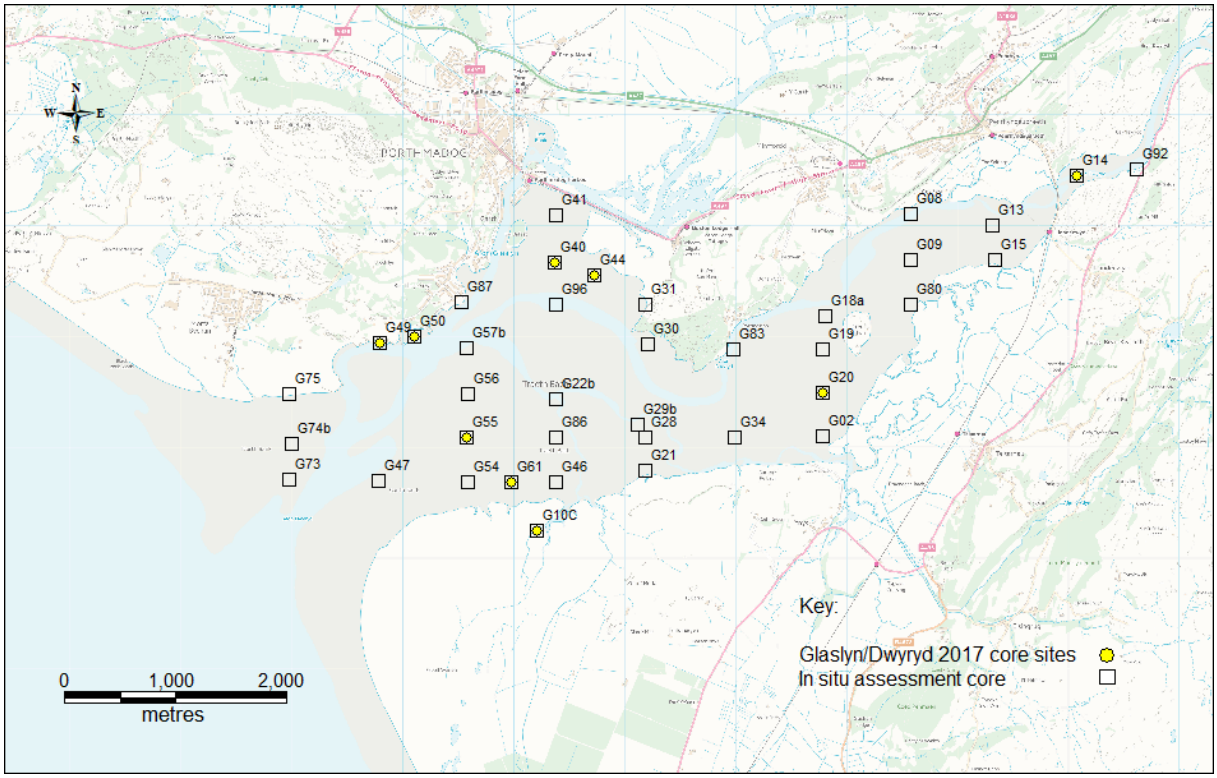


Figure 5c Glaslyn/ Dwyryd sampling locations 2017



The samples for macrofauna and granulometry analyses were taken to the NRW offices at the end of the surveys for later transfer to a macrobenthic analytical laboratory to be processed under a separate framework contract. The data created by their analyses are presented in this report.

3.5 Open coast sediment shore infaunal sampling

In addition to the annual estuary infaunal survey, in 2017 quantitative core samples were taken from mid-shore and lower shore on 4 selected open coast beach sites. The samples were analysed for their macrobenthic infaunal biotope and for the sediment particle size distribution. The four locations were on beaches previously sampled in Tremadog Bay in 2009 and 2014. They were originally selected by NRW to provide a geographical spread to the sampling, at sites where there are previous data. The surveyors navigated to the stations from the relevant car parks at low water on the early morning low tide of 27th July 2017. This was carried out using the hand-held GPS units. Figure 6 shows the location of the sampling sites and presents the details and locations of the core sampling exercise (tabulated in Table 3). At each site, the sediment was described and photographed, a sediment Particle Size Analysis sample was taken and 5 x 0.01 m^2 infaunal cores (depth 150 mm minimum) were collected and each sieved over a 0.5 mm mesh. Sample residues were then returned to base where they were fixed with 10% formalin solution, labelled and safely stored, prior to removal to NRW Bangor Office at the end of the survey.

Table 3 Location details of open coast sampling stations in north east Tremadog Bay

Site	Description	Long	Lat	East	North
Morfa Harlech	Lower shore 5 x 0.01 m^2 cores	-4.13786	52.8693	256199	332346
Morfa Harlech	Mid shore 5 x 0.01 m^2 cores	-4.13647	52.8699	256295	332404
Morfa Dyffryn	Lower shore 5 x 0.01 m^2 cores	-4.12519	52.7827	256768	322688
Morfa Dyffryn	Mid shore 5 x 0.01 m^2 cores	-4.12461	52.783	256808	322725
East Criccieth	Lower shore 5 x 0.01 m^2 cores	-4.20826	52.9154	251620	337618
East Criccieth	Mid shore 5 x 0.01 m^2 cores	-4.20826	52.9154	251660	337670
Black Rock Sands	Lower shore 5 x 0.01 m^2 cores	-4.18392	52.9071	253228	336642
Black Rock Sands	Mid shore 5 x 0.01 m^2 cores	-4.18311	52.9077	253285	336710

Results of the macrobenthic infaunal analysis are presented in the Excel file annexes that accompany this report.

Figure 6 A map of the Open Coast sampling locations in north east Tremadog Bay.

3.6 Porth Oer rocky shore quadrat surveys

During each fieldwork week the Porth Oer shore was visited at low tide and the 12 permanent quadrats were relocated, photographed and surveyed. Each quadrat's locating screws were found using the 'relocation photographs'. See Mercer (2013) for relocation details. The quadrats were originally sited in homogeneous areas of inclined rock, avoiding rock pools and large fissures where possible. The data were recorded on a form modified from Boyes & Allen (2008). This form and its instructions are presented in Appendix 2, whilst the full quadrat results are also found in the Excel file annexes that accompany this report.

3.6.1 Permanent Quadrat Recording (cell counts)

Within each 1 m^2 quadrat presence/absence data were recorded for all conspicuous species using a 25 cell grid (i.e. 20 cm x 20 cm strung cells within the quadrat). This gave a frequency score of between 0 and 25 for each species. Organisms were identified to species level where possible with specimens, collected from outside the quadrat, being returned to the laboratory for verification where necessary. Species within the following taxa were aggregated for cell counts: barnacles, limpets, flat periwinkles, rough periwinkles, amphipods, *Verrucaria* spp (except *Verrucaria mucosa* type). Only algae whose stipes were within the quadrat were counted. This requires algae growing outside the quadrat to be separated to facilitate an accurate measure of abundance. Epiphytes on macroalgae were recorded from the cell in which the macroalga was attached. Care was taken to minimize disturbance of mobile invertebrates when macroalgae species were moved.

3.6.2 Limpet Counts

Limpet abundance (all species aggregated) was recorded from 5 random 20 cm x 20 cm cells within each quadrat. This allowed the estimation of mean limpet abundance for all three zones at the Porth Oer survey location on an annual basis.

3.6.3 Limpet Monitoring

Up to 150 limpets (minimum 100) were systematically selected within the mid-shore zone adjacent to the quadrats. All limpets encountered by the surveyor were measured to ensure an unbiased, representative population sample was collected. The longest basal shell length was measured in millimetres using Vernier callipers. Once measured, each limpet was marked with chalk to prevent duplication. These data have been used to construct annual limpet population profiles for the site. The results are presented in Section 4.9.3.

3.6.4 Barnacle Abundance

Percentage cover of barnacles (all species aggregated) was recorded from 5 random 20 cm x 20 cm cells within each quadrat to allow the estimation of the annual mean Cirripedia abundance for all three zones at the Porth Oer survey site.

3.7 Photography

Photographs were taken on a variety of cameras throughout the surveys:

All the .jpg photograph files were renamed according to the following convention:

Date (year month day) underscore, Photographers Initials (up to 5 letters) underscore, Site / Station underscore and a four figure photograph number underscore, 'Any-other-useful-info'.

e.g. 20180811_TSM_Llandanwg_0013.JPG

The photographs are catalogued in the relevant spreadsheet data files. The photograph catalogues are included as a Microsoft Excel file held by NRW.

3.8 Data collation, analysis and mapping

All data were entered into Microsoft Excel spreadsheet files during the course of the survey, usually by the individual surveyors who had collected it. Species names are

according to Howson and Picton (1997), except for the lichens which are according to Dobson and Dalby (1997). The data were then validated by carrying out a series of independent checks to ensure that all the data were entered correctly and in the appropriate formats with no transcription errors.

The site location positions and survey tracks were also downloaded from the handheld GPS receiver units on a daily basis. The daily GPS downloads were converted to *MapInfo Tab* or *ESRI ArcMap* files and then displayed in GIS for data collation and map production. All relevant species and habitat data have been entered into Marine Recorder.

4 Results

During each survey, field work was carried out during five days of spring tides. A joint team of experienced marine biological surveyors from ASML and NRW took part in the day to day surveys. Over the five years the core, experienced team of Tom Mercer, Francis Bunker, Jon Moore, Paul Brazier, Lucy Kay, Anne Bunker, Gabrielle Wyn, Kathryn Birch, Laura Grant, James Moon, Natasha Lough and Ben Wray were ably assisted by Chris Dixon, Matt Ashton, Clare McCarty, Dafydd Roberts, Pippa Lewis, Eben Pirie, Eleonora Manca, Patrick Bunker, Brendan Bunker, Eurig Wyn Jones, Jake Davies, Rhodri Irranca-Davies and Becky Irvine. Figure 1 shows the locations of the survey areas. Appendix 1 presents the Field logs for the 5 years and Appendix 2 the survey data sheet templates. Accompanying Excel files contain all raw data and a catalogue of all the photographs taken during the five surveys.

4.1 *Sabellaria* data

In order to observe the reef growth and/or erosion year on year, the areas of *Sabellaria* reef at both Llandanwg and West Afon Dwyfor are mapped. At Llandanwg the area of the reef to the south of Transect 1 to the sandy beach beyond Transect 9 has been calculated for 2015, 2016, 2017, 2018 and 2019. The same has been done for the West of Afon Dwyfor reef between the transect at WAD8 and the NGR Easting line SH 247000. Table 4 presents these data and Figure 7and Figure 8 illustrate the changes over time on maps of the area.

Figure 7 and Figure 8 show the extent of mapped *Sabellaria* reef each year (showing each year displaced, for visualisation). Table 4 shows how that on these two shores the *Sabellaria* reef waxes and wanes with considerable annual fluctuations. Losses of reef can be caused by both erosion during severe winter storms and burial by influxes of sediment, which smother the low lying colonies. Stations L8 and L9 at Llandanwg are particularly susceptible to smothering, lying as they do adjacent to a sandy beach, whereas storm erosion can be clearly seen in 2018 at stations L1 and L2 which lie within a boulder field.

Table 4 *Sabellaria alveolata* reef areas within a fixed zone on each shore between 2014-2019 at Llandanwg and West Afon Dwyfor.

Year	2014	2015	2016	2017	2018	2019
Llandanwg (area - Ha)	1.826	1.708	1.688	1.367	1.661	2.195
% change from previous year	-23%	-6.4%	-1.2%	-19%	+22%	+32%
West Afon Dwyfor (area - Ha)	0.723	1.037	2.547	1.619	1.199	3.222
% change from previous year	-67%	+43%	+146%	-36 %	-26%	+169%

Figure 7 Time series map of the 'monitored area' of *Sabellaria* bed at Llandanwg

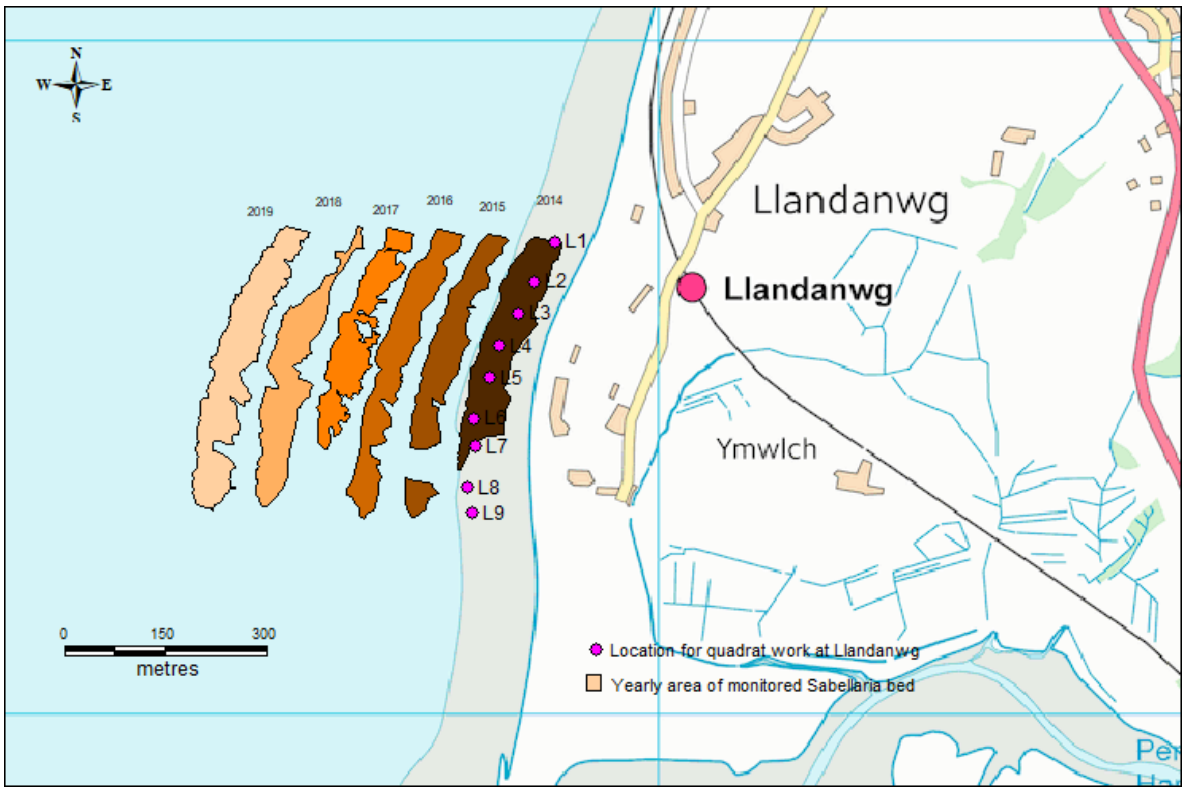


Figure 8 illustrates a similar pattern on the West Afon Dwyfor shore, with the reef clearly fluctuating in size and quality on an annual basis, depending on both weather and sediment movements. The patchy nature of the *Sabellaria* reef here has been such that it has made accurate mapping and illustration on a map difficult.

Figure 8 Time series map of the 'monitored area' of *Sabellaria* bed at West Afon Dwyfor

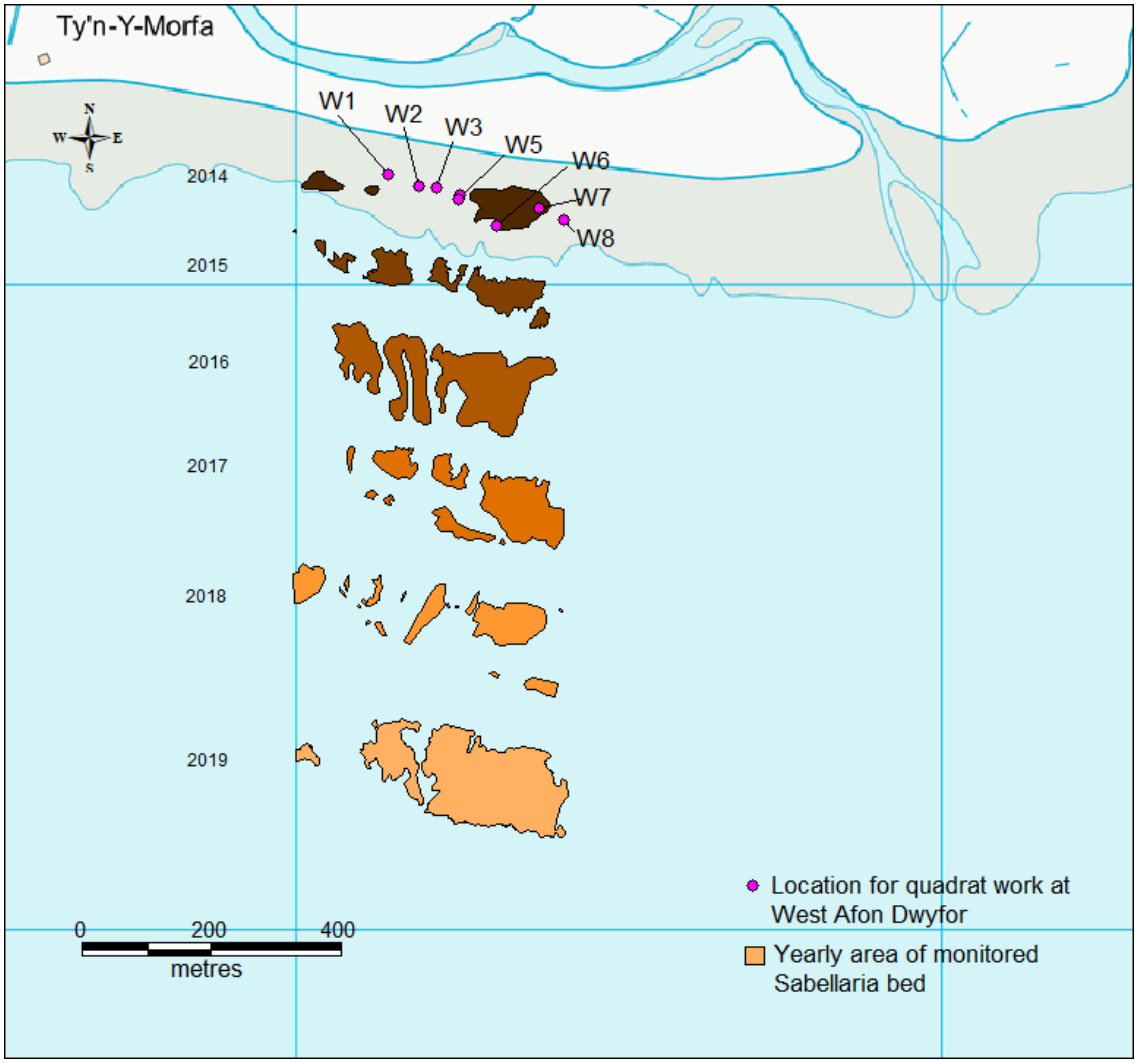


Figure 2 and Figure 3 show the locations and numbers of the survey transects and quadrat stations at Llandanwg and West of Afon Dwyfor respectively. Table 5, Table 6 and Table 7 summarise and compare the data collected from the quadrat surveys. The full data are presented in an accompanying Excel file.

Table 5 and Table 6 show that both the percentage frequency of occurrence and mean percentage cover of *Sabellaria* reef area at Llandanwg and West Afon Dwyfor were relatively stable, with both populations generally recovering from low levels of "live" worms in 2014, following the particularly damaging series of winter storms, to higher, more stable population levels by 2019.

Table 7 shows that the total number of littoral taxa recorded in the *Sabellaria* monitoring quadrats on both shores generally fluctuates a little from year to year but remains relatively stable overall. Both shores returned their lowest number of taxa in 2015 following some particularly destructive winter storms. Full annual taxa results are available in the Excel worksheets that accompany this report. Future analysis of the quadrat data will be completed in the future, for the full dataset.

Table 5 Conspicuous sentinel taxa recorded within the *Sabellaria alveolata* quadrats at Llandanwg

Taxon	Data Type	2104 % Freq	2014 Mean % cover	2015 % Freq	2015 Mean % cover	2016 % Freq	2016 Mean % cover	2017 % Freq	2017 Mean % cover	2018 % Freq	2018 Mean % cover	2019 % Freq	2019 Mean % cover
Sabellaria alveolata	T%	50.0	10.6	51.1	11.1	71.8	19.1	58.5	20.7	59.2	21.1	59.3	22.5
Sabellaria alveolata (live)	%	40.0	4.2	50.4	9.5	65.9	11.4	56.3	14.5	55.6	13.5	51.1	14.6
Cirripedia (total)	*T%	40.0	3.8	48.6	4.0	62.2	5.9	35.6	4.8	51.1	6.9	35.6	4.0
Mytilus edulis	*P	12.5	0.1	17.1	0.1	4.4	0.0	4.4	0.0	13.3	0.0	0.0	0.0
Algae (total)	*T%	95.0	47.2	88.6	55.5	100.0	61.4	91.1	69.8	91.1	69.1	64.4	32.8
Chlorophycota	*T%	77.5	8.5	60.0	1.7	95.6	11.2	68.9	4.6	75.6	5.4	62.2	4.9
Fucus serratus	*%	47.5	17.9	62.9	28.1	44.4	14.9	51.1	23.9	51.1	21.6	48.9	18.2
Fucus vesiculosus	*%	62.5	21.3	65.7	27.7	71.1	38.2	73.3	45.7	77.8	46.1	80.0	31.7

Table 6 Conspicuous sentinel taxa recorded within the *Sabellaria alveolata* quadrats at West Afon Dwyfor

Taxon	Data Type	2014 % Freq	2014 Mean % cover	2015 % Freq	2015 Mean % cover	2016 % Freq	2016 Mean % cover	2017 % Freq	2017 Mean % cover	2018 % Freq	2018 Mean % cover	2019 % Freq	2019 Mean % cover
Sabellaria alveolata	T%	31.4	4.8	29.5	2.5	43.8	5.3	46.7	8.5	44	4.8	41.9	5.5
Sabellaria alveolata (live)	%	13.3	1.2	25.7	1.9	41.0	4.0	41.9	7.2	40	3.9	40.9	5.4
Cirripedia (total)	*T%	85.7	0.7	77.1	1.3	85.7	1.5	82.9	2.8	80.0	0.9	57.1	0.2
Mytilus edulis	*P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Algae (total)	*T%	91.4	35.0	94.3	33.2	97.1	31.2	97.1	52.0	100.0	62.1	97.1	55.6
Chlorophycota	*T%	14.3	0.3	11.4	0.6	28.6	0.7	45.7	3.2	30.0	0.1	31.4	0.1
Fucus serratus	*%	42.9	7.6	11.4	2.0	34.3	7.3	31.4	5.2	27.5	3.0	28.6	1.9
Fucus vesiculosus	*%	88.6	26.0	80.0	30.3	85.7	24.7	94.3	57.7	100.0	55.2	97.1	56.6

Table 7 Total littoral taxa recorded in the monitoring quadrats.

Shore	2014	2015	2016	2017	2018	2019
Total taxa recorded - Llandanwg	48	45	65	50	53	58
Total taxa recorded - West Afon Dwyfor	58	40	58	55	62	55

4.2 *Pectenogammarus* at Marian-Y-De

Eighty one stations were sampled for the presence of the amphipod *Pectenogammarus planicrurus* on the shingle beach at Marian-Y-De between 2015 and 2019. The location of all the stations visited are mapped on Figure 4. Numerous individuals were found within the shingle scrapes as presented in

Table 8 Approximate abundance (no. dm-2) of Pectenogammarus planicrurus in 3.3 km of the shingle beach at Marian-Y-De, Pwllheli. (Most westerly point SH 35365 33456). N = 'not applicable'.

and shown on Figure 9.

Table 8 Approximate abundance (no. dm-2) of Pectenogammarus planicrurus in 3.3 km of the shingle beach at Marian-Y-De, Pwllheli. (Most westerly point SH 35365 33456). N = 'not applicable'.

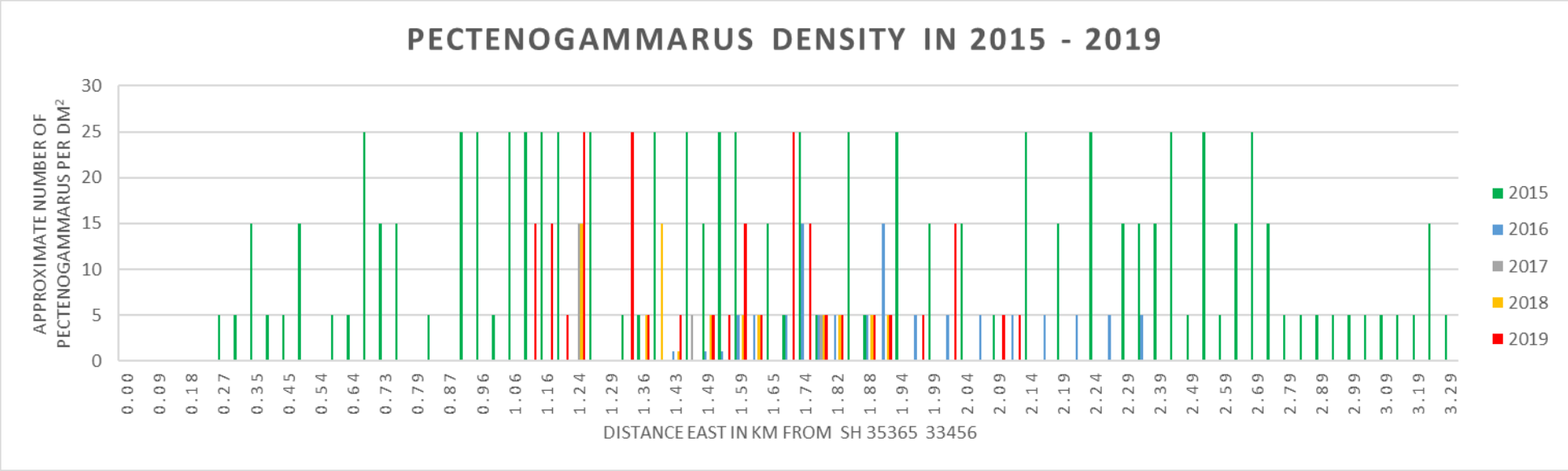
Distance east (km)	2015	2016	2017	2018	2019
0	0	n	n	n	n
0.04	0	n	n	n	n
0.09	0	n	n	n	n
0.13	0	n	n	n	n
0.18	0	n	n	n	n
0.22	0	n	n	n	n
0.27	5	n	n	n	n
0.3	5	n	n	n	n
0.35	15	n	n	n	n
0.39	5	n	n	n	n
0.45	5	n	n	n	n
0.49	15	n	n	n	n
0.54	0	n	n	n	n
0.58	5	n	n	n	n
0.64	5	n	n	n	n
0.68	25	n	n	n	n
0.73	15	n	n	n	n
0.77	15	n	n	n	n
0.83	5	n	n	n	n
0.87	0	n	n	n	n
0.92	25	n	n	n	n
0.96	25	n	n	n	n
1.01	5	n	n	n	n
1.06	25	n	n	n	n
1.1	25	n	n	n	15
1.16	25	n	n	n	15
1.19	25	n	n	n	5
1.24	n	n	15	15	25
1.26	25	n	n	n	n
1.31	5	n	n	n	25
1.36	5	n	n	5	5
1.39	25	n	n	15	n
1.43	n	1	n	1	5
1.46	25	n	5	n	n
1.49	15	1	n	5	5
1.54	25	1	n	n	5

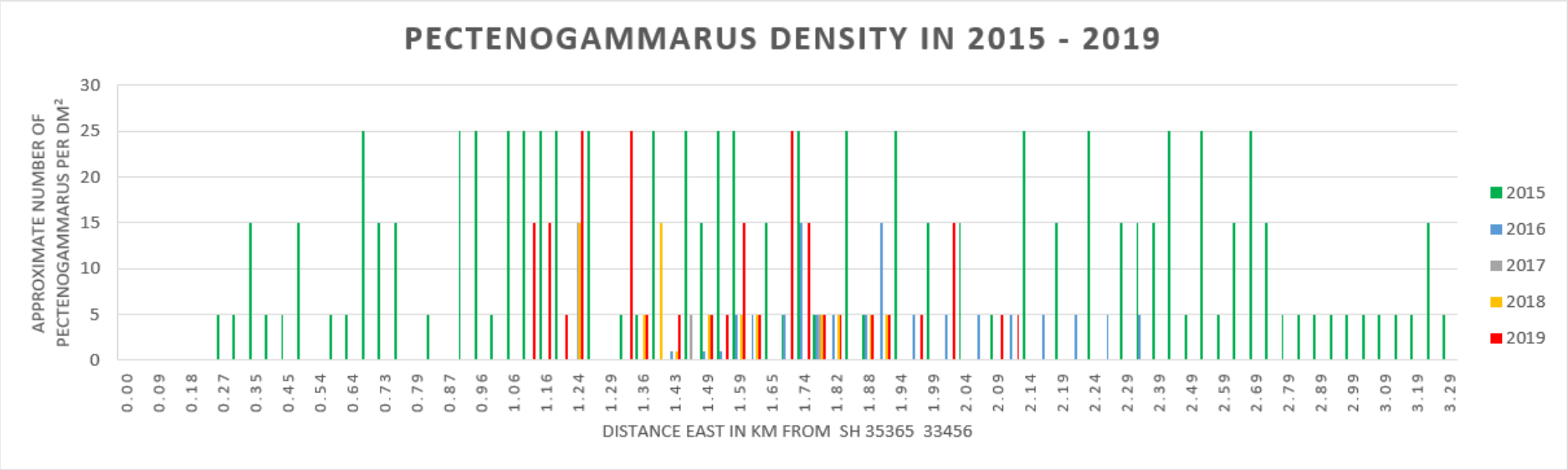
Distance east (km)	2015	2016	2017	2018	2019
1.59	25	5	n	5	15
1.63	n	5	n	5	5
1.65	15	n	n	n	n
1.68	5	5	n	0	25
1.74	25	15	n	n	15
1.79	5	5	5	5	5
1.82	n	5	n	5	5
1.85	25	n	n	n	n
1.88	5	5	n	5	5
1.93	n	15	n	5	5
1.94	25	n	n	n	n
1.98	n	5	n	n	5
1.99	15	n	n	n	n
2.03	n	5	n	n	15
2.04	15	n	n	n	n
2.07	n	5	n	n	n
2.09	5	n	n	n	5
2.13	n	5	n	n	5
2.14	25	n	n	n	n
2.17	n	5	n	n	n
2.19	15	n	n	n	n
2.22	n	5	n	n	n
2.24	25	n	n	n	n
2.26	n	5	n	n	n
2.29	15	n	n	n	n
2.34	15	5	n	n	n
2.39	15	n	n	n	n
2.44	25	n	n	n	n
2.49	5	n	n	n	n
2.54	25	n	n	n	n
2.59	5	n	n	n	n
2.64	15	n	n	n	n
2.69	25	n	n	n	n
2.74	15	n	n	n	n
2.79	5	n	n	n	n
2.84	5	n	n	n	n
2.89	5	n	n	n	n
2.94	5	n	n	n	n
2.99	5	n	n	n	n
3.04	5	n	n	n	n
3.09	5	n	n	n	n
3.14	5	n	n	n	n
3.19	5	n	n	n	n
3.24	15	n	n	n	n
3.29	5	n	n	n	n

Table 9 Number of stations sampled in each of the five years.

Year	2015	2016	2017	2018	2019
Nº. Stns sampled	69	20	3	12	21

Figure 9 Density of *Pectenogammarus planicrurus* across the shore at Marian-Y-De in 2015 – 2019.





The results show that *Pectenogammarus planicrurus* is still present within a 3 km stretch across the shingle shore at Marian-y-de, although its occurrence is patchy within the shingle and depends on suitable micro-habitat. Generally, numbers of the shrimp remain at healthy levels. The surveys of the shore were all of different lengths and so absences to the east and west during some years are not indicative of a changing distribution but are linked to the time and labour available during the specific survey. In 2018 and 2019 it was noted that where large cobbles occur in the sediment, then higher numbers of the shrimps were noted to have taken refuge beneath, apparently taking advantage of the added stability and security.

4.3 Quantitative sampling of the Dyfi Estuary sediments

In 2015, nine stations on the Dyfi sandflats, previously visited in 2013, were re-visited by teams of surveyors. At each station a particle size distribution sample and three replicate 0.01 m^2 infaunal cores were collected and sieved in the field. These samples were then fixed at the field laboratory and later sent for taxonomic analysis to an NMBAQC laboratory by NRW staff. This fieldwork was repeated again in 2018, but on this occasion the number of replicates at each station had been increased to five to improve the resolution of analysis in these less biodiverse sandy habitats. The taxonomic data were first 'cleaned' (removing juveniles, damaged specimens and amalgamating taxa such as *Hediste diversicolor* with Nereididae). The results were then run through PRIMER 7 (Plymouth Routines In Multivariate Ecological Research). This statistical analysis package consists of a wide range of univariate, graphical and multivariate routines for analysing arrays of species-by-samples data, in order to investigate their community ecology. The results are presented below with the 2013 results also included to allow some comparison with previous data. Laboratory analysis of infauna was completed by ERT (2013) and Hebog (2015, 2018). Particle Size Analysis was completed by Hebog (2013, 2015) and Thomson (2018). Full results are available in the Excel worksheets that accompany this report.

Table 10 Dyfi estuary particle size distribution in 2015 - percentage fractional data.

Size fraction \ Station	Sieve size	DY019	DY028	DY039	DY041	DY050	DY080	DY084	DY089	DY095
Medium pebble (gravel)	> 8 mm	0	0	2.05	0	0	0	0	0	0
Small pebble (gravel)	4-8 mm	0	0	0.38	0.15	0.05	0.05	0.07	0	0.14
Granule	2-4 mm	0.01	0.00	0.39	0.56	0.02	0.15	0	0.00	0.19
Sand - very coarse	1-2000 µm	0.08	0.02	0.14	0.42	0.06	0.10	0.01	0.08	0.28
Sand - coarse	500-1000 µm	0.44	0.49	0.46	0.71	0.26	0.79	0.01	0.24	0.40
Sand - medium	250-500 µm	8.74	0.79	4.60	9.57	15.31	1.62	0.89	0.75	0.68
Sand - fine	125-250 µm	84.22	41.53	39.65	84.42	82.43	59.90	91.93	72.63	75.45
Sand - very fine	63-125 µm	5.34	44.21	23.32	3.24	0.88	23.81	5.78	24.38	19.47
Silt & Clay	< 63 µm	1.16	12.96	29.01	0.93	1.00	13.58	1.30	1.91	3.39
Textural Group	n	*Muddy fine Sand*	*Muddy fine Sand*	*Gravelly Muddy fine Sand*	*Gravelly muddy fine Sand*	*Muddy fine sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*

Table 11 Dyfi estuary particle size distribution in 2018 - percentage fractional data.

Size fraction \ station	Sieve size	Dy021	Dy028	Dy039	Dy041	Dy050	Dy080	Dy084	Dy090	Dy096
Pebbles (gravel)	>4 mm	0.00	0.00	2.79	13.29	0.00	0.00	0.00	0.00	0.00
Granule	2-4 mm	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.00	0.00
Sand - very coarse	1-2000 µm	0.00	0.00	0.26	0.12	0.00	0.00	0.00	0.00	0.00
Sand - coarse	500-1000 µm	8.55	0.04	8.86	13.04	4.78	0.54	2.32	0.25	3.54
Sand - medium	250-500 µm	65.29	29.32	40.52	55.71	77.44	25.27	61.39	46.99	9.65
Sand - fine	125-250 µm	26.13	51.43	25.79	15.37	17.78	36.86	36.21	52.00	22.00
Sand - very fine	63-125 µm	0.02	6.58	3.72	0.02	0.00	8.61	0.09	0.76	17.50
Silt & Clay	< 63 µm	0.00	12.63	18.06	2.36	0.00	28.73	0.00	0.00	47.30
Textural Group	n	*Sand*	*Muddy Sand*	*Slightly Gravelly Muddy Sand*	*Gravelly Sand*	*Sand*	*Muddy Sand*	*Sand*	*Sand*	*Very muddy Sand*

Table 10 and Table 11 present the PSA results for the Dyfi estuary in 2015 and 2018 respectively. Generally the grain size profile of the sediments within the estuary shows a slight coarsening between 2015 and 2018. Dy096 close to the saltmarsh edge, which replaced Dy095, possessed sediments that were considerably muddier than Dy095.

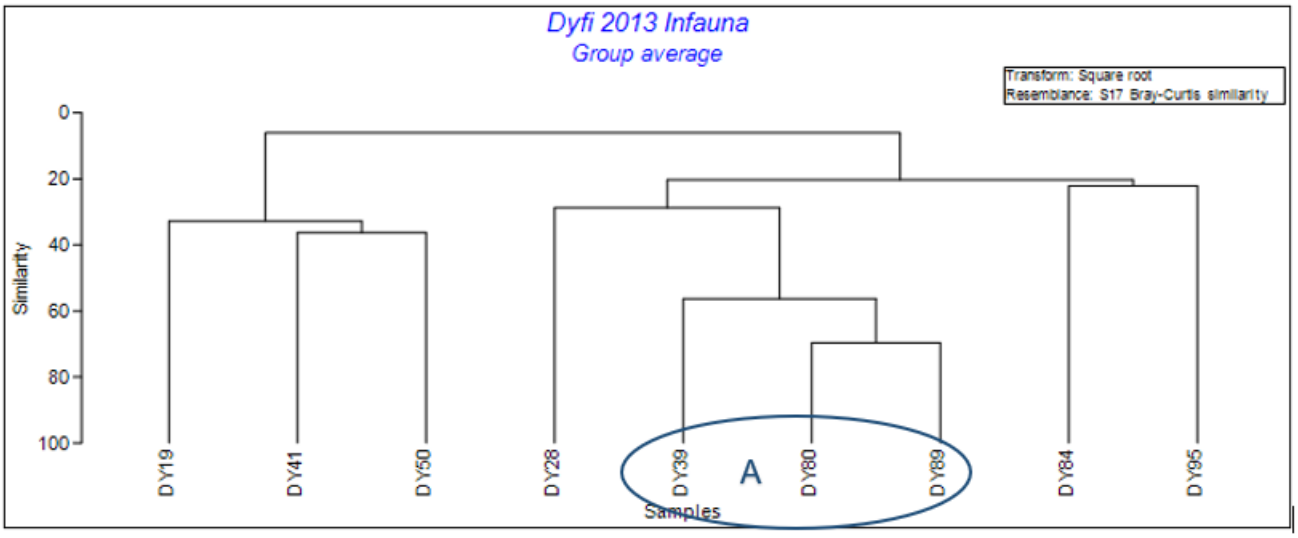
Table 12 Univariate statistics for the Dyfi estuary infaunal community, 2013, 2015 and 2018; Key

Symbol	Description
S	Number of recorded taxa
N	Mean total number of individuals: The mean number of individuals per core from all cores per site.
d	Margalef's richness for the site (S-1)/Log(N) - it is a measure of the number of taxa present, making some allowance for the number of individuals.
J'	Pielou's evenness for the site - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different taxa.
H'(loge)	Shannon-Wiener diversity index for the community
1-Lambda'	Simpson's diversity index for the community
n a	In 2018, stations 19, 89 and 95 were not accessible due to channel movements, hence nearby stations 21, 90 and 96 were included.

Univariate index	**S**	**S**	**S**	**N**	**N**	**N**	**d**	**d**	**d**	**J'**	**J'**	**J'**	**H' (loge)**	**H' (loge)**	**H' (loge)**	**1-Lambda'**	**1-Lambda'**	**1-Lambda'**
Station	**2013**	**2015**	**2018**	**2013**	**2015**	**2018**	**2013**	**2015**	**2018**	**2013**	**2015**	**2018**	**2013**	**2015**	**2018**	**2013**	**2015**	**2018**
D019	5	5	n a	8	16	n a	2.34	2.08	n a	0.91	0.82	n a	1.47	1.32	n a	**0.90**	**0.77**	n a
D021	n a	n a	6	n a	n a	5	n a	n a	3.188	n a	n a	0.790	n a	n a	1.416	n a	n a	**0.864**
D028	15	13	12	46	667	86	4.66	2.96	2.467	0.90	0.77	0.627	2.43	1.97	1.557	**0.93**	**0.81**	**0.706**
D039	14	12	11	317	409	275	3.55	3.13	1.781	0.77	0.66	0.244	2.04	1.64	0.585	**0.81**	**0.66**	**0.254**
D041	7	4	2	8	13	3	3.19	1.69	0.860	0.92	0.85	0.337	1.80	1.18	0.234	**0.95**	**0.75**	**0.171**
D050	3	5	6	2	5	2	2.61	2.58	8.506	0.97	0.98	0.936	1.06	1.58	1.677	**1.20**	**1.00**	**1.778**
D080	14	7	7	387	229	145	3.39	1.85	1.206	0.78	0.61	0.217	2.05	1.19	0.422	**0.84**	**0.56**	**0.168**
D084	3	10	10	21	59	10	1.16	3.23	3.909	0.59	0.81	0.695	0.65	1.86	1.601	**0.42**	**0.83**	**0.759**
D089	10	6	n a	417	490	n a	2.45	1.44	n a	0.76	0.62	n a	1.75	1.12	n a	**0.75**	**0.55**	n a

The table of univariate statistics shows few definitive patterns across the three sampling events in the Dyfi estuary. Though stations D028 and D039 consistently appear to have the most taxa, whilst D039, D080 and D089 (Group A below), all situated in the middle of stable sand flats, appear to support the greatest number of individuals. D028 also shows the greatest diversity year on year.

Figure 10 Dendrogram of the Bray-Curtis percentage similarity for the sampled Dyfi 2013 infaunal community.



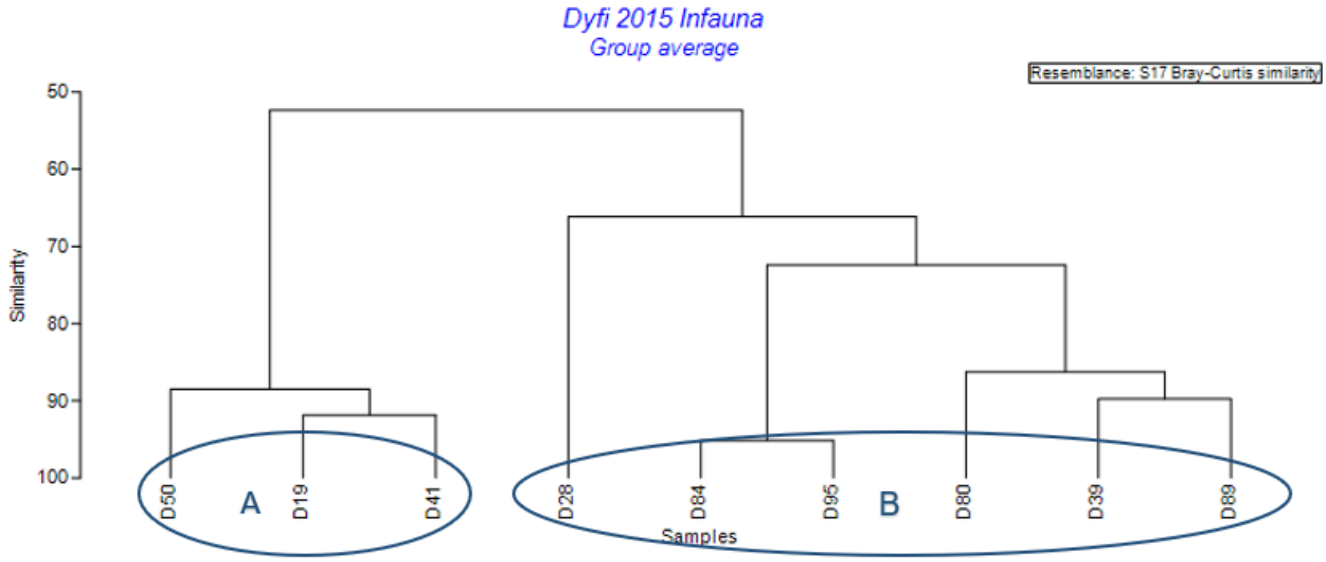
Group A has been superimposed on Figure 10, these stations possessing communities with a percentage similarity of more than 40%. The group's characterising species have been deduced using SIMPER, a routine in PRIMER 7. All species are commonly found in muddy fine sands such as those recorded in 2013 at these locations.

Table 13 SIMPER output showing 2013 Group A stations' taxa

Average similarity: 60.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	11.36	19.95	3.2	32.82	32.82
Pygospio elegans	11.83	15.91	1.12	26.18	59
Cyathura carinata	3.38	6.87	20.12	11.31	70.31

Figure 11 Dendrogram of the Bray-Curtis percentage similarity for the Dyfi 2015 infaunal community.



In the 2015 results shown in Figure 11, Groups A and B have been superimposed. These stations possess communities with a percentage similarity of more than 60%. The group's characterising species have been deduced using SIMPER, a routine in PRIMER 7.

Table 14 SIMPER output showing 2015 Group A and Group B station taxa.

Group A, Average similarity 35.64

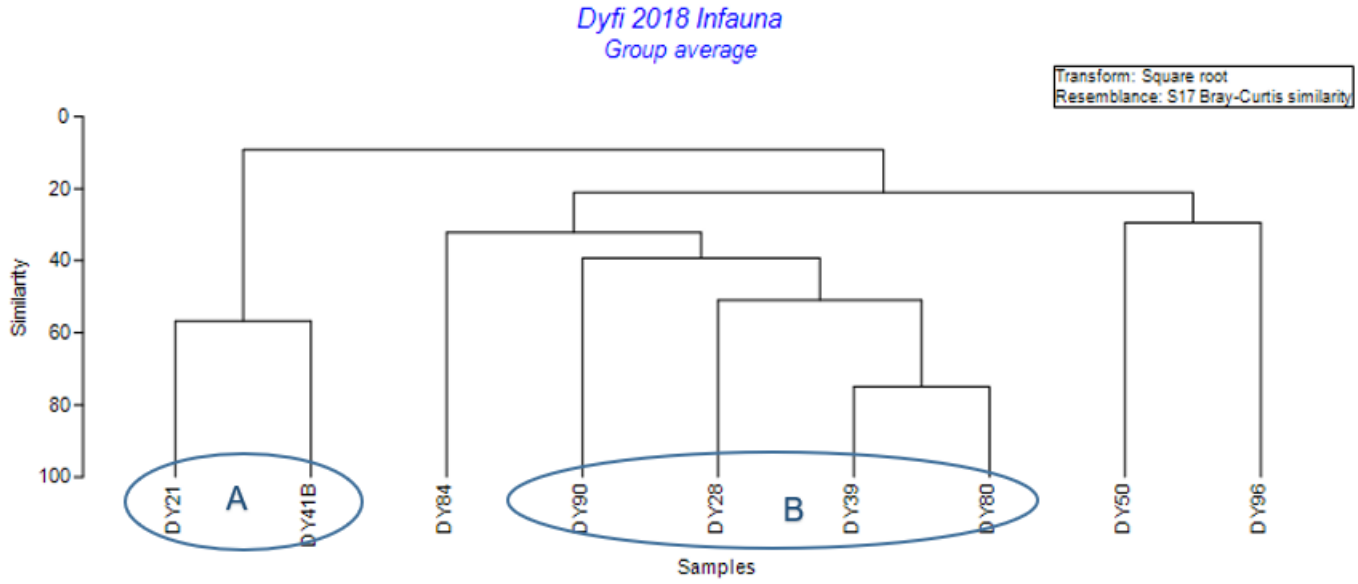
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	2.29	17.05	0.58	47.86	47.86
Eurydice truncata	0.72	6.29	0.58	17.64	65.5
Scolelepis squamata	0.54	4.7	0.58	13.2	78.7

Group B, Average similarity:34.01

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	11.24	19.23	1.17	56.54	56.54
Pygospio elegans	6.52	4.62	0.61	13.58	70.12

Effectively in 2015, A and B are sub-groupings of the whole community, since all quantitatively sampled stations possessed communities of taxa that were at least 60% similar. However the sub-Group A stations represent the slightly less-stable sediments at the outer edge of the flats shown by the presence of *Eurydice* and *Scolelepis*

Figure 12 Dendrogram of the Bray-Curtis percentage similarity for the Dyfi 2018 infaunal community



The cluster analysis shown in Figure 12 illustrates the similarity between stations. The groups A and B have been superimposed on the dendrogram and the characterising species within these groups have been deduced using SIMPER, a routine from PRIMER 7.

Table 15 SIMPER output showing 2018 Group A and Group B station taxa.

Group A, Average similarity: 35.64

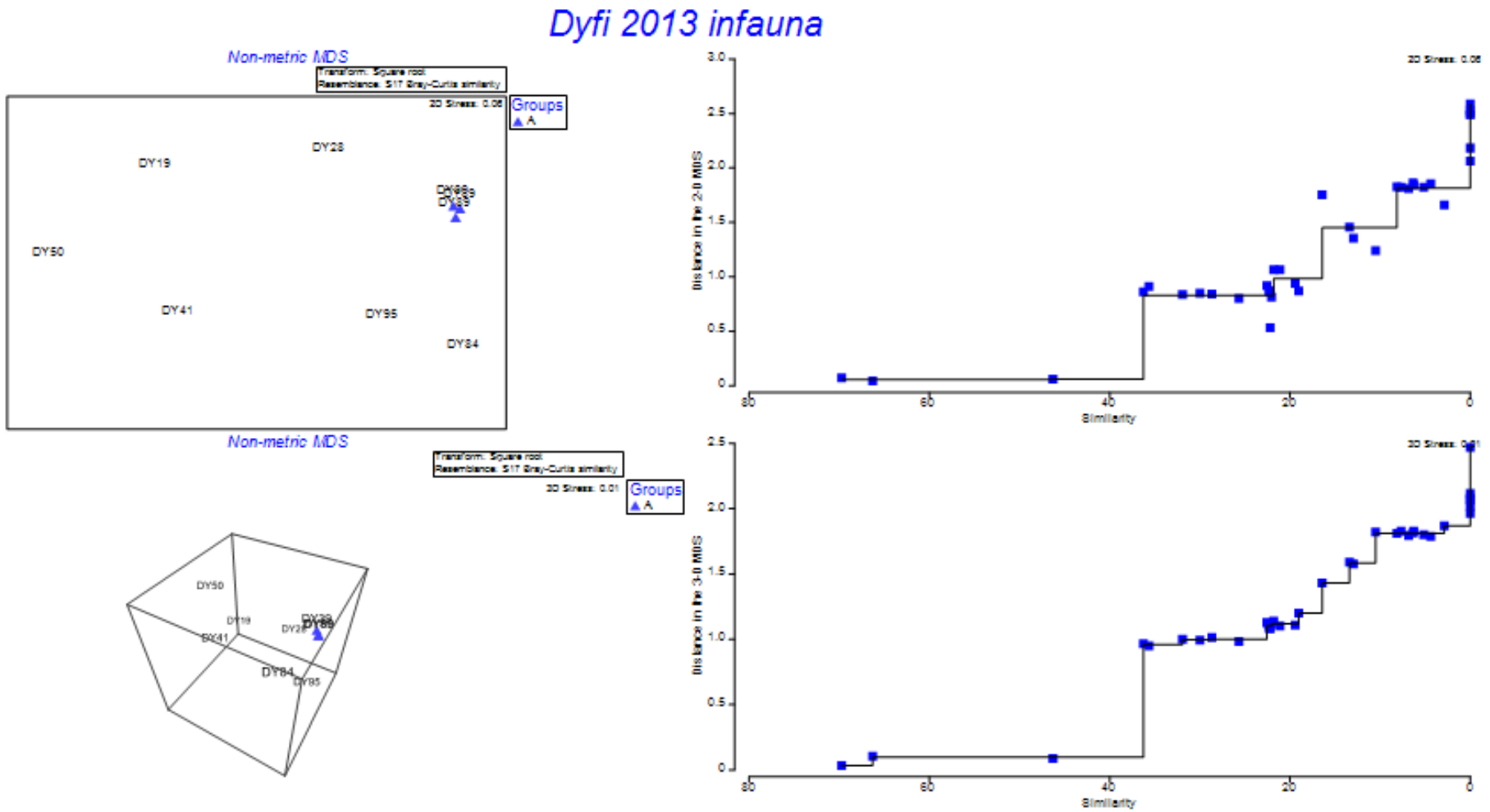
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	2.29	17.05	0.58	47.86	47.86
Eurydice truncata	0.72	6.29	0.58	17.64	65.5
Scolelepis squamata	0.54	4.7	0.58	13.2	78.7

Group B, Average similarity: 34.01

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	11.24	19.23	1.17	56.54	56.54
Pygospio elegans	6.52	4.62	0.61	13.58	70.12

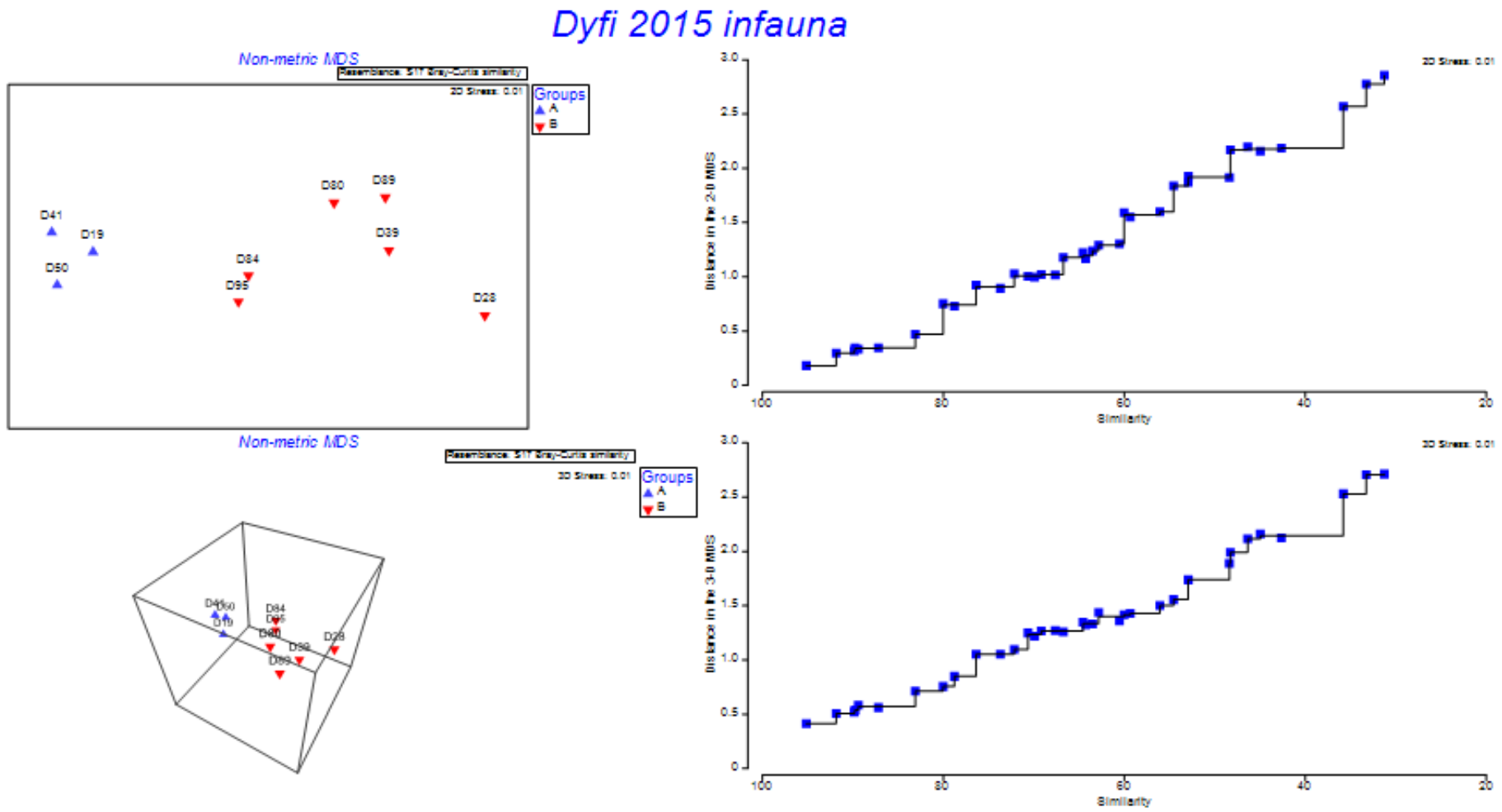
Again the Group A stations represent the slightly less-stable sediments at the outer edge of the flats shown by the presence of the robust isopod *Eurydice pulchra* and the Group B stations, the more stable, mid estuary sand flat communities dominated by *Peringia* and *Hediste*.

Figure 13 Representations of the non-metric multidimensional scaling analysis for the Dyfi 2013 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



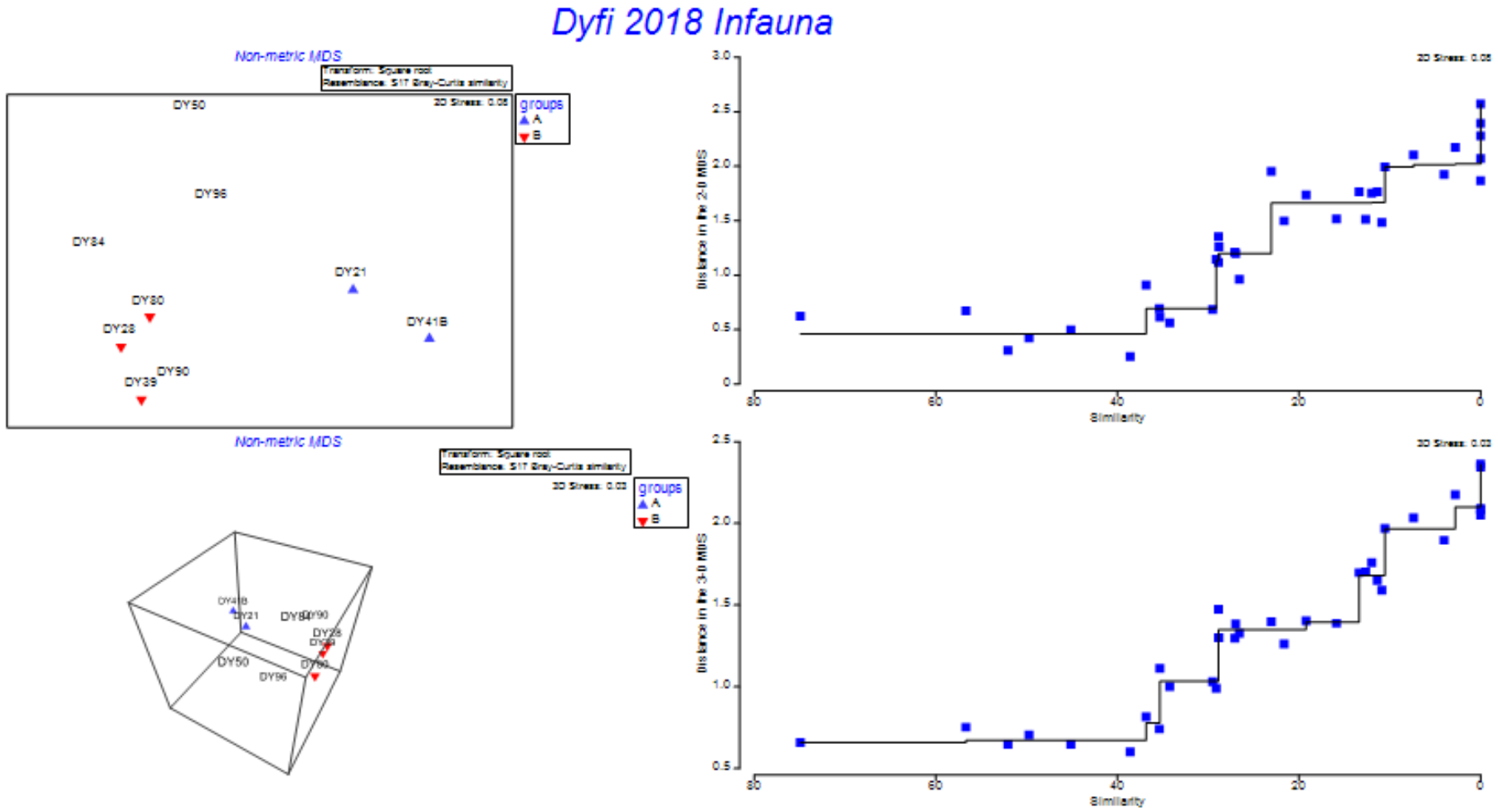
The nMDS plots in Figure 13 confirm the similarity of the stable sandflat grouping of D039, D080 and D089 (Group A here). The low stress value (<0.06) of the nMDS plots indicate the results are a good representation of the infaunal community in the Dyfi Estuary in 2013.

Figure 14 Representations of the non-metric multidimensional scaling analysis for the Dyfi 2015 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



The stable sandflat grouping are again confirmed (Group B - D039, D080 and D089) as are the slightly more depauperate outer sandflat-edge stations of D019, D041 and D050. The low stress value (0.01) of the nMDS plots in Figure 14 suggest the results are a good representation of the infaunal community in the Dyfi Estuary in 2015.

Figure 15 Representations of the non-metric multidimensional scaling analysis for the Dyfi 2018 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



Again the stable sandflat grouping (Group B) are apparent and in 2018 they are joined by D028, another station with a relatively stable substrate and more diverse infaunal community. The low stress value (<0.1) of the nMDS plots in Figure 15 suggest the results are a good representation of the infaunal community in the Dyfi Estuary in 2018.

4.4 Quantitative sampling of the Mawddach estuarine sediments

In 2016, sixteen stations (M1.1 – M4.3) were sampled on the Mawddach estuary on the four transects. In 2019, twelve of the stations were re-sampled. At each station a particle size distribution sample was taken. In 2016 three replicate 0.01 m^2 infaunal cores were collected and sieved in the field and in 2019 five replicates were taken. All samples were fixed on return to the fieldwork base. These samples were sent by NRW for taxonomic analysis to an NMBAQC laboratories. Laboratory analysis of infauna was completed by IECS (2016, 2019). Particle Size Analysis was completed by Thomson (2019). The data from these PSA and taxonomic analyses were 'cleaned' and then run through PRIMER 7 and the results are presented below. Full results are available in the Excel worksheets that accompany this report.

Table 16 Mawddach estuary particle size distribution in 2016 - percentage fractional data

Size fraction	Sieve size	M1.1	M1.2	M1.3	M1.4	M2.2	M2.6	M2.22	M'R'1	M'R'2	M'R'3	M'R'4	M3.1	M3. Extra	M4.1	M4.2	M4.3
Medium pebble (gravel)	>8 mm	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0
Small pebble (gravel)	4-8 mm	0	0	0	0	0	0	0.01	0	0	0	0	0	0.01	0	0	0
Granule	2-4 mm	0.02	0.03	0.03	0	0.02	0	0.04	0	0.07	0	0.03	0.09	0	0	0	0
Sand - very coarse	1-2 mm	0.26	0.02	0.03	0.01	0.07	0.07	0.08	0.03	0.09	0	0.01	0.16	0.01	0.04	0.01	0.01
Sand - coarse	500-999 um	0.04	0.06	0.26	0.03	0.62	0.04	0.24	0.1	0.26	0.01	0.23	0.33	0.09	1.42	0.27	0.03
Sand - medium	250-499 um	1.93	0.44	46	8.05	1.67	0.71	3.24	2.96	1.58	0.6	2.09	4.83	2.27	2.31	1.09	2.46
Sand - fine	125-249 um	30.9	84.24	51.25	89.35	16.36	46.33	81.11	76.95	74.12	90.97	55.41	22.16	13.83	46.57	80.35	91.84
Sand - very fine	63-125 um	29.55	13.79	0.42	1.06	43.26	33.88	12.32	14.73	12.41	7.47	24.44	29.1	36.72	32.63	15.23	4.8
Silt & Clay	< 63 um	37.29	1.42	2.01	1.5	38	18.98	2.85	5.22	11.47	0.95	17.78	43.34	47.08	17.02	3.05	0.85
Textural Group	n	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Fine sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Fine sand*

No pattern can be discerned from the two sets of particle size data, as so many of the stations have had to be moved due to constant channel migrations and persistent standing water bodies found in the Mawddach estuary at low tide.

Table 17 Mawddach estuary particle size distribution in 2019 - percentage fractional data

Size fraction	Sieve size	M1.1	M1.2	M1.3	M1.4	M2.2	M2.6	M2.22	M3.1	M3.2	M3. Extra	M4.1	M4.2B	M4.3B
Gravel and pebbles	>2 mm	0.05	0.02	0.01	0.39	0.02	0.01	0	0.01	1.97	0	0.29	2.15	0.05
Sand - very coarse	1-2 mm	0.18	0	0.02	0.07	0.07	0.01	0.01	0.01	0.17	0.01	0.05	0.28	0.18
Sand - coarse	500-999 um	4.1	6.44	15.4	2.16	2.64	0.89	5.31	5.61	4.26	0.06	1.54	4.26	4.1
Sand - medium	250-499 um	11.56	76.06	67.38	8.54	10.73	53.33	73.79	75.88	12.95	15.25	44.36	55.86	11.56
Sand - fine	125-249 um	20.86	17.48	17.2	19.8	20.46	45.31	20.89	18.48	21.03	31.37	46.29	30.35	20.86
Sand - very fine	63-125 um	15.62	0	0	14.85	14.83	0.45	0	0	12.86	15.19	3.06	0.18	15.62
Silt & Clay	< 63 um	47.63	0	0	54.19	51.25	0	0	0	46.77	38.12	4.42	6.92	47.63
Textural Group	n	*slightly gravelly muddy Sand*	*slightly gravelly Sand*	*slightly gravelly Sand*	*slightly gravelly sandy Mud*	*slightly gravelly sandy Mud*	*slightly gravelly Sand*	*Sand*	*slightly gravelly Sand*	*slightly gravelly muddy Sand*	*muddy Sand*	*slightly gravelly Sand*	*slightly gravelly Sand*	*slightly gravelly muddy Sand*

Table 18 Univariate statistics for the Mawddach estuary infaunal community.

Key

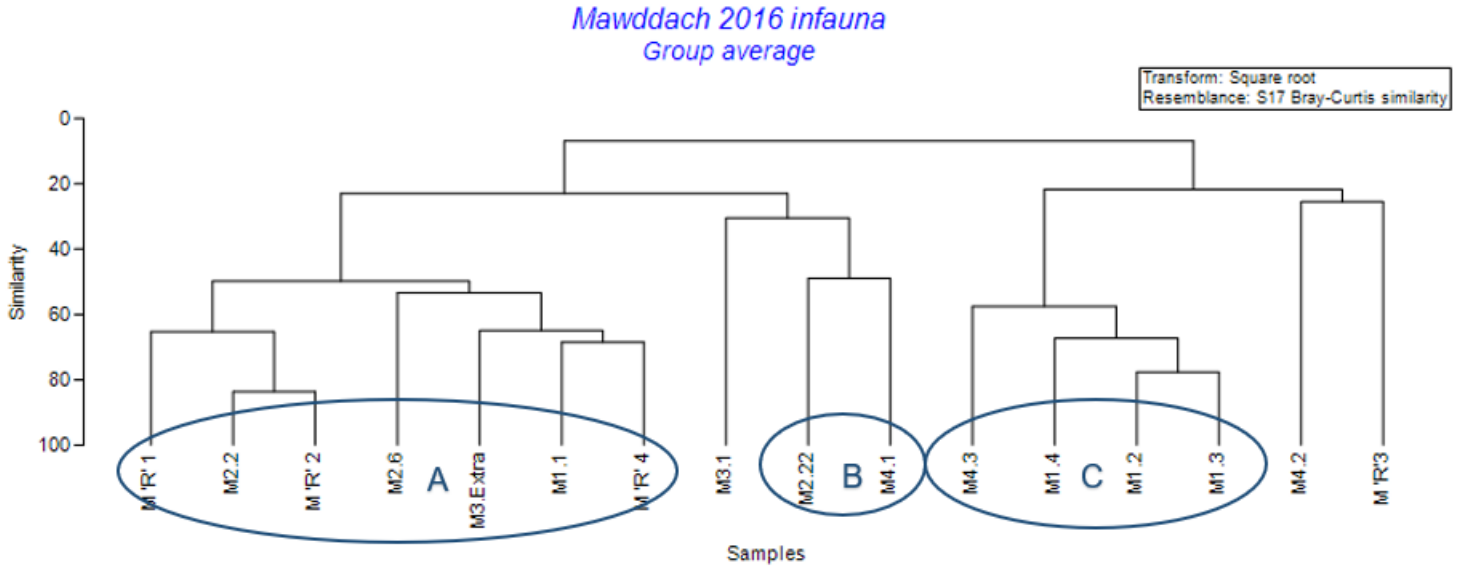
Symbol	Description
S	Number of recorded taxa
N	Mean total number of individuals: The mean number of individuals per core from all cores per site.
d	Margalef's richness for the site (S-1)/Log(N) - it is a measure of the number of taxa present, making some allowance for the number of individuals.
J'	Pielou's evenness for the site - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different taxa.
H'(loge)	Shannon-Wiener diversity index for the community
1-Lambda'	Simpson's diversity index for the community
n a	In 2016 M3.2 was not accessible due to channel movements. In 2016 an alternative 'R' transect was sampled as an "insurance policy", but it was not repeated in 2019.

Univariate index	S	S	N	N	d	d	J'	J'	H'(loge)	H'(loge)	1-Lambda'	1-Lambda'
Station	**2016**	**2019**	**2016**	**2019**	**2016**	**2019**	**2016**	**2019**	**2016**	**2019**	**2016**	**2019**
M1.1	11	10	36	56	3.54	3.12	0.92	0.86	2.22	1.97	0.93	0.87
M1.2	5	8	25	4	1.8	4.25	0.86	0.96	1.38	1.99	0.79	1.06
M1.3	5	5	21	6	1.75	2.73	0.97	0.86	1.55	1.38	0.87	0.9
M1.4	5	n a	28	n a	1.83	n a	0.8	n a	1.29	n a	0.73	n a
M2.2	9	11	58	81	2.79	3.32	0.86	0.83	1.89	1.99	0.86	0.85
M2.6	9	15	23	164	3.1	4.14	0.96	0.78	2.11	2.11	0.94	0.84
M2.22	6	15	5	217	3.17	3.82	0.95	0.82	1.71	2.22	1.01	0.88
M3.1	4	9	166	7	1	4.05	0.75	0.95	1.04	2.09	0.61	1
M3.2	n a	5	76	4	n a	2.74	n a	0.99	n a	1.6	n a	1.04
M3 Extra	14	20	14	69	3.94	5.6	0.92	0.91	2.42	2.74	0.93	0.95
M4.1	9	3	2	3	3.44	1.99	0.95	0.93	2.08	1.03	0.96	0.98
M4.2	5	11	9	111	3.51	3.18	0.99	0.79	1.6	1.89	1.17	0.83
M4.3	3	4	150	2	1.36	2.97	0.84	0.98	0.92	1.36	0.71	1.16
M 'R' 1	6	n a	66	n a	1.56	n a	0.90	n a	1.61	n a	0.79	n a
M 'R' 2	8	n a	1	n a	2.41	n a	0.88	n a	1.83	n a	0.85	n a
M 'R' 3	2	n a	52	n a	3.01	n a	0.98	n a	0.68	n a	1.72	n a
M 'R' 4	14	n a	36	n a	4.19	n a	0.92	n a	2.44	n a	0.94	n a

In 2019 the M4 transect was effectively completely repositioned due to channel movements. M4.2 and M4.3 now reflect decreasing tidal height rather than any specific change in particle size.

The M2 transect stations and the M3extra station appear to be the communities with the greatest number of taxa present and the greatest infaunal diversity from year to year.

Figure 16 Dendrogram of the Bray-Curtis percentage similarity for the Mawddach 2016 infaunal community



The groups A-C have been superimposed on Figure 16 where stations cluster at similarity levels greater than 40%. Characterising species within these groups have been deduced using SIMPER, a routine from PRIMER 7.

Table 19 SIMPER output showing Mawddach 2016 Group A, Group B and Group C station taxa

Group A, Average similarity: 55.76

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	3.36	11.43	1.69	20.49	20.49
Cyathura carinata	2.75	10.92	3.48	19.58	40.07
Hediste diversicolor	2.7	9.85	3.33	17.66	57.74
Scrobicularia plana	1.82	6.6	1.5	11.83	69.57
Pygospio elegans	2.81	6.29	2.68	11.28	80.85

Group B, Average similarity: 48.92

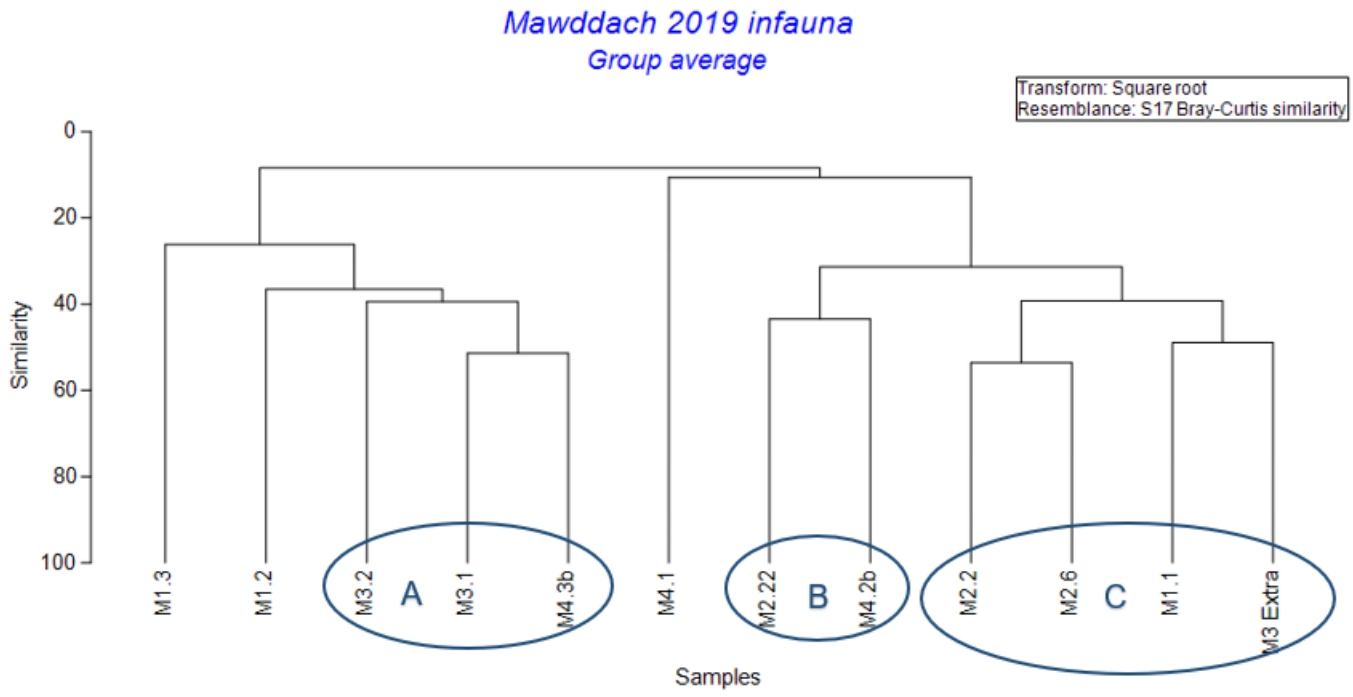
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Pygospio elegans	1.84	20.29	SD=0!	41.48	41.48
Cyathura carinata	1	13.29	SD=0!	27.16	68.64
*Corophium*_Juv	0.87	7.67	SD=0!	15.68	84.32

Group C, Average similarity: 64.14

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Bathyporeia pilosa	3.63	37.4	6.53	58.32	58.32
Eurydice pulchra	1.37	9.8	1.75	15.28	73.6

The fauna associated with Groups A and B appear to represent relatively stable muddy sand communities, whereas Group C species represent the unstable more mobile sediments found in the Mawddach estuary.

Figure 17 Dendrogram of the Bray-Curtis percentage similarity for the Mawddach 2019 infaunal community



The groups A-C have been superimposed on Figure 17 where stations cluster at similarity levels greater than 40%. Characterising species within these groups have been deduced using SIMPER, a routine from PRIMER 7.

Table 20 SIMPER output showing Mawddach 2019 Group A, Group B and Group C station taxa

Group A, Average similarity: 43.43

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	0.88	16.98	3.82	39.1	39.1
Bathyporeia pilosa	1.04	13	3.1	29.94	69.04
Capitella	0.6	5.98	0.58	13.76	82.8

Group B, Average similarity: 43.47

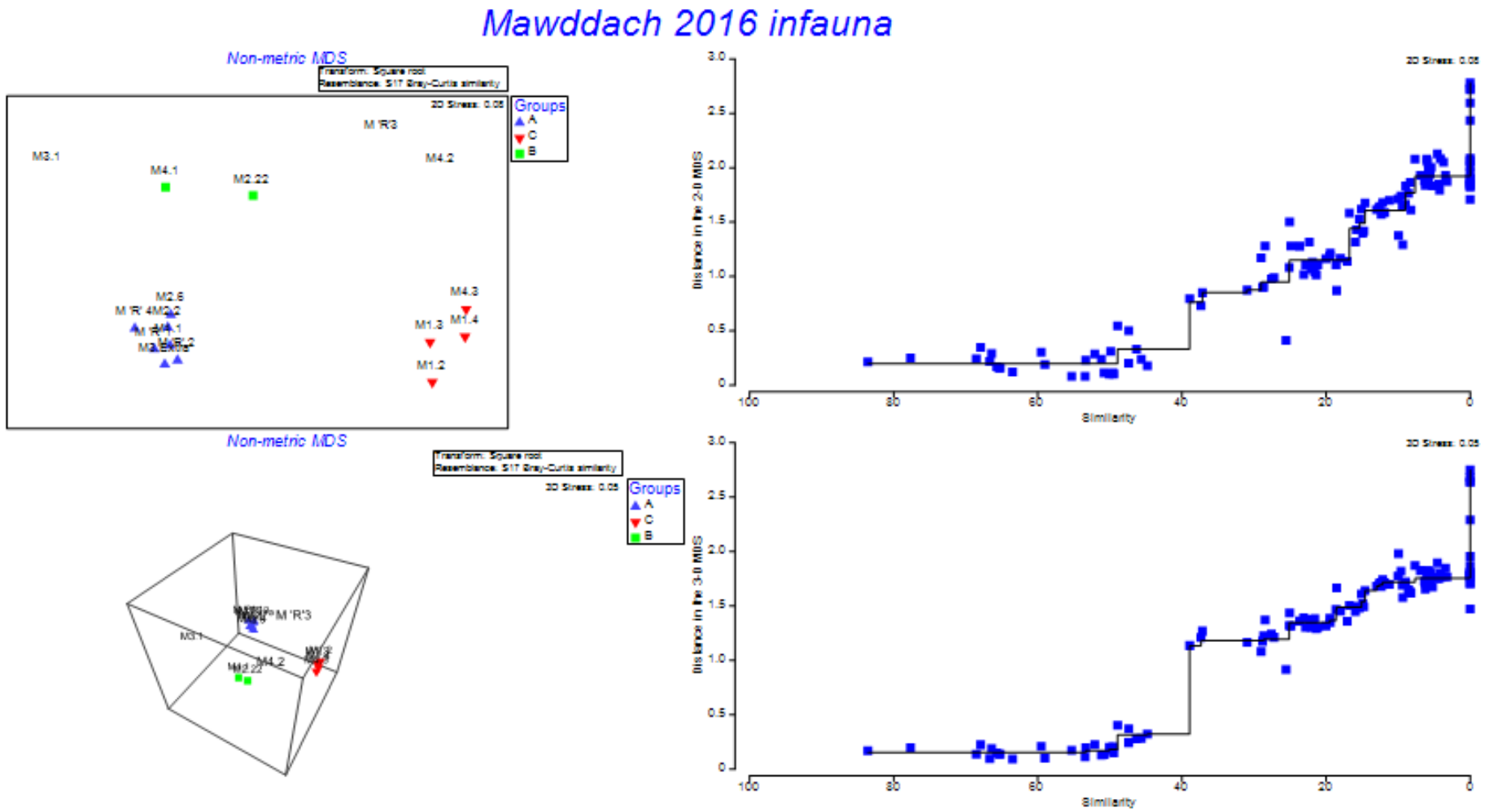
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Pygospio elegans	8.66	26.79	SD=0!	61.63	61.63
Bathyporeia pilosa	2.6	7.03	SD=0!	16.16	77.79

Group C, Average similarity:43.26

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Hediste diversicolor	3.03	8.57	1.39	19.8	19.8
Peringia ulvae	4.02	7.28	0.83	16.82	36.63
Cyathura carinata	2	7.18	4.06	16.59	53.22
Pygospio elegans	2.38	6.55	2.23	15.13	68.35
Scrobicularia plana	1.26	4.31	2.82	9.97	78.32

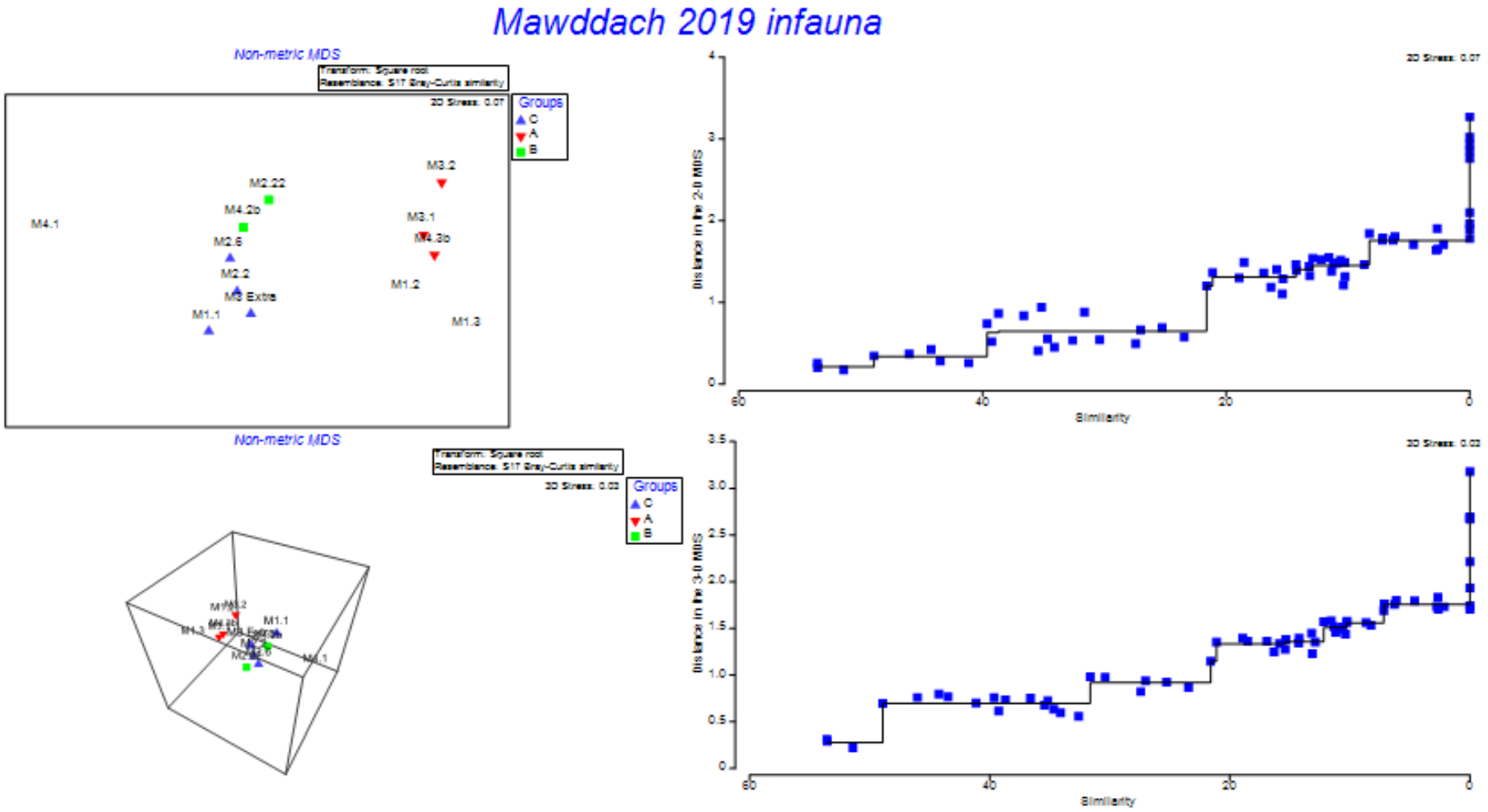
The results for 2019 in the Mawddach, shown in Figure 17 are similar to those for 2016. Group C represents the more stable communities given the presence of the medium sized bivalve *Scrobicularia plana* and the ragworm *Hediste diversicolor,* both of which thrive in stable muddy sand environments.

Figure 18 Representations of the non-metric multidimensional scaling analysis for the Mawddach 2016 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



The low stress values of <0.1 for the nMDS plots in Figure 18 indicate the results are probably an excellent representation of reality for the infaunal communities of the Mawddach Estuary in 2016.

Figure 19 Representations of the non-metric multidimensional scaling analysis for the Mawddach 2019 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



The low stress values of <0.1 for the nMDS plots in Figure 19 indicate the results are probably an excellent representation of reality for the infaunal communities of the Mawddach Estuary in 2019.

4.5 Quantitative sampling of the Glaslyn/Dwyryd estuarine sediments

In 2017, nine stations were sampled on the Glaslyn/Dwyryd estuary system (G10b-G61). These nine stations were previously sampled in 2014. In 2014 three replicate cores were collected at each station and in 2017 the number of replicates had been increased to five. A particle size distribution sample was also collected at each station. All infaunal samples were sieved in the field and later that day fixed at the fieldwork base. All samples were then sent for analysis to an NMBAQC laboratory by NRW. Laboratory analysis of infauna was completed by Hebog (2014, 2017). Particle Size Analysis was completed by Hebog (2014) and IECS (2017). The resulting data from the taxonomic analysis were 'cleaned' and analysed with PRIMER 7 and the results are presented below.

Table 21 Glaslyn/ Dwyryd estuary particle size distribution in 2014 - percentage fractional data

Size fraction	Sieve size	G10b	G14	G20	G40	G44	G49	G50	G55	G61
Gravel and pebbles	>4 mm	0	0	0	0	0	0	0	0	0.26
Granule	2-4 mm	0.01	0.02	0.01	0.02	0.02	0.01	0	0.07	0.06
Sand - very coarse	1-2000 µm	0.01	0.01	0.03	0	0.02	0.02	0.01	0.09	0.12
Sand - coarse	500-1000 µm	0.01	0.03	0.02	0.01	0.07	0.05	0.07	0.12	0.15
Sand - medium	250-500 µm	0.51	0.65	0.29	1.46	0.34	0.41	7.35	1.14	1.28
Sand - fine	125-250 µm	75.83	73.86	72.61	88.83	72.54	84.12	83.77	77.27	71.40
Sand - very fine	63-125 µm	21.81	23.26	24.71	8.71	22.19	13.25	7.33	18.49	22.60
Silt & Clay	< 63 µm	1.82	2.17	2.33	0.97	4.82	2.14	1.47	2.83	4.12
Textural Group	n	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*	*Muddy fine Sand*

Table 22 Glaslyn/ Dwyryd estuary particle size distribution in 2017 - percentage fractional data

Size fraction	Sieve size	G10b	G14	G20	G40	G44	G49	G50	G55	G61
Small pebble (gravel)	>4 mm	0.0	0.0	0.3	0.0	0.5	0.0	0.0	0.0	0.1
Granule	2-4 mm	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Sand - very coarse	1-2000 µm	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Sand - coarse	500-1000 µm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sand - medium	250-500 µm	5.6	4.1	8.8	8.5	11.1	22.9	18.5	10.8	8.1
Sand - fine	125-250 µm	66.8	71.9	69.5	76.7	64.4	73.0	70.4	77.7	68.5
Sand - very fine	63-125 µm	27.6	24.0	21.3	14.9	15.0	4.1	11.1	11.5	23.2
Silt & Clay	< 63 µm	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0
Textural Group	n	*Fine Sand*	*Fine Sand*	*Fine Sand*	*Fine Sand*	*Muddy fine Sand*	*Sand*	*Sand*	*Sand*	*Fine Sand*

Table 23 Univariate statistics for the Glaslyn/ Dwyryd estuary system infaunal community.

Key

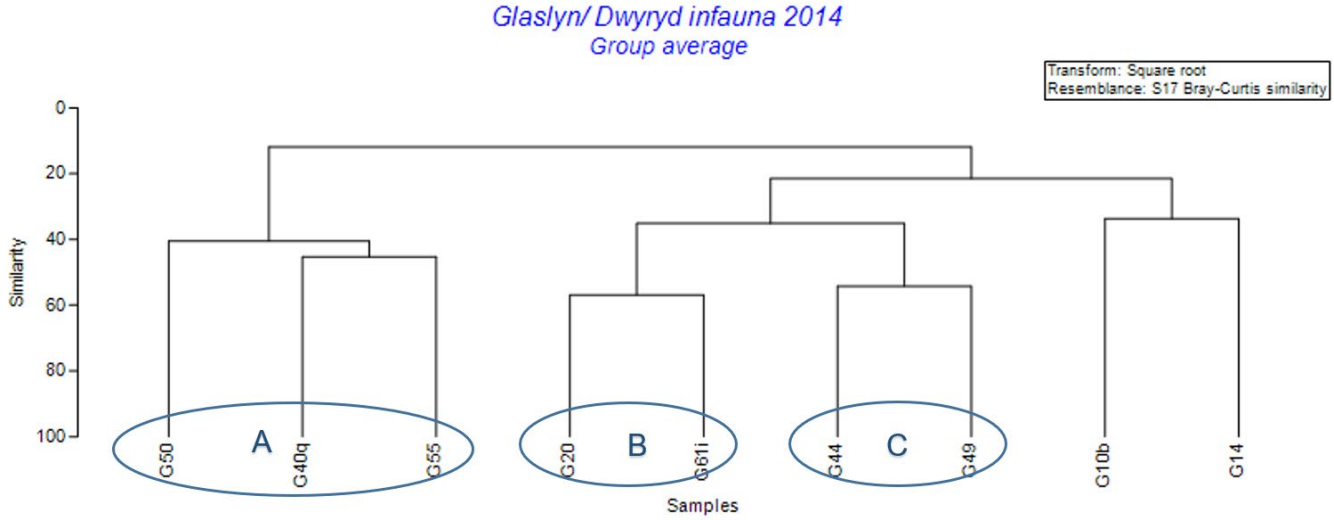
Symbol	Description
S	Number of recorded taxa
N	Mean total number of individuals: The mean number of individuals per core from all cores per site.
d	Margalef's richness for the site (S-1)/Log(N) - it is a measure of the number of taxa present, making some allowance for the number of individuals.
J'	Pielou's evenness for the site - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different taxa.
H'(loge)	Shannon-Wiener diversity index for the community
1-Lambda'	Simpson's diversity index for the community

Univariate index	S	S	N	N	d	d	J'	J'	H'(loge)	H'(loge)	1-Lambda'	1-Lambda'
Station	2014	2017	2014	2017	2014	2017	2014	2017	2014	2017	2014	2017
G10b	7	4	5	3	3.502	2.69	0.984	0.93	1.915	1.30	1.035	1.04
G14	4	3	2	1	2.985	3.24	0.9762	0.98	1.353	1.08	1.155	1.41
G20	9	14	32	113	3.115	3.86	0.8728	0.87	1.918	2.30	0.8794	0.89
G40	7	18	5	302	3.575	4.49	0.9689	0.78	1.885	2.26	1.03	0.86
G44	20	15	282	322	5.06	3.73	0.7818	0.78	2.342	2.10	0.8657	0.84
G49	13	10	123	7	3.78	4.46	0.7924	0.94	2.032	2.18	0.8192	1.00
G50	6	11	3	11	3.439	4.40	0.9769	0.93	1.75	2.24	1.067	0.98
G55	6	13	7	19	2.793	4.58	0.9671	0.94	1.733	2.42	0.9774	0.97
G61	11	14	97	247	3.176	3.79	0.8496	0.72	2.037	1.89	0.8577	0.77

Full results for the infaunal sampling programme are available in the Excel worksheets that accompany this report.

A comparison between Table 22 and Table 23 shows that there has been a distinct change in the sediments of the system. Most of the stations have become cleaner with the loss of the small mud fraction seen in 2014. The exception to this was site G44, where the mud fraction had increased slightly. Few trends are apparent in the infaunal univariate statistics (Table 24) relating to the quantitative samples taken from stations in the Glaslyn/Dwyryd estuary in 2014 and 2017. G44 adjacent to the 'Cob' is the muddiest and most mixed sediment and routinely supports the greatest number of taxa and individuals per core. Site G14 is the most depauperate community, situated at the top of the estuary and highly influenced by the freshwater of the Afon Dwyryd.

Figure 20 Dendrogram of the Bray-Curtis percentage similarity for the Glaslyn/Dwyryd 2014 infaunal community



The groups A-C have been superimposed on Figure 20 where stations cluster at similarity levels greater than 40%. Characterising species within these groups have been deduced using SIMPER, a routine from PRIMER 7.

Table 24 SIMPER output showing Glaslyn/Dwyryd 2014 Group A, Group B and Group C station taxa

Group A, Average similarity:42.06

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Macomangulus tenuis	1.37	23.79	19.34	56.56	56.56
Nephtys cirrosa	0.66	11.13	12.26	26.47	83.03

Group B, Average similarity:56.88

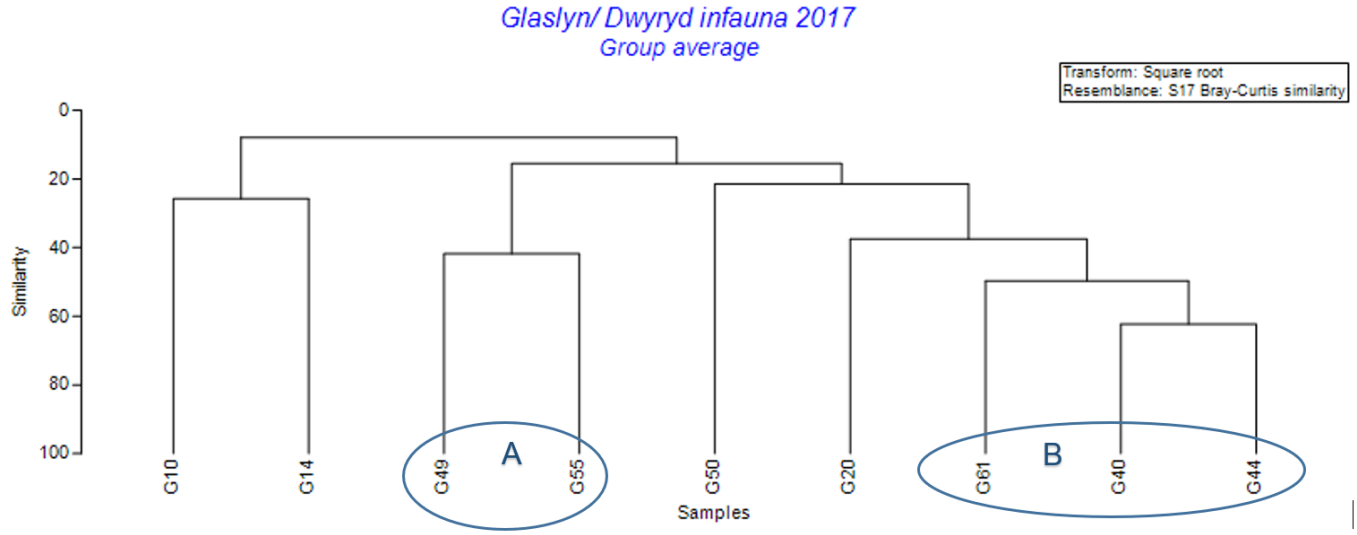
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	6.32	24.8	SD=0!	43.61	43.61
Bathyporeia pilosa	2.45	9.53	SD=0!	16.75	60.36
Pygospio elegans	2.21	7.78	SD=0!	13.68	74.04

Group C, Average similarity: 54.22

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Pygospio elegans	10.6	30.3	SD=0!	55.89	55.89
Peringia ulvae	6.6	6.48	SD=0!	11.95	67.84
Corophium arenarium	1.29	3.87	SD=0!	7.14	74.99

Figure 20 illustrates the 2014 situation where a less stable, clean, mobile sand community (Group A), with cat worms *Nephtys cirrosa* and the small bivalve *Macomangulus tenuis* exist towards the mouth of the system and a pair of similar groups (B and C) exist where more stable conditions prevail further into the estuarine complex.

Figure 21 Dendrogram of the Bray-Curtis percentage similarity for the Glaslyn /Dwyryd 2017 infaunal community.



The groups A and B have been superimposed on Figure 21 where stations cluster at similarity levels greater than 40%. Characterising species within these groups have been deduced using SIMPER, a routine from PRIMER 7.

Table 25 SIMPER output showing Glaslyn/Dwyryd 2017 Group A and Group B station taxa

Group A, Average similarity: 41.82

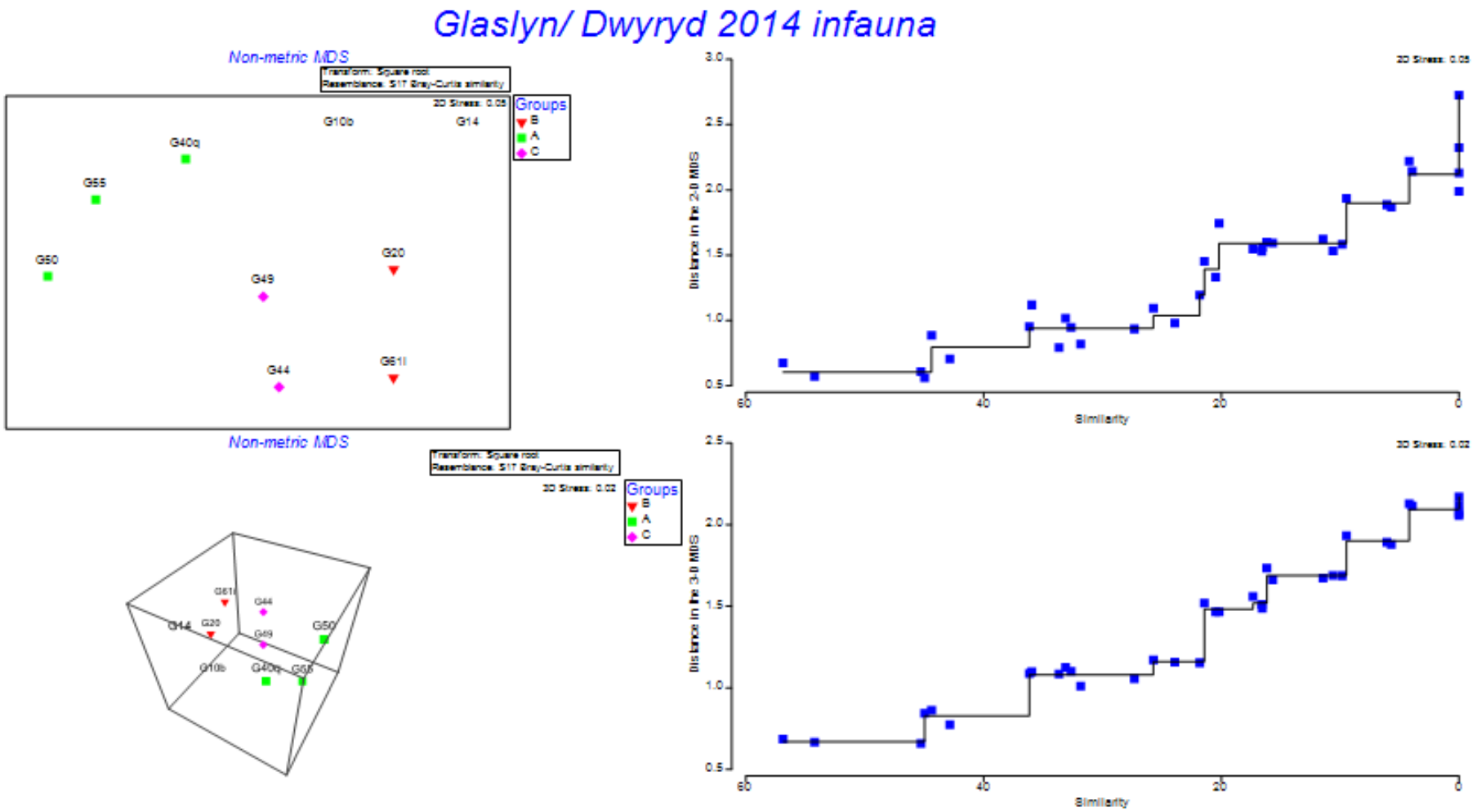
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Macomangulus tenuis	1.79	16.3	SD=0!	38.97	38.97
Eteone longa	1.05	9.41	SD=0!	22.5	61.47
Peringia ulvae	0.63	5.95	SD=0!	14.23	75.71

Group B, Average similarity: 53.89

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	12.95	29.21	3.22	54.2	54.2
Pygospio elegans	7.35	9.98	1.88	18.51	72.71

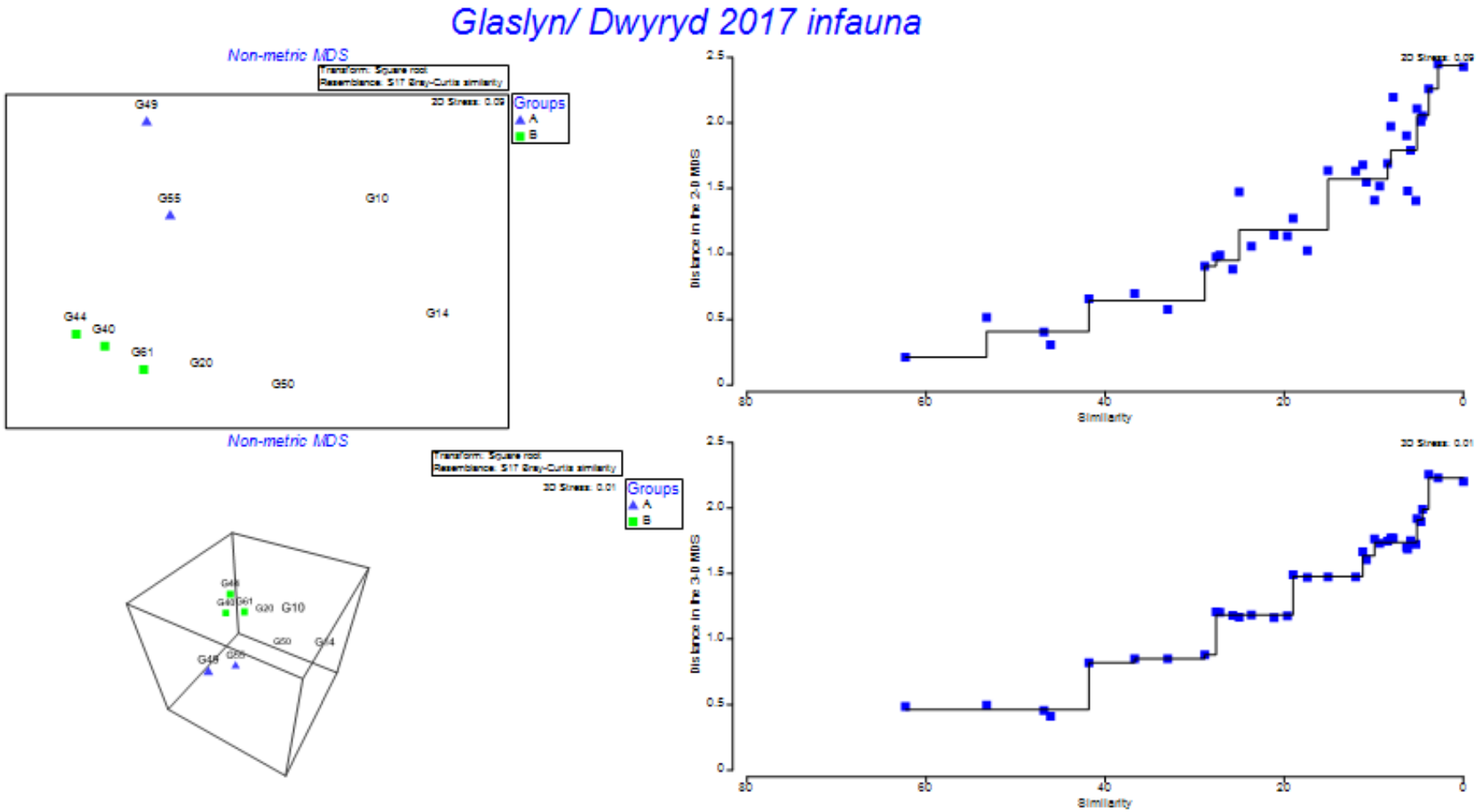
Figure 21 illustrates a different distribution of samples in the dissimilarity plot in 2017, but the same types of habitats are present as in 2014 where a less stable, cleaner, sand community (Group A) with the bivalve *Macomangulus tenuis* exists towards the mouth of the system and a group B community, characterised by higher numbers of *Peringia ulvae,* existing where more stable conditions prevail further into the estuary complex.

Figure 22 Representations of the non-metric multidimensional scaling analysis for the Glaslyn/ Dwyryd 2014 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



The low stress values of <0.05 for the nMDS plots in Figure 22 indicate the results are probably an excellent representation of reality for the infaunal communities of the Glaslyn/Dwyryd estuarine system in 2014.

Figure 23 Representations of the non-metric multidimensional scaling analysis for the Glaslyn/ Dwyryd 2017 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



The low stress values of <0.1 for the nMDS plots in Figure 23 indicate the results are probably an excellent representation of reality for the infaunal communities of the Glaslyn/Dwyryd estuarine system in 2017.

4.6 Littoral infaunal biotopes in the estuaries of the SAC

When all the *in situ* grid sampling records and the quantitative infaunal community data were combined, littoral sediment biotopes were assigned to all stations sampled. The results in **Error! Reference source not found.**, Table 27 and Table 28 show that the biotopes appear to be relatively stable where the stations are undisturbed by the channel movements. It can be seen that the assigned biotopes generally only vary due to fluctuations in the dominance of one or two taxa, such as *Eurydice pulchra* or *Macomangulus* (*Angulus*) *tenuis* from year to year.

Table 26 Littoral biotopes assigned to the infaunal communities of the Dyfi estuary on each sampling occasion between 2013 and 2019. 'nr' = not recorded.

Station	2013	2015	2018
Dy003	nr	nr	LS.LSa.FiSa
Dy019	LS.LSa.MoSa	LS.LSa.MoSa	nr
Dy020	nr	nr	LS.LSa.FiSa
Dy021	nr	nr	LS.LSa.MoSa.AmSco.Eur
Dy028	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.CerPo
Dy039	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr
Dy041	LS.LSa.MoSa	LS.LSa.MoSa	LS.LSa.MoSa.AmSco.Eur
Dy045B	nr	nr	LS.LSa.FiSa
Dy047	nr	nr	LS.LMu.MEst.HedMac
Dy050	LS.LSa.FiSa.Po.Aten	LS.LSa.MoSa	LS.LSa.FiSa.Po.Ncir
Dy057	nr	nr	LS.LSa.MuSa.CerPo
Dy059B	nr	nr	LS.LSa.MoSa.AmSco.Eur
Dy060B	nr	nr	LS.LSa.MoSa.AmSco.Eur
Dy073	nr	nr	LS.LMu.MEst.HedMacScr
Dy075	nr	nr	LS.LMu.MEst.HedMacScr
Dy078	nr	nr	LS.LMu.MEst.HedMacScr
Dy080	LS.LMu.MEst.HedMacScr	LS.LSa.MuSa.CerPo	LS.LMu.MEst.HedMacScr
Dy082	nr	nr	LS.LMu.UEst.Hed
Dy084	LS.LMu.MEst.HedMac	LS.LSa.MoSa	LS.LSa.MuSa.CerPo
Dy086	nr	nr	LS.LMu.MEst.HedMacScr
Dy089	LS.LMu.MEst.HedMac	LS.LMu.UEst	nr
Dy090	nr	nr	LS.LMu.MEst.HedMacScr
Dy095	LS.LMu.UEst.Hed.Cvol	LS.LMu.UEst	nr
Dy096	nr	nr	LS.LMu.UEst
Dy106C	nr	nr	LS.LSa.MuSa
Dy108	nr	nr	LS.LMu.UEst.Hed
Dy109	nr	nr	LS.LSa.MuSa

Table 27 Littoral biotopes assigned to the infaunal communities of the Mawddach estuary on each sampling occasion between 2013 and 2019. 'nr' = not recorded.

Station	2012	2014	2016	2019
M1.1	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr
M1.2	LS.LSa.MuSa.MacAre ?	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.CerPo
M1.3	LS.LSa.MoSa.AmSco.Eur?	LS.LSa.MoSa.AmSco.Eur	LS.LSa.MoSa.AmSco.Eur	LS.LSa.FiSa.Po.Pful
M1.4	LS.LSa.MoSa.AmSco.Eur	nr	LS.LSa.MoSa.AmSco.Eur	LS.LMp.Sm
M2.2	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr
M2.6	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr
M2.22	LS.LSa.MuSa.MacAre	LS.LSa.MoSa.Ol.VS	LS.LSa.MoSa.Ol.VS	LS.LSa.MuSa.CerPo
M2extra	nr	LS.LMu.MEst.HedMacScr	nr	nr
M3.1	LS.LMu.UEst.Hed.Ol?	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	LS.LSa.FiSa.Po.Pful
M3.2	LS.LMu.UEst.Hed.Cvol	LS.LMu.MEst.HedMacScr	nr	LS.LSa.FiSa.Po.Pful
M3.3	LS.LSa.MoSa.AmSco.Eur	LS.LSa.MoSa.Ol.VS	nr	nr
M3.4	nr	LS.LMu.MEst.HedMacScr	LS.LMu.MEst.HedMacScr	nr
M3extra	LS.LMu.MEst.HedMacScr?	nr	nr	LS.LMu.MEst.HedMacScr
M4.1	LS.LMu.UEst.Hed.Cvol	nr	LS.LMu.UEst	nr
M4.2	nr	nr	LS.LMu.UEst	LS.LSa.MuSa.BatCare
M4.3	nr	nr	LS.LSa.MoSa	LS.LSa.MoSa
M4.4	LS.LSa.MoSa.BarSa	nr	nr	nr
M-R.1	LS.LMu.UEst.Hed.Cvol	nr	LS.LMu.MEst.HedMacScr	nr
M-R.2	LS.LMu.MEst.HedMacScr	nr	LS.LMu.MEst.HedMacScr	nr
M-R.3	LS.LMu.UEst.Hed.Cvol	nr	LS.LSa.MoSa	nr
M-R.4	LS.LMu.UEst.Hed.Ol?	nr	LS.LMu.MEst.HedMacScr	nr

Table 28 Littoral biotopes assigned to the infaunal communities of the Glaslyn / Dwyryd estuaries on each sampling occasion between 2013 and 2019. 'nr' = not recorded.

Station	2008	2014	2017
G02	nr	LS.LSa.MuSa.BatCare	LS.LSa.MoSa.AmSco
G08	nr	nr	LS.LSa.MuSa
G09	nr	LS.LMu.MEst.HedMacScr	LS.LSa.MuSa.BatCare
G10b	LS.LMu.UEst.Hed.Cvol	LS.LSa.MuSa.BatCare	LS.LSa.MuSa
G13	nr	LS.LSa.MuSa.BatCare	LS.LSa.MuSa.BatCare
G14	LS.LSa.MoSa.BarSa	LS.LSa.MoSa	LS.LSa.MoSa
G17	LS.LMu.UEst.Hed.Str	LS.LMu.UEst.Hed.Cvol	LS.LMu.UEst.Hed.Cvol
G18a	nr	nr	LS.LSa.MuSa
G19	nr	nr	LS.LSa.MuSa.BatCare
G20	LS.LSa.MoSa.AmSco.Eur	LS.LMu.MEst.NhomMacStr	LS.LSa.MuSa.BatCare
G21B	nr	LS.LSa.MuSa.MacAre	LS.LMu.UEst.Hed.Cvol
G22	nr	LS.LSa.MoSa	nr
G28	nr	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.BatCare
G29B	nr	LS.LSa.MuSa.MacAre	nr
G30b	nr	LS.LSa.MoSa.AmSco	LS.LSa.FiSa.Po.Aten
G31	nr	LS.LMp.Sm	LS.LMx
G34	nr	LS.LSa.MoSa	LS.LSa.MuSa
G35b	nr	LS.LSa.MuSa.CerPo	nr
G40	LS.LSa.MoSa.AmSco.Eur?	LS.LMu.MEst.NhomMacStr	LS.LSa.MuSa.CerPo
G41q	nr	LS.LMu.MEst.NhomMacStr	LS.LSa.MuSa
G44	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.CerPo
G46	nr	LS.LSa.MuSa.CerPo	LS.LSa.MuSa.CerPo
G47	nr	LS.LSa.MoSa	LS.LSa.MuSa.BatCare
G49	LS.LSa.MoSa.AmSco.Sco	LS.LSa.MuSa.MacAre	LS.LSa.FiSa.Po.Aten
G50	nr	LS.LMu.MEst.NhomMacStr	LS.LSa.MoSa
G51	LS.LSa.FiSa.Po.Aten	nr	nr
G54	nr	LS.LSa.MuSa.BatCare	LS.LMu.MEst.HedMacScr
G55	LS.LSa.MoSa.AmSco.Eur	LS.LSa.FiSa.Po.Ncir	LS.LSa.MuSa.CerPo
G56	nr	LS.LSa.MoSa	LS.LSa.MoSa
G57b	nr	LS.LSa.MoSa	LS.LSa.FiSa.Po.Ncir
G61	LS.LSa.MoSa.AmSco.Eur	LS.LSa.MuSa.BatCare	LS.LSa.MuSa.CerPo
G62b	nr	LS.LSa.MuSa.CerPo	nr
G68	nr	LS.LSa.MoSa	nr
G73	nr	nr	LS.LSa.MoSa
G74b	nr	nr	LS.LSa.MoSa
G75	nr	nr	LS.LSa.MoSa
G80	nr	LS.LMu.MEst.HedMacScr	LS.LMu.UEst.Hed.Cvol
G83	nr	nr	LS.LSa.MuSa
G86	nr	LS.LSa.MuSa.CerPo	LS.LMu.MEst.HedMac
G87b	nr	LS.LMu.MEst.NhomMacStr	LS.LSa.MoSa
G91	nr	LS.LSa.MuSa.MacAre	nr
G92	nr	nr	LS.LSa.FiSa
G96	nr	LS.LSa.MuSa.CerPo	LS.LSa.MoSa

4.7 Quantitative sampling of the Tremadog Bay Open Coast infaunal communities

In 2017, the eight open coast stations were sampled on the four beaches in Tremadog Bay. These eight stations were previously sampled in 2014. In 2014 five replicate cores were collected at each station and this was repeated in 2017. A particle size distribution sample was also collected at each station. All infaunal samples were sieved in the field and later that day fixed at the fieldwork base. These samples were sent for taxonomic and grain size distribution analysis to NMBAQC laboratories under separate contracts. The data from these analyses were 'cleaned' and processed with infaunal data run through the PRIMER 7 package. The results of these analyses are presented below.

Table 29 and Table 30 possibly show a slight coarsening of the particle size distributions between 2014 and 2017. What can be clearly seen is that the silt/clay fraction that is present at most sites in 2014 is no longer present by 2017. The initial presence of the silt/clay fraction correlates with observations made across the whole of the Welsh coast in the spring/summer of 2014, following the series of severe winter storms of 2013/14. These storms caused the deposition of mobilised fine material across the intertidal zone. This temporary increase in silt/clay levels had gone again by 2017. East Criccieth middle shore clearly has the most mixed particle size distribution.

Table 29 shows the suite of univariate statistics for the infaunal communities in which there are few discernible trends apparent. The most obvious trend to note is that East Criccieth lower shore is consistently the station supporting the highest number of taxa (17 and 12) and greatest number of individuals per core (41 and 24). Laboratory analysis of infauna was completed by Hebog (2014, 2017). Particle Size Analysis was completed by Hebog (2014) and IECS (2017). Full results are available in the Excel worksheets that accompany this report.

Table 29 Open Coast sediment survey particle size distribution - percentage fractional data in 2014

Size fraction	Sieve size	MH-LS	MH-MS	MD-LS	MD-MS	BRS-LS	BRS-MS	EC-LS	EC-MS
med pebble	>8000	0	2.96	0	0	0	0	0	8.04
small pebble	4000-8000	0	0.08	0	0	0	0.06	1.43	4.15
Granule	2000-4000	0.26	1.29	0.08	0.52	0.02	0.22	0.44	3.77
v coarse sand	1000-2000	0.43	2.57	0.18	0.45	0.06	0.12	0.24	2.26
coarse sand	500-1000	1.19	10.81	0.53	1.21	0.15	0.38	0.10	0.90
medium sand	250-500	7.59	40.94	5.81	20.92	3.96	5.31	0.13	11.29
fine sand	125-250	82.97	36.36	57.80	71.98	69.97	84.89	46.02	61.78
v fine sand	63-125	5.89	4.48	31.93	3.16	23.80	7.02	47.41	6.16
silt & clay	<63um	1.67	0.50	3.67	1.76	2.04	2.00	4.23	1.65
n	Textural group	*Fine sand*	*Sand*	*Fine sand*	*Fine sand*	*Fine sand*	*Fine sand*	*Very fine sand*	*Fine sand*

Table 30 Open Coast sediment survey particle size distribution - percentage fractional data in 2017

Size fraction	Sieve size	MH-LS	MH-MS	MD-LS	MD-MS	BRS-LS	BRS-MS	EC-LS	EC-MS
med pebble	>8000	0.0	0.0	0.0	1.6	0.0	0.0	0.0	1.1
small pebble	4000-8000	0.0	0.1	0.7	0.2	0.0	0.0	0.1	7.8
Granule	2000-4000	0.2	0.5	0.6	0.4	0.0	0.0	0.0	8.9
v coarse sand	1000-2000	0.6	1.1	1.5	0.5	0.0	0.0	0.0	6.2
coarse sand	500-1000	4.9	6.1	1.3	14.7	0.0	0.0	0.0	0.4
medium sand	250-500	50.7	35.9	16.9	59.3	17.8	22.7	1.7	15.2
fine sand	125-250	41.5	49.4	60.8	23.3	75.8	73.3	62.0	45.5
v fine sand	63-125	2.1	6.9	18.3	0.1	6.4	4.1	36.1	14.9
silt & clay	<63um	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
n	Textural group	*Medium sand*	*Fine sand*	*Fine sand*	*Medium sand*	*Fine sand*	*Fine sand*	*Fine sand*	*Fine sand*

Table 31 Univariate statistics for the Open Coast sites infaunal community.

Key

Symbol	Description
S	Number of recorded taxa
N	Mean total number of individuals: The mean number of individuals per core from all cores per site.
d	Margalef's richness for the site (S-1)/Log(N) - it is a measure of the number of taxa present, making some allowance for the number of individuals.
J'	Pielou's evenness for the site - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different taxa.
H'(loge)	Shannon-Wiener diversity index for the community
1-Lambda'	Simpson's diversity index for the community

Univariate index	S	S	N	N	d	d	J'	J'	H'(loge)	H'(loge)	1-Lambda'	1-Lambda'
Station	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**
MH-LS	7	7	4	5	4.68	3.73	0.87	0.83	1.69	1.61	1.08	0.94
MH-MS	7	8	3	6	5.83	3.91	0.89	0.89	1.73	1.84	1.22	0.98
MD-LS	8	10	5	6	4.59	4.93	0.91	0.88	1.89	2.02	1.06	1.00
MD-MS	3	4	2	2	2.89	5.10	0.82	0.95	0.90	1.31	1.08	1.61
BRS-LS	14	9	9	4	5.92	5.99	0.85	0.87	2.25	1.91	0.97	1.09
BRS-MS	3	6	14	4	0.76	3.38	0.69	0.95	0.75	1.70	0.45	1.04
EC-LS	17	12	41	24	4.30	3.44	0.71	0.71	2.00	1.76	0.82	0.80
EC-MS	6	6	5	17	3.28	1.75	0.78	0.51	1.39	0.92	0.86	0.51

Figure 24 Dendrogram of the Bray-Curtis percentage similarity for the Open Coast 2014 infaunal community.

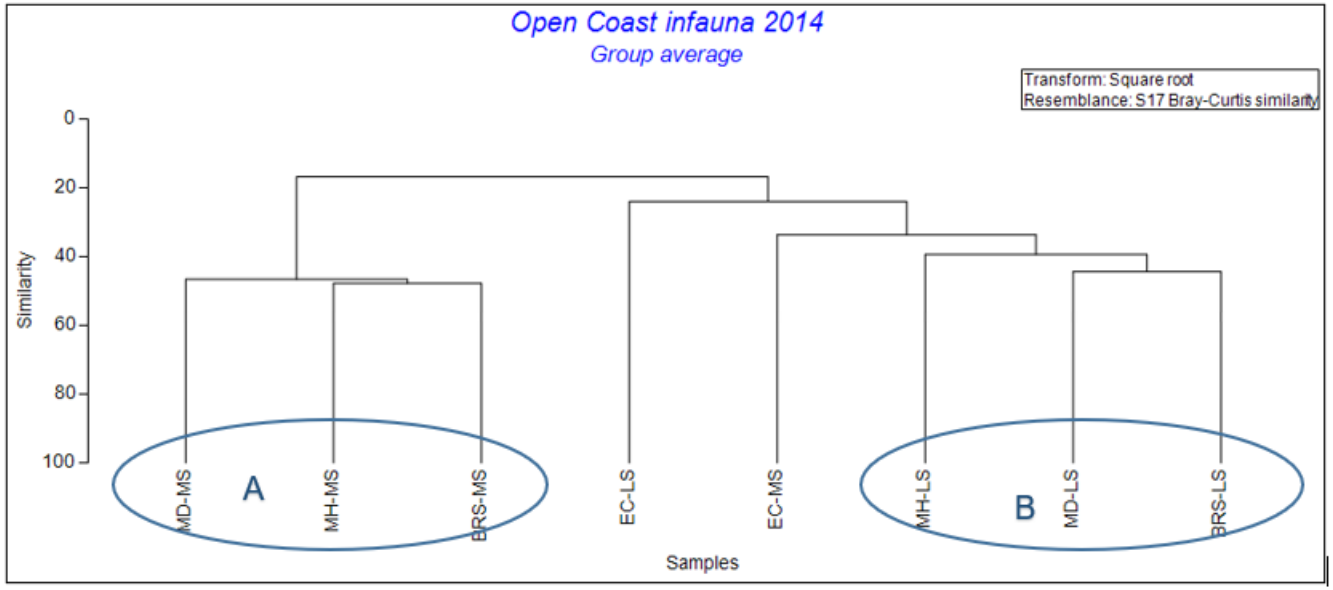


Table 32 SIMPER output showing Open Coast stations 2014 Group A and Group B station taxa.

Group A, Average similarity: 47.00

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Scolelepis squamata	1.07	21.97	3.73	46.74	46.74
Haustorius arenarius	1.04	20.85	8.06	44.36	91.09

Group B, Average similarity: 41.05

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Spiophanes bombyx	1.03	15.05	4.25	36.68	36.68
Nephtys cirrosa	0.94	11.06	5	26.95	63.62
Macomangulus tenuis	0.45	2.85	0.58	6.94	70.56

In 2014 the communities of infauna split quite clearly into a middle shore group (A) and a lower shore group (B) -

Figure 24. Group A are dominated by the robust polychaete species *Scolelepis squamata* and the similarly robust amphipod *Haustorius arenarius,* both are taxa characteristic of unstable unconsolidated mobile sediments. Group B on the other hand are taxa indicative of slightly finer more stable sediments.

Figure 25 Dendrogram of the Bray-Curtis percentage similarity for the Open Coast 2017 infaunal community.

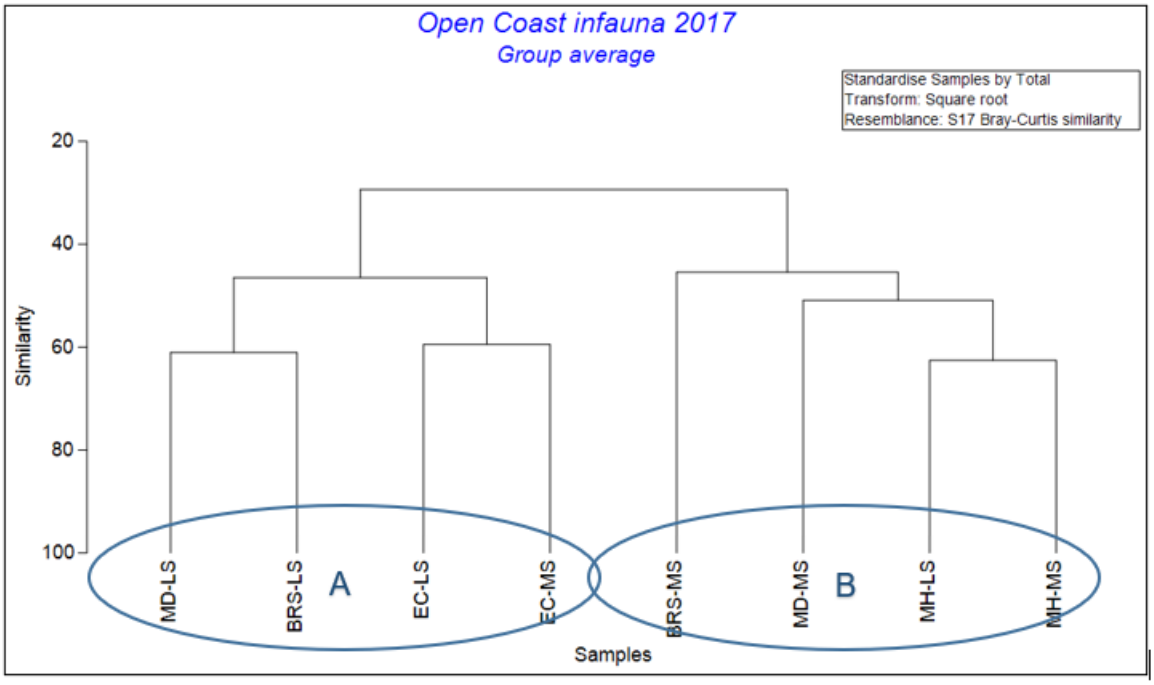


Table 33 SIMPER output showing Open Coast stations 2017 Group A and Group B station taxa.

Group A, Average similarity: 47.80

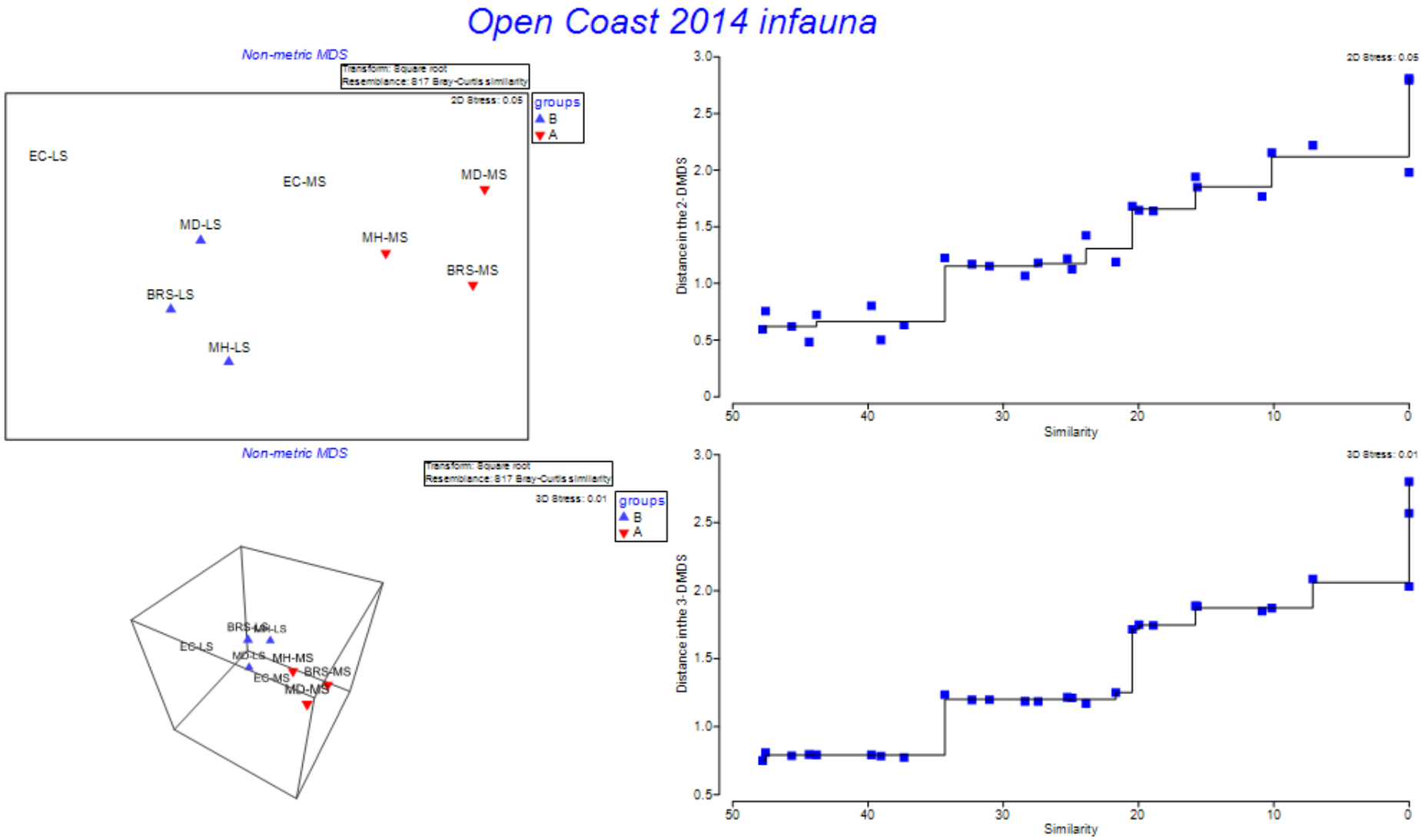
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Haustorius arenarius	0.66	10.25	3.03	21.44	21.44
Pontocrates arcticus	0.85	9.61	0.91	20.1	41.53
Bathyporeia pelagica	0.7	7.98	0.91	16.69	58.22
Spiophanes bombyx	0.5	6.68	0.81	13.97	72.19

Group B, Average similarity: 46.33

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Spiophanes bombyx	2.19	16.7	2.67	36.04	36.04
Nephtys cirrosa	1.12	11.41	5.26	24.62	60.67
Macomangulus tenuis	1.24	8.38	1.8	18.09	78.76

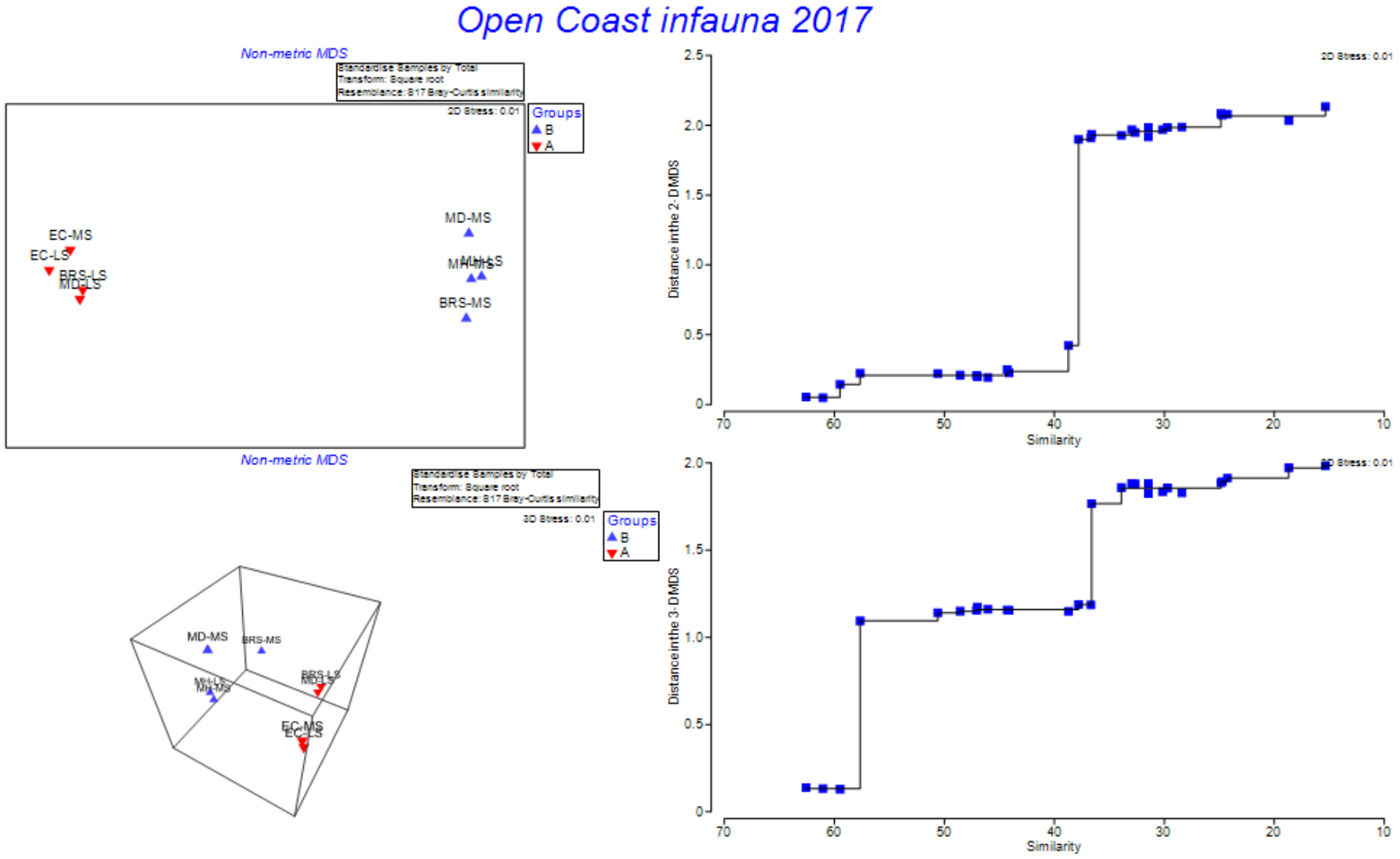
In 2017 the communities are less markedly split, but they do generally divide between a lower shore group (A) and a middle shore group (B) as seen in Figure 25.

Figure 26 Representations of the non-metric multidimensional scaling analysis for the Open Coast 2014 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



The very low stress values of <0.05 for the nMDS plots in Figure 26 indicate the results are probably an excellent representation of reality for the infaunal communities of the Open Coast shores of Tremadog Bay in 2014.

Figure 27 Representations of the non-metric multidimensional scaling analysis for the Open Coast 2017 infauna: - nMDS 2D and 3D plots (to visualise dissimilarity between points) and 2D and 3D Shepard diagrams (illustrating fit of individual samples to the resemblance).



The very low stress values of 0.01 for the nMDS plots in Figure 27 indicate the results are probably an excellent representation of reality for the infaunal communities of the Open Coast shores of Tremadog Bay in 2017.

4.8 Littoral biotopes of the Open Coast sampling stations

Table 34 Littoral biotopes assigned to the infauna at the Open Coast sampling stations in 2014 and 2017.

2014		2017	
Shore	**Biotope**	**Shore**	**Biotope**
Morfa Dyffryn LS	LS.LSa.FiSa.Po.Ncir	Morfa Dyffryn LS	LS.LSa.FiSa.Po.Aten
Morfa Dyffryn MS	LS.LSa.MoSa	Morfa Dyffryn MS	LS.LSa.MoSa
Morfa Harlech LS	LS.LSa.FiSa.Po.Ncir	Morfa Harlech LS	LS.LSa.FiSa.Po.Ncir
Morfa Harlech MS	LS.LSa.MoSa	Morfa Harlech MS	LS.LSa.FiSa.Po.Aten
Black Rock Sands LS	LS.LSa.FiSa.Po.Ncir	Black Rock Sands LS	LS.LSa.FiSa.Po.Aten
Black Rock Sands MS	LS.LSa.MoSa.AmSco.Eur	Black Rock Sands MS	LS.LSa.MoSa
East Criccieth LS	LS.LSa.FiSa.Po.Aten	East Criccieth LS	LS.LSa.FiSa.Po.Aten
East Criccieth MS	LS.LSa.FiSa.Po.Ncir	East Criccieth MS	LS.LSa.FiSa.Po.Ncir

Again when the *in situ* records and the quantitative infaunal results are combined for the open coast sampling stations it can be seen that the biotopes are generally stable from year to year. Table 33 shows the assigned littoral biotopes and biotope tags only tend to vary due to fluctuations in the dominance of one or two taxa such as *Nephtys cirrosa* or *Macomangulus* (*Angulus*) *tenuis* from year to year.

4.9 Porth Oer Rocky shore quadrats

The 12 rocky shore quadrats were surveyed and photographed during July and August 2015 - 2019 and the results are summarised below. These are fully presented in the accompanying excel files. A full multi-variate analysis will be presented in a future report.

4.9.1 Littoral taxa abundance data

The 102 taxa that were recorded in the quadrats between 2015 – 2019 are shown in Table 35. Overall the taxa assemblage remains stable on the Porth Oer reef, with approximately 70 species recorded annually, with the majority being recorded in the lower shore.

Table 35 Species/taxa recorded in the fixed quadrats at Porth Oer between 2015 and 2019. y = taxon recorded; n = taxon not recorded.

Species	2015	2016	2017	2018	2019
Acari	**y**	**y**	**y**	**y**	**y**
Acrosiphonia arcta	n	n	n	**y**	**y**
Actinia equina	**y**	**y**	**y**	**y**	**y**
(Aglaothamnion) Gaillona	**y**	n	**y**	**y**	**y**
Aglaothamnion gallicum	n	n	n	**y**	**y**
Aglaothamnion hookeri	**y**	n	n	**y**	**y**
Aglaothamnion seposita	n	n	**y**	n	n
Amphipoda	n	**y**	n	n	n
Anurida maritima	**y**	**y**	**y**	**y**	**y**

Species	2015	2016	2017	2018	2019
Austrominius modestus	n	**y**	**y**	**y**	**y**
Boergeseniella thuyoides	**y**	**y**	**y**	**y**	**y**
Callithamnion granulatum	**y**	**y**	**y**	n	**y**
Caloplaca marina	**y**	n	**y**	**y**	**y**
Carcinus maenas	**y**	n	n	n	n
Catenella caespitosa	**y**	**y**	**y**	**y**	**y**
Ceramium botryocarpum	n	n	**y**	n	n
Ceramium ciliatum	n	**y**	**y**	n	n
Ceramium gaditanum	n	n	n	**y**	**y**
Ceramium shuttleworthianum	**y**	**y**	n	**y**	**y**
Ceramium virgatum	n	**y**	n	**y**	**y**
Cereus pedunculatus	n	n	**y**	n	n
Chaetomorpha ligustica	**y**	**y**	**y**	**y**	n
Chondrus crispus	**y**	**y**	**y**	n	n
Chromophycota indet.(crusts)	**y**	n	n	n	n
Chthamalus montagui	**y**	**y**	**y**	**y**	**y**
Chthamalus stellatus	**y**	**y**	**y**	**y**	**y**
Cirripedia	**y**	**y**	**y**	**y**	**y**
Cladophora sp.	**y**	**y**	**y**	**y**	**y**
Cladophora albida	n	n	n	**y**	**y**
Cladophora rupestris	**y**	**y**	n	n	**y**
Corallina spp.	**y**	**y**	**y**	**y**	**y**
Corallina caespitosa	n	**y**	**y**	**y**	**y**
Corallina officinalis	n	n	n	**y**	**y**
Corallinaceae	**y**	**y**	**y**	**y**	**y**
Dictyota dichotoma	n	n	n	**y**	n
Dumontia contorta	n	**y**	n	n	**y**
Dynamena pumila	n	n	n	n	**y**
Ectocarpaceae	**y**	**y**	n	**y**	**y**
Elisolander elongata	n	n	n	**y**	**y**
Fucus spiralis	**y**	**y**	**y**	**y**	**y**
Fucus sporelings	n	n	n	n	**y**
Fucus vesiculosus var. linearis	**y**	**y**	n	**y**	**y**
Gammaridae	n	n	n	n	**y**
Giffordia sp.	n	**y**	n	**y**	n
Halichondria panicea	**y**	**y**	**y**	**y**	**y**
Hildenbrandia	n	**y**	n	n	n
Himanthalia elongata	**y**	**y**	**y**	**y**	**y**
Hymeniacidon perlevis	**y**	**y**	**y**	**y**	**y**
Jania squamata	n	n	n	**y**	**y**
Laminaria	n	n	n	**y**	n
Leathesia marina	**y**	**y**	**y**	**y**	**y**
Lichina pygmaea	**y**	**y**	n	n	n
Ligia oceanica	**y**	**y**	**y**	**y**	**y**
Littorina (small in crevices)	**y**	**y**	**y**	**y**	**y**
Littorina littorea	**y**	**y**	**y**	n	**y**
Littorina obtusata	**y**	n	n	n	n
Littorina saxatilis	**y**	**y**	**y**	**y**	**y**
Lomentaria articulata	**y**	**y**	**y**	**y**	**y**
Mastocarpus stellatus	**y**	n	n	**y**	**y**
Melarhaphe neritoides	**y**	**y**	**y**	**y**	**y**
Membranoptera alata	**y**	**y**	**y**	**y**	**y**

Species	2015	2016	2017	2018	2019
Mytilus edulis	**y**	**y**	**y**	**y**	**y**
Nemalion helminthoides	**y**	**y**	**y**	**y**	**y**
Neosiphonia harveyi	n	**y**	n	n	n
Nemertean	n	n	n	**y**	n
Nucella lapillus	**y**	n	n	**y**	**y**
Osmundea hybrida	n	**y**	**y**	**y**	**y**
Osmundea pinnatifida	**y**	**y**	**y**	**y**	**y**
Palmaria palmata	**y**	**y**	n	**y**	**y**
Patella depressa	n	**y**	n	n	n
Patella ulyssiponensis	**y**	n	**y**	n	n
Patella vulgata	**y**	**y**	**y**	**y**	**y**
Pelvetia canaliculata	**y**	**y**	**y**	**y**	**y**
Petrospongium berkeleyi	**y**	**y**	**y**	**y**	**y**
Plocamium maggsiae	**y**	**y**	**y**	**y**	**y**
Plumaria plumosa	**y**	**y**	n	**y**	**y**
Polysiphonia	**y**	**y**	**y**	**y**	n
Polysiphonia atlantica	n	**y**	**y**	**y**	**y**
Polysiphonia brodiae	n	n	n	**y**	n
Polysiphonia fibrata	n	n	n	**y**	**y**
Polysiphonia fibrillosa	**y**	n	n	n	n
Polysiphonia stricta	n	**y**	n	n	n
Pterothamnion pluma	n	n	n	n	**y**
Porphyra	**y**	n	n	**y**	n
Porphyra umbilicalis	**y**	n	n	**y**	n
Pyliella littoralis	n	n	n	**y**	n
Pyrenocollema	**y**	**y**	**y**	**y**	**y**
Ralfsia verrucosa	**y**	**y**	**y**	**y**	**y**
Rhodochorton purpureum	**y**	n	**y**	**y**	**y**
Rhodophycota (crustose)	n	n	n	n	**y**
Rhodophycota (filamentous)	n	**y**	**y**	**y**	**y**
Scytosiphon lomentaria	n	n	n	**y**	n
Semibalanus balanoides	**y**	**y**	**y**	**y**	**y**
Sphacelaria sp.	n	n	n	**y**	n
Spirobranchus sp.	n	**y**	n	**y**	n
Spongonema tomentosum	n	n	n	**y**	n
Ulva sp.	**y**	**y**	**y**	**y**	**y**
Ulva compressa	**y**	**y**	n	**y**	**y**
Ulva prolifera	**y**	**y**	**n**	**n**	**y**
Verrucaria black	**y**	**y**	**y**	**y**	**y**
Verrucaria green	**y**	n	**y**	**y**	**y**
Total taxa for the year	**62**	**63**	**53**	**75**	**71**

4.9.2 Limpet density count data

Table 36 Random limpet counts and their densities in the fixed quadrats at Porth Oer 2015

Key

US	Upper shore
MS	Middle shore
LS	Lower shore

2015

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	1	0	4	0	13	10	5	5	13	13	12	9
2	0	1	3	0	11	9	5	8	15	23	8	14
3	0	0	0	3	13	7	4	10	7	16	12	9
4	0	0	0	9	8	9	4	9	9	7	13	7
5	0	0	0	3	16	11	3	4	18	7	8	15

Mean no. (m-2)	US 30	MS 201	LS 294
% change from 2014	US 118%	MS -2%	LS -25%

Table 36. Random limpet counts and their densities in the fixed quadrats at Porth Oer 2016

2016

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	1	0	0	0	8	3	9	10	8	7	10	16
2	1	0	0	0	10	10	6	11	11	6	5	8
3	4	1	1	0	12	11	5	3	11	12	6	9
4	4	0	4	0	11	11	4	11	8	9	6	19

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
5	7	6	2	0	4	7	6	4	15	10	10	16

Mean no. (m-2)	US 38.75	MS 195	LS 252.5
% change from 2014	US 29%	MS -4.90%	LS -14%

Table 37. Random limpet counts and their densities in the fixed quadrats at Porth Oer 2017

2017

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0	0	0	0	4	11	7	6	14	9	8	10
2	0	0	0	1	4	11	6	9	11	10	6	13
3	0	0	0	4	5	8	8	4	10	12	6	8
4	0	1	4	6	8	9	4	12	9	10	7	16
5	0	1	0	3	6	9	5	13	5	9	15	11

Mean no. (m-2)	US 25	MS 186.25	LS 248.75
% change from 2014	US -35%	MS -4.50%	LS -1.50%

Table 38. Random limpet counts and their densities in the fixed quadrats at Porth Oer 2018

2018

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0	0	0	1	8	4	5	4	11	18	19	17
2	0	0	0	1	7	9	5	5	8	8	10	27
3	0	0	0	0	6	13	10	10	14	19	8	24

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
4	0	0	1	3	5	8	7	7	7	10	13	20
5	0	1	1	4	1	7	4	7	13	9	11	14

Mean no. (m-2)	US 15	MS 165	LS 350
% change from 2014	US -40%	MS -11.40%	LS 41%

Table 39. Random limpet counts and their densities in the fixed quadrats at Porth Oer 2019

2019

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0	0	0	0	12	13	8	9	12	20	20	19
2	0	0	0	0	13	8	6	9	17	19	22	15
3	0	0	0	0	10	7	11	10	12	21	15	14
4	0	0	1	8	17	18	6	7	12	17	13	16
5	0	0	0	5	12	6	8	9	8	14	12	14

Mean no. (m-2)	US 17.5	MS 248.75	LS 390
% change from 2014	US 16.70%	MS 50.75%	LS 11.43%

Table 36 shows how the limpet population changed between 2015 and 2019 in the fixed quadrats at Porth Oer. All zones on the shore showed an increase in limpet density from 2018. However the middle shore showed by far the greatest change, with an increase of over 50%. The lower shore showed the smallest variation, with an increase of only 11%.

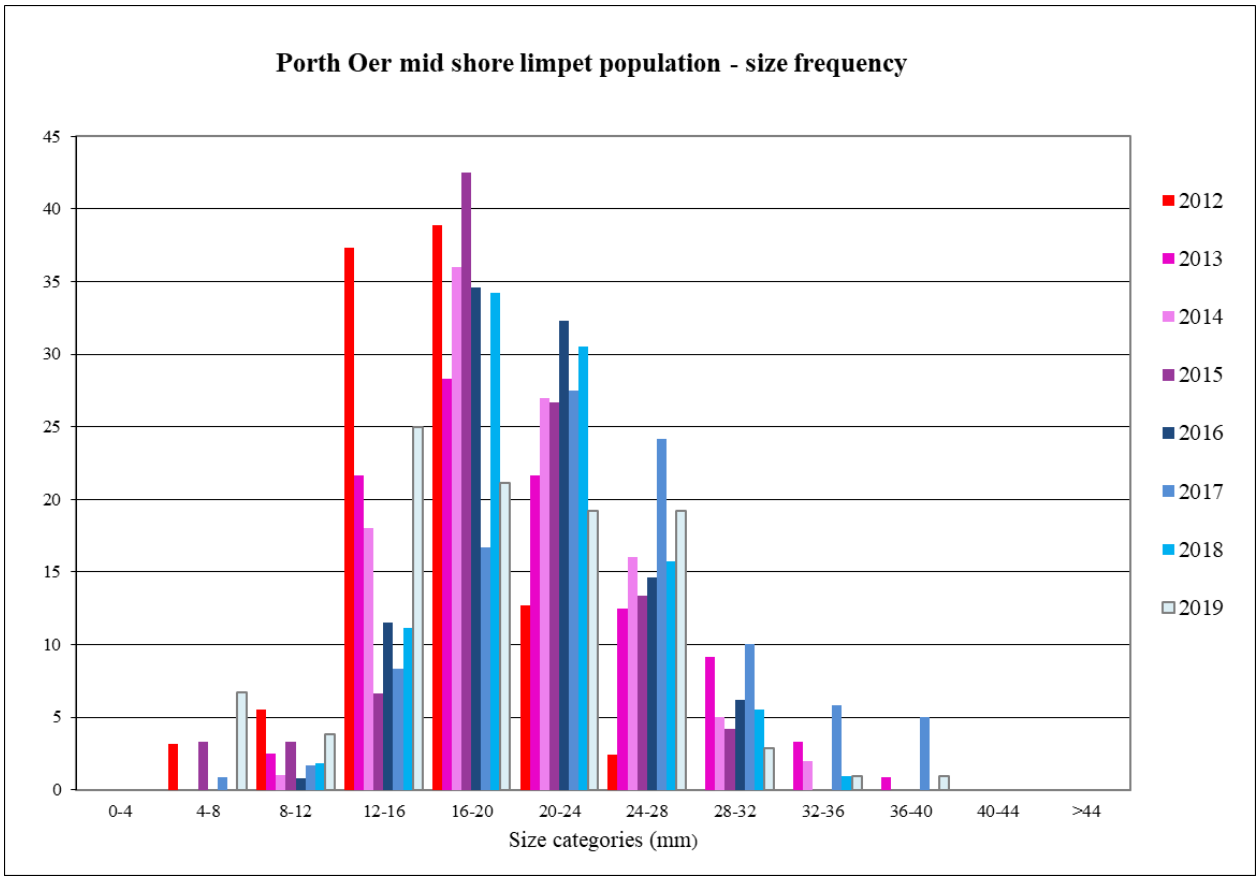
4.9.3 Middle shore limpet population data

Table 37 Mean maximum length measurements of 100+ randomly selected limpets on the middle shore at Porth Oer

Year	Mean size (mm)	Percentage change from previous year	Sample size (n)
2014	20.9	+1.5%	105
2015	19.7	-9%	120
2016	21.4	+9%	130
2017	24.9	+16%	120
2018	20.0	-20%	107
2019	19.5	-2.5%	105

Table shows the mean size of limpets between 2014 and 2019 in the middle shore. The results are illustrated in the histograms presented in Figure 28. The limpet population sustains at a mean maximum length of approximately 21 mm, with an annual fluctuation of up to ±20%. It can also be seen that the large increase in middle shore limpet density in 2019 correlates with a slight decrease in mean size of limpet from the 2018 figures.

Figure 28 Size frequency histograms for the middle shore limpet population at Porth Oer



4.9.4 Cirripedia population abundance data

Table 38 Percentage cover of all barnacle species in 5 random cells within the fixed quadrats

Year	2014	2014	2014
Zone	**Upper shore**	**Middle shore**	**Lower shore**
Mean %. (m^{-2})	0.06%	51.5%	31.75
% change from 2013	-37.5%	-14.9%	-15.1%

Key

US	Upper shore
MS	Middle shore
LS	Lower shore

2015

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0.25	0	0.25	0.25	30	65	60	60	10	10	20	30
2	0	0.25	0.25	0	20	70	60	65	10	12	5	20
3	0.25	0.25	0	0.25	20	50	40	45	10	20	7	30
4	0	0.25	0	0.25	35	55	70	45	1	5	2	80
5	0	0	0	0.25	30	75	70	40	5	50	30	25

Mean no. (m-2)	US 0.14	MS 50.25	LS 19.1
% change from 2014	US -77%	MS -2%	LS -40%

2016

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0.25	0	0.25	0	30	60	70	50	15	20	20	40
2	0.25	0.25	0	0	20	65	55	80	20	10	30	60
3	0.25	0.25	0	0	20	50	80	40	25	20	45	30
4	0.25	0.25	0	0	15	55	40	40	40	35	8	80
5	0	0	0	0	10	50	50	55	15	25	8	30

Mean no. (m-2)	US 0.1	MS 46.75	LS 28.8
% change from 2014	US -37%	MS -7%	LS 46%

2017

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0	0	0	0	16	85	88	50	25	25	3	95
2	0	0	0	0.25	16	80	70	40	25	8	4	90
3	0	0.25	0	0.25	12	90	80	60	25	15	2	85
4	0	0	0.25	0.25	12	40	80	35	20	70	15	80
5	0	0.25	0.25	0.25	8	50	75	46	10	50	20	90

Mean no. (m-2)	US 0.1	MS 51.65	LS 37.85
% change from 2014	US 0%	MS 10%	LS 31%

2018

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0	0	0	0	40	75	85	50	40	20	45	70
2	0	0	0.25	0.25	25	80	80	50	30	15	40	75
3	0	0.25	0	0.25	30	75	60	50	30	10	40	70
4	0	0.25	0.25	0.25	35	80	75	40	10	15	40	50
5	0	0.25	0.25	0.25	35	85	85	75	8	3	8	60

Mean no. (m-2)	US 0.125	MS 60.5	LS 33.95
% change from 2014	US 25%	MS 17%	LS -10%

2019

Quadrat	US 1	US 2	US 3	US 4	MS 1	MS 2	MS 3	MS 4	LS 1	LS 2	LS 3	LS 4
1	0	0	0	0	45	70	60	70	15	15	17	10
2	0	0.25	0.25	0.25	25	40	50	65	20	2	15	5
3	0.25	0.25	0.25	0.25	30	55	50	80	22	5	2	5
4	0	0	0.25	0.25	35	50	60	85	15	15	5	10
5	0	0	0.25	0.25	30	30	75	90	15	3	1	5

Mean no. (m-2)	US 0.138	MS 54.75	LS 10.1
% change from 2014	US10%	MS -10%	LS -336%

Table shows that the Cirripedia population exhibits both decreases and increases in population density in the upper, middle and lower shore, with the largest percentage fall being a 77% decrease in the upper shore (2014-2015) and of 336% in the lower shore (2018-2019), whilst the lower shore exhibited the largest increase of 46% in one year (2015-2016).

The substantial change in lower shore barnacle percent cover between 2018 and 2019 can be seen in the images in Figure 29 and Figure 30. It is not clear what has caused this, but could be the result of extreme conditions (heat or cold), particularly at time of settlement, grazing or predation.

Figure 29 Close up of the same quadrat cell in lower shore Quadrat 1 in 2018 and 2019

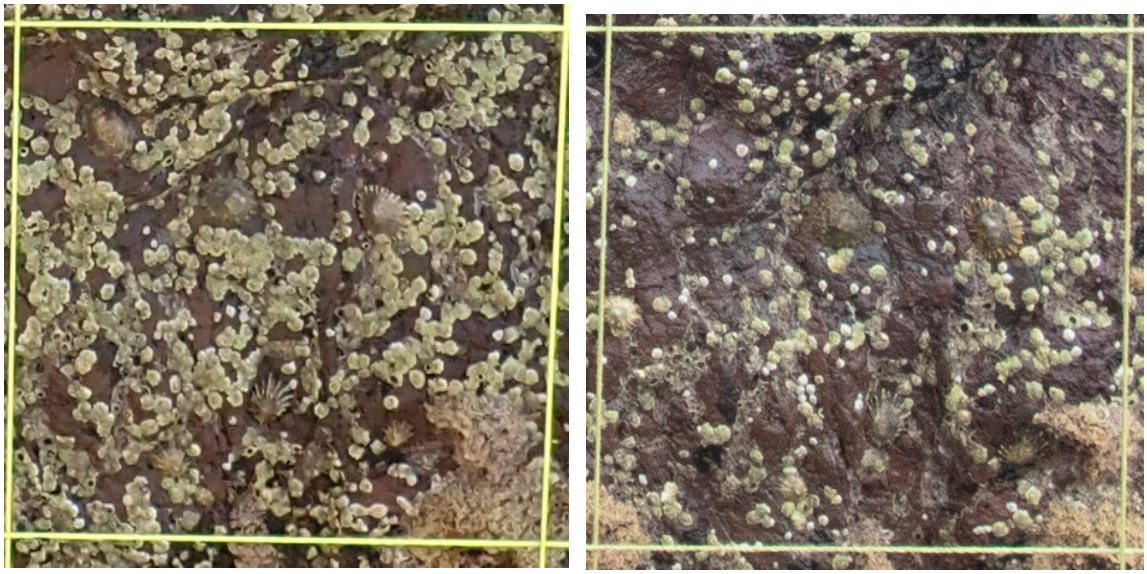
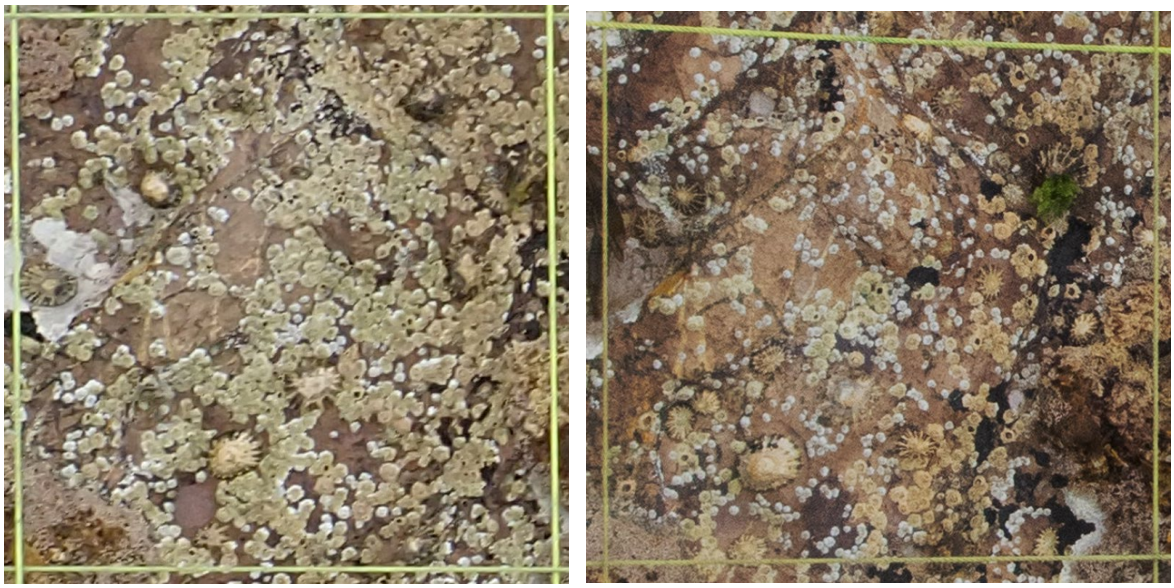


Figure 30 Close up of the same quadrat cell in lower shore Quadrat 4 in 2018 and 2019



5 Discussion

5.1 *Sabellaria* Reef in Pen Llŷn a'r Sarnau

There are now data for ten consecutive years, making it a valuable data set for looking at natural variations and long-term trends.

Honeycomb worm reefs clearly fluctuate in size and quality within the Pen Llŷn a'r Sarnau SAC. Similarly the community of littoral flora and fauna associated with the *Sabellaria* reefs cycles with them as they are inextricably linked. The colonisation and growth of algae and invertebrate populations occurs as the reef growth modifies the local environment. Hence as weather and time play their vital organising roles in the structure of these communities, the situation is in a continual state of flux.

On a specific point within Tremadog Bay, the pelagic larval dispersion of *Sabellaria* may also affect the local population dynamics. This larval dispersion, which is approximately 30 days, was studied by Bush *et al* (2015). They showed that the *Sabellaria* reef on West of Afon Dwyfor will supply larvae to shores south of Criccieth as they drift in the gyre that operates in this part of north Cardigan Bay. The West of Afon Dwyfor site population may therefore provide larval recruitment to the *Sabellaria* populations at Llandanwg, Shell Island and Barmouth etc. to the south. However, the West of Afon Dwyfor shore itself may not receive larvae from other populations because of this specific local water movement. Hence recruitment to this population is possibly more sporadic as it may solely rely on self-recruitment in years when weather conditions are suitable.

Other influences on the West of Afon Dwyfor site include freshwater that seeps through the shingle bank that separates the Afon Dwyfor itself from the beach, and also sand supply, which is expected to move eastwards by long-shore drift. Some erosional features here suggest that shortage of sand for tube building may be influencing the extent of the *Sabellaria* reef at West Afon Dwyfor.

5.2 *Pectenogammarus* in Pen Llŷn a'r Sarnau

The *Pectenogammarus planicrurus* amphipods have been shown to be present from year to year at Marian-Y-De and they continue to thrive in the shingle shore found there. Future monitoring studies should endeavour to regularly cover a greater length of the shore, in order to keep the distribution characteristics of this population under closer observation.

5.3 Infaunal communities in Pen Llŷn a'r Sarnau

Infaunal littoral communities in the Pen Llŷn a'r Sarnau SAC, although generally depauperate, appear to remain relatively stable. The exception to this occurs in the estuaries, where constant channel movements within the main estuaries disturb many established communities, as the meanders naturally travel seaward through the sand flats over time. Monitoring transects 3 and 4 on the north bank of the Mawddach have been particularly affected during the period of this report and both were severely truncated by the summer of 2019. It is likely that transect 4, the most landward, will begin to recover first throughout the next few years as the sand flats build out beyond the saltmarsh again. The infaunal biotopes of the estuaries and the open coast have been shown to be quite stable from year to year.

5.4 The rocky shore community at Porth Oer

The littoral taxa complement within the monitoring quadrats on the rocky shore at Porth Oer is stable over the long-term. The slight variations noted by the monitoring programme occur mainly within the annual foliose red algal species that colonise the lower shore. Limpet and barnacle populations exhibit quite substantial annual fluctuations in density, but the mean size of the limpets in the middle shore remains constant from year to year at approximately 20 mm, suggesting a population that is in equilibrium. The drop in barnacle cover in 2019 may relate to the steady increase in limpet populations over the previous years, resulting in increased grazing of new recruits from the rock surface. No anthropogenic influence has been detected and it is thought that the fluctuations are natural. This demonstrates the necessity and value of the long-term data sets when looking for change that deviates from natural patterns.

6 Conclusion

The data from the 5 years of monitoring in the Pen Llŷn a'r Sarnau SAC suggests that the conservation objectives for the site have not been undermined and therefore that the features monitored are in favourable conservation condition.

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Appendix 1 Field Logs:

Field log of PLAS survey August 2015

Survey Team: Tom Mercer (TM) (survey leader)
Jon Moore (JM)
Paul Brazier (PB)
Chris Dixon (CD)
Lucy Kay (LK)
Gabriel Wyn, (GW)
Eurig Wyn Jones (EJ)
Clare McCarty (CMc)
Matt Ashton (MA)
NRW IT apprentices x2

(Low tide times and heights are for Barmouth – Porth Oer is approximately 30 minutes later, Aberdyfi is approximately 15 minutes earlier. Times are all given as BST).

1 Aug (Sat)

pm/eve TM & CD drive to Harlech from NE England
JM drives to Harlech from S. Wales.
Arrive and settle into *Trem y Mor* cottage in Llanfair. Dinner in cottage. NRW officers stay at Morlyn Guest House.

2 Aug (Sun)

Weather: Dry and mostly bright with some sun and light southerly breeze
Low tide: 0.7m @ 17:50

am	Survey preparation
1100	PB, GW, EWJ, & CMc arrive at Trem y Mor. Survey planning and preparation.
1400	Teams head out in 2 cars. TM, JM & PB to Porth Oer, meeting LK there. GW, CD, EWJ & CMc to Pwllheli.
1530-1930	Porth Oer rocky shore survey TM & JM survey midshore quadrats 2 to 4, then upper shore quadrats 1 to 4, then measure midshore limpets. PB & LK survey midshore quadrat 1, then lower shore quadrats 1 to 4 and photograph barnacles. Then head back to *Trem y Mor.*
1515-1830	GW, CD, EWJ & CMc survey Pectenogammarus populations. GW & CD heading west; EWJ & CMc heading east; making scrapes and recording Pectenogammarus.

3 Aug (Mon)

Weather: Mostly dry and bright, but with fast moving clouds and some showers. Fresh westerly breeze, creating rough seas and swell onto open coast.
Low tide: 0.6m @ 06:19; 0.7m @ 18:35

am	Photo and GPS downloads, photo cataloguing, data entry and GIS mapping. Survey planning and preparation.
1345	Teams head out in 3 cars. PB & TM to Borth; LK, EWJ & CMc to Ynys Hir (RSPB reserve); GW, JM & CD to Machynlleth to pick up MA from train station (delayed), then to Ynys Las.
1545-1800	PB & TM use WFD restricted species list methodology to survey rocky shore algae at Borth.
1600-1900	LK, EWJ & CMc walk out across marsh and sand / mud flats to survey stations Dy080, Dy084, Dy089 & Dy095.
1630-1900	GW, JM, CD & MA walk out across marsh and sand / mud flats to survey stations Dy028 (all together), then Dy041 and Dy050 (JM & CD) and Dy039 and Dy019 (GW & MA)

4 Aug (Tues)

Weather:	Mostly dry and bright but cloudy, with some rain showers and fresh southerly breeze creating rough seas and swell onto open coast.
Low tide:	0.6m @ 07:00; 0.8m @ 19:14
am/pm	Photo and GPS downloads, photo cataloguing, data entry and GIS mapping. Survey planning and preparation
1400	Teams head out in 3 cars. TM, CMc, LK & GW drive to Cae-du. PB & MA drive to Nant-geseiliog. JM, EWJ & CD drive to Shell Island reception and get permission for access to Shell Island shores.
1600-2000	Wide area *Sabellaria* surveys at Friog: TM & CMc survey transects FR14 to FR10. LK & GW survey transects FR15 to FR19. PB & MA survey transects FR01 to FR08. (FR09 was missed).
1630-2000	Wide area *Sabellaria* surveys at Shell Island: JM, EWJ & CD survey transects SI07, SI08 and SI06. Then drive to Llandanwg and survey transects SI05, SI04, SI03, SI02 & SI01.

5 Aug (Wed)

Weather:	Initially very dim light, with some rain, becoming drier and nicer, with fresh southerly breeze.
Low tide:	0.7m @ 07:39; 0.9m @ 19:55
0500	Teams head out in 2 cars. TM, JM, CD & CMc drive to west of Criccieth and walk to West of Afon Dwyfor (WAD). PB, LK, GW, EWJ & MA drive to Llandanwg.
0600-0910	TM & CD survey stations WAD1, 3, 7 and 8. JM & CMc survey stations WAD2, 5 and 6, then repeat full quadrats at WAD8.
0545-0920	PB & EWJ survey stations LL08, 6 and 4. GW, LK & MA survey stations LL09, 7, 5 and 3.
am	TM, JM, CD & CMc have breakfast in Café in Criccieth, then return to *Trem y Mor*. PB, LK, GW, EWJ & MA return to Morlyn Guest House.
am/pm	Photo and GPS downloads, photo cataloguing, data entry and GIS mapping. Survey planning and preparation

6 Aug (Thurs)

Weather:	Initially cloudy with some rain showers and light breeze, becoming drier and brighter.
Low tide:	0.9m @ 08:21; 1.2m @ 20:42
0600	NRW IT apprentices meet with PB, LK, GW, EWJ & MA at Criccieth & then drive to west of Criccieth and walk to West of Afon Dwyfor (WAD).
0700	TM, JM, CD & CMc drive to Llandanwg and walk down steps at north end of boulder shore.
0700-0945	GW & EWJ map boundary of *Sabellaria* reef. LK & MA carry out wide area *Sabellaria* surveys on transects WC07 to WC01. PB & IT apprentices carry out wide area *Sabellaria* surveys on transects WC10 to WC08.
0730-1000	TM & CD map boundary of Llandanwg *Sabellaria* reef. JM & CMc survey stations LL01 and LL02.
1030	Teams return to *Trem y Mor* and Morlyn Guest House.
am/pm	Photo and GPS downloads, photo cataloguing, data entry and GIS mapping. Teams gradually disperse.
1730	TM, JM, CD & CMc leave Trem y Mor. TM & CD head north. JM heads south.

Field log of PLAS survey August 2016

Survey Team: Tom Mercer (TM) (ASML survey leader)
Francis Bunker (FB) (ASML)
Jon Moore (JM) (ASML)
Lucy Kay (LK) (NRW)
Paul Brazier (PB) (NRW)
Ben Wray (BW) (NRW)
Clare McCarty (CM) (ASML)
Jake Delwyn Davies (JD) (NRW)
Dafydd Roberts (DR) (Snowdonia National Park)
Pippa Lewis (PL) (Volunteer)
Eben Pirie (EP) (Volunteer)

Low tide times and heights are for Aberdaron (Barmouth approx. 20 mins later). All times are BST

31 July (Sun)

Weather: Fine sunny day. A little rain in north Wales in evening.

pm/eve	TM & CMc drive from Co. Durham to north Wales. FB drives from Pembrokeshire to north Wales. Arrive at self-catering cottage Ymwlch Bach, near Criccieth @ 21.00

1 August (Mon)

Weather: Rain and light wind. Heavy rain in afternoon.
Low tide: 0.77m @ 15:03

1000	JD, PB and LK arrive at cottage. Team briefing and get equipment etc. together.
1200	Team leaves for Mawddach. TM/CMc to north side transects, parking at Glendwr Lodge, FB/LK and PB/JD to south side after getting key to cycle path from Snowdonia NP warden.
1330	FB and LK commence transect MT2, PB and JD commence transect MT1. Both teams also undertook extra sampling at four sites labelled R. TM/CMc undertook MT3 and MT4. Due to channel movements not all stations could be reached.
1700	Leave site for Ymwlch Bach. LK drops gate key back to Snowdonia NP office in Dolgellau.
eve	FB and TM transcribe data sheets to Excel and download photographs.

2 August (Tues)

Weather: Initially fine misty rain and fog. Sea state good and weather fine during fieldwork. Wind getting up from SW.
Low tide: 0.59m @ 15:49

0800-1200	Entering data from the Mawddach and QA of data. BW arrives at Ymwlch Bach with van to collect fixed samples from the Mawddach and help with field work @ Porth Oer.
1230	Lunch and briefing of field teams for Porth Oer.
1300-1400	TM and JD drive to undertake *Pectenogammarus* survey at Pwllheli. Rest of team drive to Porth Oer in 2 cars. Then TM & JD join the rest of the field team at Porth Oer.
1430-1730	At Porth Oer rocky shore monitoring site. FB, PB & BW survey lower shore, LK & CMc survey middle shore and TM and JD survey upper shore and measure middle shore limpets.
1730	Travel back to respective accommodations. BW drives back to Bangor
eve	FB and TM download and label photographs. PB and LW look at specimens.

3 August (Wed)

Weather: Some light rain but mostly dry and cloudy with strong (force 7) SW winds
Low tide: 0.49m @ 16:30

0800-1230	Specimen identification, logistic planning, recording form production and data entry. JD, PB and LK arrive and join in work.

1230-1330	Briefing for fieldwork. JM and EP arrive from Pembrokeshire. JM taking place of FB on survey (FB leaves for Pembrokeshire).
1330	Field team drive to Porth Dinllaen in 2 cars. Meet BW on site.
1430-1730	Wait for tide to go down; but it is held up by strong westerly winds and does not drop sufficiently to uncover the low shore *Zostera* bed. Team attempt some mapping (JM/EP) and quadrat surveying (TM/CMc and PB/PL) whilst LK BW & JD carry out mooring and disturbance observations.
1800	Watch lifeboat launch, then team disperses.

4 August (Thurs)

Weather:	Mostly dry and cloudy with moderate (force 3 to 4) SW winds
Low tide:	0.49m @ 17:08
0900-1400	Data entry, photos download and catalogue, GPS download and editing in GIS, specimen identification, specimen log production and data entry and editing, data QA checking.
1430	Drive to Llandanwg (via Snowdonia National Park offices to pick up DR) and walk to *Sabellaria* quadrat sites.
1500-1840	Survey *Sabellaria* reef condition. JM/PL survey stations LL7, LL4 & LL1; TM/LK survey stations LL8, LL5 & LL2; PB/CMc survey stations LL9, LL6 & LL3. JD/EP map boundary of *Sabellaria* bed.
1850	Leave site and team disperses.

5 August (Fri)

Weather:	Mostly dry and bright, cloudy with v. light (force 2) SW winds
Low tide:	0.37m @ 0536, 0.56m @ 1743
0415	Drive to Afon Dwyfor and walk to *Sabellaria* quadrat site West Afon Dwyfor, in 2 cars.
0500-0730	Survey *Sabellaria* reef condition. JM/PL survey stations WAD1 & WAD7; TM/LK survey stations WAD2, WAD5 & WAD8; PB/CMc survey stations WAD3, WAD6 & WAD4. JD/EP map boundary of *Sabellaria* bed.
0800	All drive to Porthmadog. Huge breakfast in the Grapevine café.
1000-1600	Return to cottage. Data entry, photos download and catalogue, GPS download and editing in GIS, specimen identification, specimen log and data editing, data QA checking.
1600	Packing and NRW team leaves for Bangor. ASML team leave Ymwlch Bach. TM/JM/CMc/EP/JD drive to Pwllheli.
1800	TM/JM/CMc/EP/JD survey *Pectenogammarus* distribution and density at Marian y De beach, Pwllheli. Establish additional stations and collect sediment samples for granulometric analysis.
eve	TM/CMc drive to Co. Durham. JM/EP drive to Pembrokeshire

Jon Moore, Francis Bunker & Tom Mercer

Aquatic Survey & Monitoring Ltd.

Field log of PLAS survey July 2017

Survey team:

TM = Tom Mercer, ASML, (survey leader)

FB = Francis Bunker ASML

DPB = Paul Brazier, NRW

BW = Ben Wray, NRW

KB = Kathryn Birch, NRW (23rd July)

EM = Eleonora Manca, JNCC

PHB = Patrick Bunker ASML (Undergraduate Chester University)

RID = Rhodri Irranca-Davies (Bangor University student placement with NRW)

TM, FB, PHB and BW stay at Ty Glaslyn, Prenteg, Porthmadog, Gwynedd LL49 9SP. Others (NRW and JNCC) stay at local B&B (Secret Garden Cottages). KB commutes from home.

Saturday, July 22nd, 2017

21:30 TM arrives at survey accommodation

22:30 FB and PHB also arrive at survey accommodation.

Sunday, July 23rd, 2017

Weather. Sunny with light breeze.

10:00 Team meet at Ty Glaslyn. Methods and day's work discussed with team and H&S briefing.

13:00 Leave for the field and survey of Glaslyn Dwyryd. Teams as follows:

TM and PHB – survey spots 21, 28, 29, 46, 86, 22, 61 (cores), 54, 55 (cores), 56, 47 and 34
FB and KB – survey spots 50 (cores), 49 (cores), 75, 74, 73 and 41
DPB – survey spots 14 (cores), 25
BW and EM – survey spots 15, 13, 8, 9, 80, 2, 20 (cores), 19, 18, 83, 10 (cores)

19:00 FB, KB and DPB finish on shore (by The Cob).

20:00 BW and EM finish on shore

22:00 Personnel retire to their respective accommodation

Monday, July 24th, 2017

Weather fine but with a strong N wind (5 to 6).

07:00 TM up and fixes the 7 sets of G/D cores with formalin.

09:00 Everyone convened at Ty Glaslyn and started transcribing data. FB sets up shared wireless hard drive for others to access. Unfortunately, the NRW Windows PCs didn't connect. However, ASML have three macs and data is entered. FB gives BW lesson in Lightroom!

13:00 Lunch outside in the sun and briefing on day's work.

13:30 Leave for Llandanwg Sabellaria Quadrat site.

14:30 Start Sabellaria monitoring quadrats at Llandanwg. Three teams on the Sabellaria: FB and EM, TM and BW and DPB on the sandy sites 8 & 9. PHB had the difficult job of *Sabellaria* mapping using a GPS under DPB's instruction.

17:30 Finish fieldwork and return to base.

Tuesday, July 25th, 2017

Sunny and fine. Little wind from the SW.

07:00 FB gets up for a run. BW up doing emails for Press Release on Angel Sharks.

09:00 DPB and EM arrive. Team all do data entry, photo logs and GPS downloads and FB does specimens until 14:00 with a break for lunch in the sun. FB id's Gymnogongrus griffithsiae in one of TM and BW's samples.

14:00 TM briefs team on day's work having made the decision to swap the WAD Sabellaria for Porth Oer Rocky shore, given the forecast of strong winds on Wednesday.

14:30 FB and EM in FB's car, DPB and BW in NRW car to Porth Oer and TM and PHB in TM's car to Pwllheli to survey the Pectenogammarus at Marian y de and then on to Porth Oer to catch up with the rest of the team.

15:30 Start Porth Oer survey. DPB and FB do LS quadrats while EM measures limpets. TM and PHB do MS and US quadrats. Very good conditions and lovely and sunny. Lots of tourists on the Whistling Sands.

18:30 Finish shore at Porth Oer. BW leaves for Bangor and his imminent press release.

21:00 Drive back to accommodation.

Wednesday, July 26th, 2017

Strong Winds from the SW with showers but stayed dry for most of the day.

09:00 Team meet at Ty Glaslyn to enter data from previous day into spreadsheets and identify specimens.

10:30 RID arrives from Bangor, replacing BW, bringing the spare buckets and pots.

13:00 Lunch at Ty Glaslyn.

14:00 TM and PHB, FB and EM form teams to survey *Sabellaria* along the shore West of Afon Dwyfor. DPB and RID finish off the sediment survey on the Glaslyn/Dwyryd. Collecting the remaining cores from the missed sites at GD40 and GD44 as well as *in situ* records from stations 31, 30 and 96b.

15:00 Sabellaria teams on shore to commence work. FB and EM survey stations 1, 3 and 5. TM surveys stations 2, 6, 8 and 7. PHB maps Sabellaria. Conditions difficult but workable. Dry with a strong onshore wind. Luckily the rain held off.

19:30 Leave shore and back to Ty Glaslyn to prepare for the early start on Thursday. TM fixes GD40 and GD44 cores.

Thursday, July 27th, 2017

Dull and blustery start to the day leading to wind and rain then strong winds. Cold.

04:4 FB and PHB up and prepare for fieldwork.

05:15 FB and PHB leave for Morfa Harlech.

06:00 TM and RID leave for Black Rock Sands sample site and sample mid and lower shore BRS1 and BRS2 stations

06:15 FB and PHB on beach and start sampling stations MH1 and MH2.

06:30 DPB and EM leave for East Criccieth and sample EC1 and EC2 mid and lower shore stations

07:30 FB and PHB finish at Morfa Harlech and travel to Morfa Dyffryn MD1 and MD2. TM and RID go on to 'The Cob' and collect the missing PSA sample from GD40.

08:00 TM and RID shop in Tesco's for last day breakfast items.

08:30 All leave for Ty Glaslyn.

09:00 DPB calls in briefly at Ty Glaslyn to drop off samples and then takes EM to the train at Bangor.

09:30 FB and PHB arrive at Ty Glaslyn with their samples.

10:00 TM cooks all remaining surveyors breakfast.

11:00 PHB arrives back at Ty Glaslyn after dropping Eleanora at Bangor Station. Team spend day entering data and catching up with survey loose ends.

12:30 PHB leaves survey with house mate from Chester. TM fixes remaining "Open Coast" samples.

13:00 RID leaves for Bangor.

17:00 TM, FB and DPB finish work.

18:30 DPB leaves for home. FB and TM for Ty Glaslyn to continue with loose ends and pack up house.

Friday, July 28th, 2017

06:00 TM up and leaves Glaslyn and journey home

07:30 FB up, pack and leave and journey home.

Field log of PLAS survey July 2018

Survey team:
Tom Mercer (TSM) ASML Survey leader
Francis Bunker (FDB) ASML
Brendan Bunker (BAB) ASML
Paul Brazier (DPB) NRW leader
Rhodri Iranca-Davies (RID) NRW sandwich student
Survey base: Tyddyn-y-Felin (Cwm Bychan, Harlech, LL46 2TL) holiday

Saturday, 14 July 2018

Hot and sunny.

Low Water Criccieth 17:10 0.1 m

06:00 BAB and FDB leave Berkhamsted and drive to Criccieth.

06:00 TSM Leaves Frosterley for Criccieth

11:00 PDB leaves home for Criccieth

11:30 TSM, FDB and BAB meet in Criccieth at Cadwalladr's meeting room to discuss logistics.

12:30 All meet at layby west of Llanystumdwy, near Bont Fechan Farm off the A497.

Figure 31 Meeting and car parking base for the West of Afon Dwyfor *Sabellaria* survey

13:00 Walked to the shore and had lunch on the edge of the dunes, waiting for the tide to go down. TM & PB briefed BAB on the Sabellaria bed mapping technique.

15:30 Started work on the quadrat recording at the monitoring stations as follows:

WAD1 FDB
WAD2 TSM
WAD3 FDB
WAD4 TSM
WAD5 DPB
WAD6 DPB
WAD7 DPB
WAD8 FDB/TSM

BAB mapped the boundaries using a Garmin GPS exploiting the tracking mode to enable export into a GIS package.

Figure 32 Tom Mercer studying a quadrat in station WAD2. Note abundance of *Sargassum muticum*

18:00 Finished on shore and walked back to the cars

18:30 Drove to Tyddyn-y-Felin, holiday cottage accommodation.

19:15 Tyddyn-y-Felin is in the hills to the east of Harlech and quite pleasantly remote. The landlady is Heulwen Haf Evans. We unloaded the cars and set up the survey base.

19:45 Drove south of Harlech to and eat at the Hafan Artro, Llanbedr. We sat outside with a big screen showing an Athletics meet. Pleasant enough but basic pub grub. England had lost their 3rd place play off to Belgium in the World Cup.

22:00 Back at base. TV and bed.

Figure 33 Tyddyn-y-Felin and surrounding environment.

Sunday, July 15, 2018

Warm and sunny.

Low water Porth Ysgaden 18:10 0.4 m

08:00 Breakfast

09:00 Start work writing up Saturday's results.

13:00 Lunch (sandwiches outside).

14:00 TSM and BAB to Pwllheli to study *Pectenogammarus*. FDB and DPB to Porth Oer for rock shore monitoring.

15:45 Arrive at Porth Oer and meet KB. Start lower shore. FDB, DPB and KB study lower shore and measure limpets in the MS.

Figure 34 Sun bleached *Osmundea pinnatifida* in the lower shore at Porth Oer

17:00 TSM and BAB arrive Porth Oer to start work (completed MS and US in the time the others just study the lower shore).

Figure 35 Brendan Bunker and Tom Mercer working in Upper shore at Porth Oer

19:00 All finish at Porth Oer. KB drove home and the rest of the team drove to Llanbedrog to eat. France won the world cup final against Croatia.

20:00 Arrive at Craig Y Glyn. Pub grub again but not bad.

21:00 Leave for Tyddyn-y-Felin.

22:00 Arrive at Tyddyn-y-Felin. Wind down then bed.

Monday, 16 July 2018

Low water: Aberdovey 18:20 0.7 m (apparently later going up Dyfi estuary).

Rain until early afternoon until we got out into the field. Well timed really.

09:00 Morning spent on entering data, writing up and working up specimens.

10:30 RID arrives to join team – bringing formaldehyde and enthusiasm. BAB starts cooking lunch.

15:00 FB and BAB leave for Ynyslas. DPB travelled to Aberdovey on his own to sites on the north shore where he didn't have to walk far in order to rest his Achilles' tendon. FDB and BAB working near the Ynyslas seaward end of the estuary. TSM and RID work at the Ynys-Hir, landward end of the estuary. FDB team meet 20-minute traffic jam in Machynlleth

Teams timings / work schedule as follows:

17:00 DPB on beach and sampling stations: Dy045b, Dy060b, Dy108, Dy109, Dy106c.

17:10 TSM and RID on beach. Sample the following stations: Dy096 (5 cores), Dy086, Dy082, Dy078, Dy073 and Dy075, Dy080 (5 cores), Dy084 (5 cores), Dy090 (5 cores).

18:00 FDB and BAB start first station after a 2 km walk over difficult terrain to reach it.
Stations Dy020, Dy021 (5 cores), Dy039 (5 cores) and Dy028 (5 cores) completed.

19:50 DPB finishes and returns to base.

20:10 Finish on beach.

20:39 FDB and BAB finish on shore.
21:00 Chips in Machynlleth on the way home.
21:37 Back at car after being turned back by owner of Aberystwyth Haulage and Storage trying to get a path to the car. He was extremely aggressive and cross at our 'trespassing'.
22:15 Back at base.
22:45 Arrive back at base.

Figure 36 Sand habitat at Dy020

Tuesday, 17 July 2018

Low water Aberdovey 19:00 0.9m.

Low water Criccieth 06:50 0.5m and 19:30 0.4m.

Overcast but generally fine. Sunny at times.

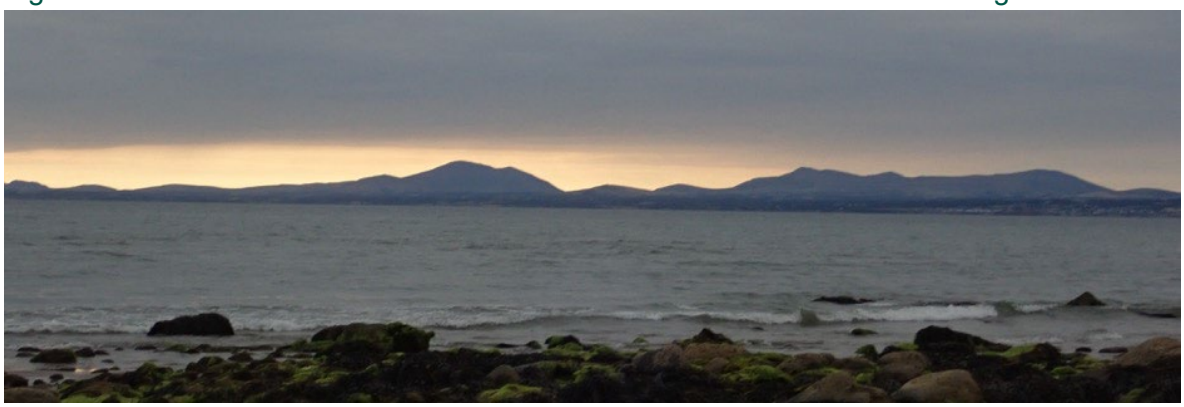
06:00 TSM, DPB and RID up, breakfast and off to Llandanwg to start the Sabellaria. The survey team studied sites 9 to 4.
08:30 FDB and BAB start writing up Monday's data.
09:30 Team return from Llandanwg. Everyone writing up for rest of day.
13:00 Lunch for all.
15:00 TSM and RID drive to Dyfi estuary to finish the sediment sampling.
16:41 Started on beach and completed stations: Dy003, Dy057, Dy059b, Dy041b (5 cores), Dy050 (5 cores), Dy047.
17:00 FDB, BAB and DPB drive to Llandanwg to finish the Sabellaria quadrats. BAB carried out the *Sabellaria* bed mapping, FDB studied stations 1 and 2, DPB station 3.
19:00 DPB leaves the shore.
20:16 FDB finishes quadrat study.
20:30 BAB and FDB leave shore.

Figure 37 *Sabellaria* and *Cladostephus spongiosus* plus green algae on sand inundated rocks in LdS02

21:00 Back at base and eat remains of food: Lentils, chicken and risotto.

21:30 TSM and RID return safely and eat scraps left for them. All do bits and pieces of data and watch TV before bed.

Figure 38 Sunset as field team leave the beach after a late tide at Llandanwg



Wednesday, 18th July 2018

Rain first thing then warm and sunny.

A day spent catching up with data entry, photo cataloguing and QA of all data.

08:30 Team starts work. TSM working on data entry and photo cataloguing from yesterday's Dyfi field trip. FDB carries out data entry and photo cataloguing from yesterday's' Llandanwg survey. DPB working in Arc on the shapefiles of Sabellaria maps from West of Afon Dwyfor and Llandanwg. BAB and RID commence QA.

16:30 RID leaves for Bangor. DPB packs NRW equipment and takes copies of collected data. Rest of team continue QA.

16:30 QA finished. FDB, TSM and BAB go for a conference at Cadwallader's meeting room in Criccieth.

17:00 DPB leaves for Bangor.

18:30 Return to Tyddyn-y-Felin buying charcoal en-route.

Thursday, 19 July 2018

Warm and sunny.

08:00 Breakfast, pack vehicles and clean house.

10:00 Leave Tyddyn-y-Felin having paid the £9 electricity bill.

14:30 FDB and BAB arrive in Pembrokeshire after a brief coffee stop (Aberystwyth) and honey ice cream stop at Aberaeron.

14:15 TM arrives home in Weardale

Field log of PLAS survey July 2019

Survey Team

TM	Tom	Mercer – ASML (Monday to Friday)
FB	Francis Bunker – ASML (Monday to Friday)	
BW	Ben Wray- NRW - (Monday to Friday)	
BB	Brendan Bunker – ASML (Monday to Friday)	
RI	Rebecca Irvine – NRW (Monday to Friday)	
JM	James Moon – NRW (Monday to Thursday)	
NL	Natasha Lough – NRW (Tuesday to Thursday)	
LG	Laura Grant - (Tuesday to Wednesday)	
PB	Paul	Brazier - (Wednesday)

Survey accommodation and base for ASML and BW:

Tyn Y Buarth, Dyffryn Ardudwy, Gwynedd, LL44 2BS

Rest of NRW team staying in the Cadwgan Inn, Dyffryn Ardudwy.

ASML arrive 1900 on Sunday 30th June.

Monday, 1st July 2019 – Low water 15:10 at 0.89m

Cloudy with sunny intervals and fresh wind.

Tasks for day: Team 1 - FB, BB and JM survey Gracilaria vermiculophylla in the Glaslyn /Dwyryd system.
Team 2 - TM, BW and RI to survey *Pectenogammarus* at Pwllheli and then survey upper and middle shore quadrats at Porth Oer rocky shore.

09:00 Morning spent in Tyn Y Buarth sorting out day's tasks. JM, BW and RI arrived by mid-morning. Signed RA.

11:00 Briefing for the day's fieldwork exercises. Make lunch and depart.

Team 1

12:00 Leave Tyn Y Buarth for the Glaslyn Dwyryd. BB and FB went to the Dwyryd to look for and map *Gracilaria vermiculophylla* from Talsarnau, west along the south shore. JM went to the Glaslyn to map the presence along the Cob.
FB and BB found one large area of plants and some big plants with cystocarps in a water channel. Elsewhere *G. vermiculophylla* was widespread but sparse.
JM found dense areas near Porthmadog (where found in 2017) but none elsewhere.

15:20 BB left FB on the shore at 15:20 in order to buy food for supper.
FB then walked north-eastwards from Talsarnau in the Dwyryd to continue the *Gracilaria* survey. However none was to be found. JM attempted to access the north shore of the Dwyryd from the road but was unable to reach the foreshore. He then met FB at Talsarnau and drove him back to Tyn Y Buarth.

16:00 JM and FB began downloading data and transcribing. BB started preparing supper.

Team 2

12:00 TM, BW and RI went to Marian y De (Pwllheli) to survey the *Pectenogammarus* in the shingle beach.

13:15 *Pectenogammarus* study

14:00 Finish and leave for Porth Oer

14:40 Arrive at Porth Oer and survey middle and upper shore.

18:00 Travel back to Tyn Y Buarth. (It took 1hr 40 mins drive back with normal traffic conditions).

19:30 Back at Tyn Y Buarth for supper.

20:30 Download cameras, GPS' and data input.

Tuesday 2nd July 2019 – Low water at 15:58 and 0.69m

Sunny day and warm, completely still with wind getting up midday then dying down.

Task for day is for the team to complete the sediment monitoring transects T1 to T4 on the Mawddach estuary.
TM has previously liaised with Simon Llewelyn Roberts from the National Park (07734 799249 or 01766 772241) R.E the access to the Mawddach cycle path via the access gates for the southern shore sites.

07:15 FB, BW, RI and JM go for sea swim at Llandanwg

08:30 Teams have breakfast then everyone meets at survey base Tyn Y Buarth. Then team continues with data entry from the previous day in the holiday cottage.

11:00 NL and LG arrive to join survey from Bangor.

11:40 TM convenes meeting about methods and data sheets etc. Field teams prepare equipment: TM and BB (T4), FB and BW (T3) to go to N. side. TL and RI (T1) and JM and LG (T2) on south side

Figure 39 Team meeting in Tyn Y Buarth over coffee.

12:25 Leave for Mawddach

13:00 All teams meet Gethin Corps (a Ranger from the National Park – 07900 267512) to obtain the key to the Mawddach cycle path gate at Penmaenpool. Also receive instructions on where to return the key. TM gives final briefing to teams. T3 and T4 teams drive back to Glandwr Hall to gain access to the north shore transects. Access contact at Glendwr Hall. T1 and T2 teams travel along cycle path to survey the south shore of Mawddach transects.

13:45 T1 and T2 start their transects.

13:50 T3 and T4 start their transects.

16:30 T3 and T4 teams finish their transects, which are shorter than ever and neither have a fourth station so return to base with the samples.

17:15 T3 and T4 teams back at Tyn Y Buarth. Work on downloading photographs and GPS information.

17:20 T1 and T2 teams finish their much longer transects.

18:40 T1 and T2 teams arrive back at Tyn Y Buarth.

19:30 Team eat out at Hafan Artro, a pub / restaurant in Llanbedr. Absolutely dreadful food – decide it must be the chef's night off. BW sends steak back and TM believes it's not possible to make Nachos and cheese plus dips as tasteless and unappealing!!

21:00 Return to Tyn Y Buarth. Sort out sediment samples. Continue to download GPS', cameras and enter data.

22:00 TM preserves all infaunal samples.

Wednesday, 3rd July 2018 - Low water at 16:44 and 0.55m

Sunny and warm. No appreciable wind in the morning.

Task for day: *Sabellaria* reef Quadrats.

07:15 FB, BW, go for sea swim at Llandanwg, JM joins swimmers for a SUP. RI jogs from Tyn Y Buarth to Llandanwg and has a lift back. FB and BW swim into the harbour with the flooding tide. Lots of compass and barrel jellyfish.

08:30 Breakfast at Tyn Y Buarth

09:00 Teams carry on entering data from the Mawddach.

11:30 PB arrives to work with survey teams for the day.

12:05 TM gives *Sabellaria* reef quadrat survey and data sheet briefing.

13:30 TM, LG, PB, JM and BW leave for the Afon Dwyfor monitoring. TM and LG (Stn 1,3 & 5), PB and JM (2, 6, 7, 8) worked as two teams to survey Sabellaria monitoring stations. BW maps the Sabellaria reef boundary.

14:25 Afon Dwyfor monitoring team begin survey.
18:00 Afon Dwyfor team finish and leave shore and return to Tyn Y Buarth.
14:15 FB, RI, NL and BB leave for Llandanwg.
14:50 FB and RI, NL and BB work as two teams on Sabellaria monitoring stations.
FB and RI complete stations Ld08, Ld06, Ld04 and Ld02.
NL and BB complete stations Ld09, Ld07 and Ld05.
18:30 Llandanwg team returns to Tyn Y Buarth.
19:00 BB cooks pizzas and evening spent at Tyn Y Buarth entering data and eating fast food.
20:30 PB & LG drive back to Bangor in NRW Van with all the fixed Mawddach samples.
22:30 Data entry ends for evening. TL, RI and JM go back to lodgings.

Thursday, 4th July - Low water at 17:29 and 0.5m

Sunny and warm with light winds.

Tasks: Data entry and QA in morning. Afternoon fieldwork to survey the lower shore quadrats at Porth Oer and map *Zostera* at Porth Dinllaen.

07:15 FB and BI go for a run and get lost and end up doing 10 km.
08:30 Birthday breakfast for FB made by BB and BW of porridge, croissants and fresh mango. Very nice.
09:00 JM, BI and NL join team after breakfast. Team spend the morning entering data, downloading photos and doing QA on the survey's data.
10:30 PB and Hannah Brazier join team with a birthday cake celebration for FB and HB, as its Hannah's birthday too.
11:00 Team carries on working with data.
13:00 Lunch - all eat outside.
13:30 FB goes over Llandanwg specimens with NL. Then they look at the Porth Oer data from the previous year and the Rocky shore quadrat methods. TM introduces the Porth Dinllaen Zostera methods to BB, BW, JM and RI.
14:30 FB and NL travel to Porth Oer; TM, BB, BW, JM and RI travel to Porth Dinllaen.
15:45 Team arrives at Porth Dinllaen.
16:45 Team abandons *Zostera* work as tide didn't go down far enough (despite high pressure). Drive back to complete last two stations at Llandanwg. Must consider other possibilities for mapping and monitoring Zostera at Porth Dinllaen.
18:00 TM, BW, RI, JM survey stations Ld03 and Ld01 at Llandanwg. BB stays at Tyn Y Buarth to prepare barbecue for the evening.
16:00 FB and NL arrive at Porth Oer car park after a long drive in slow traffic.
16:30 FB and NL start lower shore work. Conditions are good but some difficulty was encountered finding quadrat screws.
19:30 FB and NL finish just before tide covers lower shore quadrat 4.
20:00 FB and NL leave Porth Oer. NL drives home and FB back to Tyn Y Buarth.
21:10 FB arrives back at Tyn Y Buarth.
23:00 JM and RI leave for their accommodation after a big clear up.

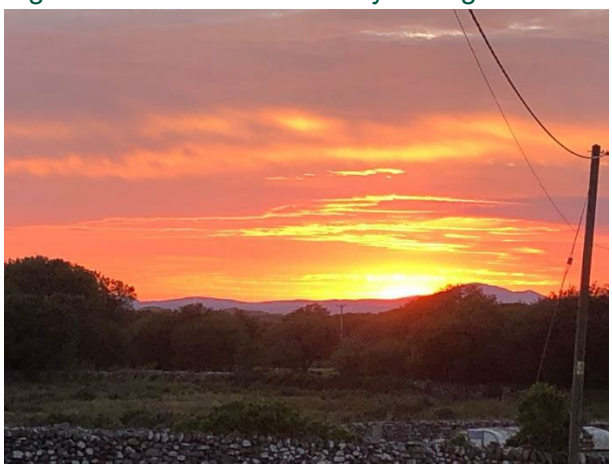
Friday, 5th July 2019 – Low water at 05:50 and 0.46m

Data QA and pack up survey – Only TM on fieldwork – Mapping Llandanwg *Sabellaria* bed boundary.

05:30 TM travels to Llandanwg
06:00 TM maps Sabellaria bed boundary
07:30 TM travels back to Dyffryn Ardudwy
07:15 FB and RI go for a 10 km run.
09:00 RI and JM come around to Tyn Y Buarth. Whole day is spent with data entry and specimens from Thursday's fieldwork and independent QA of the remaining week's data.
10:00 JM leaves survey for S. Wales.
13:00 Lunch.
15:00 BB Catches train home from Dyffryn Ardudwy.
16:00 BW and RI leave survey for Bangor. TM and FB continue clearing up the house and packing.
17:30 FB leaves survey.

18:30 TM leaves Tyn Y Buarth having waited to avoid Friday night traffic chaos on M56 and M6.
21:00 FB arrives Pembrokeshire.
23:30 TM arrives home in the North Pennines.

Figure 40 Sunset on 4th July from garden



Appendix 2 Recording forms

A2.1 Sabellaria Quadrat recording form - 2019

PLAS 2019 SAC: Sabellaria quadrats. **Site:**.. **Stn. No.:**....................

Surveyors:................................ .... **Date:**................. **Time at start:**............. **Conditions:**...................../8 cloud

GPS: .... **GPS WayPt:**...................... **OS Grid Ref: SH** .... **Camera:**......................

Quadrat No.	**1**	**2**	**3**	**4**	**5**
Photo No.					
Standing water %					
Sabellaria reef Tot%					
Live *Sabellaria* %					
Cirripedia Tot%					
Mytilus edulis %					
Algae Tot%					
Fucus serratus %					
Fucus vesic. %					
Chlorophycota Tot%					
Porifera P					
Actinia equina P					
Spirobranchus spp P					
Semibalanus P					
Austrominius modestus P					
Pagurids P					
Patella vulgata P					
Steromphala cineraria P					
Steromphala umbilicalis P					
Littorina fab/obt. P					
Littorina littorea P					
Nucella lapillus P					
Corallinaceae Tot %					
Corallina sp. %					
Chondrus crispus %					
Dumontia contorta %					
Gelidium sp. %					
Mastocarpus stell' %					
Osmundea hybrida %					
Osmundea pinn. %					
Rhodophycota(enc) T%					
Rhodophycota (fil)T%					
Dictyota dic. %					
Phaeophycota(enc)T%					
Chaetomorpha %					
Cladophora rup. %					
Ulva (flat) %					
Ulva (tubular) %					
Verrucaria (green) %					

Taxa %/P\Quadrat No.	**1**	**2**	**3**	**4**	**5**

Additional Sabellaria quadrats

Quadrat No.	**6**	**7**	**8**	**9**	**10**
Sabellaria reef Tot%					
Live *Sabellaria* %					

Quadrat No.	**11**	**12**	**13**	**14**	**15**
Sabellaria reef Tot%					
Live *Sabellaria* %					

1. Indicate 'specimens taken' with a shaded triangle in the top right corner of the box. 2. Please photograph in the field when complete! V19.1

A2.2 Rocky shore Quadrat recording form

PLAS 2019 SAC: Rockyshore quadrats - Porth Oer: Surveyors:..... Date:.....

Time at start: ....Conditions: _____ /8 Camera: ....Stn. No: US / MS

Porth Oer – Frequency counts

	Upper shore fauna				Mid shore fauna			
Quadrat No.	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Photo no.								
Himeniacidon perlevis								
Actinia equina								
Prostigmata (mites)								
Lipura maritima								
Ligia oceanica								
Cirripedia								
Chthamalus montagui								
Chthamalus stellatus								
Semibalanus balanoides								
Melarhaphe neritoides								
Small gastropods in crevices								
Littorina saxatilis								
Patella spp								
Mytilus edulis								
Nucella lapillus								
Upper shore flora					**Mid shore flora**			
Caloplaca marina								
Verrucaria black								
Verrucaria green								
Pyrenocollema (lichen)								
RHODOPHYCOTA (filamentous)								
RHODOPHYCOTA (crustose)								
Aglaothamnion hookeri								
Corallinaceae								
Corallina officinalis								
Catenella caespitosa								
Ceramium sp.								
Ceramium shuttleworthianum								
Lomentaria articulata								
Mastocarpus stellatus								
Osmundea hybrida								
Osmundea pinnatifida								
Porphyra sp								
Rhodochorton purpureum								
Pelvetia canaliculata								
Ralfsia verrucosa Fucus spiralis								
Ectocarpaceae								
Ulva sp. (flat)								
Ulva intestinalis								
Chaetomorpha ligustica								
Cladophora sp.								
Cladophora albida								

PLAS 2019 SAC: Rockyshore quadrats - Porth Oer: Surveyors:…… Date:……

Time at start:…… ….Conditions: _____ /8 Camera: …… .....Stn. No: US / MS

	Upper shore				Mid shore			
Additional species	1	2	3	4	1	2	3	4

This next table is only required if this team measures the middleshore limpets! Please measure all accessable limpets, do not be sizest!! Use chalk to mark the measured individuals.

Limpet monitoring (Middleshore zone 100+) maximum length measurements (mm)												

Barnacle species abundance photos - 5cm x 5cm quadrats (minimum of 5 to be taken in the zone - tick the box when complete)	Upper shore ☐ No. =				Middle shore ☐ No. =			
	1	2	3	4	1	2	3	4
Barnacle abundance (5no. 20x20 cells - percentage for all spp.) Random no.s 2, 9, 13, 21, 23								
	1	2	3	4	1	2	3	4
Limpet abundance (All Zones – 5no. 20x20 cell counts) Random no.s 4, 6, 13, 15, 20								

Please photograph data sheet when complete in the field?

A2.3 Rocky shore Quadrat recording form (continued)

PLAS 2019 SAC: Rockyshore quadrats - Porth Oer: Surveyors:.....Date:.....

Time at start:..... Conditions:_____.Camera: ..... Stn. No: Lower shore

Porth Oer – Frequency counts

Lower shore fauna					Additional lower shore fauna				
Quadrat No.	1	2	3	4	Taxa	1	2	3	4
Hymeniacidon perleve									
Halichondria panicea									
Actinia equina									
Cirripedia									
Chthamalus montagui									
Chthamalus stellatus									
Austrominius modestus									
Semibalanus balanoides									
Melarhaphe neritoides									
Littorina saxatilus									
Patella spp									
Small gastropods in crevices									
Mytilus edulis									
Spirobranchus sp.									
Nemertean worm									
Lipura maritima									
Prostigmata (mites)									
Lowershore flora					**Additional lower shore flora**				
Taxa	**1**	**2**	**3**	**4**	**Taxa**	**1**	**2**	**3**	**4**
Verrucaria black					Aglaothamnion gallicum				
Verrucaria green					Ceramium gaditanum				
Pyrenocollema (barnacle lichen)					Corallina caespitosa				
Himanthalia elongata					Eliosanda elongata				
Ralfsia verrucosa					Laminaria sporelings				
Leathesia difformis					Petrospongium berkeleyi				
RHODOPHYCOTA (filamentous)					Porphyra umbilicalis				
RHODOPHYCOTA (Crusts)					Palmaria palmata				
Corallinaceae					Plumaria elegans				
Corallina sp					Scytosiphon				
Mastocarpus stellatus					Spongonema tomentosa				
Plocamium maggsiae									
Osmundea pinnatifida									
Lomentaria articulata									
Nemalion helminthoides									
Aglaothamnion hookeri									
Membranoptera alata									
Polysiphonia atlantica									
Polysiphonia broadiae									
Polysiphonia fibrata									
Polysiphonia harveyi									
Boergeseniella thuyoides									
Ceramium sp.									
Ceramium shuttleworthianum									
Ceramium virgatum									
Callithamnion granulatum									
Chaetomorpha ligustica									
Cladophora sp.									
Cladophora albida									
Ulva sp. (flat)									
Ulva (tubular)									

PLAS 2019 SAC: Rockyshore quadrats - Porth Oer: Surveyors:.....Date:.....

Time at start:..... Conditions:_____Camera: ..... Stn. No: Lower shore

This table only required if this team measures the middleshore limpets! Please measure all accessable limpets, do not be sizest!! Use chalk to mark the measured individuals.

Limpet monitoring (Middle zone 100-200) maximum length measurements												

This table must be completed.....

Barnacle species abundance photos - 5cm x 5cm quadrats (minimum of 5 to be taken in the zone - tick the box when complete)	**Lower shore**			
	☐ No. taken =			
	1	**2**	**3**	**4**
Barnacle abundance (5no. 20x20 cells - percentage for all spp.)				
Random no.s 4, 11, 16, 19, 23				
	1	**2**	**3**	**4**
Limpet abundance (All Zones – 5no. 20x20 cell counts)				
Random no.s 3, 7, 14, 18, 20				

Please photograph data sheet when complete in the field?

A2.4 *In situ* sediment assessment recording sheet.

Mawddach 2019 ***In-situ* sediment records** **Date:……................** **Surveyors:…………….**

Conditions: .... **GPS/Camera: ....** **Time: Start:..................** **End:..................**

Station	Sediment	Species
T ____________ Time: ____________ Photos: ____________ ____________ ____________ ____________ Grid Ref: SH East: ____________ North: ____________	Mud very muddy gravelly shelly very fine medium coarse Sand Gravel Shell Pebble Cobble Bould. Rock Sorting (Well/ poor 1-5): Firmness (hard-soft 1 – 5): Surface relief (even/uneven 1-5): Stability (stable/mobile 1-5) Waves >10cm Ripples <10cm Sub surf coarse Subsurface mud/clay Black layer cm: Standing water %: Sed' in sieve: Insignif. Significant Lots	**Conspicuous (No. per m^2):** Cockles >20mm <20mm Arenicola Lanice Hediste Zostera % Ent. % Green ct % **Sieve (No. per core):** Cockles >20mm <20mm Macoma Hydrobia Scrobs >20mm <20mm Hediste Nephtys Scoloplos Spionids Polychaete Bathyporeia Corophium Carcinus
T ____________ Time: ____________ Photos: ____________ ____________ ____________ ____________ Grid Ref: SH East: ____________ North: ____________	Mud very muddy gravelly shelly very fine medium coarse Sand Gravel Shell Pebble Cobble Bould. Rock Sorting (Well/ poor 1-5): Firmness (hard-soft 1 – 5): Surface relief (even/uneven 1-5): Stability (stable/mobile 1-5) Waves >10cm Ripples <10cm Sub surf coarse Subsurface mud/clay Black layer cm: Standing water %: Sed' in sieve: Insignif. Significant Lots	**Conspicuous (per m^2):** Cockles >20mm <20mm Arenicola Lanice Hediste Zostera % Ent. % Green ct % **In sieve:** Cockles >20mm <20mm Macoma Hydrobia Scrobs >20mm <20mm Hediste Nephtys Scoloplos Spionids Polychaete Bathyporeia Corophium Carcinus
T ____________ Time: ____________ Photos: ____________ ____________ ____________ ____________ Grid Ref: SH East: ____________ North: ____________	Mud very muddy gravelly shelly very fine medium coarse Sand Gravel Shell Pebble Cobble Bould. Rock Sorting (Well/ poor 1-5): Firmness (hard-soft 1 – 5): Surface relief (even/uneven 1-5): Stability (stable/mobile 1-5) Waves >10cm Ripples <10cm Sub surf coarse Subsurface mud/clay Black layer cm: Standing water %: Sed' in sieve: Insignif. Significant Lots	**Conspicuous (per m^2):** Cockles >20mm <20mm Arenicola Lanice Hediste Zostera % Ent. % Green ct % **In sieve:** Cockles >20mm <20mm Macoma Hydrobia Scrobs >20mm <20mm Hediste Nephtys Scoloplos Spionids Polychaete Bathyporeia Corophium Carcinus
T ____________ Time: ____________ Photos: ____________ ____________ ____________ ____________ Grid Ref: SH East: ____________ North: ____________	Mud very muddy gravelly shelly very fine medium coarse Sand Gravel Shell Pebble Cobble Bould. Rock Sorting (Well/ poor 1-5): Firmness (hard-soft 1 – 5): Surface relief (even/uneven 1-5): Stability (stable/mobile 1-5) Waves >10cm Ripples <10cm Sub surf coarse Subsurface mud/clay Black layer cm: Standing water %: Sed' in sieve: Insignif. Significant Lots	**Conspicuous (per m^2):** Cockles >20mm <20mm Arenicola Lanice Hediste Zostera % Ent. % Green ct % **In sieve:** Cockles >20mm <20mm Macoma Hydrobia Scrobs >20mm <20mm Hediste Nephtys Scoloplos Spionids Polychaete Bathyporeia Corophium Carcinus

Mud – M, Sand – S, Gravel – G, very –v, muddy-m, gr-gravelly, Shelly -sh, coarse-c, medium- med, fine-f, Sorting – Well to poor 1-5; Black layer depth in cm; Surface relief – even/uneven (1-5); Firmness- firm/soft (1-5); Stability – stable/mobile(1-5); Waves/ Dunes>10cm-W; Ripples <10cm-R; Subsurface coarse- ssC, Subsurface mud/clay – ssM.

Appendix 3 Data Archive

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

The data archive contains:

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

[B] Excel spreadsheets of data, including validation data, verification data and metadata.

[C] Fully attributed GIS layers of station locations and boundaries of features.

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

[E] A full set of images from the monitoring survey, in jpg format,

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue Across Wales Intertidal Monitoring Survey (naturalresources.wales) by searching 'Dataset Titles' for 'Intertidal Monitoring'.