Cyfoeth Naturiol Cymru
Natural Resources Wales

MarClim Annual Welsh Intertidal Climate Monitoring Survey 2022

Report No: 748

Date: December 2023

Author Name: Nova Mieszkowska & Heather Sugden

Author Affiliation: Marine Biological Association & Newcastle University

About Natural Resources Wales

Natural Resources Wales' purpose is to pursue sustainable management of natural resources. This means looking after air, land, water, wildlife, plants and soil to improve Wales' well-being, and provide a better future for everyone.

Evidence at Natural Resources Wales

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

We will realise this vision by:

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

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

Report series:	NRW Evidence Report
Report number:	748
Publication date:	December 2023
Contract number:	MOA0070
Contractor:	Marine Biological Association
Contract Manager:	Dr. Nova Mieszkowska
Title:	MarClim Annual Welsh Intertidal Climate Monitoring Survey 2022
Author(s):	Dr. Nova Mieszkowska, Dr. Heather Sugden
Technical Editor:	Paul Brazier
Peer Reviewer(s)	Karen Robinson
Approved By:	Andrea Winterton
Restrictions:	None

Distribution List (core)

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

Distribution List (others)

Andrea Winterton	NRW
Mike Camplin	NRW
Kate Lock	NRW
Charlotte Gjerlov	NRW
Kirsten Ramsay	NRW
Alison Palmer-Hargrave	Gwynedd County Council
Sue Burton	Pembrokeshire Marine SAC
Aethne Cooke	MHWESG
Sarah Mellor	Pembrokeshire Coast NPA

Recommended citation for this volume:

Mieszkowska, N. & Sugden, H. 2023. MarClim Annual Welsh Intertidal Climate Monitoring Survey 2022. Natural Resources Wales Evidence Report No. 748, pp x + 24, Natural Resources Wales, Bangor

Contents

List of Figures

List of Tables

Crynodeb Gweithredol

Mae'r adroddiad hwn yn crynhoi'r gwaith arolygu, casglu data a dadansoddi a gwblhawyd yn 2021 ar safleoedd rhynglanwol creigiog o gwmpas arfordir Cymru o dan brosiect â'r teitl MarClim, fel y'i disgrifir yn http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm Mieszkowska (2005). Mae'r arolwg blynyddol yng Nghymru yn ffurfio rhan o arolwg parhaus, cyson dros 22 mlynedd, sy'n cynnwys y DU gyfan, o dros 100 safle rhynglanwol creigiog sy'n destun arolygon. Mae ardal ddaearyddol yr arolwg yn cynnwys safleoedd ledled gogledd a de-orllewin Cymru lle mae data hanesyddol yn bodoli sy'n mynd yn ôl i'r 1950au, a safleoedd ychwanegol lle y rhagwelir y bydd ffin yr ardal yn ymestyn. Cafodd arolygon MarClim eu cynnal ar 35 safle yn 2021. Cynhaliwyd arolygon ar 28 safle yng ngogledd Cymru a 7 safle yn ne Cymru.

Dulliau

Caiff y dulliau eu disgrifio mewn manylder yn Adran 2. Cofnodir data SACFOR ar gyfer yr 82 rhywogaeth sydd ar restr MarClim. Cofnodir data meintiol cwadrat ar gyfer tair rhywogaeth o wystrys, pedair rhywogaeth o wyrain, a chwblheir chwiliadau meintiol wedi'u hamseru ar gyfer dwy rywogaeth o falwod.

Crynodeb o'r canlyniadau allweddol

Arweiniodd symudiad gwaddod ym Mhorth Ceiriad at ddarganfod cynefin coblau newydd ger safle MarClim yn 2021. Yn 2022 roedd rhimyn llorweddol tenau o goblau bach ar y lan uchaf, ond nid oedd unrhyw rywogaethau'n byw ar y swbstrad hwn.

Adeiladwyd amddiffynfeydd arfordirol artiffisial newydd ar hyd y blaendraeth yn y Rhyl rhwng 2020 a 2021. Ni sefydlwyd cytrefi gan unrhyw rywogaethau rhynglanwol ac eithrio'r algâu byrhoedlog *Ulva lactuca* a *Porphyra umbilicalis*.

Neyland Point a Jetty Bach Dale oedd â'r nifer uchaf o rywogaethau estron a gofnodwyd ar unrhyw safle MarClim. Cafwyd hyd i'r wyran Lwsitanaidd *Perforatus perforatus* yn Abersoch, gogledd Cymru, gan gynrychioli estyniad o 240km ym mlaenymyl ei chynefin tua'r pegwn.

Cofnodwyd y llynghyren ddiliau *Sabellaria alveolata* yn Nhrwyn y Fuwch am y pedwerydd tro yn unig ers i arolygon MarClim ddechrau, a dyma'r cofnod cyntaf yno ers 2013.

Cafodd un *Patella depressa* llawn dwf ei gofnodi ym Mhorth Oer yn 2022. Cofnodwyd chwe unigolyn llawn dwf yn 2021 a dyma'r tro cyntaf i'r rhywogaeth Lwsitanaidd hon gael ei chofnodi yma ers i bum unigolyn gael eu darganfod yn 2003 a 10 unigolyn yn 2006.

Cafwyd hyd i un *P. depressa* llawn dwf yn Aberdaron yn 2022. Yn 2021 cofnodwyd niferoedd bach (Prin), sy'n dangos bod y boblogaeth hon wedi parhau i oroesi mewn niferoedd bach dros y pedair blynedd diwethaf.

Casgliadau a phynciau trafod

Mae arolygon MarClim yn canfod newidiadau blynyddol mewn mesurau sy'n deillio o bresenoldeb ar gyfer rhywogaethau rhynglanwol creigiog. Mae'r rhain yn fetrig sensitif i olrhain bregusrwydd rhywogaethau yn wyneb newid sylweddol yn yr hinsawdd, digwyddiadau thermol eithafol sy'n digwydd yn yr hinsawdd forol, ac oherwydd bod nifer o safleoedd yn cael eu harolygu yn yr un rhanbarth, gellir canfod aflonyddwch ar

raddfa fach fel difrod sgwrio wrth i raean bras symud yn ystod digwyddiadau storm yn erbyn y patrymau mwy o newid i rywogaethau morol a yrrir gan yr hinsawdd.

Mae rhywogaethau rhynglanwol Lwsitanaidd sydd wedi'u lleoli yn agos at flaenymylon cynefin ar ledred uchel wedi dangos pa mor agored ydynt i ddigwyddiadau oerfel eithafol, fel y gwelwyd yn Llanddulas yn 2021 a 2022.

Gellir olrhain arferion cytrefu, cyfradd a maint lledaeniad rhywogaethau estron, ond hefyd eu presenoldeb ac absenoldebau amrywiol trwy arolygon blynyddol MarClim. Roedd y safleoedd â'r niferoedd uchaf o rywogaethau estron yn aber Aberdaugleddau, a dangoswyd y gall cytrefu fod yn fyrhoedlog, hyd yn oed mewn ardaloedd lle mae'n debygol fod yna gyflenwad uchel o rywogaethau estron o longau cludo rhyngwladol.

Executive summary

Background to the project

This report summarises the 2022 rocky intertidal survey work, data and analysis completed around the coastline of Wales under the project title of MarClim, as described in http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm Mieszkowska (2005). The annual survey in Wales forms part of a sustained, twenty two-year, continuous annual UK survey of over 100 long-term rocky intertidal survey sites. Geographical coverage includes sites throughout north and south-west Wales for which historical data dating back to the 1950s exist, and additional sites where range extensions have been predicted to occur. MarClim surveys were carried out at 35 sites in 2022. Twenty eight sites were surveyed in north Wales and seven sites in south Wales.

Methods

Methods are described in detail in Section 2. Categorical SACFOR data are recorded for all 82 species on the MarClim list. Quantitative quadrat data are recorded for three species of limpet, four species of barnacles, and quantitative timed searches are completed for two species of trochid.

Summary of key results

Movement of sediment at Porth Ceiriad resulted in a new cobble habitat being uncovered near the MarClim site in 2021. In 2022 there was a thin horizontal band of small cobbles at high shore, but no species were living on this substrate.

New artificial coastal defences were built all along the foreshore at Y Rhyl between 2020 and 2021. There has been no colonisation by intertidal species with the exception of the ephemeral algae *Ulva lactuca* and *Porphyra umbilicalis*.

Neyland Point and Jetty Bach Dale had the highest number of NIS recorded at any MarClim site. The Lusitanian barnacle *Perforatus perforatus* was found at Abersoch, north Wales, representing a poleward extension of the leading range edge of 240km.

The honeycomb worm *Sabellaria alveolata* was recorded at Little Orme for only the fourth time since MarClim surveys commenced, and is the first record there since 2013.

One adult *Patella depressa* was recorded at Porth Oer in 2022. Six adult individuals were recorded in 2021 for the first time this Lusitanian species has been recorded here since five individuals were found in 2003 and 10 individuals in 2006.

One adult *P. depressa* was found at Aberdaron in 2022. In 2021 small numbers (Rare) were recorded, showing this population has continued to persist in small numbers over the past four years.

Conclusions and discussion points

MarClim surveys detect annual changes in occupancy-derived measures of abundance for rocky intertidal species. These are a sensitive metric with which to track the vulnerability of species to pervasive climate change, extreme thermal events occurring in the marine climate, and because multiple sites are surveyed in the same region, small-scale disturbances such as scour damage from local movements of shingle during storm events can be detected against the larger patterns of climate-driven change to marine species.

Lusitanian intertidal species located close to high latitude leading range edges have shown their susceptibility to extreme cold events, as seen at Llanddulas in 2021 and 2022.

The colonisation, the rate and extent of spread, but also fluctuating occurrences and absences of NIS can be tracked via MarClim annual surveys. The sites with highest numbers of NIS were both located in Milford Haven estuary, and showed that colonisation can be transient, even in areas where they is likely to be a high supply of NIS from international shipping vessels.

1. Introduction

The MarClim project was established in 2001 to investigate changes that had occurred in rocky intertidal systems within the last 50 years around the UK. MarClim established a low-cost network of sites covering England, Wales and Scotland which provided subsequent annual updates to track how climate influences the marine biodiversity of the British Isles (Mieszkowska *et al*. 2005). In addition, a comprehensive survey of shores in Ireland and Northern Ireland was undertaken in 2003 (Simkanin *et al*. 2005). Natural Resources Wales (Countryside Council for Wales) has continued to fund annual surveys of the Welsh MarClim sites, including additional sites beyond species distributional limits to track range extensions as they occur.

The main aims at the outset of the MarClim project in 2001 remain as follows:

- To use existing historical information and collect new data on intertidal indicator species from the last 50-100 years to develop and test hypotheses on the impact of climatic change on marine biodiversity in Britain and Ireland.
- To forecast future marine community changes on the basis of the Met Office's Hadley Centre climate change models and the United Kingdom Climate Impacts Partnership's climate change scenarios. The broad range of species known or likely to be temperature sensitive was covered.
- To establish low-cost, fit-for-purpose, methodologies and networks to provide subsequent regular updates and track how climate influences the marine biodiversity of Britain and Ireland.
- To provide general contextual time series data to support reporting on the success or otherwise of the Marine Strategy Framework Directive, marine aspects of Biodiversity Action Plans, European initiatives including the Habitats, Birds and Water Framework Directives, and management and monitoring of marine activities and resources, including fisheries and Special Areas of Conservation.
- To evaluate whether the climate indicator species used in this work have a wider contribution to make as part of the sustainability indicators that are needed to underpin the UK sustainable development strategy.
- To record the presence, abundance and spread of invasive non-native species on rocky intertidal ecosystems, and chart the impacts on native species.
- To disseminate the results widely, and accordingly elucidate the known impact climate has had on marine biodiversity over the last 100 years, and may have in the future.
- To provide a basis for the development of a proposal for European Commission funding to establish a pan-European network with related aims.
- To assess and report on the likely consequences of the predicted changes in response to climate for society, for commercial and non-commercial users of the marine environment and the policies and frameworks that conserve, manage and protect marine biodiversity. To assess whether any more serious impacts can be ameliorated or mitigated.

1.1 Background

Prof. Alan J. Southward of The Marine Biological Association first spotted the link with climatic fluctuations, prompted in part by his own observations in changes in

competing Boreal and Lusitanian species of barnacles along the coastline of the English Channel in the 1950s. The Boreal cold water species *Semibalanus balanoides* was common in the 1930s and rarer in the warmer 1950s, when the southern species *Chthamalus stellatus* (split into two species, *C. stellatus* and *C. montagui* by Southward in the 1970s) increased in abundance. Following a switch to colder conditions in the 1960s, *S. balanoides* again became more dominant, whereas recent warming from the late 1980s onwards led to an increase in *Chthamalus species*. These changes in barnacles mirrored switches between herring and pilchard and changes in plankton, benthos and demersal fish, but the response of intertidal species was often far quicker than for other components of marine ecosystem, making then early warning indicators of environmental change.

Southward and Prof. Denis Crisp (Bangor University) carried out surveys of barnacles and other rocky intertidal invertebrates and macroalgae around the coastline of Wales, England and Scotland in the 1950s, with ad-hoc resurveys during the 1960s-1980s. Prof. Lewis and his team at the Robin Hood's Bay Laboratory (Leeds University) undertook surveys on the distribution and abundance of rocky intertidal invertebrates in the 1980s, extending the scope to include newly developed quantitative surveys for topshells and limpets and investigations of reproductive cycles in these species.

The MarClim project was established in 2001 to rescue, centrally archive and analyse these data, and to establish a current UK baseline on the distribution and abundance of keystone intertidal invertebrates and macroalgae. MarClim was consortium funded from 2001-2005 by Natural England (then English Nature), Natural Resources Wales (then Countryside Council for Wales), Scottish Natural Heritage, Scottish Government (then Scottish Executive), Defra, JNCC, The Crown Estate, States of Jersey and WWF. The MarClim project has carried out annual surveys at rocky intertidal survey sites where long-term data exists since 2002. MarClim established a low cost network of sites covering England, Wales and Scotland which provided subsequent annual updates to track how climate influences the marine biodiversity of the British Isles (Mieszkowska et al. 2005). The network was downsized at the end of MarClim Phase I in 2005 to a subset of thirty sites in England (due to cessation of funding) and 35 sites in Wales (in conjunction with Countryside Council for Wales). Natural England enabled the restart of eleven additional sites in England in 2010 that have been resurveyed again in each subsequent year to date. This network, together with the baseline information provided by the MarClim project, are being used by scientific and policy communities as key tools to track impacts on biodiversity as climate changes.

MarClim surveys around the Welsh coastline are currently funded by Natural Resources Wales with in-kind contributions from the Marine Biological Association of the UK, and academic staff from both Newcastle and Southampton Universities. These surveys form part of a wider network of long-term MarClim sites in England (funded by Natural England) and France.

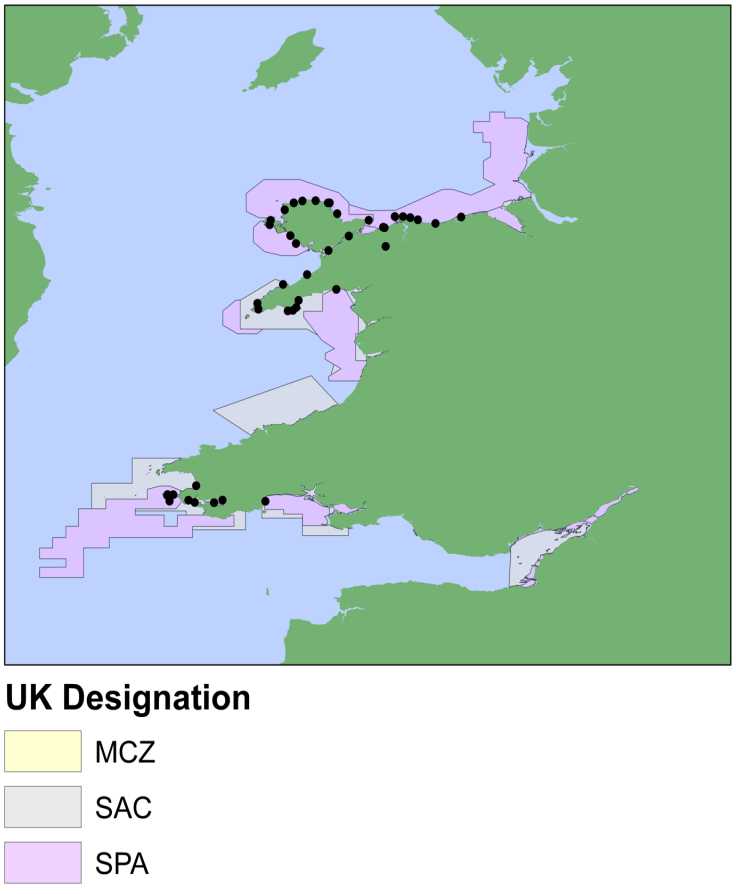
The project focuses on a robust set of temperature-sensitive, readily observed, intertidal climate indicator species of invertebrates and macroalgae for which long-term data sets and monitoring sites are available. The MarClim species list includes boreal cold-water and Lusitanian warm-water origins, native to the UK intertidal ecosystems, and invasive non-native species that pose a potential threat to native biodiversity (Appendix 2) in collaboration with the UK Marine Aliens Project http://www.marlin.ac.uk/marine_aliens/. Non-natives are also targeted due to their appearance and subsequent impacts on natural communities after introduction via escapes of associated spat from mussel and oyster aquaculture facilities and practices.

MarClim data has shown major shifts in biogeographic distributions of both cold and warm water species around the coastline of the UK since the onset of climate warming in the mid-1980s, and associated changes in abundance, population structure and physiological responses across several taxonomic groups (Mieszkowska *et al*. 2005, 2006, Mieszkowska 2009). These changes are amongst the fastest recorded globally and up to ten times faster than those recorded in terrestrial systems. The methodology is therefore field-tested and proven as a suitable broadscale climate detection tool.

Additional species have been added since 2002, to encompass those shifting distributional ranges into the UK, tracking a warming climate, and Invasive Non-Native Species identified as posing a risk to native rocky intertidal communities. In order to ensure comparability with the historical data the original methodology was retained for ACFOR (now SACFOR) scoring of species abundances and barnacle quadrat counts. Additional quantitative methodology to facilitate robust statistical analysis and modelling (e.g. Community Temperature Index (Burrows *et al*. 2019)) has been incorporated since 2002 and is detailed in the Survey Protocols section below.

Climate-driven shifts in the biogeographic ranges of native and invasive species are also being tracked by Dr Mieszkowska around the wider northern European coastline using the MarClim protocols. These surveys provide geographically extensive, contextual evidence on distributions, abundances and biological mechanisms by which intertidal species respond to large-scale climate related changes and allow Welsh data to be placed into a European context, with special relevance to the EU Marine Strategy Framework Directive 'Good Environmental Status' indicators (http://jncc.defra.gov.uk/page-6813).

Figure 1. MarClim sites surveyed in 2022.



2. Methods

The MarClim protocols (Appendix 2) were used as the standard survey methodology at all survey sites. These protocols include additional alien species of concern to NRW or pertinent to the Defra GB Non-Native Species Portal https://secure.fera.defra.gov.uk/nonnativespecies/home/index.cfm.

MarClim surveys were carried out at thirty-five sites in 2022 (Table 1, Fig. 1).

Twenty-eight rocky shores in north Wales were surveyed by Dr. Nova Mieszkowska from The Marine Biological Association, Dr. Heather Sugden from Newcastle University, Kathryn Birch from Natural Resources Wales and Gabe Wyn (recently retired from NRW) (Figure 1). Eight sites were surveyed in south Wales including seven on the mainland and one on Skokholm Island. These surveys were carried out and cross-calibration exercises undertaken by Nova Mieszkowska and Mark Burton and Kate Lock of NRW. Data entry was completed by Nova Mieszkowska with QA by Paul Brazier.

Semi-quantitative SACFOR abundance scores were recorded for a suite of 82 species of invertebrates and macroalgae, including nine Non-Indigenous Species (NIS) of invertebrate and nine NIS of macroalgae. Replicate, quantitative quadrat counts were made for barnacles (0.1 m^2) (Figure 2) and population abundances for each species counted using bespoke digital image software. Ten replicate 0.25m^2 quadrats were counted at each site to record the abundance of limpet species. These were randomly placed within the midshore zone on areas of bedrock or large boulders with homogeneous surfaces (Figure 3). Pools, cracks and crevices and patches of macroalgae were avoided. The slope of the rock, percentage cover of adult barnacles, algae and mussels were recorded in each quadrat. All limpets greater than 10 mm in size were counted and identified to species level.

Three replicate searches, each of three minutes duration were made separately for *Phorcus lineatus* and *Steromphala umbilicalis* in the area of the shore where each of the two warm water indicator species were most abundant. Cobbles and small boulders were turned to ensure all individuals were collected; they were returned to their original orientation after the search. The maximum basal diameter of every individual was measured in mm to 1 decimal place and population size frequencies calculated from the data.

All data have been submitted to NRW in electronic format. All surveyors had been trained in MarClim methodology and cross-calibrated in the field with Dr Mieszkowska. An additional site at Holyhead was added to the MarClim Wales site network in 2010 and has been re-surveyed annually to track any potential spread of the non-native ascidian *Didemnum vexillum* which has been the subject of an intense eradication program by NRW inside Holyhead marina (http://www.NRW.gov.uk/.../NRW-in-holyhead-harbour.aspx). An additional site at Llanddulas, which has been sporadically checked for absence of indicator species has been added to the list after the appearance of a population of *Steromphala (Gibbula) umbilicalis* was found in 2012 and *Phorcus lineatus* in 2016, and is now surveyed each year. The Rhyl crescent seawall and groynes were surveyed in 2014 and again annually since 2017 to ensure further range extensions of the topshells are accurately located.

Metadata and quantitative survey data were recorded on datasheets in the field. The data were transferred to electronic datasheets in the laboratory and a rigorous QA check carried out by Mieszkowska and Brazier. Photographs were labelled to allow accurate interpretation and identification of features. Data analysis was carried out by

Mieszkowska. The results are described in detail within this report. An electronic copy of data has been submitted to Natural Resources Wales as part of this report and another copy lodged with the MEDIN accredited data centre DASSH (Data Archive for Seabed Species and Habitats) at the MBA. The MarClim master dataset is accessible through the NBN via Marine Recorder.

Figure 2. A 5cm x 2cm subsection of the 5x5cm barnacle quadrat images taken during MarClim surveys being analysed using MarClim digital image software. The species are identified and marked by a unique identifier code and the number of adult and juvenile barnacles for each species is recorded in a linked Access database.

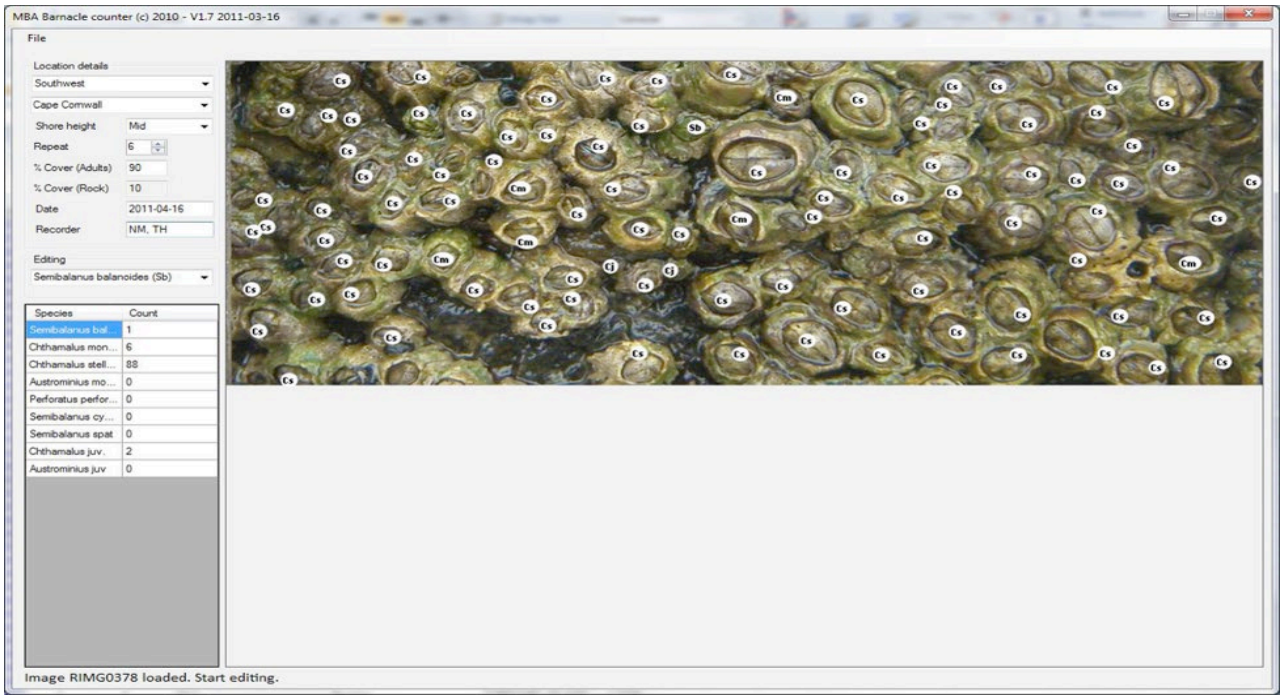


Figure 3. MarClim 0.25m^2 limpet quadrat used for surveys.

Table 1. MarClim survey site locations 2022.

Day	Month	Year	Site	Region	Recorder	Grid Ref	Lat WGS84	Long WGS84
11	7	2022	Rhyl Splash Point	North Wales	NM, HS	SJ021824	53.3299	-3.4715
11	7	2022	Llanddulas	North Wales	NM, HS	SH906787	53.2933	-3.6296
11	7	2022	Rhos-On-Sea	North Wales	NM, HS	SH843805	53.3114	-3.7381
11	7	2022	Little Orme	North Wales	NM, HS	SH812825	53.3260	-3.7852
11	7	2022	Great Orme East	North Wales	NM, HS	SH782832	53.3321	-3.8297
12	7	2022	Great Orme Trwynygogarth	North Wales	NM, HS	SH749834	53.3327	-3.8801
12	7	2022	Penmaenmawr Natural	North Wales	NM, HS	SH704763	53.2674	-3.9440
12	7	2022	Trefor	North Wales	NM, HS	SH376474	52.9992	-4.4215
12	7	2022	Caernarfon (Aber Foreshore Road)	North Wales	NM, HS	SH521671	53.1374	-4.2897
12	7	2022	Penmon North	North Wales	NM, HS	SH641813	53.3111	-4.0413
12	7	2022	Menai Bridge	North Wales	NM, HS	SH555714	53.2207	-4.1643
13	7	2022	Bull Bay	North Wales	NM, HS, KB	SH427945	53.4238	-4.3688
13	7	2022	Moelfre	North Wales	NM, HS, KB	SH513859	53.3490	-4.2354
13	7	2022	Porth Eilian	North Wales	NM, HS, KB	SH484929	53.4111	-4.2823
13	7	2022	Point Lynas	North Wales	NM	SH477929	53.4109	-4.2928
13	7	2022	Holyhead	North Wales	NM, HS, GW	SH257825	53.3108	-4.6461
13	7	2022	Porth Swtan	North Wales	NM, HS	SH298891	53.3713	-4.5598
14	7	2022	Cemlyn	North Wales	NM, HS	SH337934	53.4146	-4.5112
14	7	2022	Rhosneigr	North Wales	NM, HS	SH315725	53.2233	-4.5253
14	7	2022	Aberffraw (Briach-Lwyd)	North Wales	NM, HS	SH337674	53.1776	-4.4899
15	7	2022	Llanbedrog	North Wales	NM, HS	SH335311	52.8516	-4.4742
15	7	2022	Porth Oer	North Wales	NM, HS	SH163297	52.8344	-4.7256
15	7	2022	Nefyn	North Wales	NM, HS	SH274415	52.9430	-4.5702
16	7	2022	Martin's Haven	South Wales	MB	SM759091	51.7357	-5.2471
16	7	2022	Porth Neigwl	North Wales	NM, HS	SH288245	52.7908	-4.5404
16	7	2022	Aberdaron	North Wales	NM, HS	SH166260	52.8003	-4.7220
16	7	2022	Criccieth Castle	North Wales	NM, HS	SH494376	52.9146	-4.2412
17	7	2022	Criccieth (East)	North Wales	NM, HS	SH506380	52.9186	-4.2236
17	7	2022	Porth Ceiriad	North Wales	NM, HS	SH308247	52.7938	-4.5094
17	7	2022	Abersoch lifeboat station	North Wales	NM, HS	SH323265	52.8107	-4.4881
11	8	2022	Skokholm South Haven	South Wales	MB	SM733088	51.7319	-5.2845
13	8	2022	North Haven	South Wales	MB	SM735093	51.7365	-5.2819
26	8	2022	Aberystwyth	South Wales	NM, DLS	SN582828	52.4247	-4.0869
27	8	2022	Neyland Natural	South Wales	NM, MB	SM967047	51.7045	-4.9433
28	8	2022	Broad Haven	South Wales	NM, DLS	SM859144	51.7871	-5.1057
29	8	2022	West Angle Bay	South Wales	NM, HS, MB	SM848038	51.6916	-5.1151
30	8	2022	Monkstone Point	South Wales	NM, DLS	SN150033	51.6978	-4.6784
31	8	2022	Jetty Beach Dale	South Wales	NM, MB	SM822053	51.7041	-5.1533

3. Results

3.1. Climate change and extreme events

The UK experienced the coldest in December 2022 since 2010 (https://blog.metoffice.gov.uk/2022/12/30/cold-december-concludes-warmest-year-on-record-for-uk/). This followed on from the previous winter's records for January 2020/21 since 2010, with exceptionally wet weather recorded (https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2021/2021-a-year-in-weather-a-review). The winter had colder than average conditions based on the updated 1991-2020 UK mean temperature data.

The joint second hottest summers on record were recorded in 2018 and 2020 and 2020 was the joint second warmest year on record with 2016 (https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2019/2020-global-temperature-forecast). These records were broken again in 2022, which was the warmest year since records began in 1659 (https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2022/2022-provisionally-warmest-year-on-record-for-uk). Six of the warmest years ever recorded in the UK have now occurred since 2010. Marine warm spells have become more frequent in both summer (heatwaves) and winter (anomalously warm temperatures) since 1982, whereas cold spells are becoming less frequent in both summer and winter across the same period. This evidences a shift away from seasonal patterns of extreme cold temperature in the marine environment towards a more widespread set of warmer events throughout the year.

Marine heatwaves have become more frequent since the 1980s, and possibly longer and more intense. The heatwave of 2018 stands out as being the longest (60 days) if not the most intense on record, and with the biggest cumulative degree x days score in excess of 19°C (NOAA 2020; Reynolds et al., 2007). Between 16th to 19th July 2022 the UK experienced a brief but unprecedented extreme heatwave, as hot air moved north from the near-continent, with extreme temperatures recorded on both 18th and 19th. The temperature records of many long-running stations were exceeded by wide margins, including Aberporth, Ceredigion (33.6°C, +0.9°C, 80 years), and regional maximum temperature records were also set across all UK climate districts except western and northern Scotland; again for many by wide margins (Met Office 2022).

3.2. Community Composition across Wales

Analysis of the 2022 MarClim data showed that almost all of the sites surveyed in south Wales clustered closely together in a Multi-Dimensional Scaling plot (Figure 4), whereas the sites in north Wales had a wider spread across the plot, indicating greater differences in species composition between the north Wales sites. When all of the sites were plotted by the county they are located in, the grouping of geographic locations became more apparent, with the survey sites clustering more closely together within the counties of Conwy, Isle of Anglesey, Gwynedd, Ceredigion, and Pembrokeshire, than between the counties (Figure 5). Simper analyses (Tables 2-5) show that the differences between these sites were predominantly due to the same species: the barnacles *S. balanoides* and *C. montagui*, winkles *L. littorea* and *L. saxatilis*, the topshell *S. umbilicalis*, limpets *P. vulgata* and *P. depressa*, and the fucoids *P. canaliculata, F. spiralis, F. vesiculosus, F. serratus*, and *A. nodosum*. Most of these species are foundation species and/or ecosystem engineers that are responsible for structuring rocky intertidal communities.

Figure 4. MDS plot of MarClim data for Welsh sites in 2022.

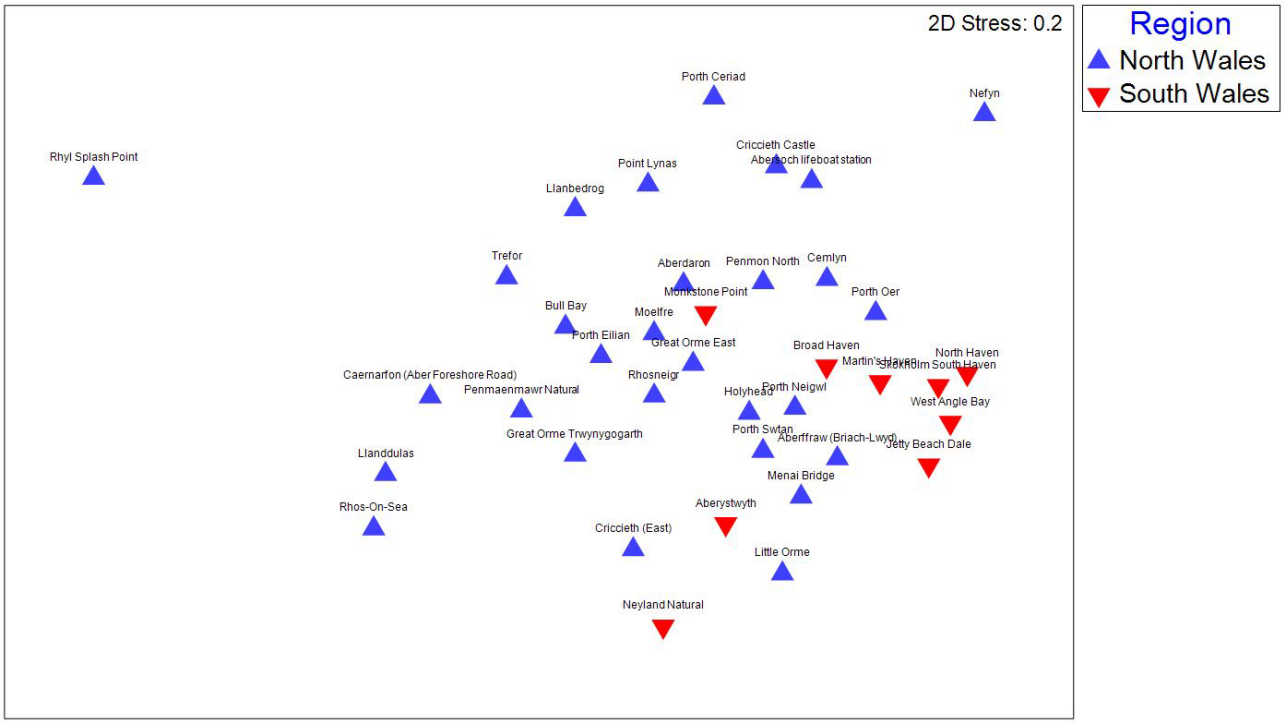


Figure 5. MDS plot of MarClim data for Welsh sites grouped by county in 2022.

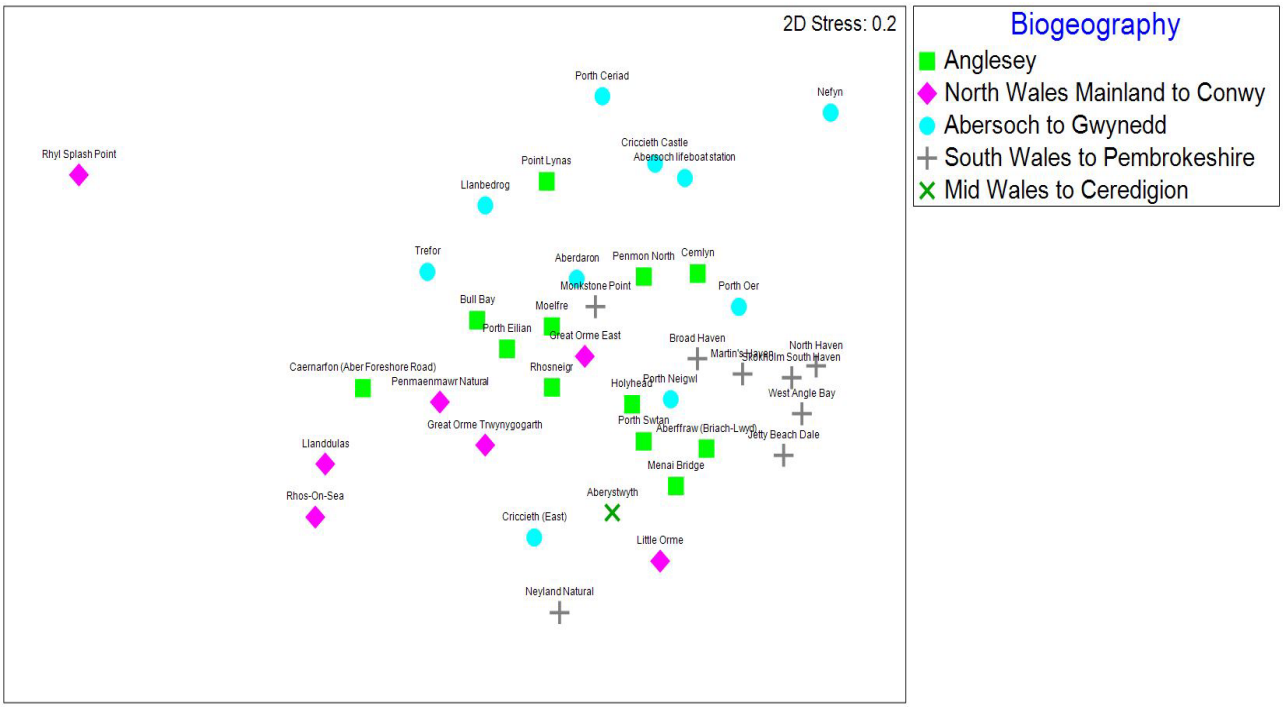


Table 2. SIMPER similarity percentages of species contributions for sites in Conwy.

Conwy

Average similarity: 56.37

	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum %
S. balanoides	2.36	9.92	3.64	17.60	17.60
L. littorea	2.00	7.71	3.42	13.68	31.28
A. modestus	1.88	7.08	1.34	12.56	43.84
S. umbilicalis	1.85	5.63	1.45	9.99	53.83
P. vulgata	1.63	4.58	1.50	8.12	61.95
A. equina	1.55	4.42	1.44	7.83	69.79
C. crispus	1.42	3.32	0.91	5.88	75.67

Table 3. SIMPER similarity percentages of species contributions for sites in Gwynedd.

Gwynedd

Average similarity: 58.07

	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum %
C. montagui	2.36	7.10	4.93	12.23	12.23
S. balanoides	2.34	6.91	5.82	11.90	24.13
F. spiralis	2.07	5.34	1.84	9.20	33.33
P. canaliculata	2.05	5.30	1.84	9.13	42.46
P. vulgata	1.94	4.90	1.86	8.45	50.91
F. vesiculosus	1.89	4.47	1.15	7.70	58.60
L. saxatilis	1.54	3.17	1.19	5.46	64.06
L. littorea	1.37	2.57	0.89	4.43	68.49

Table 4. SIMPER similarity percentages of species contributions for sites on the Isle of Anglesey.

Isle of Anglesey

Average similarity: 66.01

	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum %
S. balanoides	2.36	7.02	5.10	10.64	10.64
F. vesiculosus	2.34	7.02	5.29	10.63	21.26
P. canaliculata	2.22	6.27	3.58	9.49	30.76
F. spiralis	2.19	5.75	2.01	8.71	39.46
F. serratus	1.99	4.54	1.40	6.88	46.34
P. vulgata	1.70	4.06	1.38	6.15	52.49
L. littorea	1.74	4.05	1.33	6.14	58.63
A. nodosum	1.74	3.74	1.06	5.67	64.30
S. umbilicalis	1.65	3.74	1.34	5.66	69.96

Table 5. SIMPER similarity percentages of species contributions for sites in Pembrokeshire.

Pembrokeshire

Average similarity: 66.88

	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum %
P. vulgata	2.18	4.16	7.30	6.22	6.22
S. umbilicalis	2.17	4.15	5.11	6.20	12.42
F. serratus	2.20	4.02	7.81	6.01	18.42
L. saxatilis	2.02	3.75	4.67	5.60	24.03
S. balanoides	1.98	3.29	3.41	4.92	28.95
F. spiralis	1.90	3.27	4.69	4.88	33.83
H. perlevis	1.82	3.11	3.16	4.65	38.48
P. lineatus	1.93	3.03	1.65	4.53	43.01
C. montagui	1.97	2.93	1.58	4.38	47.39
A. nodosum	1.66	2.85	7.14	4.25	51.64
P. canaliculata	1.77	2.64	1.61	3.95	55.60
M. stellatus	1.74	2.58	1.58	3.86	59.46
P. depressa	1.71	2.58	1.68	3.85	63.31
F. vesiculosus	1.70	2.49	1.58	3.73	67.04
N. lapillus	1.60	2.46	1.50	3.67	70.71

The sites in Conwy have the lowest number of MarClim species as they are located along a stretch of coastline where several species reach their leading range edges in north Wales, and therefore they are not found at all survey sites (Table 2).

At Rhyl Splash Point, a new artificial coastal defence sea wall was constructed during 2020 and 2021, and had just started to be colonised by the ephemeral algae *Ulva lactuca* and *Porphyra umbilicalis* in 2022 (Figure 6). This structure only reaches the upper eulittoral at the lowest end, and therefore few intertidal species would colonise this high shore area. The species that were recorded were predominantly found in the small cobble patches in the soft sediment in the vicinity of the sea wall (*S. balanoides, A. modestus, L. littorea*), and on the timber groynes embedded in the sand (*Fucus spiralis*, *S. balanoides, A. modestus)*. This site is surveyed to track any future range extensions of species along the north Wales coastline.

Figure 6. New artificial coastal defence structure at Rhyl.

3.3. Range Extensions and Records of Transient Occurrences

MarClim tracks changes in the leading range edge of species that reach their distributional limits in Wales. Annual population surveys for all of the species on the MarClim list allow shifts to be tracked in real time, show how population dynamics change across longer time periods, identify established populations that are steadily increasing, as well as those that have fluctuating abundances. The most northerly population of the Lusitanian warmwater topshell *P. lineatus* in north Wales has been at Llanddulas since the first individuals were recorded there in 2015. It has not extended past this point to date. Population abundances increased until 2020 but have been lower in the past two years (Figure 7). A similar decline has been recorded for the Lusitanian warmwater topshell *Steromphala umbilicalis* in the last two years. These changes at population range edges may have been driven by the two colder than average winters that occurred in 2020/21 and 2021/22.

Figure 7. Average abundance and standard deviation of replicated timed searches for *P. lineatus* at Llanddulas.

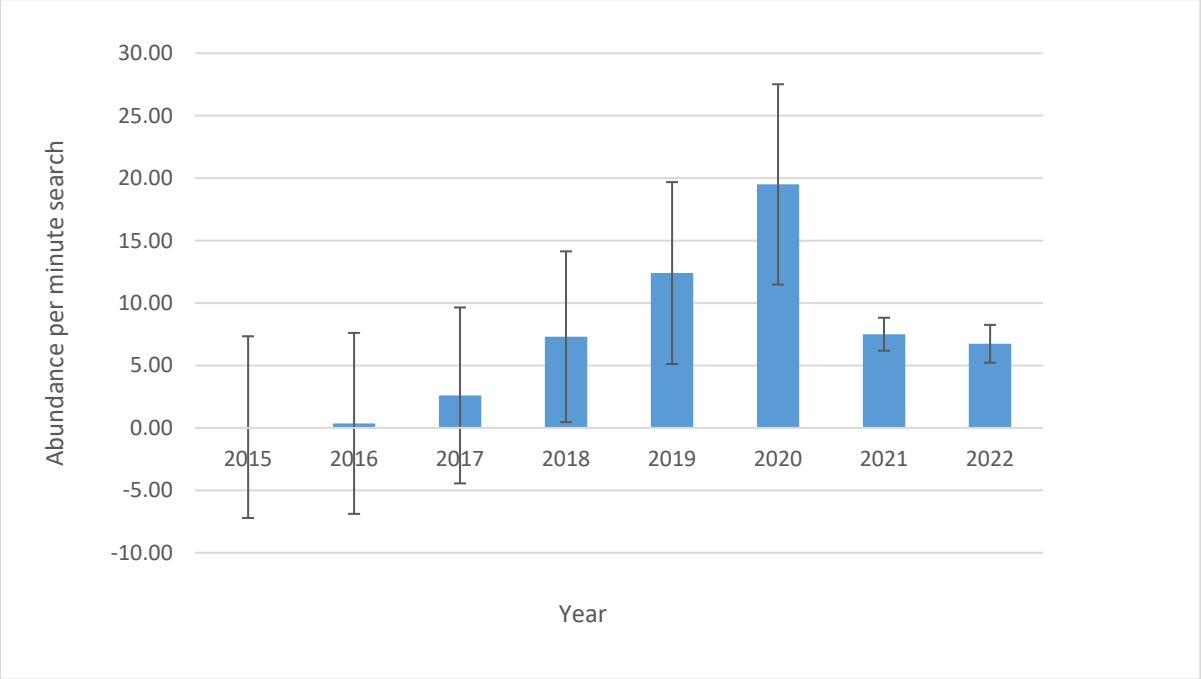


Table 6. Timed searches for *P. lineatus* at Llanddulas since the first individuals were recorded there in 2015 (see Appendix 1 for individual counts).

Year	Average number	SD
2015	0.06	7.28
2016	0.36	7.25
2017	2.60	7.05
2018	7.30	6.84
2019	12.40	7.28
2020	19.50	8.02
2021	7.50	1.32
2022	6.73	1.52

The Lusitanian barnacle *Perforatus perforatus* was found at Abersoch, north Wales in 2022, representing a poleward extension of the leading range edge of 240km from Broad Haven in Pembrokeshire. Additional surveys by S.J. Hawkins (not part of the NRW MarClim project) also found *P. perforatus* at Whitesands Bay, Pembrokeshire and Borth in Ceredigion. Samples will be taken during the 2023 MarClim surveys and

barcoded at the MBA to confirm the species identity, as this represents a massive range extension for an intertidal species.

Figure 8. *Perforatus perforatus* at Abersoch lifeboat station MarClim site.

Table 7. SACFOR abundance data for *S. alveolata* at Little Orme.

Year	Sabellaria alveolata
2004	NS
2005	NR
2006	NR
2007	C
2008	NS
2009	NS
2010	NS
2011	NS
2012	R
2013	C
2014	NS
2015	NS
2016	NS
2017	NS
2018	NS
2019	NS
2020	NS
2021	NS
2022	A

The honeycomb worm *Sabellaria alveolata* was recorded as Abundant (40% coverage around boulders) at Little Orme in 2022 (Table 7, Figure 9). It has only been recorded

at this site a few times since the start of annual surveys here in 2004: Common (10%) in 2007 and 2013, Rare (isolated individuals) in 2012, and Abundant in 2022.The MarClim time-series data are incredibly useful to track such transient populations and provide information on long-term population dynamics of UK BAP Priority Habitats like *S. alveolata* (Curd et al. 2022).

Figure 9. *Sabellaria alveolata* at Little Orme in 2022.

Movement of sediment at Porth Ceiriad between 2020 and 2021 resulted in a new cobble habitat being uncovered near the MarClim site in 2021. In 2022 there was a thin horizontal band of small cobbles at high shore, but no species were living on this substrate (Figure 10).

Figure 10. Thin band of cobbles at MHWS level at Porth Ceiriad in 2022.

3.4. Non Indigenous Species

MarClim records eight species of macroalgae NIS and fourteen species of invertebrate NIS (see Appendix 2 for full species list). These include horizon scanning for species that have only been recorded at one or a few locations in the UK to date, e.g. the crabs *Hemigrapsus sanguineus* and *H. takanoi*, and the colonial ascidian *Didemnum vexillum* that invaded Holyhead marina in 2008 (Holt & Cordingley 2011).

Most NIS on the MarClim list were not found at MarClim sites in Wales in 2022. Twenty-five sites had NIS recorded in 2022, most of which were the barnacle *Austrominius modestus*. This was the most prolific species, being recorded at 22 sites, four less sites than in 2021. Neyland Point in Pembrokeshire had the joint highest number of NIS recorded at any MarClim site in 2021 (four), with *Undaria pinnatifida, Magallana gigas,* and *Botrylloides violaceous* all being present, however, despite also having the most NIS in 2022, only *A. modestus*, *Crepidula fornicata*, and *Corella eumyota* were recorded in 2022, showing how transient populations of invasive species can be at any site. Jetty Beach at Dale also had four NIS present in 2022: *Chondracanthus acicularis, A. modestus, B. violaceous, and C. eumyota.* Both of these sites are located in Milford Haven estuary, where there are consistently the most NIS recorded for any MarClim site in the UK.

4. Relevance to NRW assessments of Annex I habitats

These data may be used for the Natural Resources Wales assessments of vulnerability of Annex I marine habitats to climate change in Wales (Oaten *et al*. 2021). MarClim has data stretching back to the 1950s, and is able to provide long-term data on the abundance and distribution of species. MarClim data are used in conjunction with biotope mapping of MPAs in England to provide additional, quantitative information on the structure, and changes to rocky intertidal habitats along the coastline.

MarClim data collected on extreme events including heatwave impacts and storm events on rocky intertidal species at sites around the Welsh coastline may also be of use in these assessments.

The collection of abundance and recruitment data in MarClim surveys can ground-truth predictions such as those made in the Oaten *et al*. (2021) report, including the potential reduction in abundances of boreal species such as *S. balanoides* and the low risk of impact to fucoid algae. To date, the abundance and recruitment of *S. balanoides* at MarClim sites in Wales has not declined. In addition, it is unlikely that the boreal kelp *L. ochroleuca* will replace the Lusitanian *L. hyperborea* in Wales (or at any other site in the UK) over the next few decades. *L. ochroleuca* only occurs in a few sites in southwest England, and is not showing significant extensions of the leading biogeographical range edge. The MarClim project collects data on all of the rocky intertidal species mentioned in this report and tracks changes in abundance and distribution annually, being able to separate out small scale changes and impacts of extreme events from pervasive climate change.

5. Overview of MarClim surveys in Wales

Most MarClim time-series sites in Wales were in a favourable condition (with respect to the methods and species recorded) in 2022 (no change against the baseline). The only evidence of anthropogenic impacts were the presence of NIS at twenty five sites across Wales. Most of these sites only contained *A. modestus* and/or *S. muticum*, and none were new colonisations in 2022. *A. modestus* has been present at Welsh sites since before the start of the time-series in 2002 and does not have any apparent detrimental effect on intertidal species or habitats. *S. muticum* has also been present at Welsh sites for the duration of the MarClim time-series. Research has not shown any negative impacts on intertidal rockpool fauna and flora on UK shores where this species has colonised since its introduction into the UK in the 1970s (Farnham 1973).

In 2022, the Lusitanian, warmwater species of topshell *P. lineatus* continued to increase in abundance, or maintained its SACFOR abundance categories at MarClim long-term monitoring sites around the Welsh coastline, with the exception of the Welsh range-edge population at Llanddulas, where the previous two cold winters had caused a reduction in the population.

6. Conclusions

There were no acute changes recorded at any MarClim shore in 2022, and abundances of both Lusitanian warm water, and boreal cold water species did not show large changes from 2021 surveys. Lusitanian species were still present at leading range edge sites in Wales in 2022, although at slightly lower abundances than in the previous two years. This is likely to have been due to two winters with prolonged low temperatures occurring in 2020 and 2021. A population of *S. alveolata* was recorded at Little Orme for the first time in several years in 2022, and NIS had not increased in site coverage from previous years. *P. perforatus* was recorded for the first time in north Wales, representing a range extension of over 240km. The identity of this species will be confirmed in 2023 by barcoding.

Significance of results and future practice

- The major findings of the MarClim project and scientific data collected by MarClim are communicated to government organisations, staff, conservation agencies, marine SAC and SSSI managers and the general public to increase the knowledge, understanding and reporting of scientifically, managerial and societally important questions relating to global climate change, ocean acidification and smaller-scale human impacts on the marine environment including development, habitation and exploitation of the coastal zone, component ecosystems and species. MarClim is used to assess and inform UK and EU policies and directives including the EU Marine Strategy Framework Directive, PEGASEAS Governance Guide, Condition Assessments for SACs, SSSIs and European Marine Sites and as baseline data for the UK Marine Conservation Zone designation process.
- The MarClim time-series dataset was developed by Mieszkowska, Burrows and Hawkins (2013) of the MarClim team as Good Environmental Status Indicators for the MSFD, with the first report published in 2014: http://jncc.defra.gov.uk/page-6813. A second phase of work to develop the MarClim time-series as species (Species Temperature Index) and community indicators of climate change (Community Temperature Index) as part of the MSFD GES indicator development process was developed by the MarClim team in 2017 (Burrows, Hawkins & Mieszkowska 2017), and an update is being prepared for JNCC in 2023 by Mieszkowska and Burrows.
- The MarClim Project and research team provide unique, essential, long-term monitoring and scientific research data and expertise. This is used by the UK SNCBs to address major national and European policy directives including the EU Marine Strategy Framework Directive, EU Habitats Directive, EU Water Framework Directive, OSPAR Commission Assessments, and the UK Marine Conservation Zone designation process as part of the Marine and Coastal Access Act.
- The MarClim team have published a paper on the impacts of extreme weather events and pervasive change in Frontiers in Marine Ecology (Mieszkowska et al. 2021). The paper demonstrates the value of the long-term time-series with

a large geographic extent in detecting both short-term, acute changes against longer time climate-driven shifts in species around the UK coastline. The paper includes information from the Welsh MarClim survey sites and species recorded there.

- Mieszkowska is a co-author on a paper that investigates the ecosystem engineer species *Sabellaria alveolata* with a naturally fragmented distribution as a case study to assess climate-driven changes in within-range occupancy across its entire global distribution (Curd et al. 2022). MarClim data on this species from Welsh surveys was included in the data modelling for this paper.

7. References

Burrows, M. T., Bates, A. E., Costello, M. J., Edwards, M., Edgar, G. J., Fox, C. J., et al. (2019). Ocean community warming responses explained by thermal affinities and temperature gradients. Nat. Clim. Chang. 9, 959–963. doi: 10.1038/ s41558-019-0631-5

Burrows, M.T, Moore, J., Hawkins ,S.J., Adams, L., Sugden, H., Firth, L. & Mieszkowska, N. (2020). Global-scale species distributions predict temperature-related changes in species composition of rocky shore communities in Britain. Glob. Change Biol., 25, 2093-2105 https://doi.org/10.1111/gcb.14968.

Curd, A., Chevalier, M, Vasquez, M., Boyé, A., Louise B. Firth, L.B., Marzloff, M.P., Bricheno, L.M., Burrows, M.T., Bush, L.E., Cordier, C., Davies, A.J., Mattias Green, J.A., Hawkins, S.J., Lima, F.P., Meneghesso, C., Mieszkowska, N., Seabra, R. & Stanislas F. Dubois, S.F. (2022). Applying landscape metrics to species distribution model predictions to characterise internal range structure and associated changes. Global Change Biology, https://doi.org/10.1111/gcb.16496.

Farnham, W.F., Fletcher, R.L. & Irvine, L.A. (1973). Attached *Sargassum*, Found in Britain. Nature 243 (5404): 231 - 232.

Holt, R. & Cordingley, A. (2011). Eradication of the non-native carpet ascidian (sea squirt) *Didemnum vexillum* in Holyhead Harbour: Progress, methods and results to spring 2011. CCW Marine Monitoring Report No. 90, pp112.

Met Office https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2019/2020-global-temperature-forecast [Accessed January 5 2021].

Met Office https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2022/2022-provisionally-warmest-year-on-record-for-uk [Accessed February 20th 2022].

Mieszkowska, N., Burrows M.T .& Sugden, H. (2020). Impacts of climate change on intertidal habitats relevant to the coastal and marine environment around the UK. MCCIP Science Review 2020, 256-271 https://doi.org/10.14465/2020.arc12.ith.

Mieszkowska, N., Burrows, M.T., Hawkins, S.J. & Sugden, H. (2021). Impacts of pervasive climate change and extreme events on rocky intertidal communities: evidence from long-term data. Frontiers in Marine Science, https://doi.org/10.3389/fmars.2021.642764.

National Oceanographic and Atmospheric Administration https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html [Accessed December 7, 2020]

National Oceanic and Atmospheric Administration https://www.ncdc.noaa.gov/cdo-web/ [Accessed December 2020].

Oaten, J., Brooks, A., Frost, N., Hull, S. & Williamson, D. (2021). Assessing the vulnerability of Annex I marine habitats to climate change in Wales. Natural Resources Wales Evidence Report number 536, pp110.

Reynolds, R.W., Smith, T.M., Lui, C., Chelton, D.B., Casey, K.S. & Schlax, M.G. (2007). Daily high-resolution-blended analysis for Sea Surface Temperature. J. Clim., 20(22), 5473-5496 https://doi.org/10.1175/2007JCLI1824.1.

Appendices

Appendix 1 – Details of the timed searches for *P. lineatus* at Llanddulas since the first individuals were recorded there in 2015.

Year	total per timed count	duration of timed count (min)	total per minute
2015	1	3	0.30
2015	0	3	0.00
2015	0	3	0.00
2015	0	3	0.00
2015	0	3	0.00
2016	1	2	0.30
2016	1	2	0.30
2016	1	2	0.30
2016	1	2	0.30
2016	2	2	0.60
2017	17	2	8.50
2017	1	2	0.50
2017	1	2	0.50
2017	4	2	2.00
2017	3	2	1.50
2018	17	2	8.50
2018	15	2	7.50
2018	9	2	4.50
2018	24	2	12.00
2018	8	2	4.00
2019	25	2	12.50
2019	25	2	12.50
2019	9	2	4.50
2019	37	2	18.50
2019	28	2	14.00
2020	29	2	14.50
2020	22	2	11.00
2020	60	2	30.00
2020	60	2	30.00
2020	24	2	12.00
2021	12	2	6.00
2021	15	2	7.50
2021	14	2	7.00
2021	16	2	8.00
2021	18	2	9.00
2022	19	3	6.33
2022	13	3	4.33
2022	22	3	7.33
2022	22	3	7.33
2022	25	3	8.33

Appendix 2 - MarClim Sampling Protocols 2022

Before you start at each site, record:

1. Site name and grid reference
2. County/Area
3. Date
4. Recorder
5. Lat long of access point (e.g. car park) and lat long of centre of survey area (e.g. midshore)
6. Exposure scale of the shore
7. Weather at the time of the survey, especially the visibility
8. Mark site on an OS Map

At each site: Semi-Quantitative Data

1. Identify area to be sampled (this might be up to 100m or more in extent)
2. Photograph approach to site
3. Photograph general view of the sample site
4. Photograph specific features of interest and any rare organisms/new records
5. Walk the whole of the sampling area and using the checklist allocate each of listed species listed to a SACFOR category. Use one or two quick quadrat counts to help in placing in the SACFOR category.
6. It is important to record *apparent* absences and the SACFOR category should be based on the locality in which the species is most abundant, this might be as small as 10m x 10m. DO NOT spend more than 30 minutes searching for species unless at a range edge. If more than 30 minutes is spent searching, record the time.
7. Use the notes section of the form for other species of interest.
8. Use GPS to record
   Midshore of the area sampled/searched
   Location of areas sampled for particular species (if different)
   Location of key features visible in the photographs
9. Note major features of the shore; bedrock, cobbles, boulders, sand scouring etc.

At each site: Quantitative Data

1. Replicated counts of limpets, barnacles, trochids will be made on each shore visit. If time is short and we are visiting a shore that has not been previously surveyed then trochids should only be recorded by SACFOR.
2. Avoid areas of heavy human disturbance.

At each site: Quantitative Barnacle Data Collection

1. Photograph at least ten replicate 5cm x 5cm quadrats containing barnacles at *low, mid* and *high* shore levels. High shore is defined as that area 1m below the very top of the barnacle zone, mid shore in the middle of the barnacle zone, low 1m above the bottom of the barnacle zone
2. Use a 5 x 2cm quadrat frame

Adults	Recruits
Semibalanus (1+ group)	*Semibalanus*
Chthamalus montagui	
Chthamalus stellatus	*Chthamalus* (Total)
Austrominius modestus	*Austrominius modestus*
Perforatus perforatus	
Balanus crenatus	

Counting Limpets and Associated Species

1. Count limpets at both *low* and *mid shore* levels
2. Use a 0.5 x 0.5 m quadrat. Where possible this should be strung at regular intervals to facilitate counting and estimation of % cover of barnacles.
3. Take at least 10 samples but not more than 20 at *each* shore height; the number should be consistent with habitat heterogeneity. True random sampling is unrealistic on a broken rocky shore hence samples should be stratified to encompass the full range of shore slopes
4. Areas with heavy shade, with pools and those that are heavily fissured should be avoided
5. Place the quadrat and record % cover of barnacles, mussels, dominant algae and bare rock. Record the number of individuals of *Phorcus lineatus, Steromphala umbilicalis* and *Nucella lapillus* present in the quadrat.
6. Count the total number of limpets >10mm. Recount to estimate the abundance of the less common species. Ticking animals using chalk is a simple way to ensure that counts and species identification are accurate and consistent. Confirm the identity of *Patella depressa* through checking all features (white tentacles, black foot, shell morphology). Where rare (i.e. at range edges) take reference photographs.

Counting Trochids

1. Count *Phorcus lineatus* and *Steromphala umbilicalis* in the region of the shore that they are most abundant. *Phorcus lineatus* occurs **upshore** of *Steromphala umbilicalis* for a large part of the year.
2. The aim is to record abundance/ structure of populations. As adults and year classes 0-2 often live in slightly different habitats a detailed search is required
3. Make 5 replicated timed counts of 3 minutes duration at each shore.
4. Select a small area in the region of the shore where the species is most abundant. Pick all individuals off visible surfaces and sample under stones and in cracks and crevices for the juveniles. Search using this method for 3 minutes and place all individuals into a bag. Remember to write the length of the search time on the form. Count the number of individuals and measure the basal diameter to the nearest 0.1mm using dial callipers.
5. In shores where there is a relatively uniform distribution of rocks < 30cm it is possible to use a $1m^2$ quadrat to sample trochids. If this sampling method is used the operator moves across the quadrat and collects all animals on the visible surfaces. Once done, each rock is turned over and a separate search is undertaken for the younger animals that seldom move far from damp locations. A substantial proportion of the population may well be under stones. Again count the number of individuals and measure the basal diameter to the nearest 0.1mm. In addition, up to five random 0.5x0.5m quadrats can be thrown randomly to provide backup for SACFOR estimates.

Before leaving, have one last walk around the sample site to confirm first impressions and please check that all equipment and cameras have been collected from the shore.

Site name:	……	Grid reference:	……
County:	……	Lat long of access point:	……
Date:	……	Lat long of centre of survey area:	……
Recorder:	……	Exposure	……
Weather conditions:	……	Low shore availability	……

Species	S	A	C	F	O	R	Not seen	Comments
Codium spp.								
Laminaria hyperborea								
Laminaria digitata								
Saccharina latissima								
Laminaria ochroleuca								
Alaria esculenta								
Himanthalia elongata								
Sargassum muticum								
Ascophyllum nodosum								
Pelvetia canaliculata								
Fucus spiralis								
Fucus vesiculosus								
Fucus serratus								
Fucus distichus								
Cystoseira spp.								
Halidrys siliquosa								
Bifurcaria bifurcata								
Mastocarpus stellatus								
Chondrus crispus								
Lichina pygmaea								
Undaria pinnatifida								
Dictyopteris polypodioides								
Dictyopteris cyanoloma								
Calliblepharis jubata								
Chondracanthus acicularis								
Asparagopsis armata								
Colpomenia peregrina								
Saccorhiza polyschides								
Grateloupia turuturu								
Palmaria palmata								
Heterosiphonia japonica								
Caulacanthus ustulatus (okamurae)								
Pikea californica								
Halichondria panacea								
Hymeniacidon perlevis								
Anemonia viridis								
Aulactinia verrucosa								
Actinia fragacea								
Actinia equina								
Diadumene (Haliplanella) lineata								
Sabellaria alveolata								
Chthamalus stellatus								
Chthamalus montagui								
Semibalanus balanoides								
Balanus crenatus								
Perforatus perforatus								
Austrominius modestus								
Pollicipes pollicipes								
Mytilus spp.								
Clibanarius erythropus								
Haliotis tuberculata								
Testudinalia testudinalis								
Patella vulgata								
Patella depressa								
Patella ulyssiponensis								
Patella pellucida								
Steromphala umbilicalis								
Steromphala pennanti								
Steromphala cineraria								
Phorcus lineatus								
Calliostoma zizyphinum								
Littorina littorea								
Littorina saxatilis agg.								
Melarhaphe neritoides								
Nucella lapillus								
Onchidella celtica								
Magallana gigas								
Crepidula fornicata								
Botrylloides violaceus								
Botrylloides diegensis								
Perophora japonica								
Corella eumyota								
Dendrodoa grossularia								
Asterocarpa humilis								
Didemnum vexillum								
Asterias rubens								
Leptasterias mulleri								
Paracentrotus lividus								
Strongylocentrotus droebachiensis								
Watersipora subatra								
Hemigrapsus sanguineus								
Hemigrapsus takanoi								

B: Barnacle count

Barnacle Count:		Recorder:	……

Quadrat size:	……	Lat long of centre of survey area:	……

Quadrat	Shore Height	% Cover barnacles	Adult count (1+)					Recruit count (O)			
			SB	CM	CS	EM	PP	SB		Total C	EM
								Cy	Sp		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

		Recorder:	……

Quadrat size:	……	Lat long of centre of survey area:	……

Quadrat	Shore Height	% Cover barnacles	Adult count (1+)					Recruit count (O)			
			SB	CM	CS	EM	PP	SB		Total C	EM
								Cy	Sp		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

		Recorder:	……

Quadrat size: …… Lat long of centre of survey area: ……

Quadrat	Shore Height	% Cover barnacles	Adult count (1+)					Recruit count (O)			
			SB	CM	CS	EM	PP	SB		Total C	EM
								Cy	Sp		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

C: Limpet Count

Shore height: …… Recorder: ……

Quadrat size: …… Lat long of centre of survey area: ……

Quadrat	x slope	% barnacles	% mussels	% algae	NL	OL	GU	Count		
								P. depressa	***P. vulgata***	***P. ulysipp***
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

D: Trochid Count: Recorder: ……

Quadrat/Timed Count: …… Lat long of centre of survey area: ……

Sample	Shore Height	Total Count	
		Phorcus lineatus	Steromphala umbilicalis
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Notes:

Appendix 3- Data Archive Appendix

Data outputs associated with this project are archived in [NRW to enter relevant corporate store and / or reference numbers] on server–based storage at Natural Resources Wales.

The data archive contains:

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

[E] A database named '**MarClim data Wales final 2022**' in Excel format with metadata described.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue https://libcat.naturalresources.wales (English Version) and https://catllyfr.cyfoethnaturiol.cymru (Welsh Version) by searching 'Dataset Titles'. The metadata is held as record no [NRW to insert this number]