MarClim Annual Welsh Intertidal Climate Monitoring Survey 2024

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Cefndir y prosiect

Mae'r adroddiad hwn yn crynhoi'r gwaith tirfesur, casglu data, a'r dadansoddi a gwblhawyd yn 2024 ar safleoedd rhynglanwol creigiog o gwmpas arfordir Cymru o dan brosiect â'r teitl MarClim, fel y'i disgrifir yn "Details for: Marine biodiversity and climate change. Assessing and predicting the influence of climatic change using intertidal rocky shore biota. Final report for United Kingdom funders › National Marine Biological Library catalog" Mieszkowska et al. (2005). Mae'r arolwg blynyddol yng Nghymru yn ffurfio rhan o arolwg parhaus, cyson dros 22 o flynyddoedd, sy'n cynnwys y DU gyfan, o dros 100 o safleoedd rhynglanwol creigiog hirdymor lle cynhelir gwaith tirfesur. 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 36 safle yn 2024.Cynhaliwyd arolygon ar 29 safle yng ngogledd Cymru, un safle yng nghanolbarth Cymru, a chwe safle yn ne Cymru.

Dulliau

Disgrifir y dulliau yn fanwl yn Adran 2. Cofnodir data SACFOR ar gyfer yr 82 rhywogaeth sydd ar restr MarClim. Cofnodir data cwadrat meintiol ar gyfer tair rhywogaeth o frennig, pedair rhywogaeth o gregyn llong, a chwblheir chwiliadau meintiol wedi'u hamseru ar gyfer dwy rywogaeth o falwod. Mae ecolegwyr o Cyfoeth Naturiol Cymru yn mynd i arolygon, ac y mae eu data arolwg, a'u technegau adnabod tacsonomaidd, yn cael eu traws-raddnodi gyda thîm MarClim.

Crynodeb o'r prif ganlyniadau

Ni ddarganfuwyd unrhyw effeithiau o'r cyfnodau o dywydd poeth yn 2023, na'r cyfnod o dywydd poeth ym mis Mai 2024 yn arolygon 2024. Er bod rhai rhywogaethau o wymonau codog glannau uchel a rhai rhywogaethau o algâu coch glannau canolig-isel unwaith eto wedi cael eu niweidio oherwydd gwres yn 2024, ni welwyd unrhyw farwolaethau, ac ni chafwyd unrhyw leihad yn y niferoedd mewn unrhyw safle.

Mae sawl rhywogaeth oresgynnol wedi ymddangos yma ac acw mewn safleoedd yn ne Cymru dros yr ychydig flynyddoedd diwethaf. Mae rhai o'r rhywogaethau wedi ymddangos mewn niferoedd bach mewn safleoedd am flwyddyn neu ddwy, ac yna'n diflannu o'r safleoedd hynny, ond yn parhau i fod yn bresennol yn y rhanbarth. Mae'r rhain yn cynnwys *Dasysiphonia japonica, Didemnum vexillum, Watersipora subatra* a *Botrylloides violaceus*. Cafodd wystrysen y Môr Tawel, *Magallana gigas,* ei chofnodi am y tro cyntaf yn hanes 19 mlynedd arolwg MarClim yn Aberffraw (Braich-lwyd) yn 2024. Cafwyd hyd i un o'r rhywogaeth hon yn Aberffraw, ac un yn Neyland, Aberdaugleddau, sef yr ail dro i'r rhywogaeth gael ei chofnodi yn y saith mlynedd diwethaf.

Arweiniodd yr amddiffynfeydd arfordirol artiffisial newydd a adeiladwyd ar hyd blaendraeth y Rhyl rhwng 2020 a 2021 at newid ecolegol erbyn 2023. I ddechrau, yr *Ulva intestinalis* oedd y rhywogaeth sylfaen drechaf, ond fe'i holynwyd gan y *Fucus spiralis*, sy'n addasu'r ecosystem, fel y rhywogaeth drechaf. Yn 2024 roedd poblogaeth y rhywogaeth hon wedi dyblu, gan ddangos cyfradd y newid ar gynefin caled rhynglanwol.

Casgliadau a phwyntiau trafod

Mae arolygon MarClim yn synhwyro newidiadau blynyddol mewn mesurau o helaethrwydd sy'n deillio o ddefnydd o ran rhywogaethau rhynglanwol creigiog. Mae'r rhain yn fetrig sensitif i dracio'r perygl sy'n cael ei beri i rywogaethau gan newid treiddiol yn yr hinsawdd a digwyddiadau thermol eithafol sy'n digwydd yn yr hinsawdd forol. Hefyd, gan fod nifer o safleoedd yn cael eu harolygu yn yr un rhanbarth, gellir synhwyro aflonyddwch ar raddfa fach, fel difrod sgrafelliadau gan symudiadau lleol graean bras yn ystod stormydd yn erbyn patrymau mwy y newid i rywogaethau morol a yrrir gan yr hinsawdd.

Ni newidiodd y cyfansoddiad cymunedol yn aruthrol yn 2024 o gymharu â blynyddoedd diweddar mewn unrhyw safle arolwg. Mae arolygon blynyddol MarClim yn tracio'r cytrefiad, a'r gyfradd ac ehangder ymledu, ond hefyd yn nodi pan fo rhywogaethau anfrodorol yn bresennol, neu'n absennol, mewn safle fel y crybwyllwyd uchod. Roedd cyfansoddiad cymunedol safleoedd yng ngogledd Cymru yn fwy tebyg i'w gilydd na'r rhai yn ne Cymru, gyda llai o rywogaethau yn bresennol ar safleoedd yng ngogledd Cymru. Mae hyn hefyd yn adlewyrchu'r duedd hirdymor o ran amlder a niferoedd rhywogaethau.

Cyflawnwyd gwaith traws-raddnodi gyda Paul Brazier, Mark Burton, Kate Lock, Jen Jones, Ali Massey, a Kathryn Birch o Cyfoeth Naturiol Cymru ar arolygon MarClim Cymru. Mae croes-raddnodi rheolaidd rhwng tirfesurwyr yn sicrhau bod modd cymharu data ar draws tirfesurwyr, safleoedd a blynyddoedd.

Mae Mieszkowska, fel siaradwr gwadd, wedi cyflwyno'r Prosiect MarClim yng nghynhadledd flynyddol 2024 Fframwaith Arsylwi Amgylcheddol y DU (UKEOF) ar 'Newid yn yr hinsawdd: tystiolaeth ac effeithiau ar amgylchedd ac adnoddau'r DU'. Yn ogystal, cyflwynodd Sugden a Mieszkowska y Prosiect MarClim i Grŵp Llywio Newid Hinsawdd Cynghrair Morol yr Alban ar gyfer Gwyddoniaeth a Thechnoleg (MASTS) ym mis Ebrill 2024.

Executive summary

Background to the project

This report summarises the 2024 rocky intertidal survey work, data and analysis completed around the coastline of Wales under the project title of MarClim, as described in "Details for: Marine biodiversity and climate change. Assessing and predicting the influence of climatic change using intertidal rocky shore biota. Final report for United Kingdom funders › National Marine Biological Library catalog" Mieszkowska et al. (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 36 sites in 2024. Twenty nine sites were surveyed in north Wales, one in mid Wales, and six 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. Ecologists from Natural Resources Wales attend surveys and their survey data and taxonomic identification techniques are cross-calibrated with the MarClim team.

Summary of key results

No effects of the 2023 heatwaves or the May 2024 heatwave were found in the 2024 surveys. Whilst some species of high shore fucoids and some mid-low shore red algae once again showed heat damage in 2024, no mortalities were seen and there were no reductions in abundance at any site.

Several invasive species (NIS) have shown sporadic occurrences at sites in south Wales over the past few years, with some species appearing in small abundances at sites for one or two years, then disappearing from those sites but still being present in the region. These include *Dasysiphonia japonica, Didemnum vexillum, Watersipora subatra* and *Botrylloides violaceous*. The Pacific oyster *Magallana gigas* was recorded for the first time in the 19 year survey history of MarClim at Aberffraw (Braich-Lwyd) in 2024. One individual was found at Aberffraw, and one individual at Neyland, in Milford Haven, the second occurrence in the past seven years.

The new artificial coastal defences built along the foreshore at Y Rhyl between 2020 and 2021 showed succession in 2023 from dominance by foundation species (*Ulva intestinalis*) to an ecosystem engineer, *Fucus spiralis*. In 2024 the abundance of this species had doubled, demonstrating the rate of succession on intertidal hard habitat.

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.

Community composition did not massively change in 2024 compared to recent years at any survey site. MarClim annual surveys track colonisation, the rate and extent of spread, but also fluctuating occurrences and absences of NIS as mentioned above. Community composition of sites in north Wales showed greater similarity to each other than those in south Wales, with fewer species being present at sites in north Wales. This also echoes the long-term trend in species occurrence and abundance.

Cross-calibration with Paul Brazier, Mark Burton, Kate Lock, Jen Jones, Ali Massey, and Kathryn Birch from Natural Resources Wales was carried out on Welsh MarClim surveys. Regular cross-calibration between surveyors ensures comparability of the data across surveyors, sites, and years.

Mieszkowska has presented the MarClim Project at the 2024 UKEOF annual conference on Climate change: evidence and impacts on UK environment and resources as an invited speaker, and Sugden and Mieszkowska are presenting the MarClim Project at the **MASTS** Marine Alliance for Science and Technology for Scotland Climate Change Steering Group in April 2024.

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.

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 them early warning indicators of environmental change.

Southward and Prof. Dennis 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. J. R. 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.

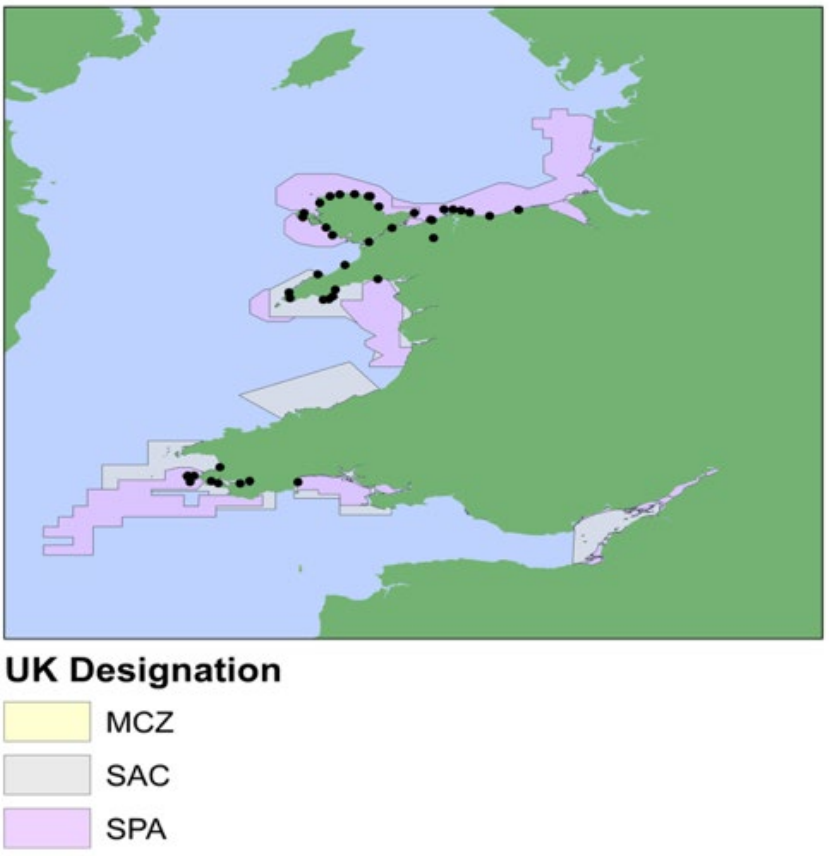
The project focuses on a robust set of temperature-sensitive, readily observed, intertidal climate indicator species of invertebrates and macroalgae for which long-term data sets and monitoring sites are available. The MarClim species list includes boreal cold-water and Lusitanian warm-water origins, 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-native species are also targeted due to their appearance and subsequent impacts on natural communities after introduction via escapes of associated spat from aquaculture facilities and practices.

MarClim data have 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 2024



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 seven sites in 2024 (Table 1, Figure. 1). Twenty nine rocky shores in north Wales were surveyed by Dr. Nova Mieszkowska from The Marine Biological Association, Dr. Heather Sugden from Newcastle University, and

Kathryn Birch from Natural Resources Wales. Eight sites were surveyed in central and south Wales including on Skomer and Skokholm Islands. These surveys were carried out and cross-calibration exercises undertaken by Nova Mieszkowska from the MBA, Mark Burton, Kate Lock, Jen Jones and Alison Massey of NRW (Figure 2). Data entry was completed by Nova Mieszkowska with QA by Paul Brazier.

Figure 2. Mark Burton and Alison Massey from NRW completing topshell measurements

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 3) 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 4). 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* in 2012 and *Phorcus lineatus* in 2016 and is now surveyed each year. The Y Rhyl 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 3. A 5 cm x 2 cm subsection of the 5 x 5 cm 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.

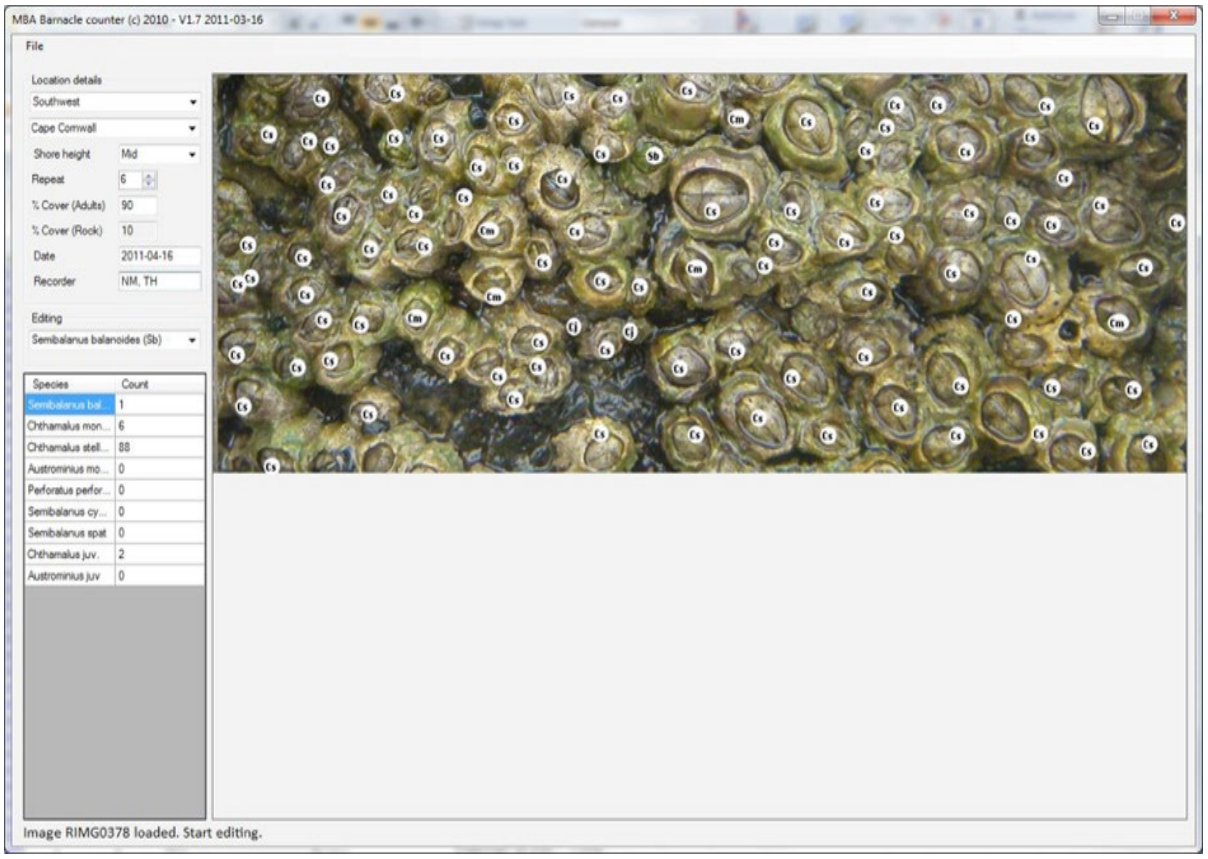


Figure 4. MarClim 0.25 m^2 limpet quadrat used for surveys

Table 1. MarClim survey site locations 2024

Day	Month	Year	Site	Grid	Lat (WGS84)	Long (WGS84)
21	7	2024	Rhyl Splash Point	SJ021824	53.3299	-3.4715
21	7	2024	Llanddulas	SH906787	53.2933	-3.6296
21	7	2024	Rhos-on-Sea	SH843805	53.3114	-3.7381
21	7	2024	Little Orme	SH812825	53.3260	-3.7852
21	7	2024	Great Orme Trwynygogarth	SH749834	53.3327	-3.8801
21	7	2024	Great Orme East	SH782832	53.3321	-3.8297
21	7	2024	Penmaenmawr Natural	**SH704763**	53.2674	-3.9440
22	7	2024	Trefor	SH376474	52.9992	-4.4215
22	7	2024	Caernarfon (Aber Foreshore Road)	SH521671	53.1374	-4.2897
22	7	2024	Penmon North	SH641813	53.3111	-4.0413
22	7	2024	Menai Bridge	SH555714	53.2207	-4.1643
22	7	2024	Broad Haven	SM859144	51.7871	-5.1057
23	7	2024	Bull Bay	SH427945	53.4238	-4.3688
23	7	2024	Moelfre	SH513859	53.3490	-4.2354
23	7	2024	Porth Eilian	SH484929	53.4111	-4.2823
23	7	2024	Point Lynas	SH477929	53.4109	-4.2928
23	7	2024	Holyhead	SH257825	53.3108	-4.6461
23	7	2024	Porth Swtan	SH298891	53.3713	-4.5598
23	7	2024	Martin's Haven	SM759091	51.7357	-5.2471
24	7	2024	North Haven	SM735093	51.7365	-5.2819
24	7	2024	Rhosneigr	SH315725	53.2233	-4.5253

Day	Month	Year	Site	Grid	Lat (WGS84)	Long (WGS84)
24	7	2024	Cemlyn	SH337934	53.4146	-4.5112
24	7	2024	Aberffraw (Braich-Lwyd)	SH337674	53.1776	-4.4899
26	7	2024	Porth Oer	SH163297	52.8344	-4.7256
26	7	2024	Nefyn	SH335311	52.8516	-4.4742
26	7	2024	Aberdaron	SH166260	52.8003	-4.7220
26	7	2024	Criccieth Castle	SH494376	52.9146	-4.2412
26	7	2024	Criccieth (East)	SN582828	52.4247	-4.0869
27	7	2024	Porth Ceriad	SH308247	52.7938	-4.5094
27	7	2024	Abersoch Lifeboat Station	SH323265	52.8107	-4.4881
27	7	2024	Porth Neigwl	SH288245	52.7908	-4.5404
27	7	2024	Llanbedrog	SH335311	52.8516	-4.4742
19	8	2024	Aberystwyth	SN582828	52.4247	-4.0869
20	8	2024	Monkstone Point	SN150033	51.6978	-4.6784
21	8	2024	South Haven	SM733088	51.7319	-5.2845
22	8	2024	Neyland Natural (by Brunel Wall)	SM967047	51.7045	-4.9433
24	8	2024	Skokholm South Haven	SM741051	51.6992	-5.2701

Results

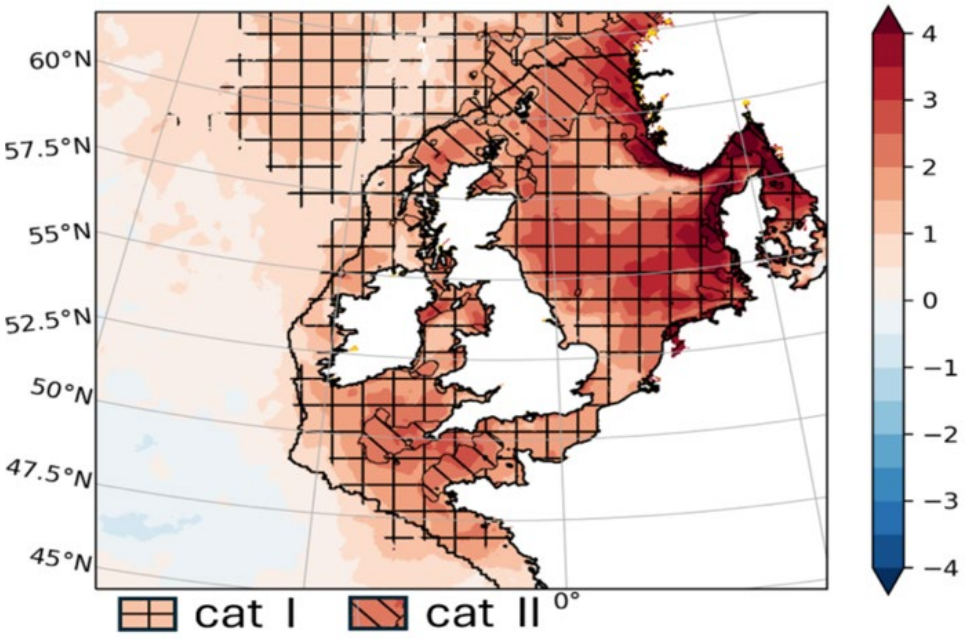
Climate change and extreme events

May 2024 was the warmest on record for UK mean temperature, and the average temperatures in both May and the wider Spring season in 2024 broke previous records in a series dating back to 1884 (Berthou et al. 2024).

Marine heatwaves are defined as periods of at least 5-days exceeding the 90th percentile of sea surface temperature (SST), calculated from the first 30-years of the satellite observation period (1982-2012). They are then categorized on a scale of I (moderate) to IV (extreme) based on deviation from local climatology. For the waters around the UK in May, the marine heatwave threshold is 11.3°C. The SSTs around the UK were nearly 1°C above this threshold in May 2024 (Figure 5). The SSTs in 2024 started warm, with an anomaly close to a category I marine heatwave, this warm anomaly persisted until the start of May, when it amplified and reached marine heatwave status. This marine heatwave lasted for the whole month of May and the first week of June. It peaked to category II on the week of 18th-24th May (Berthou et al. 2024).

The heatwave in 2024 follows on from an increase in the frequency and intensity of marine heatwaves in the UK. 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). Heatwaves occurred in June and in September, when there was a record breaking heatwave event in the UK which was the longest in September exceeding 30°C on record (https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2023/2023_05_september_heatwave.pdf).

Figure 5. Sea surface temperature anomaly for 18-25th May from 1982-2012 climatology. Squared hatches: marine heatwave category I, backslashes: marine heatwaves category II. 18-25 May is peak week of Marine Heatwaves (from Berthou et al. 2024).

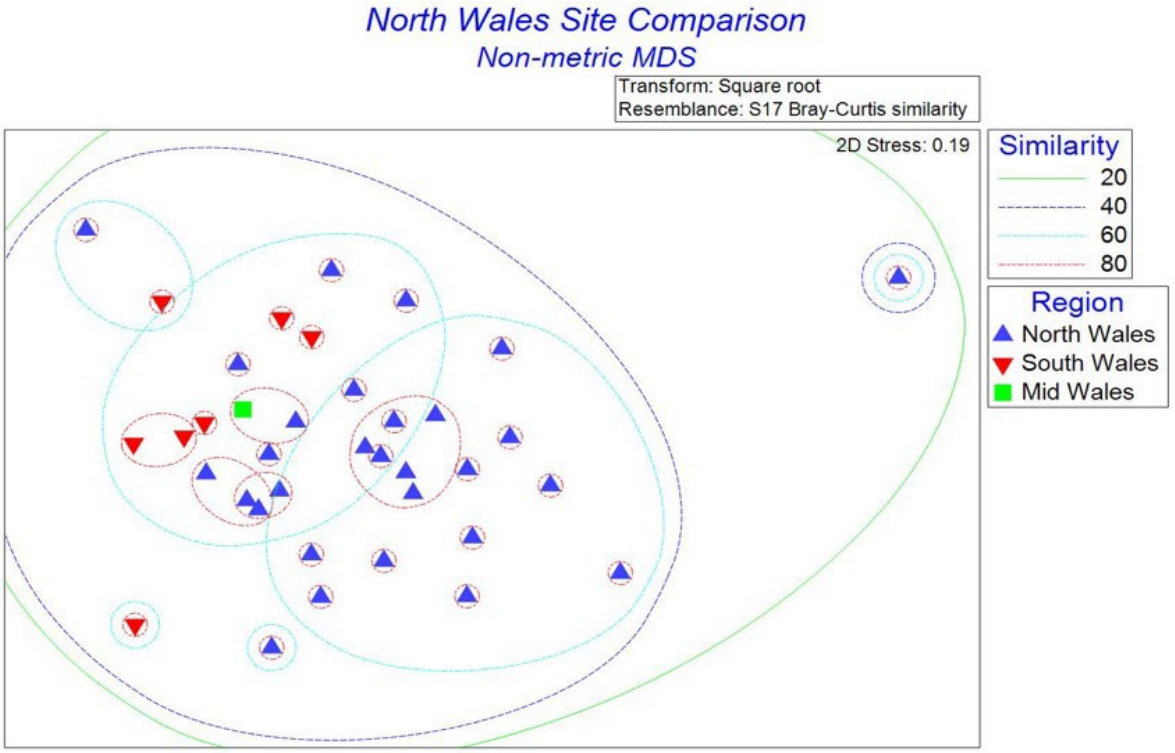


There has been an increase in heat extremes and humid heat extremes, a decrease in cool extreme air temperatures, and an increase in extreme precipitation over the past few decades (Berthou et al. 2024). There has also been an increase in marine heat waves and a decrease in marine cool waves over the past four decades. 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.

Community Composition at Sites Across Wales

Data from all 82 species on the MarClim protocols list were analysed to look for biogeographic trends or groupings along the coastline of Wales (Figure 6). In 2024 sites across the Welsh coastline showed a high degree of similarity in community composition and species abundances. North Wales sites showed a high degree of similarity with each other (60%) with the exception of Y Rhyl Splash Point (outlier triangle in the far right of the plot), a new artificial structure that was constructed between 2021-2022. This sea defence showed signs of early community establishment by high shore species. In addition, this structure does not extend below high shore, so many rocky intertidal species will not be able to colonise this structure due to the extended emersion time within each tidal cycle. SIMPER analysis shows that the species contributing most to the similarity between sites are a mix of Boreal and Lusitanian species. In descending order of contribution, *S. balanoides, P. vulgata, F. spiralis, N. lapillus, S. umbilicalis, P. canaliculata,* and *F. vesiculosus* comprise 50% of the contribution to average similarity between the north Wales sites.

Figure 6. MDS plot of community composition at MarClim sites



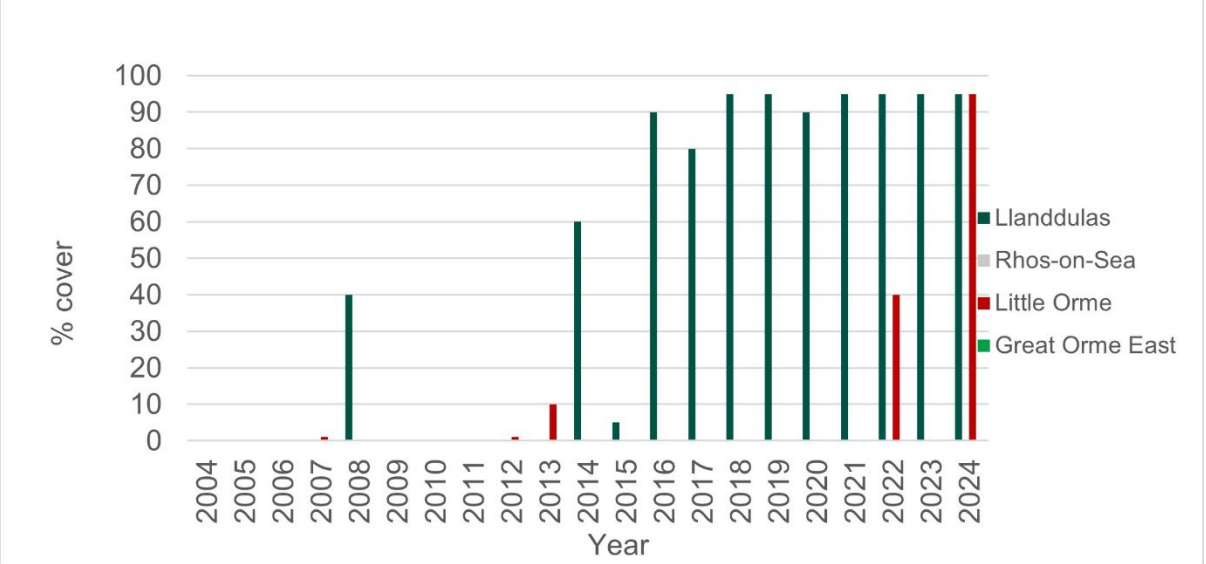
Sites in south Wales also show clustering of up to 60% similarity with each other (Figure 6). SIMPER analysis identifies the key species as *P. lineatus, S. umbilicalis, P. vulgata, F. vesiculosus, M. neritoides, C. montagui, N. lapillus, L. littorea, F. serratus*, and *S. balanoides*. These are the same species that made the greatest contributions to community similarities in north Wales, with the exception of *P. lineatus,* which reaches the leading range edge in north Wales and is not as abundant at sites in comparison to south Wales.

Range Extensions and Records of Transient Occurrences

MarClim tracks changes in the leading range edge of species that reach their distributional limits in Wales in response to climate change. Annual population surveys for all species on the MarClim list allow shifts to be tracked in real time, show changes in population dynamics across longer time periods, identify established populations that are steadily increasing, as well as those that have fluctuating abundances.

The honeycomb worm *Sabellaria alveolata* has sporadic records at MarClim sites on the northern coast of north Wales across the past two decades. In 2024 the coverage of the two-dimensional reef at Llanddulas that was present between mid and low shore was 95%, the same abundance as for the past seven out of eight years (Figure 7). The time-series data show that this reef has become established at Llanddulas over the past decade. It has not been recorded at two MarClim sites to the west, Rhos-on-Sea and Great Orme East since the time-series started in 2002, however, it had been recorded in low densities in 2007, 2012, and 2013, before disappearing. In 2022 a two dimensional reef with 40% coverage was recorded at Little Orme. It was not seen in 2023, however, there was 90% coverage of the midshore in 2024 in the region where the boulder field begins, approximately 200m from the cliff at Little Orme (Figure 7).

Figure 7. Percent cover of *Sabellaria alveolata* in reefs on north coast mainland shores in north Wales.



Sabellaria alveolata reef is listed as a Priority Habitat under Section 7 of the Environment (Wales) Act 2016 within the category of 'Littoral Rock' (NRW 2021). Time-series data for this species can inform understanding of long-term population dynamics and provide information to help manage this Priority Habitat.

Table 2. SACFOR and abundance data for *Phorcus lineatus* at Little Orme.

Year	SACFOR	Number of individuals per min search
2004	NS	
2005	NS	
2006	NR	
2007	NS	
2008	NS	
2009	R	0.07
2010	R	
2011	NS	
2012	NS	
2013	NS	
2014	NS	
2015	NS	
2016	NS	
2017	NS	
2018	NS	
2019	NS	
2020	NS	
2021	NS	
2022	NS	
2023	NS	
2024	O	0.66

Figure 8. *Phorcus lineatus*, Little Orme 2024

The toothed topshell *Phorcus lineatus* was also found at Little Orme in 2024 for the first time in 14 years (Figure 8). In 2024 ten individuals were found across five

replicate searches, each of three minutes duration. In both 2009 and 2010 only one individual was found in the five replicate three minute searches carried out in each year, with none found in intervening years until 2024 (Table 2).

Non Indigenous Species

MarClim records eight species of macroalgal 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).

No *Dasysiphonia japonica* was recorded in 2024. It was first recorded by MarClim at Monkstone Point in 2016 (Common), and the only record in north Wales at a MarClim site was Menai Bridge (Occasional) in 2020. These sporadic records of low coverage suggest that there are a few populations being maintained around the Welsh coastline and that there are temporary colonisations of shores that do not appear to be sustained over multiple years.

The invasive Pacific oyster, *Magallana gigas* was recorded for the first time in the 19 year survey history of MarClim at Aberffraw (Braich-Lwyd) in 2024. One individual adult was found at midshore. The only other MarClim site in Wales where it was recorded as Rare (1 individual) in 2024 was Neyland, in Milford Haven. In 2021 one individual was found at Neyland, however, it has not been recorded here in any other year since the first MarClim survey at this site in 2017.

The invasive colonial tunicate *Didemnum vexillum* was recorded at Neyland Spit (Natural shore) in Milford Haven estuary in 2023, but was not found in 2024 despite a thorough search by five people. Samples barcoded at the Marine Biological Association confirmed the identity of this species at Neyland in 2023. It was, however, Superabundant at Carr Rocks in Pembrokeshire (Figure 9).

Caulacanthus ustulatus (*okamurae*) was found in a range of abundances from Occasional at Broad Haven to Abundant at South Haven in 2024. This species was not seen at any MarClim sites in mid or north Wales in 2023, nor in 2024. In 2024 it was Frequent at Martin's Haven and North Haven, Abundant (50%) at South Haven and Frequent at Skokholm South Haven, suggesting that small populations are appearing at multiple sites each year.

The only MarClim site where *Botrylloides violaceous* was recorded in 2024 was at Neyland (Rare). *Botrylloides violaceous* was Rare at Jetty Beach Dale in 2023. This is the first record since 2015 at this site, and it was not seen in 2024. This suggests a small, potentially transient population that is either repopulated from the subtidal zone or from intertidal areas not surveyed by MarClim.

Figure 9. *Didemnum vexillum* at Carr Rocks, Pembrokeshire (image Mark Burton)

Artificial Coastal Defences

Natural Resources Wales' Well-being Objective 2: *Communities are resilient to climate change* includes the risks of climate change being managed and adapted includes in the steps to take: 'Reducing the risk to life from flooding through managing our flood assets and infrastructure for current and future flood risk and planning for change through maintaining and adapting the flood assets and infrastructure we are accountable for (Natural Resources Wales / Business plan 2026-27). The Measure 'Maintain flood risk assets in high-risk systems at target condition' includes repairing and/or construction of new flood defences including artificial sea walls such as the Y Rhyl foreshore. New artificial coastal defences were built all along the foreshore at Rhyl Splash Point between 2020 and 2021.

In 2002, this wall had begun to be colonised by the ephemeral algae *Ulva intestinalis* and *Porphyra umbilicalis*. In 2023, early colonising ephemeral algae recorded initially in 2022 had been supplemented by *Fucus spiralis* Abundant 50% on artificial boulders, *Austrominius modestus* Superabundant 90%, *Semibalanus balanoides* Common 30%, and *Littorina littorea* Rare (Figure 10). In 2024 *F. spiralis* had increased to Superabundant with 100% coverage of the upper shore on the artificial boulders placed at high shore as part of the 2020/21 rebuild of the coastal defences (Figure 11). This demonstrates the speed at which foundation species can be outcompeted by ecosystem engineer species such as *F. spiralis*.

Figure 10. New artificial coastal defence structure at Rhyl with Abundant *F. spiralis* in 2023

Figure 11. New artificial coastal defence structure at Rhyl with Superabundant *F. spiralis* in 2024

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 during and after 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. MarClim surveys in future years will track these populations to see if this decline continues in the mid to long-term.

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 2024 (no change against the baseline). The only evidence of anthropogenic impacts was the presence of NIS at thirty one sites across Wales. Most of these sites only contained *A. modestus* and/or *S. muticum*, and none were new colonisations in 2024. *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.

Didemnum vexillum is still present along the shorelines of Milford Haven estuary, however, it was not found at Neyland Point despite a thorough search by several people in 2024. NIS other than *A. modestus* and *S. muticum* appear to have sporadic occurrences and form transient, low populations that appear and disappear from sites across the time-series, but maintain a presence at neighbouring sites or shores that are not recorded as

part of MarClim (e.g. surveys carried out by the Skomer Marine Conservation Zone (MCZ) team).

Conclusions

A reduction in the abundance of the boreal barnacle *Semibalanus balanoides* has been noted at several sites in Pembrokeshire in both 2023 and 2024. This echoes a decline in the abundance of this species on MarClim sites around southwest England, and will be monitored closely in future years. The large spatial scale of this reduction suggests climate change is the likely factor driving a decline in this cold water species.

No acute changes in community composition recorded at any MarClim shore in 2023, and abundances of both Lusitanian warm water and Boreal cold water species did not show large changes from 2022 surveys. Lusitanian species were still present at leading range edge sites in Wales in 2024. Heatwave events occurring in 2022, 2023, and 2024 did not have any long-lasting impacts on rocky intertidal species at MarClim sites.

A population of the honeycomb worm *S. alveolata* was recorded at Little Orme for the first time in several years in 2022. It was not seen in 2023 but was present again in 2024. *S. alveolata* was still present as flat and three-dimensional reefs at Llanddulas (Superabundant) and this is the likely source population for the transient population at the Little Orme.

The abundance and distribution of *Didemnum vexillum* in south Wales has changed slightly in the last twelve months, with it not being found at the MarClim site at Neyland in 2024. Additional surveys carried out by the Skomer MCZ team in 2024 have, however, found it at other sites within the Milford Haven estuary again in 2024. *Caulacanthus ustulatus* was recorded at sites on Skomer and Skokholm islands in 2024, and these new populations suggest that the species is getting a foothold in south Wales and needs continual monitoring to track colonisation and spread in future years.

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.
- Cefas has engaged Mieszkowska in the development of the Marine Warming Pathways project in 2024, which also used data from the MarClim time-series. Phase 2 is anticipated to be carried out in 2025.
- 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: https://hub.jncc.gov.uk/assets/dd8c7802-0faa-428d-a0d2-3550fa21c827. 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 Marine Strategy GES indicator development process was developed by

the MarClim team in 2017 (Burrows, Hawkins & Mieszkowska 2017), and an update was prepared for JNCC in 2024 (Burrows & Mieszkowska 2024).

- 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 dataset has been used in an assessment of British Seaweeds as part of an evaluation of the IUCN Red List for non-standard marine organisms (Brodie et al. 2023).

References

Berthou, S., Holliday, R., Pirret, J. & Wallace, A. (2024). Investigating driving factors for the UK-average temperatures in May 2024: A study of the impact of local sea surface temperatures and of climate change. Met Office Hadley Centre pp. 34 https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/climate-science/attribution/rapidattributionsummary_may2024_v2.pdf.

Brodie, J., Wilbraham, J., Maggs, C.A., Baldock, L., Bunker, F., Mieszkowska, N., Scanlan, C., Tittley, I., Wilkinson, M., & Yesson, C. (2023). Red List for British seaweeds: evaluating the IUCN methodology for non-standard marine organisms. Biodiversity and Conservation: 1-19. https://doi.org/10.1007/s10531-023-02649-0 .

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. https://doi.org10.1038/s41558-019-0631-5 .

Burrows, M.T. & Mieszkowska, N. (2024). UK Marine Strategy Assessment. Intertidal Community Index. Report for the Joint Nature Conservation Committee. Pp 25.

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.

Hawkins, S. J., Burrows, M. T., & Mieszkowska, N. (2023). Shoreline sentinels of global change show the consequences of extreme events. Global Change Biology 29(1): 7-9 https://doi.org/1.1111/gcb.16477 .

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.

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

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.

National Oceanic and Atmospheric Administration https://www.ncdc.noaa.gov/cdo-web/.

Natural Resources Wales 2021. Benthic habitat assessment guidance for marine developments and activities. Guidance Note Reference number: GN030d, pp66 https://naturalresources.wales/media/695526/gn030d-sabellaria-final-accessible.pdf.

Natural Resources Wales. 2026. Natural Resources Wales / Business plan 2026-27.

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.

Prentice, M.B., Vye, S.R., Jenkins, S.R., Shaw, P.W. & Ironside, J.E. (2021). Genetic diversity and relatedness in aquaculture and marina populations of the invasive tunicate *Didemnum vexillum* in the British Isles. *Bio*logical Invasions, 23(12), pp.3613-3624 https://doi.org/10.10007/s10530-021-02615-3.

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.

Salonna, M., Gasparini, F., Huchon, D., Montesanto, F., Haddas-Sasson, M., Ekins, M., McNamara, M., Mastrototaro, F. and Gissi, C., 2021. An elongated COI fragment to discriminate botryllid species and as an improved ascidian DNA barcode. Scientific reports, 11(1), p.4078.

Appendix 1 - MarClim Sampling Protocols 2024

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

7. 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.
8. 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
9. Make 5 replicated timed counts of 3 minutes duration at each shore.
10. 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.
11. In shores where there is a relatively uniform distribution of rocks < 30cm it is possible to use a 1m2 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 details	**Notes**
Site name:	---
County:	---
Date:	---
Recorder:	---
Weather conditions:	---
Grid reference:	---
Lat long of access point:	---
Lat long of centre of survey area:	---
Exposure	---
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								

Species	S	A	C	F	O	R	Not seen	Comments
Paracentrotus lividus								
Strongylocentrotus droebachiensis								
Watersipora subatra								
Hemigrapsus sanguineus								
Hemigrapsus takanoi								

B: Barnacle count

Barnacle Count: **Recorder:** **x**

Quadrat size: x **Lat long of centre of survey area: x**

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

Recorder: x

Quadrat size: x **Lat long of centre of survey area: x**

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

Recorder: x

Quadrat size: x **Lat long of centre of survey area: x**

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

C: Limpet Count

Shore height: x Recorder: x

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

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

D: Trochid Count: x Recorder: x

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

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

Notes:

Appendix 2- 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.

[B] A database named '**MarClim data Wales final 2024**' in Excel format with metadata described.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue Search - Soutron LMS (English Version) and Chwiliad - Soutron LMS (Welsh Version) by searching the Catalogue.

Further copies of this report are available from library@cyfoethnaturiolcymru.gov.uk