Cyfoeth Naturiol Cymru
Natural Resources Wales

THE MARINE BIOLOGICAL ASSOCIATION

MarClim Annual Welsh Intertidal Climate Monitoring Survey 2020

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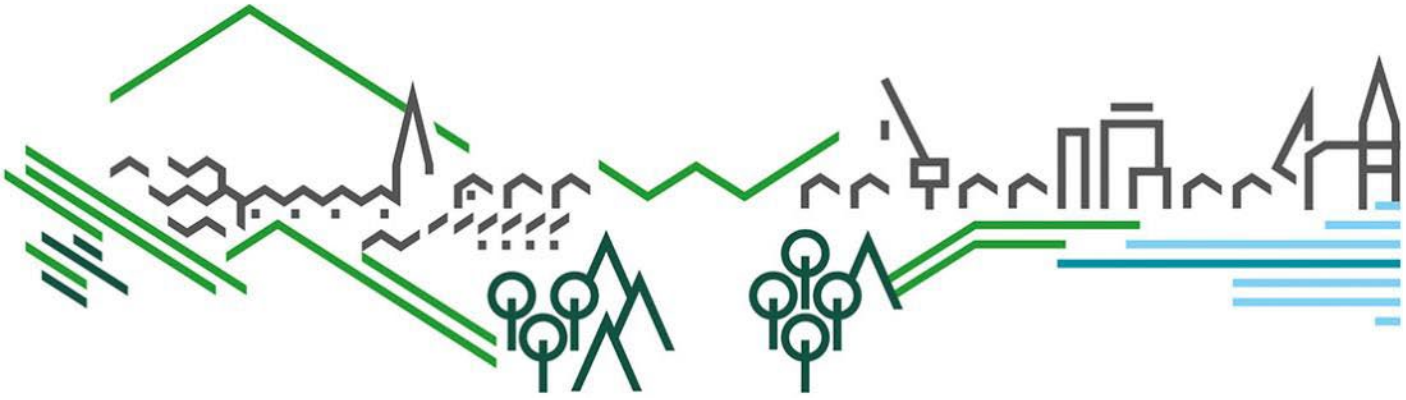

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Crynodeb Gweithredol

Mae'r adroddiad hwn yn crynhoi'r gwaith arolygu, casglu data a dadansoddi a gwblhawyd yn 2020 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 15 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 36 safle yn 2020. Cynhaliwyd arolygon ar 27 safle yng ngogledd Cymru a 9 safle yn ne Cymru.

Dulliau

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 prif ganlyniadau

- Ar ôl y tywydd poeth hanesyddol yn ystod hafau 2018 a 2020, cofnododd arolygon MarClim ddifrod gwres lled angheuol mewn macroalgâu mewn rhai safleoedd.
- Yn 2020, roedd terfyn fertigol uwch cwmpas gwyrain wedi symud am i lawr yn y lan uchel yn Rhiwledyn a Phorth Oer, ac roedd terfyn fertigol is cwmpas gwyrain wedi symud am i fyny yn y lan isel ger Castell Cricieth. Mae'n debygol bod y colledion hyn o ganlyniad i sgrafelliadau tywod a graean bras yn cael gwared ar wyrion sydd wedi setlo o gyrion pellaf y dosbarthiadau fertigol yn y tri safle.
- Mewn perthynas â blynyddoedd blaenorol, roedd cwmpas macroalgâu wedi cynyddu ar y maes cerrig crynion ym Moelfre, ac ar y lan isel yng Nghemaes.
- Neyland Point oedd â'r nifer uchaf o rywogaethau estron a gofnodwyd mewn unrhyw safle MarClim, gyda *Undaria pinnatifida, Magallana gigas, Crepidula fornicata* a *Botrylloides violaceus* oll yn bresennol.
- Roedd y rhywogaeth estron *Sargassum muticum* yn tyfu ar garreg agored yng ngorsaf bad achub Abersoch. Dyma'r cofnod cyntaf o *S. muticum* ar y safle hwn, ac mae'n anarferol dod o hyd i'r rhywogaeth yn tyfu ar garreg agored mewn lleoliad mor ogleddol yn y DU.

Casgliadau a phwyntiau trafod

Mae arolygon MarClim yn synhwyro newidiadau blynyddol mewn mesurau o helaethrwydd sy'n deillio o ddefnydd ar gyfer rhywogaethau rhynglanwol creigiog. Mae'r rhain yn fetrig sensitif i dracio'r perygl a berir i rywogaethau gan newid treiddiol yn yr hinsawdd, digwyddiadau thermol eithafol sy'n digwydd yn yr hinsawdd forol, a 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 digwyddiadau storm yn erbyn patrymau ar raddfa fwy o newid i rywogaethau morol a yrrir gan yr hinsawdd. Mae rhywogaethau rhynglanwol tymherus yn gallu goddef cyfnodau byr o wres eithafol neu dywydd oer, ac maent yn fwy ymatebol i newidiadau treiddiol yn yr hinsawdd sy'n digwydd ar draws amserlenni degawdol, gan ddylanwadu perfformiad yn y pen draw o ran twf ac allbwn atgynhyrchiol sy'n arwain at recriwtio.

Gellir tracio'r cytrefu a'r gyfradd ac ehangder lledaeniad rhywogaethau estron drwy arolygon blynyddol MarClim. Gellir hefyd fonitro'r effeithiau ar rywogaethau brodorol yn y gymuned sy'n cael eu cytrefu gan rywogaeth estron dros nifer o flynyddoedd er mwyn synhwyro unrhyw newidiadau i fioamrywiaeth ranbarthol a lleol.

Arwyddocâd canlyniadau ac ymarfer yn y dyfodol

Mae gwybodaeth am brosiect MarClim a'r data gwyddonol a gesglir ganddo'n cael eu trosglwyddo i sefydliadau'r llywodraeth, staff, asiantaethau cadwraeth, rheolwyr Ardaloedd Cadwraeth Arbennig (ACAau) a Safleoedd o Ddiddordeb Gwyddonol Arbennig (SoDdGAau) morol a'r cyhoedd er mwyn cynyddu gwybodaeth, dealltwriaeth ac adrodd ynghylch cwestiynau sy'n wyddonol, rheolaethol a chymdeithasol bwysig mewn perthynas â newid hinsawdd byd-eang, asideiddio'r cefnforoedd ac effeithiau dynol ar raddfa lai ar yr amgylchedd morol, gan gynnwys datblygu, anheddu ac ymelwa ar y parth morol, ecosystemau cydrannol a rhywogaethau. Defnyddir MarClim i asesu a llywio polisïau a chyfarwyddebau'r DU a'r UE, gan gynnwys Cyfarwyddeb Fframwaith Strategaeth Forol yr UE, Canllawiau Llywodraethu PEGASEAS, Asesiadau Cyflwr ar gyfer ACAau a SoDdGAau a Safleoedd Morol Ewropeaidd, ac fel data gwaelodlin ar gyfer proses dynodi Parthau Cadwraeth Morol y DU.

Cafodd set ddata cyfres-amser MarClim ei datblygu gan Mieszkowska, Burrows a Hawkins (2013) o dîm MarClim fel Dangosyddion Statws Amgylcheddol Da ar gyfer Cyfarwyddeb Fframwaith y Strategaeth Forol, gyda'r adroddiad cyntaf wedi'i gyhoeddi yn 2014: http://jncc.defra.gov.uk/page-6813. Datblygwyd ail gam o waith er mwyn datblygu cyfres-amser MarClim fel dangosyddion newid hinsawdd rhywogaethol (Mynegai Tymheredd Rhywogaethau) a chymunedol (Mynegai Tymheredd Cymunedau) fel rhan o'r broses datblygu dangosyddion Statws Ecolegol Da Cyfarwyddeb Fframwaith y Strategaeth Forol gan dîm MarClim yn 2017 (Burrows, Hawkins a Mieszkowska 2017). Mae prosiect a thîm ymchwil MarClim yn darparu monitro unigryw, hanfodol, tymor hir a data ymchwil ac arbenigedd gwyddonol. Mae'r rhain yn cael eu defnyddio gan gyrff cadwraeth natur statudol y DU i fynd i'r afael â chyfarwyddebau polisi cenedlaethol ac Ewropeaidd ar raddfa fawr, gan gynnwys Cyfarwyddeb Fframwaith Strategaeth Forol yr UE, Cyfarwyddeb Cynefinoedd yr UE, Cyfarwyddeb Fframwaith Dŵr yr UE, Asesiadau Comisiwn OSPAR, a phroses dynodi Parthau Cadwraeth Morol y DU fel rhan o Ddeddf y Môr a Mynediad i'r Arfordir.

Mae'r tîm MarClim wedi cyhoeddi papur ar effeithiau digwyddiadau tywydd eithafol a newid treiddiol yng ngororau ecoleg morol (Mieszkowska ac eraill, 2021). Mae'r papur yn arddangos gwerth cyfres-dreigl tymor hir gydag ehangder daearyddol mawr yn synhwyro newidiadau tymor byr, llym yn erbyn symudiadau tymor hwy a yrrir gan yr hinsawdd mewn rhywogaethau o amgylch arfordir y DU. Mae'r papur hwn yn cynnwys gwybodaeth o safleoedd yr arolwg MarClim Cymru a'r rhywogaethau a gofnodwyd yno.

Executive Summary

This report summarises the 2020 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, fifteen-year, continuous annual UK survey of over 100 long-term rocky intertidal survey sites. Geographical coverage includes sites throughout north and southwest 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 Wales in 2020. 27 sites were surveyed in north Wales and 9 sites in south Wales.

Methods

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

- After the record heatwaves in the summers of 2018 and 2020, MarClim surveys recorded sublethal heat damage in macroalgae at some sites.
- In 2020, the upper vertical limit of barnacle coverage had retracted downwards in the high shore at Little Orme and Porth Oer, and the lower vertical limit of barnacle coverage had retracted upwards in the low shore at Criccieth castle. These losses are likely due to sand and shingle abrasion removing settled barnacles from the extremities of the vertical distributions at all three sites.
- Macroalgal coverage had increased on the cobble field at Moelfre, and in the low shore at Cemaes in relation to previous years.
- Neyland Point had the highest number of Non Indigenous Species (NIS) recorded at any MarClim site, with *Undaria pinnatifida, Magallana gigas, Crepidula fornicata* and *Botrylloides violaceus* all being present.
- The NIS *Sargassum muticum* was growing on open rock at Abersoch lifeboat station. This is the first record of *S. muticum* at this site, and it is unusual to find the species growing on open rock this far north in the UK.

Conclusions and discussion points

MarClim surveys detect annual changes in occupancy-derived measures of abundance for rocky intertidal species. These are sensitive metrics 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. Temperate intertidal species are able to tolerate short periods of extreme heat or cold weather, and they are more responsive to pervasive changes in the climate that occur across decadal timescales, ultimately influencing performance in terms of growth and reproductive output leading to recruitment.

The colonisation and the rate and extent of spread of NIS can be tracked via MarClim annual surveys. The impacts on native species in the community that is colonised by

an NIS can also be monitored across multiple years to detect any changes to both local and regional biodiversity.

Significance of results and future practice

The MarClim project and scientific data collected by MarClim is 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). 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.

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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 non indigenous (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), NatureScot (formerly 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 indigenous species that pose a potential threat to native biodiversity (Appendix 1) in collaboration with the UK Marine Aliens Project https://www.webarchive.org.uk/wayback/archive/20130423092151/http://www.marlin.ac.uk/marine_aliens/. Non indigenous species 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 indigenous Species identified as posing a risk to native rocky intertidal communities. 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 has been incorporated since 2002 and is detailed in the Survey Protocols section below.

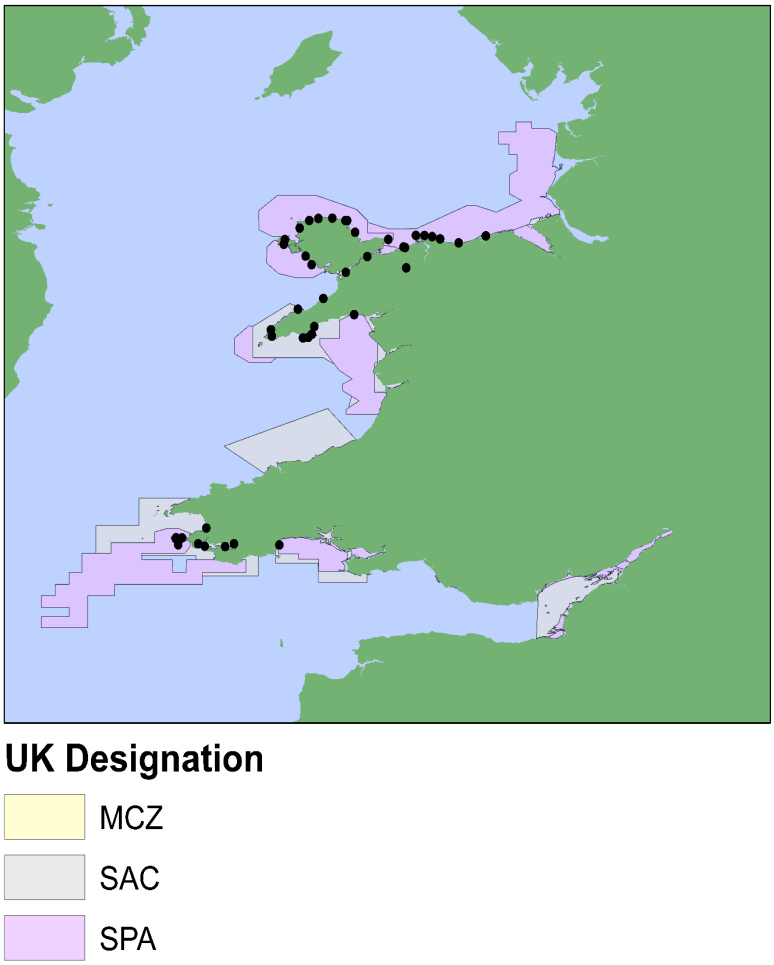
Climate-driven shifts in the biogeographic ranges of native and non indigenous species are also being tracked by Dr Mieszkowska around the wider northern European coastline using the MarClim protocols. These surveys provide geographically extensive, contextual evidence on distributions, abundances, biological 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).

2. METHODS

The MarClim protocols (Appendix 1) 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.

A total of 36 sites were surveyed in Wales, consisting of 27 sites in north Wales and 9 sites in south Wales; these locations included 34 long-term sites (Table 1, Figure 1).

Figure 1. MarClim sites across Wales



Twenty-seven 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 (NRW). 9 sites were surveyed in south Wales including 2 sites in the Skomer Island Marine Conservation Zone and 1 on Skokholm Island. These surveys were carried out and cross-calibration exercises undertaken by Mark Burton, Phil Newman, Kate Lock, Jen Jones of NRW and John Archer-Thomson (independent). All surveyors have previously been trained in MarClim methodology and cross-calibrated in the field with Dr Mieszkowska. Surveyors have carried out cross-calibrations with Mieszkowska in several previous years including on-site training to ensure accurate continuation of sample methodologies and protocols. 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 9 Invasive Non Indigenous Species of invertebrate and 9 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 0.25 m^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, and returned to their original orientation after the search. The maximum basal diameter of every individual was measured in millimetres to 1 decimal place and population size frequencies calculated from the data.

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 indigenous ascidian *Didemnum vexillum* which has been the subject of an intense eradication program by NRW inside Holyhead marina (Carpet Seasquirt eradication). 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 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 5 cm x 2 cm subsection of the 5 cm 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.

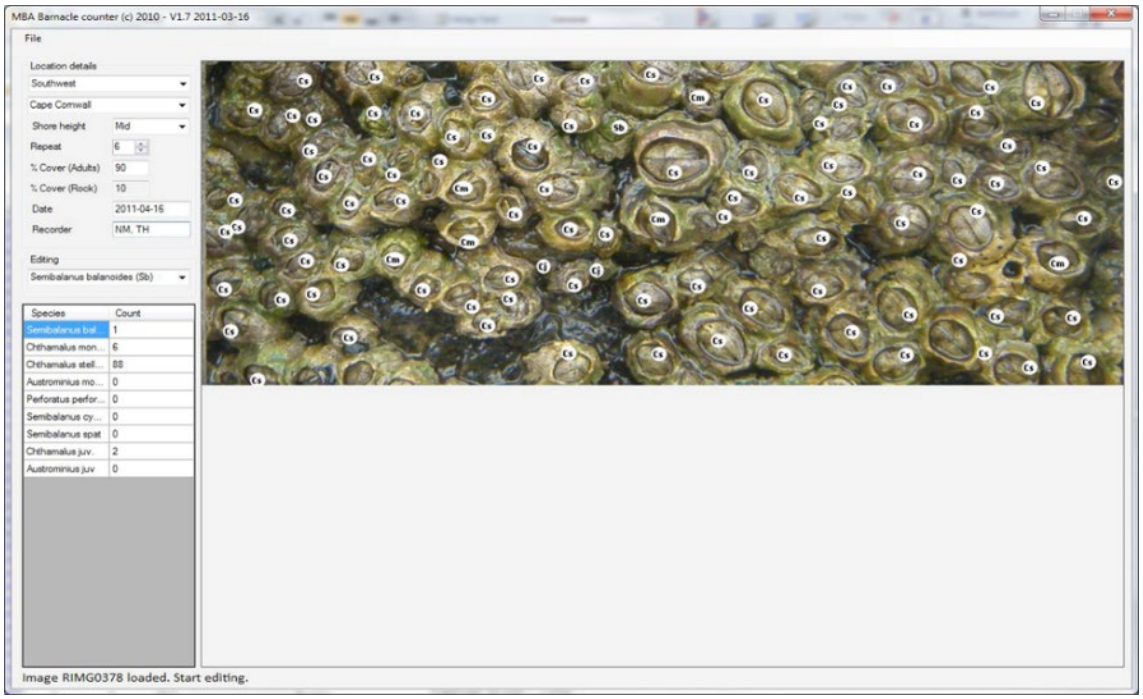


Figure 3. Survey method with 0.25 m^2 quadrat to enumerate and speciate limpets on rocky shores.

Table 1. MarClim Survey Site Locations 2020

Day	Month	Year	Site	Grid	Lat (WGS84)	Long (WGS84)
21	7	2020	Llanddulas	SH906787	53.2933	-3.6296
21	7	2020	Rhos on Sea	SH843805	53.3114	-3.7381
21	7	2020	Little Orme	SH812825	53.3260	-3.7852
21	7	2020	Great Orme East	SH782832	53.3321	-3.8297
21	7	2020	Great Orme Trwynygogarth	SH749834	53.3327	-3.8801
21	7	2020	Penmaenmawr Natural	SH704763	53.2674	-3.9440
22	7	2020	Bull Bay	SH427945	53.4238	-4.3688
22	7	2020	Moelfre	SH513859	53.3490	-4.2354
22	7	2020	Porth Eilian	SH477929	53.4109	-4.2928
22	7	2020	Point Lynas	SH484929	53.4111	-4.2823
22	7	2020	Trefor	SH376474	52.9992	-4.4215
22	7	2020	Caernarfon (Aber Foreshore Road)	SH521671	53.1374	-4.2897
22	7	2020	Penmon North	SH641813	53.3111	-4.0413
22	7	2020	Menai Bridge	SH555714	53.2207	-4.1643
23	7	2020	Cemlyn	SH337934	53.4146	-4.5112
23	7	2020	Cemaes Bay Llanbadrig	SH372944	53.4219	-4.4502
23	7	2020	Holyhead	SH257825	53.3108	-4.6461
23	7	2020	Porth Swtan	SH298891	53.3713	-4.5598
24	7	2020	Aberffraw (Briach-Lwyd)	SH337674	53.1776	-4.4899
24	7	2020	Rhosneigr	SH315725	53.2233	-4.5253
24	7	2020	Porth Oer	SH163297	52.8344	-4.7256
24	7	2020	Nefyn	SH274415	52.9430	-4.5702
25	7	2020	Porth Neigwl	SH288245	52.7908	-4.5404
26	7	2020	Porth Ceriad	SH308247	52.7938	-4.5094

Day	Month	Year	Site	Grid	Lat (WGS84)	Long (WGS84)
26	7	2020	Abersoch lifeboat station	SH323265	52.8107	-4.4881
26	7	2020	Aberdaron	SH166260	52.8003	-4.7220
26	7	2020	Llanbedrog	SH335311	52.8516	-4.4742
21	8	2020	Broad Haven	SM859144	51.7871	-5.1057
22	8	2020	Pembroke Power station	SM930032	51.6896	-4.9956
22	8	2020	West Angle Bay	SM848038	51.6916	-5.1151
23	8	2020	Neyland Natural (by Brunel Wall)	SM967047	51.7045	-4.9433
23	8	2020	Monkstone Point	SN150033	51.6978	-4.6784
24	8	2020	Martin's Haven	SM759091	51.7357	-5.2471
24	8	2020	Jetty Beach Dale	SM822053	51.7041	-5.1533
25	8	2020	Abercastle	SM851338	51.9610	-5.1294
25	8	2020	Abereiddy	SM792315	51.9381	-5.2137

3. RESULTS and DISCUSSION

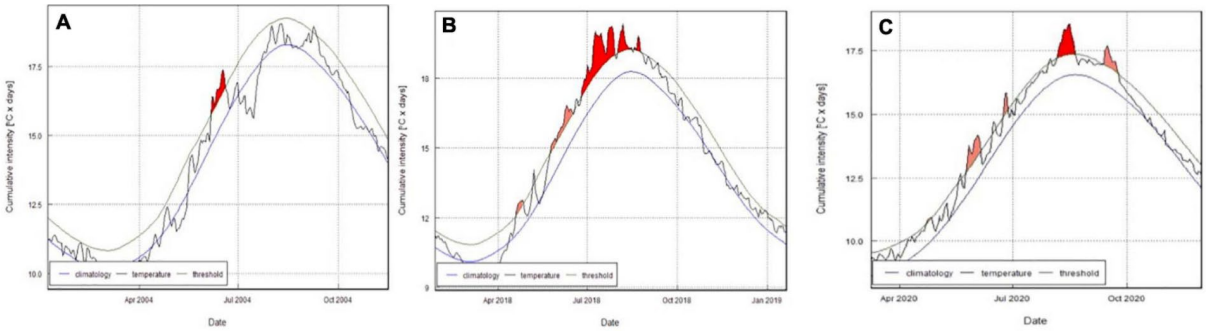
3.1 Climate change and extreme events

The joint hottest summers on record were recorded in 2018 and 2020, and 2020 was the joint warmest year on record with 2016 (https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2019/2020-global-temperature-forecast). Five of the warmest years ever recorded in the UK 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 are becoming more frequent since the 1980s, and possibly longer and more intense (Figure 4). 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 occur most frequently in June (11 events between 1982 and 2020), July (13 events) and August (10 events).

After the record heatwaves in the summers of 2018 and 2020, MarClim surveys recorded sublethal heat damage in macroalgae at some sites. The damage in 2018 did not result in any loss or noticeable reduction in algal cover at any MarClim site in 2019, and impacts from the 2020 heatwave will be looked for in the 2021 surveys.

Figure 4. Heatwave events from 2004 – 2020 (Mieszkowska et al. 2021).



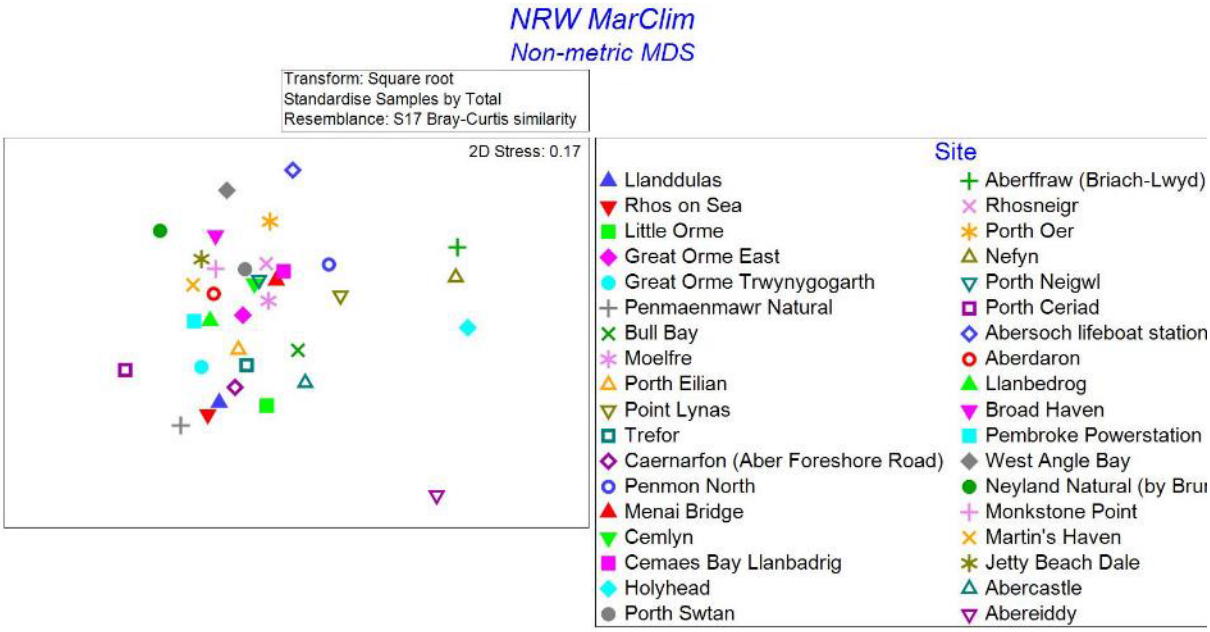
The MarClim 2020 surveys showed evidence of local-scale removal of barnacles at a few shores in north Wales, which was probably due to storm events causing scouring of the rock by shingle. Almost complete loss of barnacle coverage from the high shore was recorded at Little Orme and Porth Oer. At Criccieth Castle the low shore showed a reduction in the density of barnacles compared to previous years, which was again likely due to shingle scouring. The loss of barnacles at all three sites was visually

evident, and confirmed by comparison to previous year's photo images of the survey sites.

3.2 Community Composition across Wales

Patterns of abundance of MarClim species within the intertidal communities at MarClim sites across Wales were visualised using multidimensional scaling (MDS) ordination (Figure 5). MDS were based on Bray Curtis similarity coefficient calculated from non-standardised, square root transformed data.

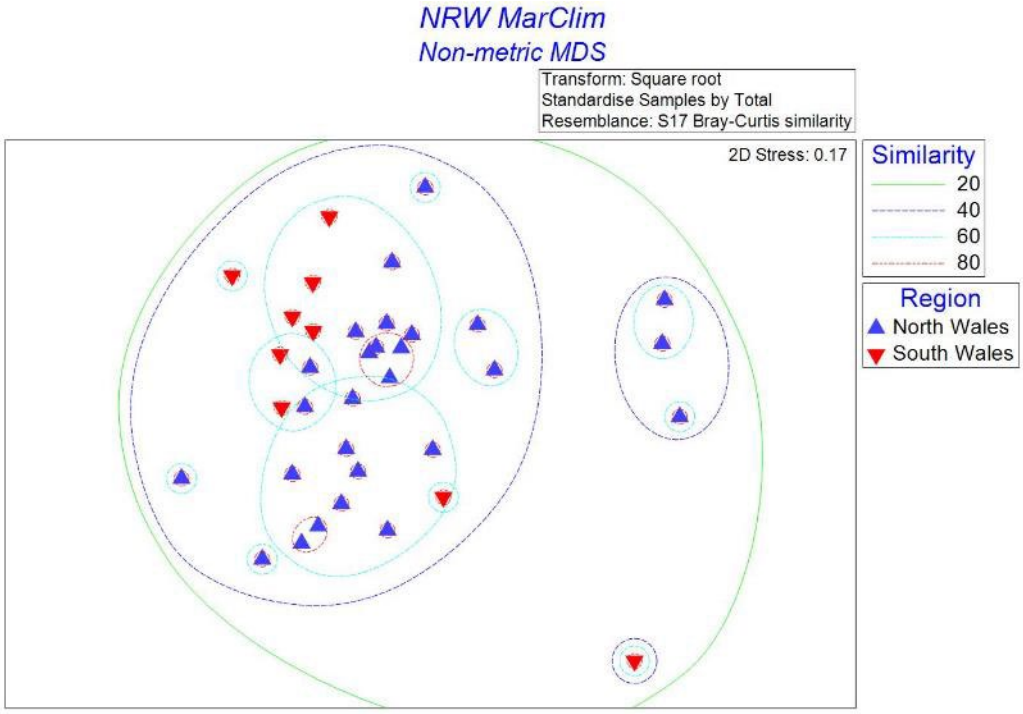
Figure 5. Multidimensional Scaling plot of the community abundance and composition at all MarClim sites across Wales in 2020.



The plot shows sites that are closer together in multidimensional space have more similar species composition and abundance than those spread further apart. Abereiddy was the most different site to all others. This site has not been sampled since the early 2000s and was done on an opportunistic basis in 2020. Species diversity is very low at this site which is why it has not been surveyed regularly since then. Aberffraw, Nefyn and Holyhead all have fewer species than the rest of the MarClim sites, which is why they cluster together out on the right of the plot.

Figure 6 shows sites in the north and south of Wales with clusters of survey sites in terms of percentage composition. The sites in south Wales cluster together (with the exception of Abereiddy, explained above), showing similar species composition and abundance to each other. They all have greater than 40% similarity, with many having more than 60% similarity to each other. These plots suggest that there are differences between MarClim species in communities at sites in the north and south of the country. Closer inspection of the data show that more NIS are present at sites in Pembrokeshire, and higher abundances of Lusitanian 'warm water' species are present at these sites compared to sites in the north, where several species either reach their leading range edge limits and/or have smaller population abundances.

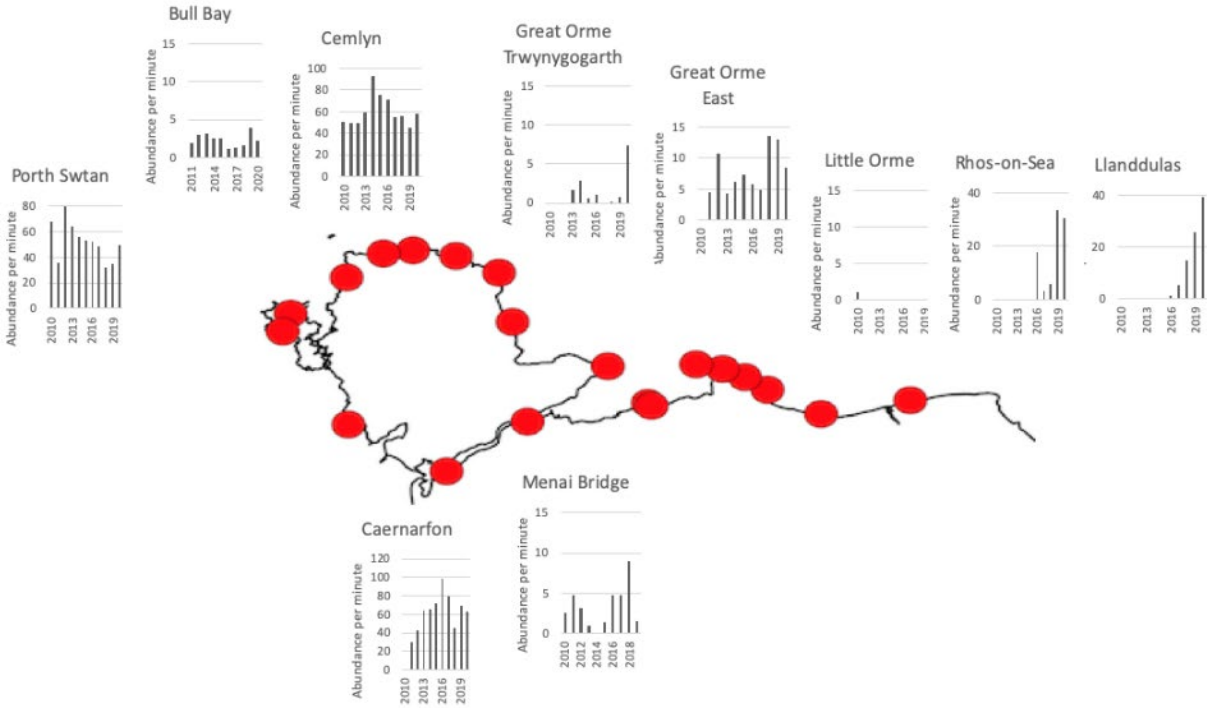
Figure 6. Multidimensional Scaling plot of the community abundance and composition at all MarClim sites across Wales in 2020, plotted as North Wales or South Wales with sites clustered in percentage similarity groups.



3.3 Range Extensions

MarClim surveys track changes in the leading range edge of species that reach their distributional limits in Wales. These species include the barnacle *Perforatus perforatus*, brown alga *Bifurcaria bifurcata*, barnacle *Chthamalus montagui* (a break in the distribution until the SW Scottish coastline rather than a definitive range edge), and the topshell *Phorcus lineatus*. 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 (Figure 7). The time-series can also flag populations that have suffered from severe declines and are at risk of local extinction. *P. lineatus* experienced a range contraction of the leading range edge at Porth Eilian in the 1940s after the extreme cold winter of 1962/3. The leading range edge of *P. lineatus* has been extending along the coastline of north Wales since MarClim surveys started in 2002. The current range edge is located at Llanddulas, representing a geographic shift of approximately 75 miles in nineteen years.

Figure 7. Population abundances of *Phorcus lineatus* at sites from the northern leading range edge at Llanddulas to Caernarfon from 2010-2020.



3.4 Non Indigenous Species

MarClim records eight species of macroalgae NIS and fourteen species of invertebrate NIS (Table 2). These include horizon scanning for species that have only been recorded at one or a few locations 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 2020. The most prolific species was *Austrominius modestus*, which was recorded at 28 sites. Thirty-one sites had NIS in 2020, most of which were *A. modestus*. The red alga *Dasysiphonia japonica* was recorded for the first time in 2020 at Menai Bridge. This is the first record at any MarClim site. Neyland Point in Pembrokeshire had the highest number of NIS recorded at any MarClim site, with *Undaria pinnatifida*, *Magallana gigas, Crepidula fornicata* and *Botrylloides violaceous* all being present in 2020. Neyland Point was added as a site in 2017 due to the observation of several NIS by Mark Burton of NRW during fieldwork he was carrying out in the area. At Neyland the NIS includes the colonial ascidian *Botrylloides violaceus*, which was first recorded at Neyland in 2018 (Occasional), increasing to Frequent in 2019 and back to Occasional in 2020. The sea squirt *Corella eumyota* was Abundant In 2019, but was not recorded previously or in 2020. The slipper limpet *Crepidula fornicata* was Common in 2018, declining to Occasional in 2019 and Rare in 2020. *Magallana gigas* was recorded here for the first time in 2020 (Rare). The brown alga *Undaria pinnatifida* was Occasional in 2017, increasing to Frequent in 2018 and Common in 2019 and 2020, suggesting a recent introduction of this species. The most abundant NIS was *Austrominius modestus* which has been Abundant for the past three years.

The brown alga *Sargassum muticum* has been recorded in MarClim surveys across Wales since they began in 2002. The largest population occurs at Porth Oer, where it has been Superabundant or Abundant for nine out of the last ten years. In Pembrokeshire, the Broad Haven population has oscillated between Superabundant

and Not Seen since 2002, and the West Angle Bay population between Occasional in 2004 and 2016 and Abundant (2003, 2018). *S. muticum* has oscillated between Frequent and Abundant at Rhosneigr since 2008, the second most prolific set of records in the MarClim database. It was recorded in low abundances in a rockpool under Menai Bridge from 2010-2015, but has not been found there since. Jetty Beach Dale has a smaller population which has peaked at Frequent (2011 and 2017) but not been recorded in some years (2002, 2009, 2010, 2013, 2020), suggesting this population is seeded by a more stable population nearby.

Table 2 .Non Indigenous Species recorded in MarClim surveys.

Species
Sargassum muticum
Undaria pinnatifida
Chondracanthus acicularis
Asparagopsis armata
Colpomenia peregrina
Grateloupia turuturu
Caulacanthus ustulatus (okamurae)
Pikea californica
Dasysiphonia (Heterosiphonia) japonica
Diadumene lineata
Austrominius modestus
Magallana gigas
Crepidula fornicata
Botrylloides violaceus
Botrylloides diegensis
Perophora japonica
Corella eumyota
Asterocarpa humilis
Didemnum vexillum
Watersipora subtorquata
Corella eumyota
Hemigrapsus takanoi

In 2020 *S. muticum* was recorded for the first time at Abersoch lifeboat station, where instead of growing in rockpools, one individual was attached to open rock in the low shore (Figure 8). Surveys in future years will track whether this species gains a permanent foothold here.

Figure 8. *Sargassum muticum* on open rock at Abersoch lifeboat station in 2020.

Table 3. Non Indigenous Species at MarClim sites in 2020

Key

S	A	C	F	O	R	P	NS
super-abundant	abundant	common	frequent	occasional	rare	present	not seen

Site	*Sargassum muticum*	*Undaria pinnatifida*	*Asparagopsis armata*	*Colpomenia peregrina*	*Grateloupia turuturu*	*Caulacanthus ustulatus (okamurae)*	*Pikea californica*	*Dasysiphonia japonica*	*Diadumene lineata*	*Austrominius modestus*	*Magallana gigas*	*Crepidula fornicata*	*Botrylloides violaceus*	*Botrylloides diegensis*	*Perophora japonica*	*Corella eumyota*	*Asterocarpa humilis*	*Didemnum vexillum*	*Watersipora subatra*	*Hemigrapsus sanguineus*	*Hemigrapsus takanoi*
Llanddulas	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rhos on Sea	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Little Orme	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Great Orme East	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Great Orme Trwynygogarth	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Penmaenmawr Natural	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bull Bay	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Moelfre	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Eilian	NS	NS	NS	NS	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Point Lynas	NS	NS	NS	NS	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trefor	NS	NS	NS	NS	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Caernarfon (Aber Foreshore Road)	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Site	*Sargassum muticum*	*Undaria pinnatifida*	*Asparagopsis armata*	*Colpomenia peregrina*	*Grateloupia turuturu*	*Caulacanthus ustulatus (okamurae)*	*Pikea californica*	*Dasysiphonia japonica*	*Diadumene lineata*	*Austrominius modestus*	*Magallana gigas*	*Crepidula fornicata*	*Botrylloides violaceus*	*Botrylloides diegensis*	*Perophora japonica*	*Corella eumyota*	*Asterocarpa humilis*	*Didemnum vexillum*	*Watersipora subatra*	*Hemigrapsus sanguineus*	*Hemigrapsus takanoi*
Penmon North	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Menai Bridge	NS	NS	NS	NS	NS	NS	NS	O	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cemlyn	NS	NS	NS	NS	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cemaes Bay Llanbadrig	NS	NS	NS	R	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Holyhead	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Swtan	NS	NS	NS	O	NS	NS	NS	NS	NS	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aberffraw (Briach-Lwyd)	C	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rhosneigr	A	NS	NS	NS	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Oer	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nefyn	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Neigwl	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Ceriad	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abersoch lifeboat station	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aberdaron	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Llanbedrog	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Broad Haven	C	NS	NS	R	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pembroke Power station	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	O	O	NS	NS	NS	NS	NS	NS	NS	NS	NS
West Angle Bay	C	NS	NS	NS	NS	F	NS	NS	NS	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Neyland Natural	NS	C	NS	NS	NS	NS	NS	NS	NS	A	R	R	O	NS	NS	NS	NS	NS	NS	NS	NS
Monkstone Point	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Site	*Sargassum muticum*	*Undaria pinnatifida*	*Asparagopsis armata*	*Colpomenia peregrina*	*Grateloupia turuturu*	*Caulacanthus ustulatus (okamurae)*	*Pikea californica*	*Dasysiphonia japonica*	*Diadumene lineata*	*Austrominius modestus*	*Magallana gigas*	*Crepidula fornicata*	*Botrylloides violaceus*	*Botrylloides diegensis*	*Perophora japonica*	*Corella eumyota*	*Asterocarpa humilis*	*Didemnum vexillum*	*Watersipora subatra*	*Hemigrapsus sanguineus*	*Hemigrapsus takanoi*
Martin's Haven	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Jetty Beach Dale	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abercastle	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abereiddy	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4. Conclusions

MarClim data covers multiple decades. The time-series shows the effect of pervasive climate change on distributional changes of species, and resultant alterations to community composition. The data also detect the impacts of extreme events, and can contextualise short-term effects with long-term changes in the abundance and distribution of species on shores across the Welsh coastline.

The colonisation and the rate and extent of spread of NIS can be tracked via MarClim annual surveys. The impacts on native species in the community that is colonised by an NIS can also be monitored across multiple years to detect any changes to both local and regional biodiversity. Neyland Point in the Milford Haven estuary had the highest number of NIS across all MarClim sites in Wales. Two sites had first records of an NIS recorded in 2020: the red alga *Dasysiphonia japonica* was recorded for the first time in 2020 at Menai Bridge, and the brown alga *Sargassum muticum* was found at Abersoch lifeboat station.

Year-to-year changes in occupancy-derived measures of abundance for rocky intertidal species 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 if multiple sites are surveyed in the same region, small-scale disturbances can be detected against the larger patterns of climate-driven change to marine species. Temperate intertidal species are able to tolerate short periods of extreme heat or cold weather, and they are more responsive to pervasive changes in the climate that occur across decadal timescales, ultimately influencing performance in terms of growth and reproductive output leading to recruitment.

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APPENDIX 1: MarClim Sampling Protocols 2020

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	8	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								
Callibepharis 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.								
Cilbenarius erythropus								
Haliotis tuberculata								
Testudinella testudinalis								
Patella vulgata								
Patella depressa								
Patella ulyssiponensis								
Patella pellucida								
Steromphala umbilicalis								
Steromphala pennanti								
Steromphala cineraria								
Phorcus lineatus								
Callostoma zizyphinum								
Littorina littorea								
Littorina saxatilis agg.								
Melarhaphe neritoides								
Nucella lapillus								
Onchidella celtica								
Magallana gigas								
Crepidula fornicata								
Botryiloides violaceus								
Botryiloides diegensis								
Perophora japonica								
Corella eumyota								
Dendrodoa grossularia								
Asterocarpa humilis								
Didemnum vexillum								
Asterias rubens								
Leptasterias muelleri								
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 2: Data Archive

The report and data collected under Natural Resources Wales contract MOA0070 are secured in the NRW document management system.

Mieszkowska, N. 2021. MarClim Annual Welsh Intertidal Climate Monitoring Survey 2020. Natural Resources Wales Evidence Report No. 563, pp x + 21, Natural Resources Wales, Bangor.

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

The data archive consists of:

[A] Digital versions of the contract report: Microsoft Word document(s); and an equivalent Adobe Portable Document Format version

[B] Excel spreadsheets of species records

[C]. Marine Recorder file that is held by DASSH

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