Cyfoeth Naturiol Cymru
Natural Resources Wales

THE MARINE BIOLOGICAL ASSOCIATION

MarClim Annual Welsh Intertidal Climate Monitoring Survey 2018

Dr. N. Mieszkowska

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We work for the communities of Wales to protect people and their homes as much as possible from environmental incidents like flooding and pollution. We provide opportunities for people to learn, use and benefit from Wales' natural resources.

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

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Crynodeb Gweithredol

Mae'r adroddiad hwn yn crynhoi'r gwaith arolygu, casglu data a dadansoddi a gwblhawyd yn 2018 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 43 safle yn 2018. Cynhaliwyd arolygon ar 33 safle yng ngogledd Cymru a deg safle yn ne Cymru.

Cafwyd nifer o ddigwyddiadau tywydd eithafol yn 2018. Rhwng diwedd mis Chwefror a dechrau mis Mawrth, cafwyd cyfnod o dywydd gaeafol eithafol â thymereddau isel iawn ym Mhrydain. Gwnaeth y 'Dihiryn o'r Dwyrain' fel y'i gelwid, sef antiseiclon Hartmut gyd-daro â storm Emma i achosi rhai o'r amodau tywydd mwyaf eithafol ers degawdau. Gwnaeth y digwyddiadau hyn achosi marwolaeth llwyth o greaduriaid morol ar hyd arfordir dwyreiniol Lloegr, fodd bynnag, ni chofnodwyd unrhyw newidiadau sylweddol yn helaethrwydd unrhyw un o'r 50 o rywogaethau di-asgwrn cefn MarClim ar unrhyw safle MarClim ar hyd arfordir Môr y Gogledd yn ystod 2018. 2018 oedd un o'r blynyddoedd cynhesaf a gofnodwyd, gyda phump o'r blynyddoedd cynhesaf yn digwydd ers 2010. Cafodd yr haf poethaf ar y cyd ar gofnod, ei gofnodi yn 2018. Cafwyd tywydd poeth ym mis Ebrill, Mehefin a Gorffennaf, gyda'r Swyddfa Dywydd yn adrodd tymheredd aer ar gyfartaledd o 1.5°C yn uwch na'r cyfartaledd hirdymor. Canfu arolygon MarClim o amgylch y DU dystiolaeth o niwed gwres i'r rhywogaethau gwymonol glannau uchel sef Pelvetia canaliculata, Fucus spiralis a Fucus vesiculosus ar safleoedd ar draws moroedd rhanbarthol y DU.

Cofnodwyd y rhywogaethau anfrodol o wymon Undaria pinnatifida am y tro cyntaf ym Mharth Cadwraeth Morol Sgomer yn 2018, lle roedd yn brin yn South Haven, Ynys Sgogwm ac yn rheolaidd (5%) yn North Haven. Ychwanegwyd safle newydd yn Neyland (ger Brunel Wall) yn Aberdaugleddau yn 2017, gan i'r gwymon goresgynnol Undaria pinnatifida gael ei weld yno. Cynhaliwyd arolwg arall o'r safle hwn yn 2018, ac roedd U. pinnatifida wedi cynyddu mewn helaethrwydd o achlysurol (2%) i reolaidd (5%). Roedd hefyd yn brin ym Mae Gorllewin Angle, y tro cyntaf i'r rhywogaeth hon gael ei chofnodi ar y safle hwn.

Cafodd yr alga coch goresgynnol Caulacanthus ustulatus ei ychwanegu at restr MarClim yn 2017 pan gafodd ei gofnodi am y tro cyntaf yng Nglanfa Dale Fort. Yn 2018 fe'i cofnodwyd eto yng Nglanfa Dale Fort a'i ddarganfod hefyd am y tro cyntaf ym Mharth Cadwraeth Morol Sgomer yn Martin's Haven, Ynys Sgogwm South Haven, Broad Haven a Bae Gorllewin Angle.

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 llai 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 sylfaenol 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 – i ddatblygu cyfres-amser MarClim fel dangosyddion newid hinsawdd rhywogaethol (Mynegai Tymheredd Rhywogaethau) a chymunedol (Mynegai Tymheredd Cymunedau) fel rhan o broses datblygu dangosyddion Statws Ecolegol Da Cyfarwyddeb Fframwaith y Strategaeth Forol – gan dîm MarClim yn 2017.

Mae prosiect MarClim a'r tîm ymchwil yn darparu monitro unigryw, hanfodol, hirdymor a data ymchwil ac arbenigedd gwyddonol. Mae'r rhain yn cael eu defnyddio gan adrannau Llywodraeth y DU i fynd i'r afael â chyfarwyddebau polisi cenedlaethol ac Ewropeaidd pwysig, 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.

Executive Summary

This report summarises the 2018 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 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 forty three sites in 2018. Thirty three sites were surveyed in north Wales and ten sites in south Wales.

Several extreme weather events occurred in 2018. Between late February and early March, Britain experienced a severe spell of winter weather with very low temperatures. Known as the 'Beast from the East', anticyclone Hartmut coincided with storm Emma to cause some of the most extreme weather conditions in decades. These events caused a mass mortality of marine creatures along the east coast of England, however, no significant changes in the abundance of any of the fifty MarClim species of invertebrate were recorded at any MarClim site along the North Sea coastline during 2018. 2018 was one of the warmest years on record, with five of the warmest years happening since 2010. The joint hottest summer on record was recorded in 2018. Heatwaves occurred in April, June and July, with the Met Office reporting an average air temperature of 1.5°C above the long-term average. MarClim surveys around the UK found evidence of heat damage to the high shore fucoid species *Pelvetia canaliculata*, *Fucus spiralis* and *Fucus vesiculosus* at sites across UK regional seas.

The Non-Indigenous Species (NIS) of kelp *Undaria pinnatifida* was recorded for the first time in the Skomer Marine Conservation Zone (MCZ) in 2018, where it was Rare at South Haven, Skokholm and Frequent (5%) at North Haven. A new site at Neyland (by Brunel Wall) in Milford Haven was added in 2017, as the invasive kelp *Undaria pinnatifida* was spotted there. This site was resurveyed in 2018, and *U. pinnatifida* had increased in abundance from occasional (2%) to Frequent (5%). It was also Rare at West Angle Bay, the first time this species has been recorded at this site.

The invasive red alga *Caulacanthus ustulatus* was added to the MarClim list in 2017 when it was recorded for the first time at Dale Fort Jetty. In 2018 it was again recorded at Dale Fort Jetty and was also found for the first time in the Skomer MCZ at Martins Haven, Skokholm, South Haven, Broadhaven and West Angle Bay.

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 Burrows, Mieszkowska 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 (Community Temperature Index) indicators of climate change as part of the MSFD GES indicator development process was developed by the MarClim team in 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 government departments 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.

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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 (as 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.

2 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. 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 habitat 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 1) in collaboration with the UK Marine Aliens Project http://www.marlin.ac.uk/marine_aliens/. Non-natives also targeted due to their appearance and subsequent impacts on natural communities after introduction via escapes of associated spat from mussel and oyster aquaculture facilities and practices. MarClim data has shown major shifts in biogeographic distributions of both cold and warm water species around the coastline of the UK since the onset of climate warming in the mid-1980s, and associated changes in abundance, population structure and physiological responses across several taxonomic groups (Mieszkowska *et al*.

2005, 2006, Mieszkowska 2009). These changes are amongst the fastest recorded globally and up to ten times faster than those recorded in terrestrial systems. The methodology is therefore field-tested and proven as a suitable broadscale climate detection tool.

Additional species have been added since 2002 to encompass those shifting distributional ranges into the UK tracking a warming climate, and Invasive Non-Native Species identified as posing a risk to native rocky intertidal communities. 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 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, 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).

3 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.

MarClim surveys were carried out at forty three long-term sites in 2018 (Table 1, Figure 1). Thirty three sites were surveyed in north Wales and ten sites in south Wales.

Rocky shores in north Wales were surveyed by Dr. Nova Mieszkowska and Leoni Adams from The Marine Biological Association, Kathryn Birch and Laura Grant from Natural Resources Wales. Ten sites were surveyed in south Wales including two sites at the Skomer Marine Conservation Zone, seven on the mainland and one on Skokholm Island. These surveys were carried out and cross-calibration exercises undertaken by Mark Burton and Kate Lock of NRW. All 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 Leoni Adams with QA by Nova Mieszkowska and Paul Brazier.

Semi-quantitative SACFOR abundance scores were recorded for a suite of 87 species of invertebrates and macroalgae, including nine Invasive Non Native Species (INNS) of invertebrate and nine NIS of macroalgae.

Replicate, quantitative quadrat counts were made for barnacles (0.1 m^2) (Figure 2) and population abundances for each species counted using bespoke digital image software. Ten replicate 0.25 m^2 quadrats were counted at each site to record the abundance of limpet species. They were randomly placed within the midshore zone on areas of bedrock or large boulders with homogeneous surfaces (Figure 3). Pools, cracks and crevices and patches of macroalgae were avoided. The slope of the rock, percentage cover of adult barnacles, algae and mussels were recorded in each

quadrat. All limpets greater than 10 mm in size were counted and identified to species level.

Three replicate searches, each of three minutes duration were made separately for *Phorcus lineatus* and *Steromphala umbilicalis* in the area of the shore where each of the two warm water indicator species were most abundant. Cobbles and small boulders were turned to ensure all individuals were collected; they were returned to their original orientation after the search. The maximum basal diameter of very 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. An additional site at Llanddulas, which has been sporadically checked for absence of indicator species has been added to the list after the appearance of a population of *Steromphala (Gibbula) umbilicalis* was found in 2012 and *Phorcus lineatus* in 2016, and is now surveyed each year. The Rhyl crescent seawall and groynes were surveyed in 2014 and again in 2017 and 2018 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.

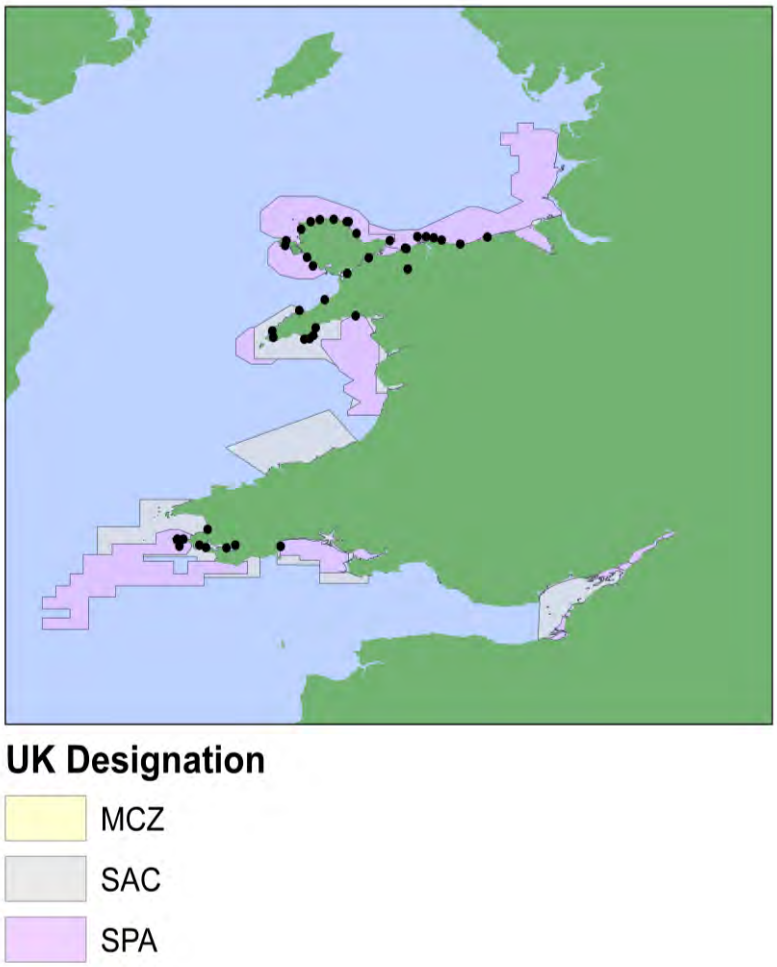

Figure 1. MarClim sites surveyed in 2018.

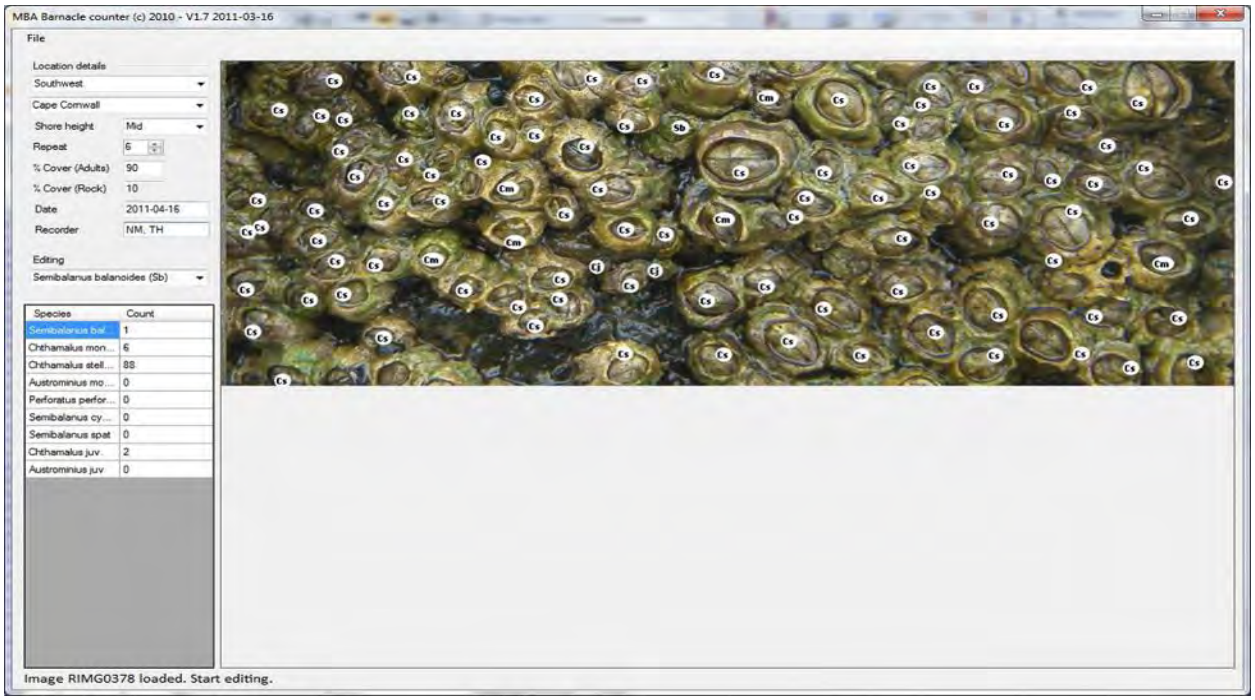

Figure 2. A 5cm x 2cm subsection of the 5cmx5cm barnacle quadrat images taken during MarClim surveys being analysed using MarClim digital image software. The species are identified and marked by a unique identifier code and the number of adult and juvenile barnacles for each species is recorded in a linked Access database.

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

Table 1. MarClim Survey Site Locations 2018

Day	Month	Year	Site	Grid	Lat (WGS84)	Long (WGS84)
18	4	2018	Pembrokeshire power station	SM930032	51.6896	-4.9956
14	6	2018	Monkstone Point	SN150033	51.6978	-4.6784
12	7	2018	Martin's Haven	SM759091	51.7357	-5.2471
12	8	2018	North Haven	SM735093	51.7365	-5.2819
12	7	2018	Rhyl crescent sea wall & groynes	SJ021824	53.3299	-3.4715
12	7	2018	Llanddulas	SH906787	53.2933	-3.6296
12	7	2018	Rhos-on-Sea	SH843805	53.3140	-3.7381
12	7	2018	Little Orme	SH812825	53.3260	-3.7852
12	7	2018	Penmaenmawr Natural	SH704763	53.2683	-3.9440
12	7	2018	Penmaenmawr Artificial	SH709763	53.1613	-3.9369
12	7	2018	Penmaenmawr Slipway	SH699766	53.2712	-3.9521
13	7	2018	Great Orme Trwynygogarth	SH749834	53.3327	-3.8801
13	7	2018	Great Orme East	SH782832	53.3321	-3.8297
13	7	2018	Trefor	SH376474	52.9992	-4.4215
13	7	2018	Caernarfon (Aber Foreshore Road)	SH521671	53.1374	-4.2897
13	7	2018	Penmon North	SH641813	53.3111	-4.0413
13	7	2018	Menai Bridge	SH555714	53.2207	-4.1643
14	7	2018	Bull Bay	SH427945	53.4238	-4.3688
14	7	2018	Moelfre	SH513859	53.3490	-4.2354

Day	Month	Year	Site	Grid	Lat (WGS84)	Long (WGS84)
14	7	2018	Point Lynas	SH484929	53.4111	-4.2823
14	7	2018	Porth Eilian	SH477929	53.4109	-4.2928
14	7	2018	Cemaes Bay	SH372944	53.4219	-4.4502
14	7	2018	Cemlyn	SH337934	53.4111	-4.5035
14	7	2018	Porth Swtan	SH298891	53.3713	-4.5598
15	7	2018	Holyhead	SH257825	53.3108	-4.6461
15	7	2018	Porth Dafarch	SH233798	53.2856	-4.6522
15	7	2018	Rhosneigr	SH315725	53.2233	-4.5253
16	7	2018	Aberffraw (Briach-Lwyd)	SH337674	53.1776	-4.4899
16	7	2018	Porth Oer B	SH163297	52.8343	-4.7279
16	7	2018	Nefyn	SH274415	52.9430	-4.5702
17	7	2018	Porth Neigwl	SH288245	52.7908	-4.5404
17	7	2018	Llanbedrog	SH335311	52.8516	-4.4742
17	7	2018	Aberdaron	SH166260	52.8003	-4.7220
18	7	2018	Porth Ceriad	SH308247	52.7938	-4.5094
18	7	2018	Abersoch Lifeboat Station	SH323265	52.8107	-4.4881
18	7	2018	Criccieth (East)	SH494376	52.9146	-4.2412
18	7	2018	Criccieth Castle	SH494376	52.9146	-4.2412
13	8	2018	South Haven	SM733088	51.7319	-5.2845
13	8	2018	Skokholm South Haven	SM741051	51.6992	-5.2701
14	8	2018	Broadhaven	SM859144	51.7871	-5.1057
14	8	2018	Jetty Beach Dale	SM822053	51.7041	-5.1533
15	8	2018	Neyland Natural (by Brunel Wall)	SM967047	51.7045	-4.9433
15	8	2018	West Angle Bay	SM848038	51.6916	-5.1151

4 RESULTS

4.1 Findings - 2018

4.1.1 Recent changes in the global and regional climate

The latest findings from the IPCC 5th Assessment Working Group I Report on the Physical Science Basis of Climate Change http://www.ipcc.ch/report/ar5/wg1/#.Uwt9YvYzmlI reveal that the earth's climate has not warmed as rapidly over the 2010s compared to the longer-term warming trend since the 1980s, due to non-anthropogenically mediated, natural variability in the earth's climate system. This recent slowdown must be placed into context; each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 in the northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years, with 2016 being globally the warmest year on record http://www.bloomberg.com/graphics/hottest-year-on-record/, and the third warmest in the UK since 1910 http://www.metoffice.gov.uk/news/releases/2016/2016-a-year-in-weather-statistics (Figure 4).

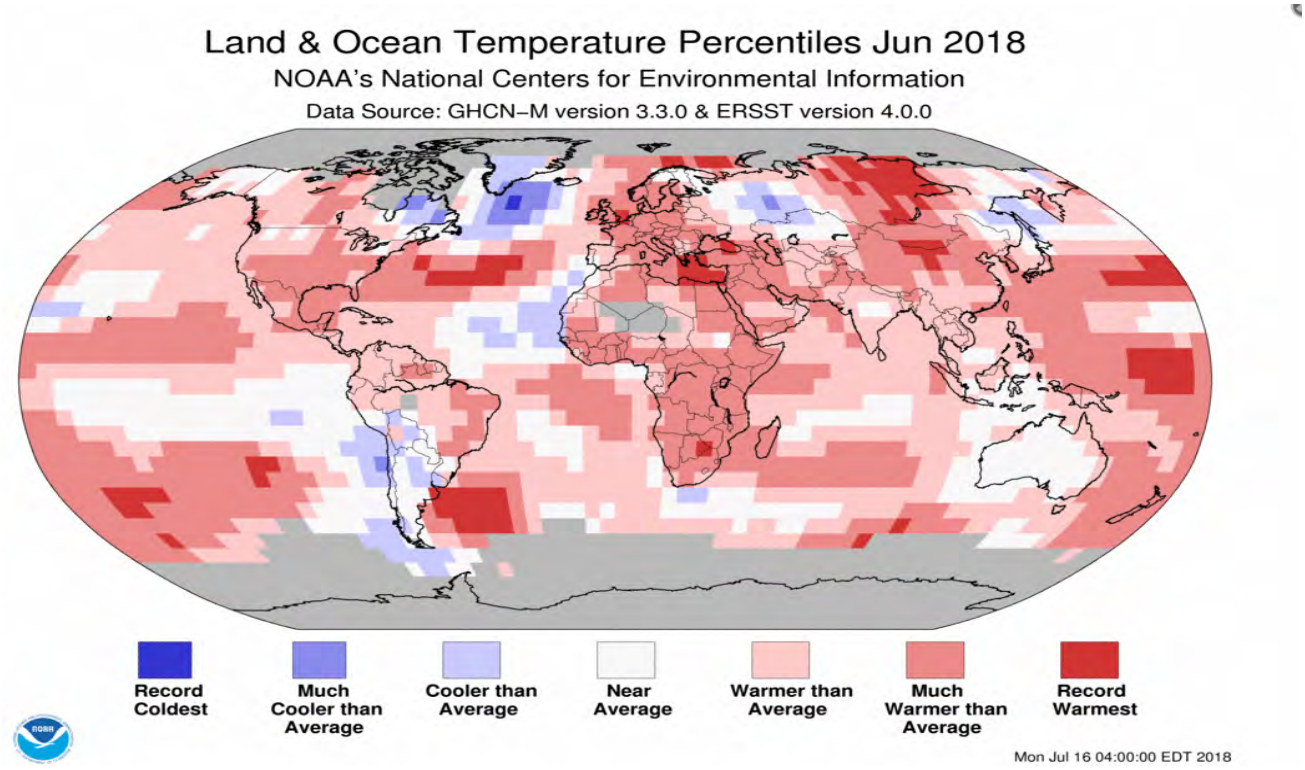

Figure 4. January to December 2018 blended land and sea surface temperature percentiles. Source: NOAA.

Sixteen of the hottest 17 years on record have occurred since 2000. On a global scale, the ocean warming is largest near the surface, and the upper 75 m warmed by 0.11 [0.09 to 0.13]°C per decade over the period 1971 to 2010. The UK's National Oceanography Centres at Liverpool and Southampton provide online data on the marine climate and climate change at spatio-temporal scales relevant to the Welsh regional and national coastline http://noc.ac.uk/. The 2014/15, 2015/16 and 2016/17 winters were, in contrast to 2013/14, three of the warmest on record https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate.

The levels of carbon dioxide in the global atmosphere passed the 400ppm threshold permanently in 2016 (Figure 6). Increased CO_2 concentrations in the atmosphere raise the global temperature and cause increased drawdown of CO_2 into the global oceans, exacerbating ocean acidification.

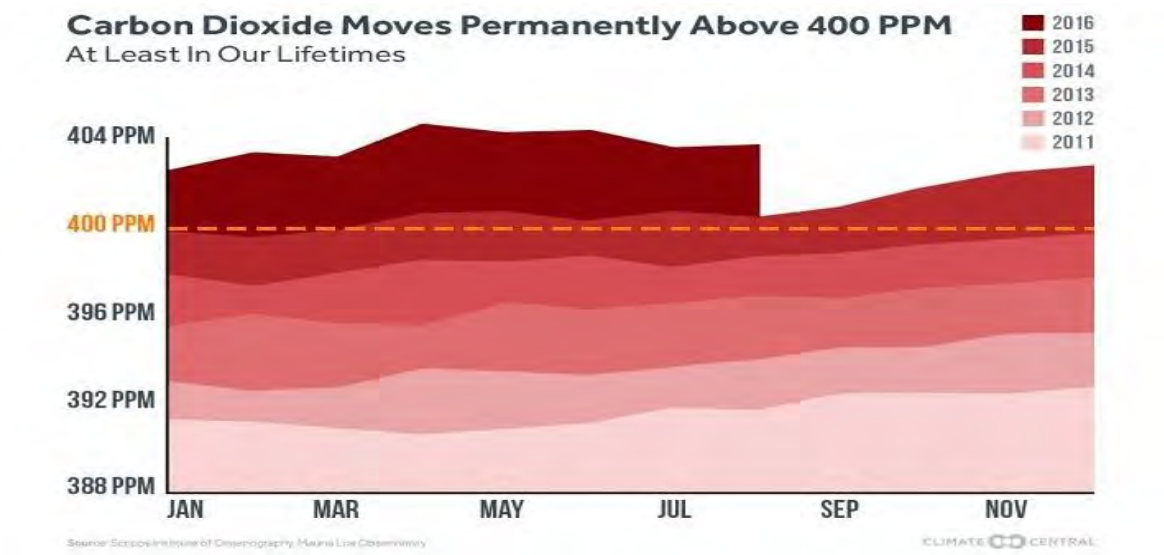

Figure 5. Atmospheric concentrations of carbon dioxide. Reproduced from Scripps Institute of Oceanography/Climate Central.

4.1.2 Regional and national trends

MarClim time-series sites in Wales were in a healthy condition in 2018 (no change against the baseline). The only evidence of anthropogenic impacts (other than climate change and storm damage) was small amounts of litter and fishing line on some shores, and a few records of Invasive Non Native Species (INNS).

Several extreme weather events occurred in 2018. Between late February and early March Britain experienced a severe spell of winter weather with very low temperatures. Known as the 'Beast from the East', anticyclone Hartmut coincided with storm Emma to cause some of the most extreme weather conditions in decades. These events caused a mass mortality of marine creatures along the east coast of England, however, no significant changes in the abundance of any of the fifty MarClim species of invertebrate were recorded at any MarClim site along the Welsh coastline during 2018. 2018 was one of the warmest years on record, with five of the warmest years happening since 2010. The joint hottest summer on record was recorded in 2018. Heatwaves occurred in April, June and July, with the Met Office reporting an average air temperature of 1.5°C above the long-term average. MarClim surveys around the UK including the Welsh shores, found evidence of heat damage to the high shore fucoid species *Pelvetia canaliculata, Fucus spiralis* and *Fucus vesiculosus* at sites across UK regional seas (Figure 6a,b), evident as desiccation and dieback of individuals.

Figure 6a. Heat damaged *F. vesiculosus* Little Orme, north Wales.

Figure 6b. Heat damaged *C. crispus,* Broadhaven, south Wales.

The oceanic sea surface temperature has been increasing globally over the past few decades, however, a region of the northeast Atlantic to the west of the UK has actually undergone a cooling of the marine surface water temperatures (Figure 4), thought to be due to a slow-down in the Gulf Stream system, caused by a global-warming driven slow-down in the Atlantic meridional overturning circulation (AMOC). Of concern are the NOAA model predictions that there is a 20% chance that the AMOC will completely break down at a "tipping point" under moderate warming (2-4°C) and a 65% chance under strong global warming (4-8°C). The moderate warming is within the predicted range of thermal increases due to global climate change by 2100 and if CO_2 emissions continue to increase, strong global warming is predicted to occur.

This change in surface ocean circulation patterns has large potential implications for Welsh marine ecosystems. The west coast ecosystems will continue to be subject to a cooling of the marine climate, favouring boreal, cold-water species, whereas the east coast ecosystems will continue to be subject to warming of the marine climate and favour the proliferation and range extensions of Lusitanian, warm water species. This may result in different coastal ecosystem responses to global climate warming if the west coast continues to cool in contrast to the east coast, which continues to warm. Such changes will have profound implications for national and EU level policy directives including the overarching Marine Strategy Framework Directive. Marine waters must be shown to maintain Good Ecological Status or Good Environmental Status against the shifting background of climate-driven changes to marine ecosystems.

In 2018, the Lusitanian, warm-water species of ectothermic invertebrates and macroalgae continued to increase in abundance, or maintained their SACFOR abundance categories at MarClim long-term monitoring sites around the Welsh coastline. Future annual surveys will be able to provide evidence of whether the long-term warming trend has resumed, or if the increase in population abundances was a short-term response to the milder winter thermal conditions experienced in 2013/14.

MarClim thus continues to assess a variety of coasts subject to different anthropogenic and non-anthropogenic factors now and in the future.

4.1.3 Invasive Non-Native Species

The invasive red alga *Grateloupia turuturu* is listed as Very High (CEFAS Rapid Risk Assessment) on the Priority Monitoring and Surveillance List for Wales (2017) https://beta.gov.wales/sites/default/files/publications/2018-02/invasive-aquatic-species-priority-marine-species.pdf. A new site at Neyland (by Brunel Wall) in Milford Haven was added in 2017 (Figure 7). *G. turuturu* was recorded as Occasional in 2017, when it was recorded for the first time in the MarClim Wales monitoring programme and was Frequent at Neyland in 2018.

The Invasive Non Native Species of kelp *Undaria pinnatifida* was recorded for the first time in the Skomer MCZ in 2018, where it was Rare at South Haven, Skokholm and Frequent (5%) at North Haven (Figure 8). *U. pinnatifida* had increased in abundance from Occasional (2%) to Frequent (5%) in the 2018 survey at Neyland (by Brunel Wall). It was also Rare at West Angle Bay, the first time this species has been recorded at this site.

The invasive red alga *Caulacanthus ustulatus* (*okamurae*) was added to the MarClim list in 2017 when it was recorded for the first time at Dale Fort Jetty. In 2018 it was again recorded as Common at Dale Fort Jetty and was also found for the first time in the Skomer MCZ at Martins Haven (Rare), Skokholm South Haven (Rare), Broadhaven (Frequent 5%) and West Angle Bay (Frequent 5%). *Sargassum muticum* was found at several sites in north and south Wales as in previous years, but has not spread to new locations in the MarClim site list. *Colpomenia peregrina* was Frequent (5%) at Cemlyn, Rare at Rhosneigr and Porth Oer, and Occasional at Porth Neigwl in 2018, but not recorded at any other MarClim site. These are different to the records for 2017, when *C. peregrina* was only recorded at Holyhead, Rhosneigr and Trefor (Occasional).

Figure 7. Neyland survey site, Milford Haven, south Wales.

Figure 8. *Undaria pinnatifida* at Skomer North Haven.

MarClim survey sites are located at exposed or semi-exposed sites away from direct influences of human activities. Given the close proximity of Holyhead and Milford Haven marinas to MarClim natural rocky shore sites, continued monitoring will enable tracking of any arrivals and increases in abundance of non-native species into local natural shores.

4.2 MarClim sites and MPAs

MarClim data contributes to the **State of Natural Resources Report (SoNaRR)** evidence on the extent, condition and trends of natural resources and ecosystems in Wales. This biodiversity data is required undersection 6 of the Environmental Protection Act 1990.

MarClim sites are located both within and outside SACs, SSSIs, SPAs, EMS and the Skomer MCZ around the coastlines of Wales (Figure 1). The time-series data from these sites assist Natural Resources Wales to work both at the landscape scale and to address smaller scale objectives in the context of the landscape scale ambition. MarClim data and expert knowledge contribute to the monitoring and assessment of healthy and resilient coastal marine systems, which enhance the natural capital. The MarClim data can be used to inform the **Natural Resource Policy** as the time-series tracks changes to the biogeography of species within and outside of the MPA network, track any declines in biodiversity, and support climate change mitigation and adaptation. MarClim data can be used for **Condition Assessments** of each attribute within MPAs as MarClim detects and tracks interannual changes in the condition of sites via attributes, such as:

- Distribution: of biological communities
- Structure: species composition of component communities
- Structure: non-native species
- Structure and function: presence and abundance of key structural and influential species

MarClim data can show when observed change is a local phenomenon resulting from an activity on a site, not inherent variability or a nation-wide trend due to some other factor. In addition, interpreting **Condition Monitoring** evidence requires contextual

information from a wider geographical area, or over longer time scales. MarClim provides these data from inside and outside of MPAs on an annual frequency, dating back to 2002, with historical data stretching back to the 1950s.

MarClim data can be used to see if **Conservation Objectives** are being met and identify any changes. The annual survey frequency and wide spatial coverage of MarClim surveys enables the objectives to be consistently applied in a standard manner across sites to identify and track changes across sites, highlight any localised impacts and determine if protection levels ensure Favourable Conservation Status and that no further degradation occurs.

MarClim data increase the Marine Evidence base, providing valuable data on the responses of intertidal organisms to climate change improving understanding thresholds and resistance/resilience in marine systems. The data can inform management as to the projected changes in community both inside and outside of marine protected areas, deliver better long-term outcomes for the environment, restoring and recovering ecosystems, and ensure a rich and resilient natural environment.

MarClim data on the annual abundance and distribution of INNS directly informs the Marine Plan policy for INNS (ENV-03), which helps to inform developers and decision makers about which species are of most concern in Welsh waters.

4.2.1 MarClim time-series analyses of intertidal communities

Multidimensional scaling of the annual survey data for sites within MPAs across the Welsh coastline are shown in Figures 9 and 10. These figures show how similar the species abundances are at each site for each survey year. The closer the years are located to each other, the more similar the species abundances are between these years.

Across all Welsh MPAs with intertidal habitat and areas of coastline that are not designated, the MarClim sites do not show any consistent patterns or trends since the surveys were started. This indicates that natural variation in the abundance of the component species of invertebrate and macroalgae but no small-scale or larger scale changes within any of these MPAs (Figures 9, 10).

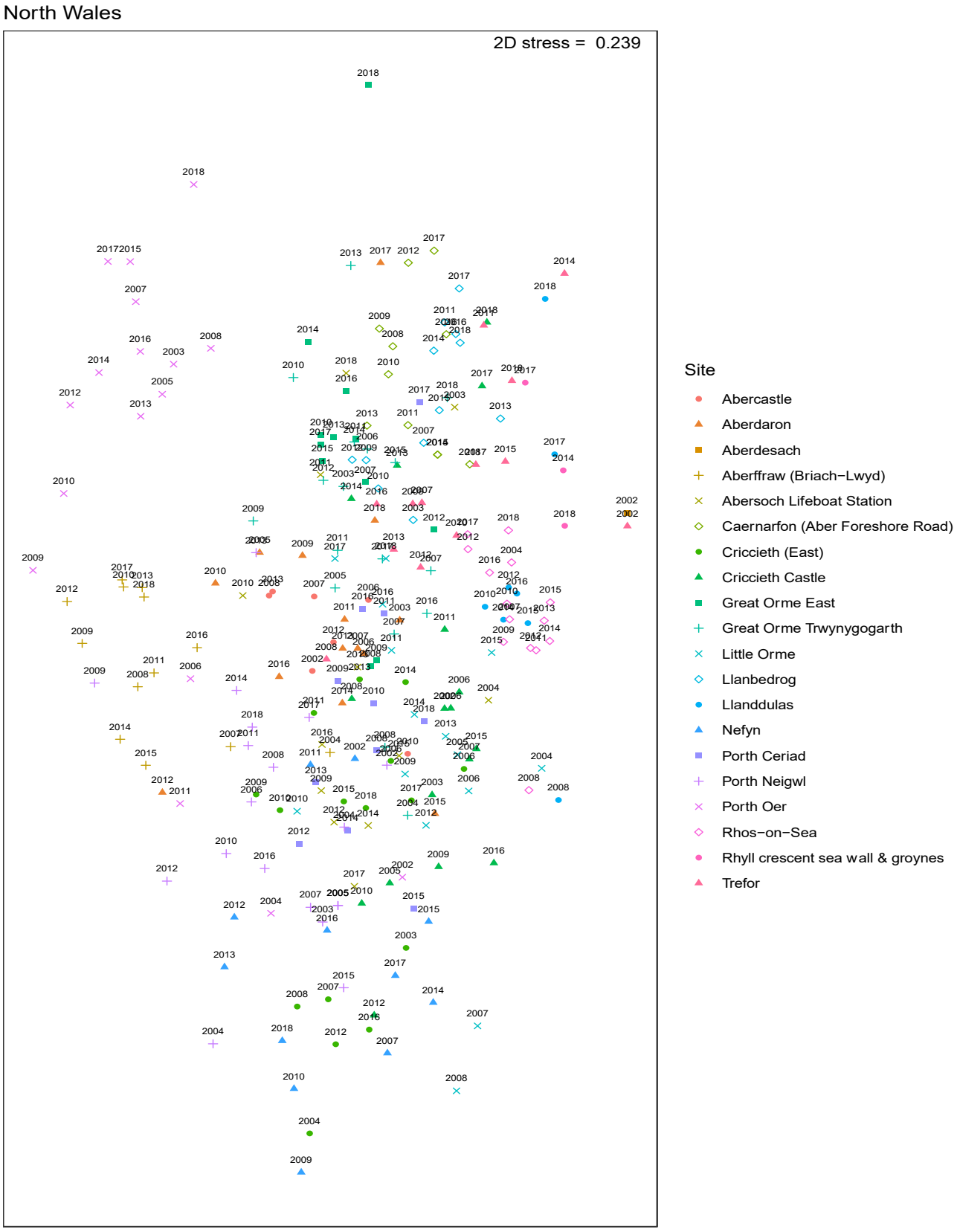

Figure 9. MarClim annual survey community analyses, north Wales.

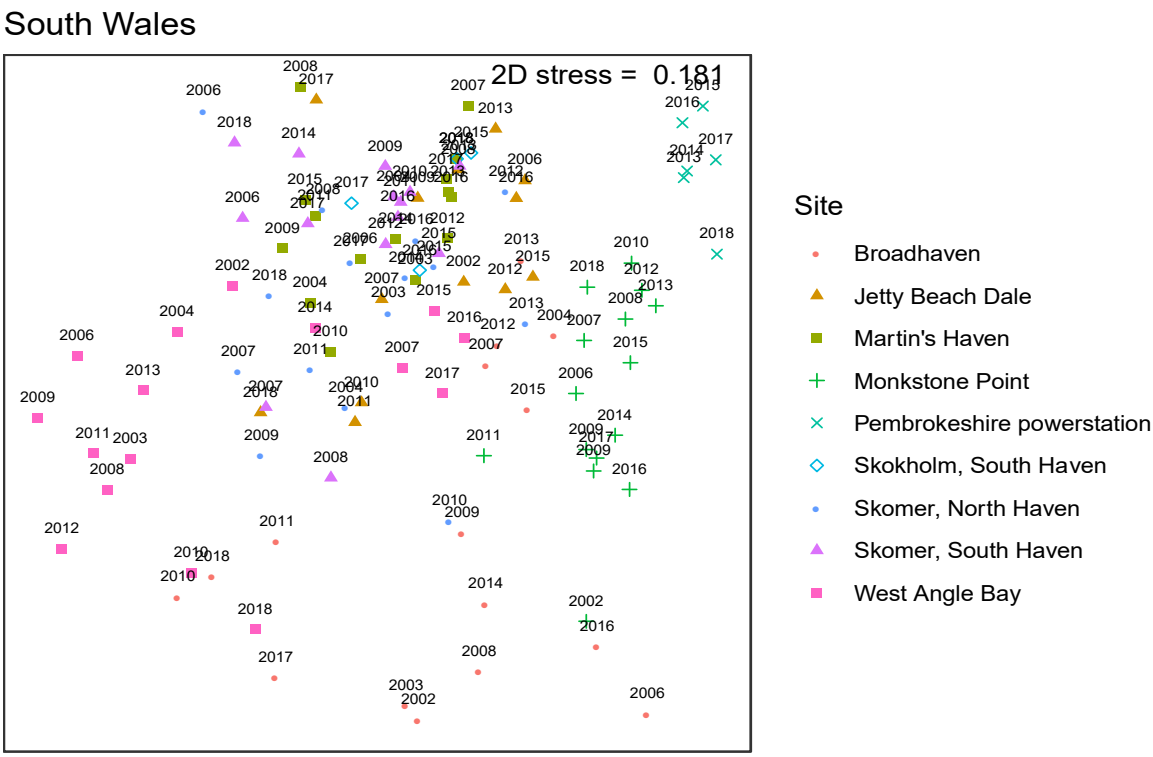

Figure 10. MarClim annual survey community analyses, south Wales.

4.3 Relevance to policy drivers and conservation objectives

The MarClim long-term sustained observation time-series dataset has been used to develop indicators for Good Environmental Status under the Descriptors 1: Biodiversity, 2: Non-indigenous Species, 4: Foodwebs and 6: Seafloor Integrity for the European Union Marine Strategy Framework Directive (http://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm; http://jncc.defra.gov.uk/page-6813). This establishes MarClim as the official, standardised monitoring project and methodology for the European MSFD assessment and policy-delivering progress. A second phase of work to develop the MarClim time-series as species (Species Temperature Index) and community (Community Temperature Index) indicators of climate change as part of the MSFD GES indicator development process was completed in 2017 by the MarClim team.

5 SUMMARY

All 43 rocky shores surveyed by the MarClim team were in good condition in 2018. The community composition at the majority of long-term sites did not show major changes in abundance in 2018 compared to recent years. All MarClim time-series sites in Wales were in a healthy condition in 2018 (no change against the baseline). The only evidence of anthropogenic impacts (other than climate change and storm damage) was small amounts of litter and fishing line on some shores, and the presence of INNS at some sites. Several extreme weather events occurred in 2018. No damage was recorded after anticyclone Hartmut and storm Emma in February, however, the heatwaves in April and June-July caused damage to high shore fucoid algae around the Welsh coastline. Future MarClim surveys will track any mortality or recovery from these heatwaves.

6 REFERENCES

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Surveyors:

NM Nova Mieszkowska, MBA
LA Leoni Adams, MBA
KB Kathryn Birch, NRW
LG Laura Grant, NRW
MB Mark Burton, NRW Skomer MCZ
KL Kate Lock, NRW Skomer MCZ
PN Phil Newman, NRW Skomer MCZ
JJ Jen Jones, NRW Skomer MCZ
HS Heather Sugden, Newcastle University

APPENDIX 1. MarClim Sampling Protocols 2018

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 calipers.
5. In shores where there is a relatively uniform distribution of rocks < 30cm it is possible to use a $1m^2$ quadrat to sample trochids. If this sampling method is used the operator moves across the quadrat and collects all animals on the visible surfaces. Once done, each rock is turned over and a separate search is undertaken for the younger animals that seldom move far from damp locations. A substantial proportion of the population may well be under stones. Again count the number of individuals and measure the basal diameter to the nearest 0.1mm. In addition, up to five random 0.5x0.5m quadrats can be thrown randomly to provide backup for SACFOR estimates.

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

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

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

B: Barnacle count

Barnacle Count: Recorder: ....

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

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

Recorder: ....

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

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

Recorder: ....

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

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

C: Limpet Count

Shore height: …… Recorder: ……

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

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

D: Trochid Count:

Recorder: ……

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

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

Notes:

APPENDIX 2: Data Archive

The report and data collected under Natural Resources Wales contract FC 73-02-359 is archived as Project No 443 Media No 1483 and is maintained in the NRW document storage software.

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] Some site photographs from each location.

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

File Path for data:

File path for the report:

File path for the archive:

Metadata for this project is publicly accessible through the Natural Resources Wales Library Catalogue:

English - https://libcat.naturalresources.wales/webview/

Welsh: - http://catllyfr.cyfoethnaturiol.cymru

by searching 'Dataset Titles'. The metadata is held as record no 16325.

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Bangor
Gwynedd
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