Cyfoeth Naturiol Cymru
Natural Resources Wales

THE MARINE BIOLOGICAL ASSOCIATION

MarClim Annual Welsh Intertidal Climate Monitoring Survey 2019

Dr. N. Mieszkowska

NRW Evidence Report No 467

Date: July 2021

About Natural Resources Wales

Natural Resources Wales is the organisation responsible for the work carried out by the three former organisations, the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales. It is also responsible for some functions previously undertaken by Welsh Government.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, used and enhanced, now and in the future.

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.

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

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

Published by: Natural Resources Wales
Maes y Ffynnon
Penrhosgarnedd
Bangor
LL57 2DW

03000 653000

Further copies of this report are available from the library

Email: library@cyfoethnaturiolcymru.gov.uk

Evidence at Natural Resources Wales

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

We will realise this vision by:

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

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

Report series:	Natural Resources Wales Evidence Report
Report number:	467
Publication date:	July 2021
Contract number:	MOA0070 (formerly M081 MFSG 10)
Contractor:	Nova Mieszkowska, Marine Biological Association
Contract Manager:	Paul Brazier
Title:	MarClim Annual Welsh Intertidal Climate Monitoring Survey 2019
Author(s):	Nova Mieszkowska
Technical Editor:	Paul Brazier
Peer Reviewer(s)	Karen Robinson
Approved By:	Andrea Winterton
Restrictions:	None

Distribution List (core)

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

Distribution List (others)

Andrea Winterton	NRW
Mike Camplin	NRW
Phil Newman	NRW
Charlotte Gjerlov	NRW
Gabrielle Wyn	NRW
Kirsten Ramsay	NRW
Sue Burton	Pembrokeshire Marine SAC
Aethne Cooke	MHWESG
Sarah Mellor	Pembrokeshire Coast NPA

Recommended citation for this volume:

Mieszkowska, N. 2021. MarClim Annual Welsh Intertidal Climate Monitoring Survey 2019. Natural Resources Wales Evidence Report No. 467, pp 22 + x, Natural Resources Wales, Bangor.

Crynodeb Gweithredol

Mae'r adroddiad hwn yn crynhoi'r gwaith arolygu, casglu data a dadansoddi a gwblhawyd yn 2019 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 39 safle yn 2019. Cynhaliwyd arolygon ar 32 safle yng ngogledd Cymru a 7 safle yn ne Cymru.

Yn yr arolygon MarClim a gynhaliwyd o gwmpas y DU yn 2018 a 2019, cafwyd tystiolaeth 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 o ganlyniad i'r haf poethaf ar y cyd a gofnodwyd 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. Yn 2019 cafwyd tywydd poeth iawn am gyfnod byr ar ddiwedd Gorffennaf, a gosodwyd y record ar gyfer y tymheredd uchaf erioed ar gyfer y DU. Ni chafwyd unrhyw dystiolaeth yn arolygon 2019 o farwolaeth ar raddfa uchel ymhlith rhywogaethau gwymonol ar unrhyw safle MarClim, sy'n dangos bod y rhywogaethau hyn yn gallu gwrthsefyll straen thermol a dysychiad o fewn yr ystod a brofwyd yn ystod tywydd poeth 2018 a 2019.

Cofnodwyd y rhywogaeth anfrodorol o algâu coch *Asparagopsis armata,* am y tro cyntaf ar safleoedd MarClim fel prin ym Mhort Oer yn 2019. Nid yw arolygon gynhaliwyd gan Cyfoeth Naturiol Cymru wedi dod o hyd iddi ar arfordir Cymru (Bunker, gohebiaeth bersonol).

Cofnodwyd y rhywogaeth anfrodorol 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 (ar bwys 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. Yn 2019 roedd wedi diflannu o bob safle heblaw Neyland, lle cofnodwyd iddi gynyddu mewn helaethrwydd i cyffredin.

Cafodd wystrysen oresgynnol y Môr Tawel, *Magallana gigas*, (8cm o hyd) unigol ei chofnodi yng Nghaernarfon ac unigolyn arall (15cm o hyd) ar safle naturiol Penmaenmawr yn 2019. Dyma'r cofnod cyntaf o *M. gigas* yng safle naturiol Penmaenmawr yn ers dechrau cyfres-amser MarClim yn 2002 a'r cofnod cyntaf ar safle Caernarfon ers 2012. Mae unigolion arunig hefyd wedi'u cofnodi ar ddwyrain Pen y Gogarth a Thrwynygogarth yn 2010, ac ym Moelfre yn 2012 yng ngogledd Cymru, ac yn ne Cymru yn Cosheston a Llanreath yn 2010 a gorsaf bŵer sir Benfro yn 2016.

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 gwaelodlin ar gyfer proses dynodi Parthau Cadwraeth Morol y DU.

Mae prosiect MarClim a'r tîm ymchwil yn darparu monitro unigryw, hanfodol, tymor hir 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 2019 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 39 sites in Wales in 2019. 32 sites were surveyed in north Wales and 7 sites in south Wales.

MarClim surveys in 2018 and 2019 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 that resulted from joint hottest summer on record 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. In 2019, there was a short but exceptional heatwave in late July, setting a new all-time UK temperature record. Despite this, the 2019 surveys in Wales did not find any evidence of mass mortality of fucoids at any MarClim site, indicating that these species are resistant to thermal and desiccation stress in the range experienced during the 2018 or 2019 heatwave events.

The first record of the Non Indigenous (non-native) Species (NIS) of red alga, *Asparagopsis armata* at MarClim sites was recorded as Rare at Porth Oer in 2019 as drift material. Surveys carried out by Natural Resources Wales have not found it on the Welsh coastline (Bunker, pers. comm.).

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 survey site at Neyland (by Brunel Wall) in Milford Haven was added in 2017, as the invasive kelp *Undaria pinnatifida* was spotted there. The 2018 resurvey found *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. In 2019 it had disappeared from all sites except Neyland, where it was recorded as having increased in abundance to Common.

One individual invasive Pacific oyster *Magallana gigas* (8 cm in length) was recorded at Caernarfon and one individual (15 cm in length) at Penmaenmawr natural site in 2019. This is the first record of *M. gigas* at Penmaenmawr natural site since the MarClim time-series began in 2002 and the first record at the Caernarfon site since 2012. Isolated individuals have also been recorded at Great Orme East and Great Orme Trwynygogarth in 2010, and at Moelfre in 2012 in north Wales, and in south Wales at Cosheston and Llanreath in 2010 and Pembrokeshire power station in 2016.

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 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.

Contents

Index of Figures

Index of Tables

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.

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 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 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.

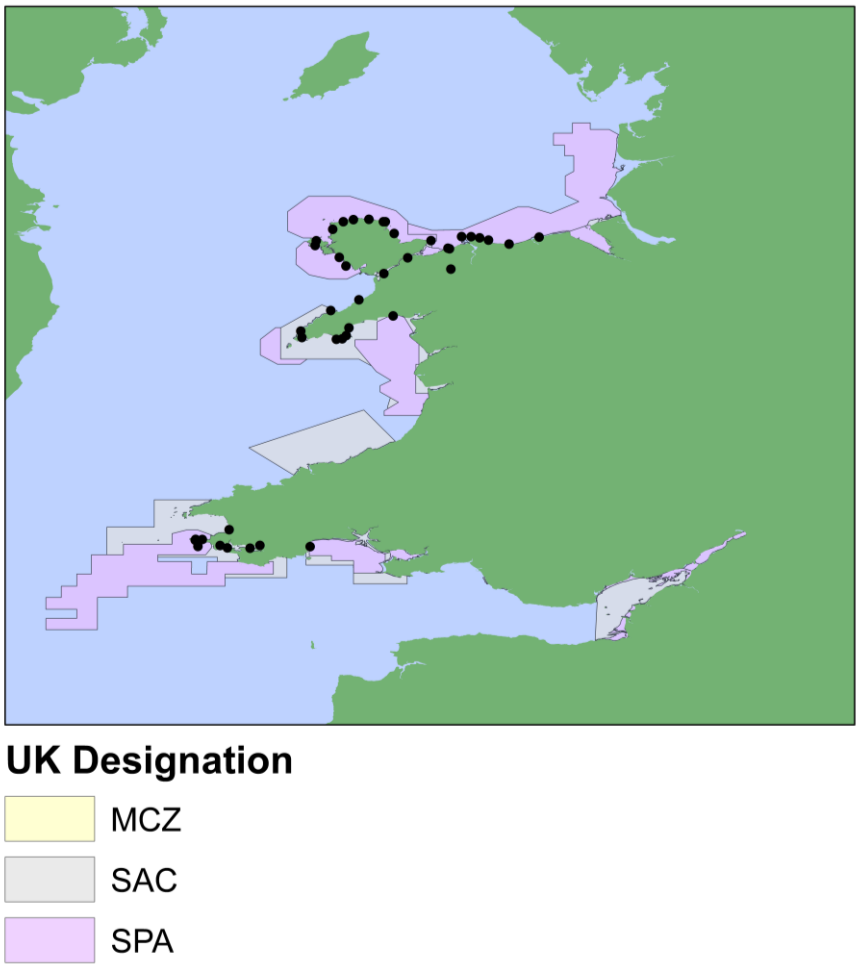
Climate-driven shifts in the biogeographic ranges of native and non indigenous species are also being tracked by Dr Mieszkowska around the wider northern European coastline using the MarClim protocols. These surveys provide geographically extensive, contextual evidence on distributions, abundances, biological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

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.

A total of 39 sites were surveyed in Wales, consisting of 32 sites in north Wales and 7 sites in south Wales; these locations included 34 long-term sites (Table 1, Figure 1).

Figure 1. MarClim sites surveyed in 2019



Thirty-two 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) (Figure 2). 7 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 and John Archer-Thomson of NRW. 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 87 species of invertebrates and macroalgae, including nine Invasive Non Indigenous Species 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 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 (http://www.NRW.gov.uk/.../NRW-in-holyhead-harbour.aspx). An additional site at Llanddulas, which has been sporadically checked for absence of indicator species has been added to the list after the appearance of a population of *Steromphala (Gibbula) umbilicalis* was found in 2012 and *Phorcus lineatus* in 2016, and is now surveyed each year. The Rhyl crescent seawall and groynes were surveyed in 2014 and again annually since 2017 to ensure further range extensions of the topshells are accurately located.

Metadata and quantitative survey data were recorded on datasheets in the field. The data were transferred to electronic datasheets in the laboratory and a rigorous QA check carried out by Mieszkowska and Brazier. Photographs were labelled to allow accurate interpretation and identification of features. Data analysis was carried out by Mieszkowska. The results are described in detail within this report. An electronic copy of data has been submitted to Natural Resources Wales as part of this report and another copy lodged with the MEDIN accredited data centre DASSH (Data Archive for Seabed Species and Habitats) at the MBA. The MarClim master dataset is accessible through the NBN via Marine Recorder.

Figure 2. Paul Brazier (NRW) & Heather Sugden

Figure 3. Mark Burton and Sam Hurst (NRW, Skomer).

Figure 4. 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.

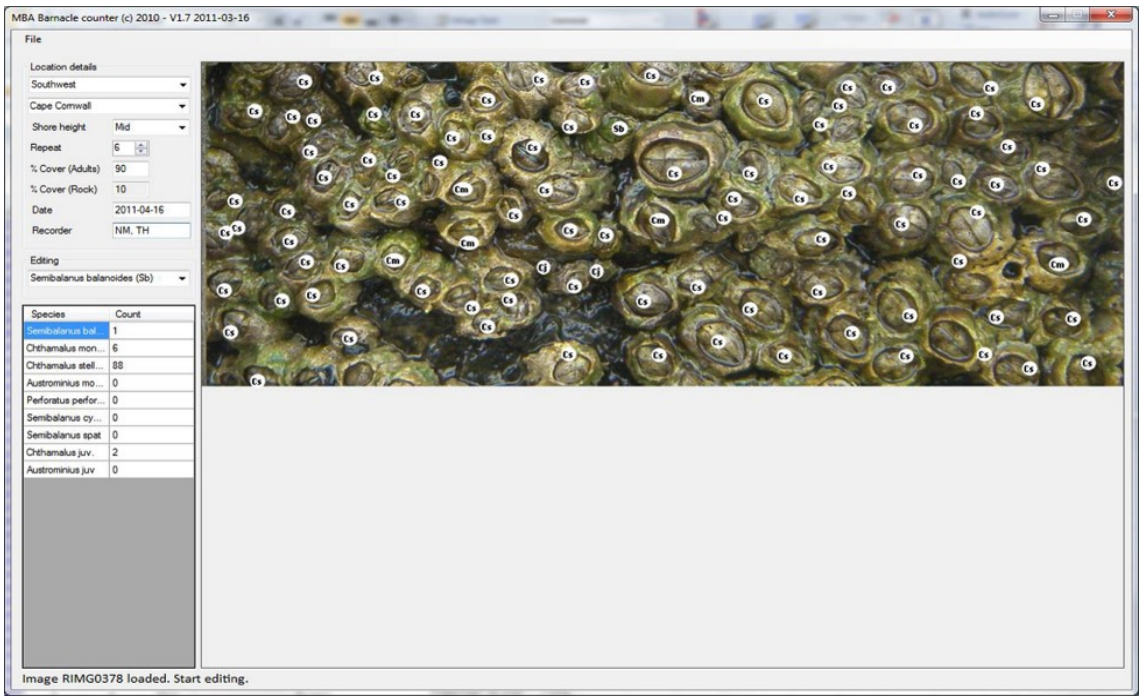


Figure 5. MarClim 0.25 m^2 limpet quadrat used for surveys.

Table 1. MarClim Survey Site Locations 2019

Date	Site Name	OS Grid Reference	Latitude (WGS84)	Longitude (WGS84)
17/05/2019	Monkstone Point	SN150033	51.6978	-4.6784
17/05/2019	Tenby	SN138004	51.6718	-4.6939
19/05/2019	Broad Haven	SM859144	51.7871	-5.1057
04/07/2019	Broad Haven	SM859144	51.7871	-5.1057
04/07/2019	Jetty Beach Dale	SM822053	51.7041	-5.1533
31/07/2019	Rhyl Splash Point	SJ021824	53.3299	-3.4715
31/07/2019	Llanddulas	SH906787	53.2933	-3.6296
31/07/2019	Rhos-on-Sea	SH843805	53.3140	-3.7381
31/07/2019	Little Orme	SH812825	53.3260	-3.7852
31/07/2019	Penmaenmawr natural	SH704763	53.2683	-3.9440
31/07/2019	Penmaenmawr artificial	SH709763	53.1613	-3.9369
31/07/2019	Penmaenmawr slipway	SH699766	53.2712	-3.9521
01/08/2019	Great Orme Trwynygogarth	SH749834	53.3327	-3.8801
01/08/2019	Great Orme East	SH782832	53.3321	-3.8297
01/08/2019	Trefor	SH376474	52.9992	-4.4215
01/08/2019	Caernarfon (Aber Foreshore Road)	SH521671	53.1374	-4.2897
01/08/2019	Penmon North	SH641813	53.3111	-4.0413
01/08/2019	Menai Bridge	SH555714	53.2207	-4.1643
02/08/2019	Bull Bay	SH427945	53.4238	-4.3688

02/08/2019	Moelfre	SH513859	53.3490	-4.2354
02/08/2019	Point Lynas	SH484929	53.4111	-4.2823
02/08/2019	Holyhead	SH257825	53.3108	-4.6461
02/08/2019	Porth Swtan	SH298891	53.3713	-4.5598
03/08/2019	Cemlyn	SH337934	53.4146	-4.5112
03/08/2019	Cemaes Bay	SH372944	53.4219	-4.4502
03/08/2019	Rhosneigr	SH315725	53.2233	-4.5253
04/08/2019	Aberffraw (Briach-Lwyd)	SH337674	53.1776	-4.4899
03/08/2019	Porth Dafarch	SH233798	53.2856	-4.6522
04/08/2019	Porth Oer	SH163297	52.8343	-4.7279
04/08/2019	Nefyn	SH274415	52.9430	-4.5702
04/08/2019	Skokholm South Haven	SM741051	51.6992	-5.2701
05/08/2019	Porth Neigwl	SH288245	52.7908	-4.5404
05/08/2019	Aberdaron	SH166260	52.8003	-4.7220
05/08/2019	Llanbedrog	SH335311	52.8516	-4.4742
06/08/2019	Criccieth East	SH308247	52.7938	-4.5094
06/08/2019	Criccieth Castle	SH494376	52.9146	-4.2412
06/08/2019	Porth Ceriad	SH308247	52.7938	-4.5094
06/08/2019	Abersoch Lifeboat Station	SH323265	52.8107	-4.4881
30/08/2019	Pembroke PowerStation	SM930032	51.6896	-4.9956
02/09/2019	Neyland Natural (by Brunel Wall)	SM967047	51.7045	-4.9433

EnvLogger temperature loggers and biomimetic sensors were deployed at three sites in north Wales and one site in south Wales in 2019 (Figure 6). These loggers are set to monitor environmental (air or sea) temperature and internal body temperature of limits every 20 minutes. These were not funded by NRW but data will be made available if requested.

4. RESULTS and DISCUSSION

4.1 Extreme weather events

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/.

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 or 2019.

Figure 6. EnvLogger (right) and biomimetic sensor (left) at Porth Oer, north Wales.

The UK experienced a short but exceptional heatwave in late July 2019, setting a new all-time UK temperature record. This mirrored the heatwaves that occurred in summer 2018. The hottest temperature ever recorded was on 25th July 2019 (https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2019/2019_007_july_heatwave.pdf). The record for the hottest December and February day was also broken in 2019. Eight high temperature records were broken in the last decades, but only one for a low temperature. In the UK, 2019 was the 11th hottest year recorded, but the 11 hottest years have occurred since 2002 (https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2019/state-of-the-uk-climate-2018).

4.2 Regional and national trends

MarClim time-series sites in Wales were in a healthy condition in 2019 (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 Indigenous Species (NIS) that are detailed below.

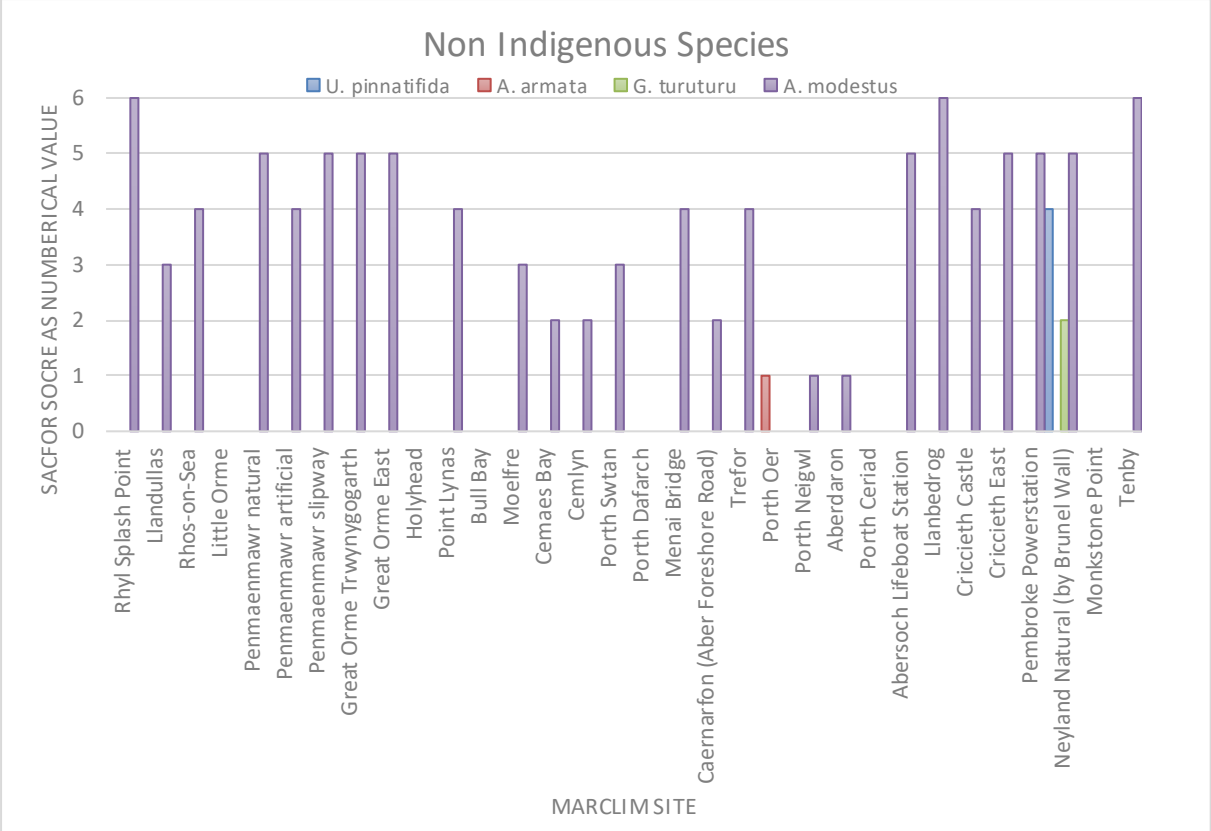
The oceanic sea surface temperature has been increasing globally over the past few decades, however, a region of the northeast Atlantic to the west of the UK has actually undergone a cooling of the marine surface water temperatures (see Figure 4 in Mieszkowska 2019), thought to be due to a slow-down in the Gulf Stream system, caused by a global-warming driven slow-down in the Atlantic meridional overturning circulation. In 2019, the Lusitanian, warmwater 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 English coastline. Future annual surveys will be able to provide evidence of whether the long-term warming trend has resumed (since the 2010s), or if the increase in population abundances was a short-term response to the milder winter thermal conditions experienced in 2013/14.

4.3 Non Indigenous Species

The most prolific non indigenous species around the Welsh coastline is the barnacle *Austrominius modestus*. This was recorded as present at 23 sites in north Wales and 7 sites in south Wales in 2019 (Table 2). The brown alga *Sargassum muticum* was not recorded at any MarClim site in 2019.

One individual invasive Pacific oyster *Magallana gigas* (8 cm in length) was recorded at Caernarfon and one individual (15 cm in length) at Penmaenmawr natural site in 2019. This is the first record of *M. gigas* at Penmaenmawr natural site since the MarClim time-series began in 2002 and the first record at the Caernarfon site since 2012. Isolated individuals have also been recorded at Great Orme East and Great Orme Trwynygogarth in 2010, and at Moelfre in 2012 in north Wales, and in south Wales at Cosheston and Llanreath in 2010 and Pembrokeshire Power Station in 2016.

Figure 7. Non Indigenous Species SACFOR Abundances at MarClim sites in Wales 2019.



The red alga *Asparagopsis armata* was Rare at Porth Oer, as drift material. This is the first time this species has been recorded in Wales in MarClim surveys. NIS surveys carried out by Francis Bunker and Jon Moore for Natural Resources Wales have not found it on the Welsh coastline (Bunker, pers. comm.).

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 8). *G. turuturu* was recorded as Occasional (2%) in 2017, when it was recorded for the first time in the MarClim Wales monitoring programme, Frequent (5%) in 2018 but had declined back to Occasional in 2019. *G. turuturu* has not been recorded at any other MarClim site in Wales.

Figure 8. Neyland survey site, Milford Haven, south Wales.

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 Martin's Haven (Rare), Skokholm South Haven (Rare), Broad Haven (Frequent 5%) and West Angle Bay (Frequent 5%). In 2019 *C. ustulatus* was still Rare at Skokholm South Haven, Frequent at Dale Fort Jetty, and Abundant at Monkstone Point, but Not Seen at Martin's Haven or Broad Haven, showing that fluctuating populations are characteristic of the invasion dynamics of south Wales for this species.

The invasive non indigenous 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 had been recorded at this site. In 2019, however, *U. pinnatifida* was not present at any of these sites with the exception of Neyland, where it had increased to Common.

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 indigenous species into local natural shores.

MarClim data on the annual abundance and distribution of NIS (=Invasive Non-Native Species INNS) directly informs the Marine Plan policy for INNS(ENV-03) helps to inform developers and decisionmakers about which species are of most concern in Welsh waters.

Table 2. Non Indigenous Species at MarClim sites in 2019

Site	Sargassum muticum	Undaria pinnatifida	Chondracanthus acicularis	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 subtorquata	Hemigrapsus sanguineus	Hemigrapsus takanoi
Monkstone Point	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Tenby	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Broad Haven (1st survey day)	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Broad Haven (2nd survey day)	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Jetty Beach Dale	R	NS	NS	NS	NS	NS	F	NS	NS	NS	A	NS	NS	NS	NS	NS	R	NS	NS	NS	NS	NS
Rhyl Splash Point	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Llanddulas	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rhos-on-Sea	NS	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	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Penmaenmawr natural	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Penmaenmawr artificial	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Penmaenmawr slipway	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Great Orme Trwynygogarth	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Great Orme East	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trefor	NS	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	NS	C	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Penmon North	F	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	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bull Bay	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Moelfre	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Point Lynas	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Site	Sargassum muticum	Undaria pinnatifida	Chondracanthus acicularis	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 subtorquata	Hemigrapsus sanguineus	Hemigrapsus takanoi
Holyhead	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Swtan	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cemlyn	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cemaes Bay	NS	NS	NS	NS	NS	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	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aberffraw (Briach-Lwyd)	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Dafarch	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Oer	S	NS	NS	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nefyn	O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Skokholm South Haven	R	NS	NS	NS	NS	NS	R	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Neigwl	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Aberdaron	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Llanbedrog	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Criccieth East	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Criccieth Castle	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Porth Ceriad	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Abersoch Lifeboat Station	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pembroke PowerStation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	A	NS	R	NS	NS	NS	NS	NS	NS	NS	NS	NS
Neyland Natural (by Brunel Wall)	NS	C	NS	NS	NS	O	NS	NS	NS	NS	A	NS	O	F	NS	NS	A	NS	NS	NS	NS	NS

4.4 Relevance to policy drivers, national policy and Marine Protected Areas

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. These biodiversity data are required under section 6 of the Environmental Protection Act 1990.

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, https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/benthic-habitats/intertidal-community-index/).

MarClim sites are located both within and outside SACs, SSSIs, SPAs, EMS and the Skomer MCZ around the coastline 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 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 can be used to help understand whether **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 localized 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, provide data to assist with the CS21 outcomes approach,

deliver better long-term outcomes for the environment, restoring and recovering ecosystems, and ensure a rich and resilient natural environment.

5. SUMMARY

All 32 rocky shores surveyed by the MarClim team were in good condition in 2019. The community composition at the majority of long-term sites did not show major changes in abundance in 2019 compared to recent years. All MarClim time-series sites in Wales were in a healthy condition in 2019 (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 NIS at some sites. An extreme heat wave event occurred in 2019, following on from heatwaves in the summer of 2018. No damage to MarClim species was recorded, however, future MarClim surveys will track any mortality or recovery from these heatwaves.

6. REFERENCES

Burrows, M.T., Hawkins, S.J., Moore, J.J.., Adams, L., Sugden, H., Firth, L. & **Mieszkowska, N.** 2019. Global-scale species distributions predict temperature-related changes in species composition of rocky shore communities in Britain. Global Change Biology.

Burrows, M.T., Hawkins, S.J., & **Mieszkowska, N.** 2017. Development of an MSFD intertidal rocky shore indicator for climate change response and an interim assessment of UK shores. Scottish Natural Heritage, pp61.

Mieszkowska, N. 2019. MarClim Annual Welsh Intertidal Climate Monitoring Survey 2018. Natural Resources Wales Evidence Report No. 345 pp 23 + x, Natural Resources Wales, Bangor.

Mieszkowska, N., Leaper, R., Kendall, M. A., Burrows, M. T., Moore, P., Lear, D., Poloczanska, E., Hiscock, K., Thompson, R. C., Herbert, R/ J., Laffoley, D., Baxter, J., Southward, A. J. & Hawkins, S. J. 2005. Assessing and Predicting the Influence of Climatic Change Using Intertidal Rocky Shore Biota. The Marine Biological Association of the U.K.

https://beta.gov.wales/sites/default/files/publications/2018-02/invasive-aquatic-species-priority-marine-species.pdf

http://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm; http://jncc.defra.gov.uk/page-6813

https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/benthic-habitats/intertidal-community-index/

https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2019/state-of-the-uk-climate-2018

https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2019/2019_007_july_heatwave.pdf

http://noc.ac.uk/

7. ACKNOWLEDGEMENTS

MarClim thanks Paul Brazier for contract management and continued support of the MarClim project since 2002, and Adam Cooper for taking over during Paul's secondment. Mark Burton, Kate Lock, Phil Newman, Jen Jones, John Archer-Thomson and Kathryn Birch for taking the time to complete another year's surveying with MarClim.

Surveyors:

NM Nova Mieszkowska, MBA

KB Kathryn Birch, 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

JAT John Archer-Thomson, NRW Skomer MCZ

SH Sam Hurst

HS Heather Sugden, Newcastle University

APPENDIX 1: MarClim Sampling Protocols 2019

Before you start at each site, record:

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

At each site: Semi-Quantitative Data

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

At each site: Quantitative Data

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

At each site: Quantitative Barnacle Data Collection

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

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

Counting Limpets and Associated Species

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

Counting Trochids

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

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

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

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

B: Barnacle count

Barnacle Count: Recorder: ………………….

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

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

Recorder: ………………….

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

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

Recorder: ………………….

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

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

C: Limpet Count

Shore height: …… Recorder: ……

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

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

D: Trochid Count: Recorder: ……

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

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

Notes:

APPENDIX 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 2019. Natural Resources Wales Evidence Report No. 467, pp 22 + x, Natural Resources Wales, Bangor.

Metadata for this project is publicly accessible through the Natural Resources Wales Library Catalogue by searching 'Dataset Titles'. The metadata is held as record no 109815.

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

Date: 10/07/2021

Published by: Natural Resources Wales
Maes y Ffynnon
Penrhosgarnedd
Bangor
LL57 2DW

03000 653000

Further copies of this report are available from the library

Email: library@cyfoethnaturiolcymru.gov.uk