Cyfoeth Naturiol Cymru
Natural Resources Wales

MarClim Annual Welsh Intertidal Climate Monitoring Survey 2023

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Mae'r adroddiad hwn yn crynhoi'r gwaith arolygu ar safleoedd rhynglanwol creigiog, y data a'r dadansoddiad, a gwblhawyd yn 2023 o amgylch arfordir Cymru o dan deitl prosiect MarClim, fel y disgrifiwyd yn http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm Mieszkowska (2005). Mae'r arolwg blynyddol yng Nghymru yn rhan o arolwg blynyddol parhaus dros gyfnod o 22 o flynyddoedd yn y DU ar dros 100 o safleoedd rhynglanwol creigiog hirdymor. Mae'r ardal ddaearyddol yn cynnwys safleoedd ar draws gogledd a de-orllewin Cymru y mae data hanesyddol sy'n dyddio'n ôl i'r 1950au yn bodoli mewn perthynas â nhw, yn ogystal â safleoedd ychwanegol lle rhagwelwyd y byddai'r ardal yn ehangu. Cynhaliwyd arolygon MarClim ar 37 o safleoedd yn 2023. Arolygwyd 29 o safleoedd yng ngogledd Cymru, dau safle yn y Canolbarth a chwe safle yn ne Cymru.

Dulliau

Ceir disgrifiad manwl o'r dulliau yn Adran 2. Cofnodwyd data SACFOR ar sail categorïau ar gyfer pob un o'r 82 o rywogaethau ar restr MarClim. Cofnodwyd data cwadrad meintiol ar gyfer tair rhywogaeth brenigen a phedair rhywogaeth cragen long, a chwblhawyd chwiliadau meintiol wedi'u hamseru ar gyfer dwy rywogaeth top môr. Mae ecolegwyr o Cyfoeth Naturiol Cymru yn mynychu arolygon ac mae eu data arolwg a'u technegau adnabod tacsonomaidd yn cael eu croesraddnodi gyda thîm MarClim.

Crynodeb o'r prif ganlyniadau

Adeiladwyd amddiffynfeydd arfordirol artiffisial newydd ar hyd y blaendraeth yn y Rhyl rhwng 2020 a 2021. Yn 2023 ychwanegwyd at algâu dros dro sy'n cytrefu'n gynnar a gofnodwyd am y tro cyntaf yn 2022 gan *Fucus spiralis,* Toreithiog 90%, *Austrominius modestus,* Toreithiog 90%, *Semibalanus balanoides,* Cyffredin 30%, a *Littorina littorea,* Prin.

Cafwyd hyd i ychydig o unigolion y gragen long Lwsitanaidd, *Perforatus perforatus,* yn Abersoch yn y gogledd am yr ail flwyddyn yn olynol, sy'n ymestyn ymyl arweiniol yr ardal tua'r pegwn 240 km. Cadarnhawyd y rhywogaeth drwy fargodio sampl gan y Gymdeithas Bioleg Forol yn 2024.

Ni chafwyd hyd i *Patella depressa* ym Mhorth Oer yn 2023. Cofnodwyd un *P. depressa* llawn dwf ym Mhorth Oer yn 2022, a chofnodwyd chwe unigolyn llawn dwf yn 2021. Ymddengys fod hon yn boblogaeth dros dro, gan na chofnodwyd yr un yn ystod 2007 – 2020, ond cafwyd hyd i bum unigolyn yn arolwg MarClim 2003 a 10 unigolyn yn arolwg 2006. Cafwyd hyd i boblogaeth fach (Aml) o *P. depressa* yn Aberdaron yn 2023. Cofnodwyd un unigolyn llawn dwf yno yn 2022, ac yn 2021 cofnodwyd niferoedd bychain (Prin), sy'n dangos bod y boblogaeth hon wedi parhau mewn niferoedd bychain dros y pedair blynedd diwethaf. Dyma ymyl arweiniol yr ardal ar hyn o bryd ar gyfer dosbarthiad bioddaearyddol y rhywogaeth Lwsitanaidd *P. depressa.*

Cofnodwyd y tiwnigog cytrefol goresgynnol, *Didemnum vexillum,* yn nhafod Neyland yn aber Aberdaugleddau yn 2023. Cadarnhawyd y rhywogaeth gan samplau a fargodiwyd gan y Gymdeithas Bioleg Forol. Roedd y bryosoad goresgynnol, *Watersipora subatra,* yn bresennol ar draeth glanfa Dale yn 2023.

Casgliadau a phwyntiau trafod

Mae arolygon MarClim yn darganfod newidiadau blynyddol o ran mesurau helaethrwydd sy'n seiliedig ar feddiannaeth ar gyfer rhywogaethau safleoedd

rhynglanwol creigiog. Dyma fetrig sensitif i dracio pa mor agored y mae rhywogaethau i newid hinsawdd treiddiol, digwyddiadau thermol eithafol yn yr hinsawdd forol ac, oherwydd y cynhelir arolygon ar sawl safle yn yr un ardal, gellir darganfod aflonyddwch ar raddfa fach, er enghraifft, difrod sgwrio yn sgil symudiadau lleol graean mân yn ystod stormydd yn ogystal â phatrymau mwy o ran newid hinsawdd i rywogaethau morol.

Ni wnaeth cyfnodau o dywydd poeth a'r flwyddyn boethaf ar gofnod yn 2023 arwain at unrhyw farwolaethau torfol o ran rhywogaethau ar safleoedd MarClim. Cafwyd un cyfnod o dywydd poeth yn ystod arolygon gogledd Cymru, fodd bynnag, ni sylwyd ar unrhyw farwolaethau. Bydd unrhyw effeithiau hirdymor posibl yn cael eu canfod yn arolygon MarClim yn 2024.

Ni wnaeth cyfansoddiad cymunedau newid yn sylweddol yn 2023 o gymharu â'r blynyddoedd diwethaf ar unrhyw safle arolygu. Mae arolygon blynyddol MarClim yn tracio cytrefu, cyflymder a maint ymlediad, ond hefyd ddigwyddiadau amrywiol ac absenoldeb rhywogaethau estron. Cofnodwyd y tiwnigog cytrefol *Didemnum vexillum* yn nhafod Neyland yn aber Aberdaugleddau yn 2023. Cadarnhawyd y rhywogaeth gan samplau a fargodiwyd gan y Gymdeithas Bioleg Forol, ac mae samplau a ddadansoddwyd ym Mhrifysgol Aberystwyth yn dangos bod poblogaethau Aberdaugleddau yng Nghreigiau Carr a Trwyn Barnlake yn fwyaf tebyg i'r rheiny yn Herne Bay yng Nghaint. Bydd y rhywogaeth hon yn parhau i gael ei thracio yn arolwg MarClim mewn blynyddoedd yn y dyfodol.

Gwnaed gwaith croesraddnodi gyda Paul Brazier, Mark Burton, Kate Lock, Jen Jones, Ali Massey, Rebekah Newstead a Natasha Lough o Cyfoeth Naturiol Cymru, wardeiniaid Skokholm, Ellyn Baker ac Amelia Corvin-Czarnodolski, a John Archer-Thomson, ar arolygon MarClim yng Nghymru. Cynhaliodd Mike Camplin a Mark Burton chwiliad manwl o dafod Neyland yn ystod arolygon MarClim i ddogfennu cytrefi penodol o *D. vexillum* a chael sampl yr aethpwyd ag ef i'r Gymdeithas Bioleg Forol i'w fargodio.

Executive summary

Background to the project

This report summarises the 2023 rocky intertidal survey work, data and analysis completed around the coastline of Wales under the project title of MarClim, as described in http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm Mieszkowska (2005). The annual survey in Wales forms part of a sustained, twenty two-year, continuous annual UK survey of over 100 long-term rocky intertidal survey sites. Geographical coverage includes sites throughout north and south-west Wales for which historical data dating back to the 1950s exist, and additional sites where range extensions have been predicted to occur. MarClim surveys were carried out at 37 sites in 2023. Twenty nine sites were surveyed in north Wales, two in mid Wales, and six sites in south Wales.

Methods

Methods are described in detail in Section 2. Categorical SACFOR data are recorded for all 82 species on the MarClim list. Quantitative quadrat data are recorded for three species of limpet, four species of barnacles, and quantitative timed searches are completed for two species of trochid. Ecologists from Natural Resources Wales attend surveys and their survey data and taxonomic identification techniques are cross-calibrated with the MarClim team.

Summary of key results

New artificial coastal defences were built along the foreshore at Y Rhyl between 2020 and 2021. In 2023 early colonising ephemeral algae first recorded in 2022 had been supplemented by *Fucus spiralis* Superabundant 90%, *Austrominius modestus* Superabundant 90%, *Semibalanus balanoides* Common 30%, and *Littorina littorea* Rare.

A few individuals of the Lusitanian barnacle *Perforatus perforatus* were found at Abersoch, north Wales for the second year running, representing a poleward extension of the leading range edge of 240 km. Barcoding of a sample by the Marine Biological Association in 2024 confirmed the species identity.

No *Patella depressa* were found at Porth Oer in 2023. One adult *P. depressa* was recorded at Porth Oer in 2022, and six adult individuals were recorded in 2021. This appears to be a transient population as none were recorded in 2007 – 2020, but five individuals were found in 2003 and 10 individuals in 2006 MarClim surveys. A small population (Frequent) of *P. depressa* was found at Aberdaron in 2023. One adult was recorded there in 2022, and in 2021 small numbers (Rare) were recorded, showing this population has continued to persist in small numbers over the past four years. This is the current leading range edge of the biogeographic distribution for the Lusitanian species *P. depressa.*

The invasive colonial tunicate *Didemnum vexillum* was recorded at Neyland Spit in Milford Haven estuary in 2023. Samples barcoded at the Marine Biological Association confirmed the identity of this species. The invasive bryozoan *Watersipora subatra* was present on Dale Jetty Beach in 2023.

Conclusions and discussion points

MarClim surveys detect annual changes in occupancy-derived measures of abundance for rocky intertidal species. These are a sensitive metric with which to track the vulnerability of species to pervasive climate change, extreme thermal events

occurring in the marine climate, and because multiple sites are surveyed in the same region, small-scale disturbances such as, for example, scour damage from local movements of shingle during storm events can be detected against the larger patterns of climate-driven change to marine species.

Heatwave events and the hottest year on record in 2023 did not result in any mass mortalities of species at MarClim sites. One heatwave occurred during the north Wales surveys, however, no mortalities were observed. Any potential longer-term impacts will be picked up in the 2024 MarClim surveys.

Community composition did not massively change in 2023 compared to recent years at any survey site. MarClim annual surveys track colonisation, the rate and extent of spread, but also fluctuating occurrences and absences of NIS. The colonial tunicate *Didemnum vexillum* was recorded at Neyland Spit in Milford Haven estuary in 2023. Samples barcoded at the Marine Biological Association confirmed the identity of this species, and samples analysed at Aberystwyth University indicate that the Milford Haven populations at Carr Rocks and Barnlake Point show most similarity to those at Herne Bay in Kent. This species will continue to be tracked in future MarClim survey years.

Cross-calibration with Paul Brazier, Mark Burton, Kate Lock, Jen Jones, Ali Massey, Rebekah Newstead, and Natasha Lough from Natural Resources Wales, Skokholm wardens Ellyn Baker and Amelia Corvin-Czarnodolski, and John Archer-Thomson was carried out on Welsh MarClim surveys. Mike Camplin and Mark Burton carried out a detailed search of Neyland Spit during the MarClim surveys to document specific colonies of *D. vexillum* and to obtain a sample that was taken to the Marine Biological Association for barcoding.

Introduction

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

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

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

1.1 Background

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

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

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

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

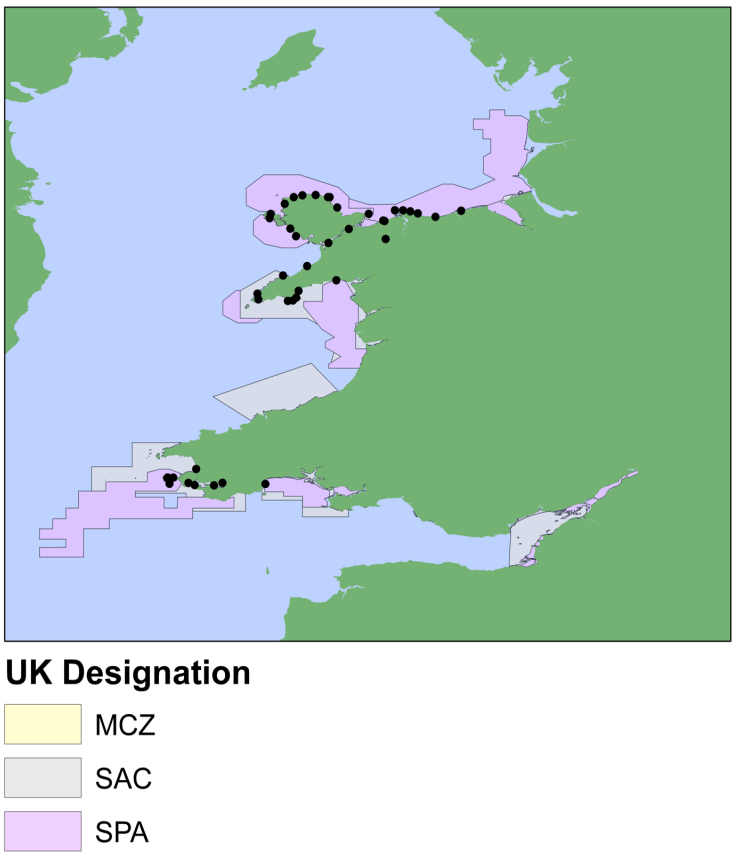
The project focuses on a robust set of temperature-sensitive, readily observed, intertidal climate indicator species of invertebrates and macroalgae for which long-term data sets and monitoring sites are available. The MarClim species list includes Boreal cold-water and Lusitanian warm-water origins, native to the UK intertidal ecosystems, and invasive non-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. In order to ensure comparability with the historical data the original methodology was retained for ACFOR (now SACFOR) scoring of species abundances and barnacle quadrat counts. Additional quantitative methodology to facilitate robust statistical analysis and modelling (e.g. Community Temperature Index (Burrows *et al*. 2019)) has been incorporated since 2002 and is detailed in the Survey Protocols section below.

Figure 1. MarClim sites surveyed in 2023.



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

which intertidal species respond to large-scale climate related changes and allow Welsh data to be placed into a European context, with special relevance to the EU Marine Strategy Framework Directive 'Good Environmental Status' indicators (Marine Biodiversity Indicators | JNCC - Adviser to Government on Nature Conservation).

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 Non-native species » NNSS (nonnativespecies.org)

MarClim surveys were carried out at 37 sites in 2023 (Table 1, Figure 1). Twenty nine rocky shores in north Wales were surveyed by Dr. Nova Mieszkowska from the Marine Biological Association (MBA), Dr. Heather Sugden from Newcastle University, Paul Brazier, Natasha Lough, Kathryn Birch, and Rebeka Newstead from Natural Resources Wales (Figure 1). Eight sites were surveyed in central and south Wales including five on the mainland and one on Skokholm Island. These surveys were carried out and cross-calibration exercises undertaken by Nova Mieszkowska and Belle Heaton from the MBA, Paul Brazier, Mark Burton, Kate Lock, Jen Jones, and Alison Massey of NRW, John Archer-Thompson, and the Skokholm wardens Ellyn Baker and Amelia Corvin-Czarnodolski (Figure 2). Mike Camplin of NRW carried out an additional detailed survey of Neyland Spit as part of the MarClim 2023 survey trip. Data entry was completed by Nova Mieszkowska with QA by Paul Brazier.

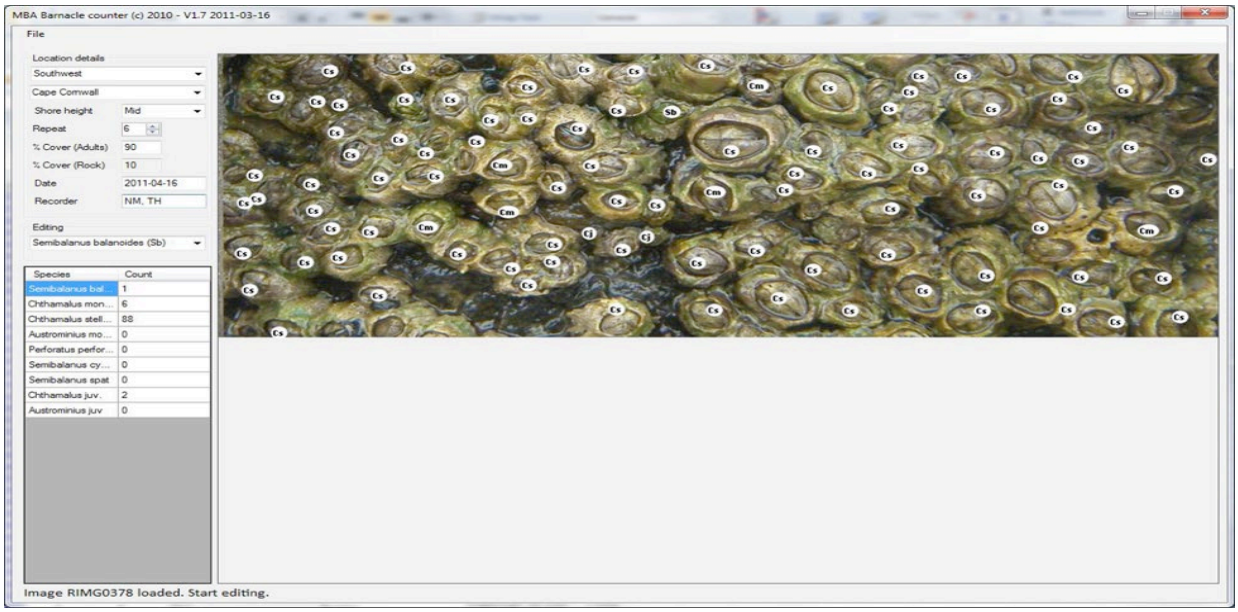
Figure 2. Belle Heaton from the MBA and Paul Brazier from NRW doing a MarClim survey.

Semi-quantitative SACFOR abundance scores were recorded for a suite of 82 species of invertebrates and macroalgae, including 9 invertebrate NIS and 9 macroalgae NIS. Replicate, quantitative quadrat counts were made for barnacles (0.1 m^2) (Figure 3) and population abundances for each species counted using bespoke digital image software. Ten replicate 0.25 m^2 quadrats were counted at each site to record the abundance of limpet species. These were randomly placed within the midshore zone on areas of bedrock or large boulders with homogeneous surfaces (Figure 4). Pools, cracks and crevices and patches of macroalgae were avoided. The slope of the rock,

percentage cover of adult barnacles, algae and mussels were recorded in each quadrat. All limpets greater than 10 mm in size were counted and identified to species level.

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

Figure 3. A 5 cm x 2 cm subsection of the 5 x 5 cm barnacle quadrat images taken during MarClim surveys being analysed using MarClim digital image software. The species are identified and marked by a unique identifier code and the number of adult and juvenile barnacles for each species is recorded in a linked Access database.



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 invasive non-indigenous ascidian *Didemnum vexillum* which was the subject of an intense eradication program by NRW inside Holyhead marina.

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

Table 1. MarClim survey site locations 2023.

Day	Month	Year	Site	Region	Recorder	Grid	Lat (WGS84)	Long (WGS84)
2	7	2023	Rhyl Splash Point	North Wales	NM, HS	SJ021824	53.3299	-3.4715
2	7	2023	Llanddulas	North Wales	NM, HS, DLS	SH906787	53.2933	-3.6296
2	7	2023	Rhos on Sea	North Wales	NM, HS, DLS	SH843805	53.3114	-3.7381
2	7	2023	Little Orme	North Wales	NM, HS, DLS	SH812825	53.3260	-3.7852
2	7	2023	Great Orme East	North Wales	NM, HS, DLS	SH782832	53.3321	-3.8297
2	7	2023	Great Orme Trwynygogarth	North Wales	NM, HS, DLS	SH749834	53.3327	-3.8801
3	7	2023	Penmaenmawr Natural	North Wales	NM, HS, DLS	SH704763	53.2674	-3.9440
3	7	2023	Trefor	North Wales	NM, HS, DLS	SH376474	52.9992	-4.4215
3	7	2023	Caernarfon	North Wales	NM, HS	SH521671	53.1374	-4.2897
3	7	2023	Penmon North	North Wales	NM, HS, GW, PB	SH641813	53.3111	-4.0413
3	7	2023	Menai Bridge	North Wales	NM, HS, GW	SH555714	53.2207	-4.1643
4	7	2023	Bull Bay	North Wales	NM, HS, KB	SH427945	53.4238	-4.3688
4	7	2023	Moelfre	North Wales	NM, HS, KB	SH513859	53.3490	-4.2354
4	7	2023	Porth Eilian	North Wales	NM, HS, KB	SH484929	53.4111	-4.2823
4	7	2023	Point Lynas	North Wales	NM, HS, KB	SH477929	53.4109	-4.2928
4	7	2023	Holyhead	North Wales	NM, SJH, HS	SH257825	53.3108	-4.6461
4	7	2023	Porth Swtan	North Wales	NM, HS, DLS	SH298891	53.3713	-4.5598
5	7	2023	Rhosneigr	North Wales	NM, HS, DLS	SH315725	53.2233	-4.5253
5	7	2023	Aberffraw	North Wales	NM, HS, DLS	SH337674	53.1776	-4.4899
5	7	2023	Cemlyn	North Wales	NM, HS	SH337934	53.4146	-4.5112
6	7	2023	Nefyn	North Wales	NM, HS, JH, RN	SH335311	52.8516	-4.4742
6	7	2023	Porth Oer	North Wales	NM, HS, JH, RN	SH163297	52.8344	-4.7256
7	7	2023	Porth Neigwl	North Wales	NM, HS	SH288245	52.7908	-4.5404
7	7	2023	Llanbedrog	North Wales	NM, HS	SH335311	52.8516	-4.4742
7	7	2023	Aberdaron	North Wales	NM, HS	SH166260	52.8003	-4.7220

Day	Month	Year	Site	Region	Recorder	Grid	Lat (WGS84)	Long (WGS84)
7	7	2023	Criccieth Castle	North Wales	NM, HS	SH494376	52.9146	-4.2412
7	7	2023	Criccieth Boulders	North Wales	NM, DLS	SN582828	52.4247	-4.0869
8	7	2023	Abersoch Lifeboat Station	North Wales	NM, HS	SH323265	52.8107	-4.4881
8	7	2023	Porth Ceriad	North Wales	NM, HS	SH308247	52.7938	-4.5094
3	8	2023	Broad Haven	South Wales	MB, LA	SM859144	51.7871	-5.1057
3	8	2023	Dale Jetty	South Wales	KL JAT AM	SM822053	51.7041	-5.1533
3	8	2023	Monkstone Point	South Wales	MB	SN150033	51.6978	-4.6784
28	8	2023	Aberystwyth	Mid Wales	NM, MB	SN582828	52.4247	-4.0869
29	8	2023	Borth	Mid Wales	NM, MB	SN605888	52.4792	-4.0556
30	8	2023	Skokholm South Haven	South Wales	NM, BH, MB	SM733088	51.7319	-5.2845
31	8	2023	West Angle Bay	South Wales	NM, BH, PB	SM848038	51.6916	-5.1151
31	8	2023	Neyland Natural	South Wales	NM, MB, BH	SM967047	51.7045	-4.9433

An additional site at Llanddulas, which has been sporadically checked for absence of indicator species was added to the list after the appearance of a population of *Steromphala* (*Gibbula*) *umbilicalis* in 2012 and *Phorcus lineatus* in 2016 and is now surveyed each year. The Rhyl crescent seawall and groynes were surveyed in 2014 and again annually since 2017 to ensure further range extensions of the topshells are accurately located.

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

1.1. eDNA sampling to detect MarClim species

Alongside visual surveys, eDNA metabarcoding has been conducted to characterise biodiversity patterns of intertidal marine species across Wales as part of a larger national project. Over 100 1 litre water samples across 13 Welsh sites were collected during 2022 and 2023 field seasons. By utilising universal barcoding regions (CO1 and 18S), the project has targeted not only common taxonomic groups monitored within the MarClim Project, but also a wide range of additional macrofauna and meiofauna. Samples were processed and sequenced on Illumina MiniSeq and MiSeq platforms between October 2023 and January 2024 at the NERC Environmental Omics Facility (NEOF). Currently, the sequencing data is being passed through the DADA2 bioinformatics pipeline ready for ecological analyses. The project hopes to 1) reveal if eDNA-based methods are suitable for intertidal monitoring by testing newly developed protocols, 2) directly compare data derived from eDNA with traditional visual survey data, and 3) test whether eDNA can be used as a predictive tool for estimating future expansions of species distributions.

Upon completion, all field and lab protocols will be made available to NRW via protocols.io, as well as data and scripts via Dryad and GitHub. A section in the

MarClim annual report to NRW will expand on the findings of the eDNA sample analyses.

Results

1.2. Range Extensions and Records of Transient Occurrences

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

The Lusitanian barnacle *Perforatus perforatus* was found for the first time at Abersoch Lifeboat Station, north Wales in 2022, representing a huge poleward extension of the leading range edge of 240 km from Broad Haven in Pembrokeshire. Additional surveys by S.J. Hawkins (not part of the NRW MarClim project) also found *P. perforatus* at Whitesands Bay, Pembrokeshire and Borth in Ceredigion in 2022. A few individuals were again found at Abersoch Lifeboat Station in 2023 (Figure 5). Samples taken during this survey were barcoded at the MBA and confirmed the species identity.

Tissue from four barnacles was dissected from the shells and DNA extraction was carried out using the Qiagen Mouse Blood and Tissue kit. The cytochrome oxidase I (COI) DNA fragment was amplified using Folmer primers, as adapted from Chan *et al*. (2007). The COI barcodes were sequenced by Sanger sequencing. The sequences were run on BOLD and all four barnacles had a >95.5% match with other *P.* perforatus sequences.

Figure 5. *Perforatus perforatus* at Abersoch lifeboat station MarClim site.

The honeycomb worm *Sabellaria alveolata* was recorded as Abundant (40% coverage around boulders) at Little Orme in 2022. It has only been recorded at this site a few times since the start of annual surveys here in 2004: Common (10%) in 2007 and 2013, Rare (isolated individuals) in 2012, and Abundant in 2022. It was not seen at

this site on the 2023 MarClim survey. *S. alveolata* was still present as flat and three-dimensional reefs at Llanddulas (Superabundant) and was Abundant at Criccieth boulder field in three dimensional reefs in gaps around the bottom of large boulders, and Abersoch Lifeboat Station where it was colonising a narrow band along the bottom of the rock to the west of and underneath the slipway. *S. alveolata* was Common in 2 dimensional sheets at Aberystwyth.

1.3. Non Indigenous Species

MarClim records 8 species of macroalgal NIS and 14 species of invertebrate NIS (see Appendix 1 for full species list). These include horizon scanning for species that have only been recorded at one or a few locations in the UK to date, e.g. the crabs *Hemigrapsus sanguineus* and *H. takanoi*, and the colonial ascidian *Didemnum vexillum* that invaded Holyhead marina in 2008 (Holt & Cordingley 2011).

Most NIS on the MarClim list were not found at MarClim sites in Wales in 2023. Thirty one sites had NIS recorded in 2023. *Austrominius modestus* was the most prolific species, being recorded at 24 sites. The brown alga *Sargassum muticum* was present at 7 sites in north Wales, and 5 sites in south Wales in 2023. *Colpomenia peregrina* was recorded as Common 10% at Porth Swtan in 2023, not having been recorded last year at a MarClim site.

Neyland Spit had the highest number of NIS recorded at any MarClim site in 2023 (seven). In addition to the common-place species (in Pembrokeshire) *Austrominius modestus*, *Sargassum muticum* and *Crepidula fornicata*, the less frequently recorded species *Undaria pinnatifida, Grateloupia turuturu, Asterocarpa humilis* and *Didemnum vexillum* were found. Whilst also having the most NIS in 2022, only *A. modestus*, *Crepidula fornicata*, and *Corella eumyota* were recorded in that year, showing how transient populations of invasive species can be at any site. Jetty Beach at Dale, with six NIS recorded in 2023 had *Caulacanthus ustulatus* (*okamurae*), *Botrylloides violaceus* and *Watersipora subatra*. Jetty Beach also had four NIS present in 2022: *A. modestus, B. violaceous, and C. eumyota.* Both of these sites are located in Milford Haven estuary, where there are consistently the most NIS recorded from any of the MarClim sites in the UK.

The colonial tunicate *Didemnum vexillum* was recorded at Neyland Spit in Milford Haven estuary in 2023 (Figure 6, Figure 7). Samples barcoded at the Marine Biological Association confirmed the identity of this species. Tissue was dissected from the sample and DNA extraction was carried out using the Qiagen Mouse Blood and Tissue kit. The cytochrome oxidase I (COI) DNA fragment was amplified using Ascidian-specific primers (DinF and Nux1R), adapted from Salonna *et al*. (2021). The COI barcode was sequenced by Sanger sequencing. The sequence was run through the BOLD database and had a 100% match with other *Didemnum vexillum* sequences, thereby confirming its identity.

Samples analysed at Aberystwyth University to compare genotypes with other populations around the UK indicate that the Milford Haven populations at Carr Rocks and Barn Lake show most similarity to those at Herne Bay in Kent.

Using seven microsatellite loci, the Aberystwyth team compared samples from eight locations around the UK and Ireland:

1 Hearne Bay, Kent (natural rocky substrate, rock armour, wood and concrete structures, old tyres)
2 Strangford Lough, Northern Ireland (floating lightship)

3 Clew Bay, Ireland (oyster trestles and natural rocky substrate)

4 Dunmanus Bay, Ireland (oyster trestles and natural rocky substrate)

5 Galway Bay, Ireland (oyster trestles and natural rocky substrate)

6 Malahide Marina, Dublin Bay, Ireland (floating pontoons)
7 Holyhead Marina, Wales (floating pontoons)
8 Milford Haven (natural rocky substrate)

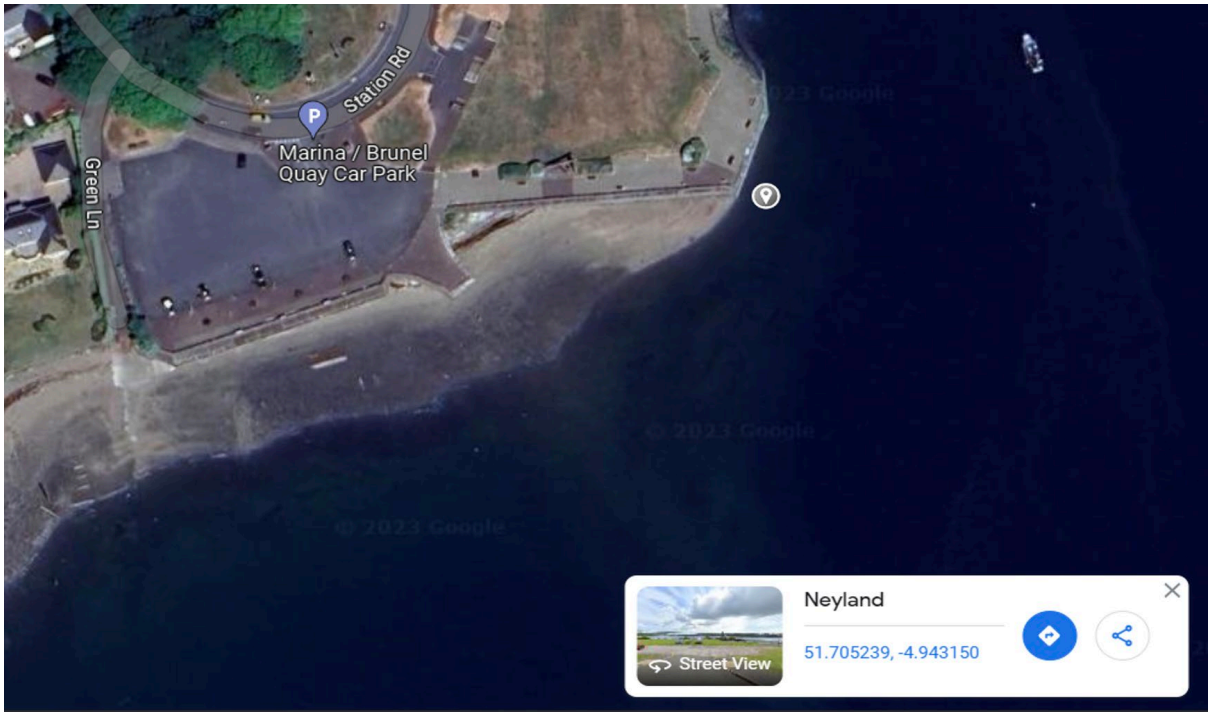
Using data analysis described in Prentis *et al*. (2021), Joe Ironside found that the Milford Haven samples fall mainly within a cluster that predominates in Kent and Strangford Lough, is common in Clew Bay and Dunmanus Bay and is almost completely absent from marina populations in Malahide and Holyhead. This suggests that the Milford Haven population of *Didemnum vexillum* has not come from the marina populations in Holyhead or Dublin (Ironside, pers comm.).

Additional surveys carried out by Mark Burton and Mike Camplin from NRW in and around Neyland Spit on August 31st, 2023, recorded eight colonies of *D. vexillum* in the following exact locations (Table 2).

Table 2. *Didemnum vexillum* colony locations August 2023.

ID	Name	Date	Time	Latitude	Longitude
1	Dvex1	2023-08-31	11:56:22	51.70559898	-4.942877283
2	Dvex2	2023-08-31	11:57:02	51.70547753	-4.942978537
3	Dvex3	2023-08-31	11:57:24	51.70544819	-4.942910559
4	Dvex4	2023-08-31	11:58:02	51.7055994	-4.942939812
5	Dvex5	2023-08-31	11:59:05	51.70559496	-4.942901339
6	Dvex6	2023-08-31	11:59:23	51.70563083	-4.942907207
7	Dvex7	2023-08-31	12:00:29	51.70564449	-4.942948613
8	Dvex8	2023-08-31	12:01:50	51.70572102	-4.942982057
9	Dvex81	2023-08-31	12:02:58	51.70576335	-4.942972669

Figure 6. Neyland Spit survey site where eight colonies of *D. vexillum* were found on 31/08/2023. Image: Google Maps.



All *D. vexillum* colonies located on seaweed were removed from the site for sampling and then destroyed. One colony was left as it was on a large boulder which couldn't be removed from the site. These were used as the samples that were sent to the MBA, Plymouth for confirmation of the species identification.

Figure 7 – a). *Didemnum vexillum* at Neyland Spit in 2023, b). close-up image of *D. vexillum* at Neyland Spit.

Watersipora subatra was present on Dale Jetty Beach in 2023. This species is Occasional on the north facing side of the concrete jetty itself, especially the vertical surfaces. Similarly on the nearby boulders it favours steep slopes. *Caulacanthus ustulatus (okamurae)* was found in a range of abundances from Occasional at Broad Haven to Superabundant at West Angle Bay in 2023. This species was not seen at any MarClim sites in mid or north Wales in 2023. *Botrylloides violaceous* was Rare at Jetty Beach Dale. This is the first record since 2015 at this site, and it is the only MarClim site where the species has ever been recorded.

1.4. Artificial Coastal Defences

Natural Resources Wales' Well-being Objective 2: 'Communities are resilient to climate change' includes '*the risks of climate change being managed and adapted'*, with the steps to take:

- '*Reducing the risk to life from flooding through managing our flood assets and infrastructure for current and future flood risk'* and
- '*planning for change through maintaining and adapting the flood assets and infrastructure we are accountable for'* (https://naturalresources.wales/about-us/what-we-do/strategies-and-plans/business-plan-2023-24/?lang=en).

The Measure '*Maintain flood risk assets in high-risk systems at target condition'* requires repairing and/or construction of new flood defences including artificial sea walls such as the Y Rhyl foreshore. New artificial coastal defences were built all along the foreshore at Rhyl Splash Point between 2020 and 2021. This wall had just started to be colonised by the ephemeral algae *Ulva* sp and *Porphyra* sp in 2022. This structure only reaches the upper eulittoral at the lowest end, and therefore few intertidal species would colonise this high shore area. In 2023 early colonising ephemeral algae recorded initially in 2022 had been supplemented by *Fucus spiralis* Superabundant 90%, *Austrominius modestus* Superabundant 90%, *Semibalanus balanoides* Common 30%, and *Littorina littorea* Rare (Figure 8). This site is surveyed to track any future range extensions of species along the north Wales coastline.

Figure 8. New artificial coastal defence structure at Y Rhyl with *F. spiralis* and *A. modestus* visible in 2023.

2. Relevance to NRW assessments of Annex I habitats

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

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

The collection of abundance and recruitment data in MarClim surveys can ground-truth predictions such as those made in the Oaten *et al*. (2021) report, including the potential reduction in abundances of Boreal species such as *S. balanoides* and the low risk of impact to fucoid algae. Analysis of barnacle data collected at sites on Skomer Island every year since 2003 show that the relative ratio of *S. balanoides* compared to the Lusitanian warmwater species *Chthamalus montagui* and *C. stellatus*, and the invasive *Austrominius modestus* showed a severe decline in 2023 compared to the previous years in the time-series (Figure 9-Figure 11). This was particularly evident in the low and midshore, where this species is more prevalent. No reductions were recorded at any north Wales sites, but reductions in abundance were also recorded at Jetty Beach, Dale, where it had reduced to Occasional (2%) from Abundant in 2022 and was Superabundant, Abundant, or Common in the previous 21 years, and West Angle Bay, where it was Frequent (5%) in 2023, down from Superabundant or Abundant for every year (except 2015 when it was Common) across the 22 years of the time-series. MarClim surveys in future years will track these populations to see if this decline continues in the mid to long-term.

Figure 9. Species ratios in the high shore on Skomer Island.

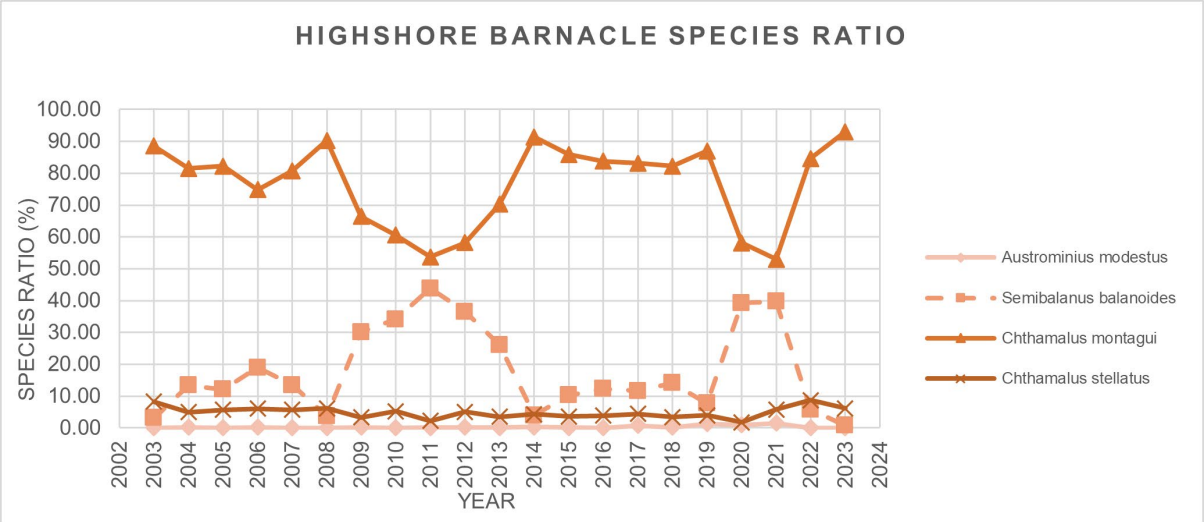


Figure 10. Species ratios in the mid shore on Skomer Island.

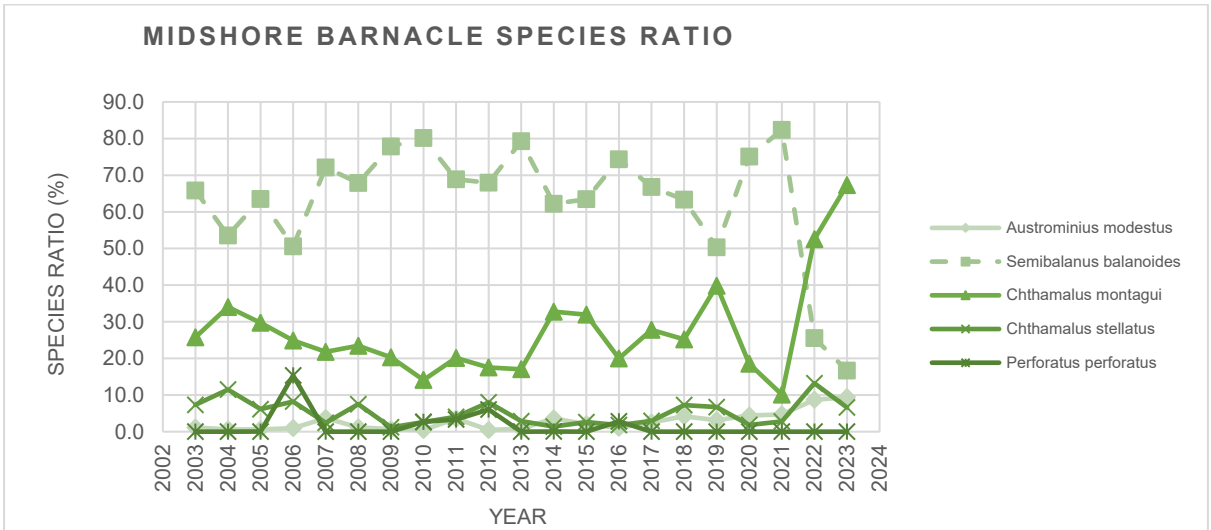
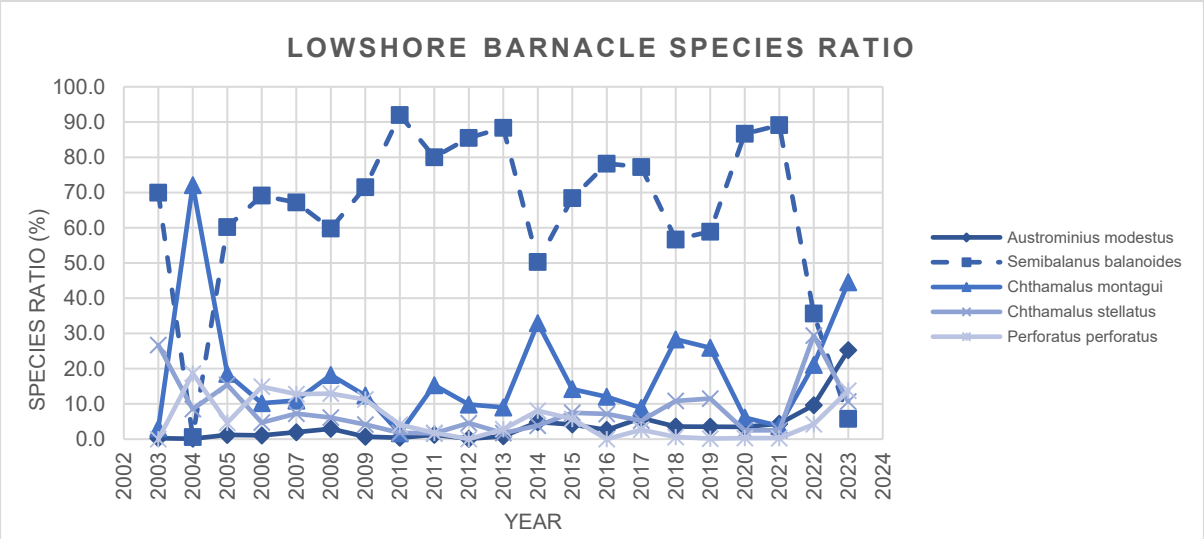


Figure 11. Species ratios in the low shore on Skomer Island.



3. Overview of MarClim surveys in Wales

Most MarClim time-series sites in Wales were in a favourable condition (with respect to the methods and species recorded) in 2023 (no change against the baseline). The only evidence of anthropogenic impacts were the presence of NIS at thirty one sites across Wales. Most of these sites only contained *A. modestus* and/or *S. muticum*, and none were new colonisations in 2023. *A. modestus* has been present at Welsh sites since before the start of the time-series in 2002 and does not have any apparent detrimental effect on intertidal species or habitats. *S. muticum* has also been present at Welsh sites for the duration of the MarClim time-series.

The record of a population of *Didemnum vexillum* in Milford Haven estuary in 2023 on a MarClim survey, plus two more sites surveyed for the work carried out by Joe Ironside from Aberystwyth University confirm that this non-indigenous species has colonised multiple intertidal habitats in the Milford Haven area. The record of *Watersipora subatra* on Dale Jetty Beach in 2023 is another NIS sighting that will need to be tracked in future years to see if the species persists and / or spreads to neighbouring shores.

The reduction in Boreal cold-water native barnacles in Skomer MCZ in 2023 is of concern and will be monitored in future years on MarClim surveys. This decline was not mirrored in the SACFOR surveys of other sites across Wales in MarClim surveys in 2023 except for Jetty Beach, Dale and West Angle Bay, where abundances had also declined.

Conclusions

3.5. Climate change and extreme events

The year 2023 was the hottest year on record globally (https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2024/2023-the-warmest-year-on-record-globally) with June 2023 being the hottest June on record in the UK and September 2023 being the world's warmest September on record for global average temperature according to the Copernicus Climate Change Service (https://climate.copernicus.eu/copernicus-2023-hottest-year-record). The UK monthly mean temperature was 2.5°C above the 1991-2020 average,

this being the highest monthly anomaly since December 2015 (https://blog.metoffice.gov.uk/2023/12/28/2023-in-weather/). Summer 2023 was also wetter than average (https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2023/summer2023ukweather).

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

Marine heatwaves have become more frequent since the 1980s, and possibly longer and more intense. The heatwave of 2018 stands out as being the longest (60 days) if not the most intense on record, and with the biggest cumulative degree x days score in excess of 19°C (NOAA 2020; Reynolds *et al*. 2007). Heatwaves occurred in June and in September, when there was a record breaking heatwave event in the UK which was the longest in September exceeding 30°C on record (https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2023/2023_05_september_heatwave.pdf).

With the exception of the sudden, massive reduction in abundance of the Boreal barnacle *S. balanoides* in Skomer MCZ and at Jetty Beach Dale and West Angle Bay in Pembrokeshire, no acute changes in community composition recorded at any MarClim shore in 2023, and abundances of both Lusitanian warm water, and Boreal cold water species did not show large changes from 2022 surveys. Lusitanian species were still present at leading range edge sites in Wales in 2023. Heatwave events occurring in 2022 and 2023 did not have any long-lasting impacts on rocky intertidal species at MarClim sites. In 2022, *P. perforatus* was recorded for the first time in north Wales, representing a range extension of over 240 km. A few individuals were again present in 2023 and the identity of this species was confirmed by barcoding at the Marine Biological Association.

Two NIS were recorded at sites in Pembrokeshire for the first time in MarClim surveys in 2023. These will be monitored at all MarClim sites in future years to track any potential increase in existing populations and spread to other rocky shores in the area.

3.6. Significance of results and future practice

- The major findings of the MarClim project and scientific data collected by MarClim are communicated to government organisations, staff, conservation agencies, marine SAC and SSSI managers and the general public to increase the knowledge, understanding and reporting of scientifically, managerial and societally important questions relating to global climate change, ocean acidification and smaller-scale human impacts on the marine environment including development, habitation and exploitation of the coastal zone, component ecosystems and species. MarClim is used to assess and inform UK and EU policies and directives including the EU Marine Strategy Framework

Directive, PEGASEAS Governance Guide, Condition Assessments for SACs, SSSIs and European Marine Sites and as baseline data for the UK Marine Conservation Zone designation process.

- The MarClim time-series dataset was developed by Mieszkowska, Burrows and Hawkins (2013) of the MarClim team as Good Environmental Status Indicators for the MSFD, with the first report published in 2014: https://hub.jncc.gov.uk/assets/dd8c7802-0faa-428d-a0d2-3550fa21c827. A second phase of work to develop the MarClim time-series as species (Species Temperature Index) and community indicators of climate change (Community Temperature Index) as part of the Marine Strategy GES indicator development process was developed by the MarClim team in 2017 (Burrows, Hawkins & Mieszkowska 2017), and an update was prepared for JNCC in 2024 (Burrows & Mieszkowska 2024).
- The MarClim Project and research team provide unique, essential, long-term monitoring and scientific research data and expertise. This is used by the UK SNCBs to address major national and European policy directives including the EU Marine Strategy Framework Directive, EU Habitats Directive, EU Water Framework Directive, OSPAR Commission Assessments, and the UK Marine Conservation Zone designation process as part of the Marine and Coastal Access Act.
- The MarClim dataset has been used in an assessment of British Seaweeds as part of an evaluation of the IUCN Red List for non-standard marine organisms (Brodie *et al*. 2023).

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

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Appendix 1 - MarClim Sampling Protocols 2023

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 Appendix

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

The data archive contains:

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

[B] A database named '**MarClim data Wales final 2023**' in Excel format with metadata described.

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