Cyfoeth Naturiol Cymru
Natural Resources Wales

THE MARINE BIOLOGICAL ASSOCIATION

MarClim Annual Welsh Intertidal Climate Monitoring Survey 2014

Dr. N. Mieszkowska

NRW Evidence Report No 050

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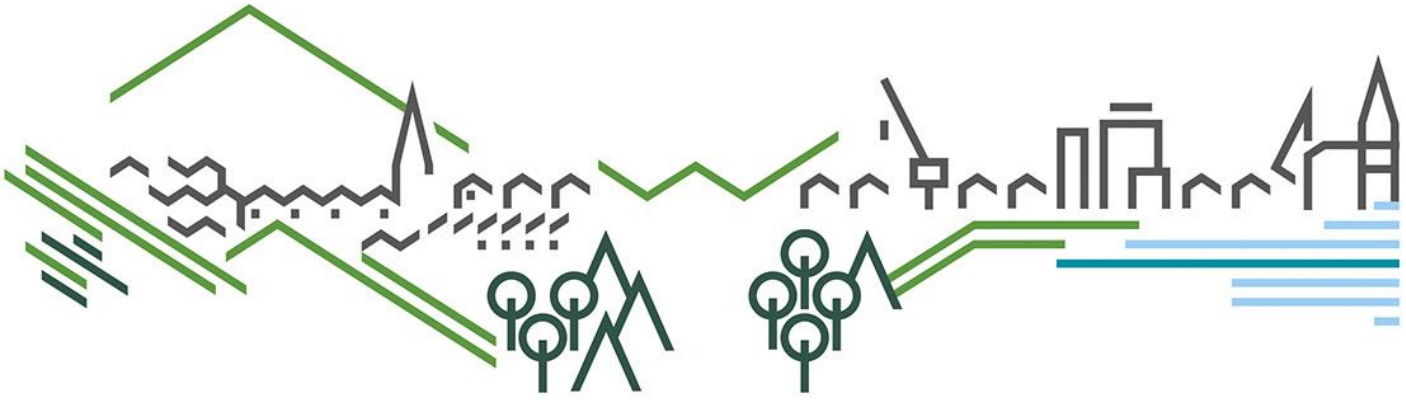

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Natural Resources Wales is the organisation responsible for the work carried out by the three former organisations, the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales. It is also responsible for some functions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

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- 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.

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Crynodeb Gweithredol

Mae'r adroddiad hwn yn crynhoi'r gwaith o gynnal arolygon, y data a'r dadansoddi a gyflawnwyd yn 2014 o dan y teitl prosiect MarClim fel y'i disgrifiwyd yn yr adroddiad gan Mieszkowska (2005) http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm. Mae'r arolwg blynyddol yng Nghymru'n ffurfio rhan o arolwg hirach a pharhaus y DU dros dair blynedd ar ddeg. Mae'r cwmpas daearyddol yn cynnwys safleoedd trwy ogledd, canolbarth a de orllewin Cymru y mae data hanesyddol sy'n dyddio'n ôl i'r 1950au'n bodoli ar eu cyfer, a safleoedd ychwanegol lle rhagwelwyd y byddai estyniadau i wasgariadau'n digwydd. Cynhaliwyd arolygon MarClim ar bedwar deg pedwar o safleoedd yn 2014. Arolygwyd tri deg saith o safleoedd yng ngogledd Cymru a saith safle yn ne Cymru.

Tarodd stormydd difrifol forliniau gorllewinol y DU yn ystod gaeaf 2013/14, lle cofnodwyd yr uchder tonnau a'r cyflymder gwynt uchaf erioed. Arsylwyd ychydig yn unig o effeithiau biolegol ar gymunedau biolegol yn ystod arolygon MarClim yng Nghymru chwe mis yn dilyn tymor y stormydd. Nid oedd effeithiau'r stormydd wedi newid strwythur y gymuned yn sylweddol yn y safleoedd arolygu hirdymor hyn, er y gwelwyd gwaddodiad ym Mhorth Niwgwl ac Aberdaron o draethau tywodlyd gerllaw, a gorchuddiwyd ardaloedd sylweddol o greigiau ewrynglanwol canol-isel mewn algâu dros dro neu roeddent wedi'u sgwrio'n lân o rywogaethau. Roedd y tymereddau yn ystod gaeaf 2013/14 yn debyg i'r duedd ddegawdol heb gyfnodau oer iawn.

Cynyddodd helaethrwydd poblogaeth gwymon dyfroedd cynnes Lwsitanaidd a chregyn crib o gwmpas Cymru trwy gydol y 2000au o ganlyniad i'r hinsawdd forol yn cynhesu, ond dechreuodd ddirywio o 2010-2013 fwy na thebyg oherwydd y bwlch a ganfuwyd mewn cynhesu byd-eang yn ystod y 2000au (Mieszkowska 2013 Adroddiad MarClim i Cyfoeth Naturiol Cymru). Dengys yn yr arolygon a gynhaliwyd yn y safleoedd hir-dymor hyn yn 2014 fod y duedd ddirywio ddiweddar wedi stopio, a gwelir cynnydd yn nifer yr unigolion o fewn poblogaethau o ffiniau'r ystod ogleddol yng ngogledd Cymru yr holl ffordd ar hyd morliniau Cymru a Lloegr ac ar hyd y Sianel (arolygwyd gan dîm MarClim trwy gyllid gan Natural England) i ffin ystod y gogledd ddwyrain. Bydd arolygon blynyddol y dyfodol yn gallu darparu tystiolaeth o ran a yw'r duedd o gynhesu hirdymor wedi ailddechrau, neu a oedd y cynnydd yn helaethrwydd poblogaethau yn ymateb byr-dymor i amodau thermol mwynach y gaeaf yn ystod 2013/14.

Nodwyd protocolau MarClim fel enghraifft o arfer gorau ar gyfer casglu cyfres amser yn *Governance Guide for Policymakers in the EU* PEGASEAS https://www.pegaseas.eu/wp-content/uploads/2015/01/PEGASEAS-Compendium-English-Version.pdf.

Datblygwyd set ddata cyfres amser MarClim gan Mieszkowska, Burrows a Hawkins o dîm MarClim fel Dangosyddion Statws Amgylcheddol Da ar gyfer Cyfarwyddeb Fframwaith y Strategaeth Forol, a chyhoeddwyd yr adroddiad llawn yn 2014: http://jncc.defra.gov.uk/page-6813. Mae cyfres amser MarClim yn cael ei mabwysiadu gan yr International Network for the Study of Rocky Shore Ecosystems INSHORE fel y safon fyd-eang http://rockyinshore.org/about/.

Mae MarClim wedi'i nodi mewn asesiad gwyddonol byd-eang ar yr angen i ddylunio ymchwil wyddonol yn briodol i ddarparu gwybodaeth addas at y diben ar raddfeydd gofodol a thymhorol perthnasol o ran lle ac amser sy'n ddefnyddiol i reolwyr ardaloedd gwarchodedig, cyrff statudol a gwneuthurwyr polisi. Mae'r papur hwn yn dangos pa mor arloesol y bu prosiect MarClim a'r cydweithio hirdymor â Cyfoeth Naturiol Cymru a Chymdeithas Fiolegol Forol y DU o ran darparu gwybodaeth berthnasol ar Gyflwr a Statws cynefinoedd rhynglanwol yng Nghymru yn erbyn newid treiddiol yn yr hinsawdd http://www.biomedcentral.com/content/pdf/s40665-014-0006-0.pdf.

Mae prosiect MarClim hefyd wedi'i ddewis fel y gyfres amser brawf ar gyfer yr INSHORE *International Network for Research in Rocky Intertidal Systems* http://rockyinshore.org/about/ gan ddangos effaith fyd-eang y prosiect hwn.

Executive Summary

This report summarizes the 2014 survey work, data and analysis completed under the project title of MarClim as described in the report by Mieszkowska (2005) http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm. The annual survey in Wales forms part of a longer, thirteen-year continuous UK survey. Geographical coverage includes sites throughout north, mid 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 forty four sites in 2014. Thirty seven sites were surveyed in north Wales and seven sites in south Wales.

Severe storms hit the western coastlines of the UK during the winter of 2013/14, with record wave heights and wind speeds recorded. Few biological impacts on biological communities were observed during the MarClim surveys in Wales six months after the storm season. The storm impacts had not significantly changed the community structure at these long-term survey sites although at Porth Neigwl and Aberdaron that were influenced by sedimentation from nearby sandy beaches, significant areas of mid-lower eulittoral rock were either covered in ephemeral algae or scoured free of species. Temperatures during the winter of 2013/14 were similar to the decadal trend with no severe cold snaps.

Population abundances of Lusitanian warm water kelps and topshells around Wales increased throughout the 2000s in response to warming of the marine climate, but began to decline from 2010-2013 in likely response to the hiatus in global warming detected during the 2000s (Mieszkowska (2013) MarClim Report to Natural Resources Wales). Surveys at these long-term sites in 2014 showed that the recent declining trend had stopped, with increased numbers of individuals within populations from northern range limits in North Wales right around the Welsh and English coastlines and along the English Channel (surveyed by the MarClim team with funding from Natural England) to the northeast range limit. Future annual surveys will be able to provide evidence of whether the long-term warming trend has resumed, or if the increase in population abundances was a short-term response to the milder winter thermal conditions experienced in 2013/14.

MarClim protocols have been cited as an example of best practice for time-series collection in the PEGASEAS Governance Guide for Policymakers in the EU https://www.pegaseas.eu/wp-content/uploads/2015/01/PEGASEAS-Compendium-English-Version.pdf.

The MarClim time-series dataset was developed by Mieszkowska, Burrows and Hawkins of the MarClim team as Good Environmental Status Indicators for the MSFD, with the full report published in 2014: http://jncc.defra.gov.uk/page-6813. The MarClim time-series is being adopted by the INSHORE International Network for the Study of Rocky Shore Ecosystems as the global standard http://rockyinshore.org/about/.

MarClim has been highlighted in a global scientific assessment of the need for scientific research to be appropriately designed to provide fit-for-purpose information at relevant spatial and temporal scales useful to managers of protected areas, statutory bodies and policymakers. This paper demonstrates how ground-breaking the MarClim project and the long-term collaboration with Natural Resources Wales and the Marine Biological Association of the UK has been in delivering relevant information on the Condition and Status of intertidal habitats in Wales against a backdrop of pervasive climate change http://www.biomedcentral.com/content/pdf/s40665-014-0006-0.pdf .

MarClim has also been selected as the test time-series for the INSHORE International Network for Research in Rocky Intertidal Systems http://rockyinshore.org/about/ demonstrating the global impact of this project.

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1. INTRODUCTION

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

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

- To use existing historical information and collect new data on intertidal indicator species from the last 50-100 years to develop and test hypotheses on the impact of climatic change on marine biodiversity in Britain and Ireland.
- To forecast future marine community changes on the basis of the Met Office's Hadley Centre climate change models and the United Kingdom Climate Impacts Partnership's climate change scenarios. The broad range of species known or likely to be temperature sensitive was covered.
- To establish low-cost, fit-for-purpose, methodologies and networks to provide subsequent regular updates and track how climate influences the marine biodiversity of Britain and Ireland.
- To provide general contextual time series data to support reporting on the success or otherwise of the Marine Strategy Framework Directive, marine aspects of Biodiversity Action Plans, European initiatives including the Habitats, Birds and Water Framework Directives, and management and monitoring of marine activities and resources, including fisheries and Special Areas of Conservation.
- To evaluate whether the climate indicator species used in this work have a wider contribution to make as part of the sustainability indicators that are needed to underpin the UK sustainable development strategy.
- To 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. 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. 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 change.

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 National University of Ireland Galway University of Newcastle on their own time. 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, and non-native species that pose a potential threat to native biodiversity (Appendix 1) in collaboration with the UK Marine Aliens Project http://www.marlin.ac.uk/marine_aliens/. Climate-driven shifts in the biogeographic ranges of these and other species are being tracked by Dr Mieszkowska around northern Europe

using the MarClim protocols. Non-natives 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-Native Species identified as posing a risk to native rocky intertidal communities. To ensure comparability with the historical data the original methodology was retained for ACFOR (now SACFOR) scoring of species abundances and barnacle quadrat counts. Additional quantitative methodology to facilitate robust statistical analysis and modelling has been incorporated since 2002 and is detailed in the Survey Protocols section below.

3. METHODS

The MarClim protocols (Appendix 1) were used as the standard survey methodology. These protocols include additional alien species of concern to NRW or pertinent to the Defra GB Non-Native Species Portal https://secure.fera.defra.gov.uk/nonnativespecies/home/index.cfm.

MarClim surveys were carried out at forty four sites in 2014 (Table 1, Figure 1). Thirty seven sites were surveyed in north Wales and seven sites in south Wales. 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 *Gibbula umbilicalis* was found in 2012 for the first time, and a new location of artificial habitat at Rhyl checked for the presence of *G. umbilicalis* in 2013 and 2014 as potential locations for the further spread of this species along the north Wales coastline.

Rocky shores in north Wales were surveyed by Dr. Nova Mieszkowska and Leoni Adams from the Marine Biological Association, Paul Brazier, Gabe Wyn, Kirsten Ramsay, Mark Burton, Jen Jones, and Barney Letheren from Natural Resources Wales, Dr. Heather Sugden from Newcastle University and Dr. Louise Firth from National University Ireland Galway. Seven sites were surveyed in south Wales including two sites on the Skomer MNR and five on the mainland. These surveys were carried out and cross-calibration exercises undertaken by Mark Burton of NRW and Leoni Adams (MBA). All surveyors have either carried out cross-calibrations with Mieszkowska in several previous years or were trained on site to ensure accurate continuation of sample methodologies and protocols. Data entry was completed by Leoni Adams with a QA by Nova Mieszkowska and Leoni Adams.

Semi-quantitative SACFOR abundance scores were recorded for a suite of 77 species of invertebrates and macroalgae, including nine non-native invertebrate and nine macroalgal species. Non-native species added to the list in 2014 were the shore crabs *Hemigrapsus sanguineus* and *Hemigrapsus takanoi*, both species having had a single record of a potential sighting in the UK, with rapid colonization of rocky shores on the French coastline of the English Channel. *Hemigrapsus sanguineus* (Figure 2) has also invaded the US coastline of the North Atlantic in recent years, out-competing the green crab *Carcinus maenas* that is native to the UK, and therefore poses a potential risk for invasion of natural rocky intertidal communities.

Replicate, quantitative quadrat counts were made for barnacles (10 cm^2) (Figure 3) and population abundances counted using digital image software. Ten replicate 0.35 m quadrats 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.

Five replicate searches of three minutes duration were made separately for *Phorcus (Osilinus) lineatus* and *Gibbula 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 very individual was measured in mm to 2 decimal places and population size frequencies calculated from the data.

All data have been submitted to NRW in electronic format. All surveyors had been trained in MarClim methodology and cross-calibrated in the field with Dr Mieszkowska. An additional site at Holyhead was added to the MarClim Wales site network in 2010 and has been re-surveyed annually to track any potential spread of the non-native ascidian

Didemnum vexillum which has been the subject of an intense eradication program by NRW inside Holyhead marina (http://www.NRW.gov.uk/.../NRW-in-holyhead-harbour.aspx). *D. vexillum* continues to be present, at low levels within the confines of the marina (P Brazier pers comms).

Metadata and quantitative survey data were recorded on sheets in the field. The data were transferred to electronic datasheets in the laboratory and a rigorous QA check carried out by Adams and Mieszkowska. Photographs were labelled to allow accurate interpretation and identification of features. Data analysis was carried out by Dr. Mieszkowska and 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. Charly Griffiths (MBA) compiled the GIS-referenced MarClim survey map.

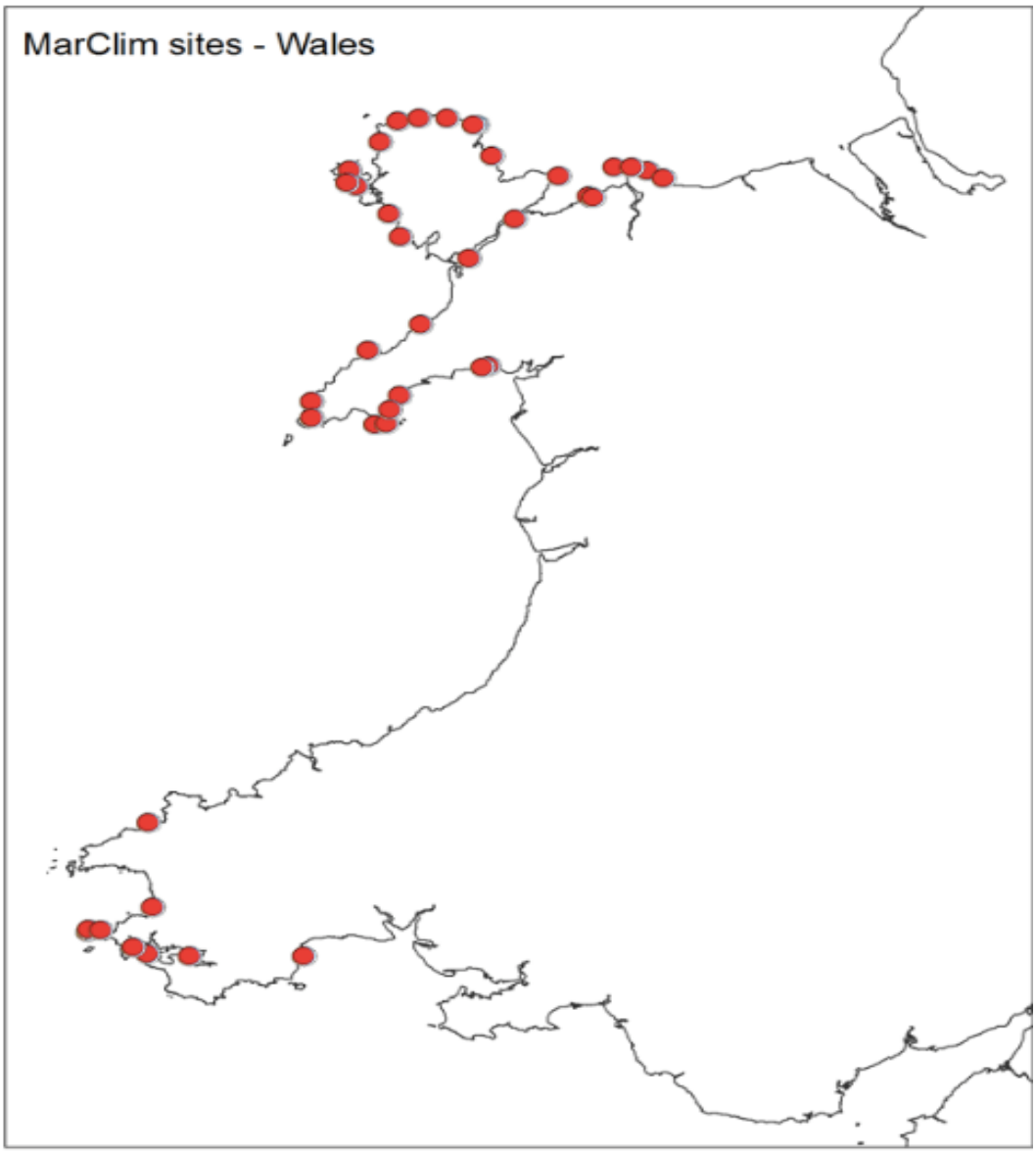

Figure 1. Sites surveyed by MarClim for NRW in 2014

Figure 2. *Hemigrapsus sanguineus*, image taken at Nahant, MA, USA by Nova Mieszkowska

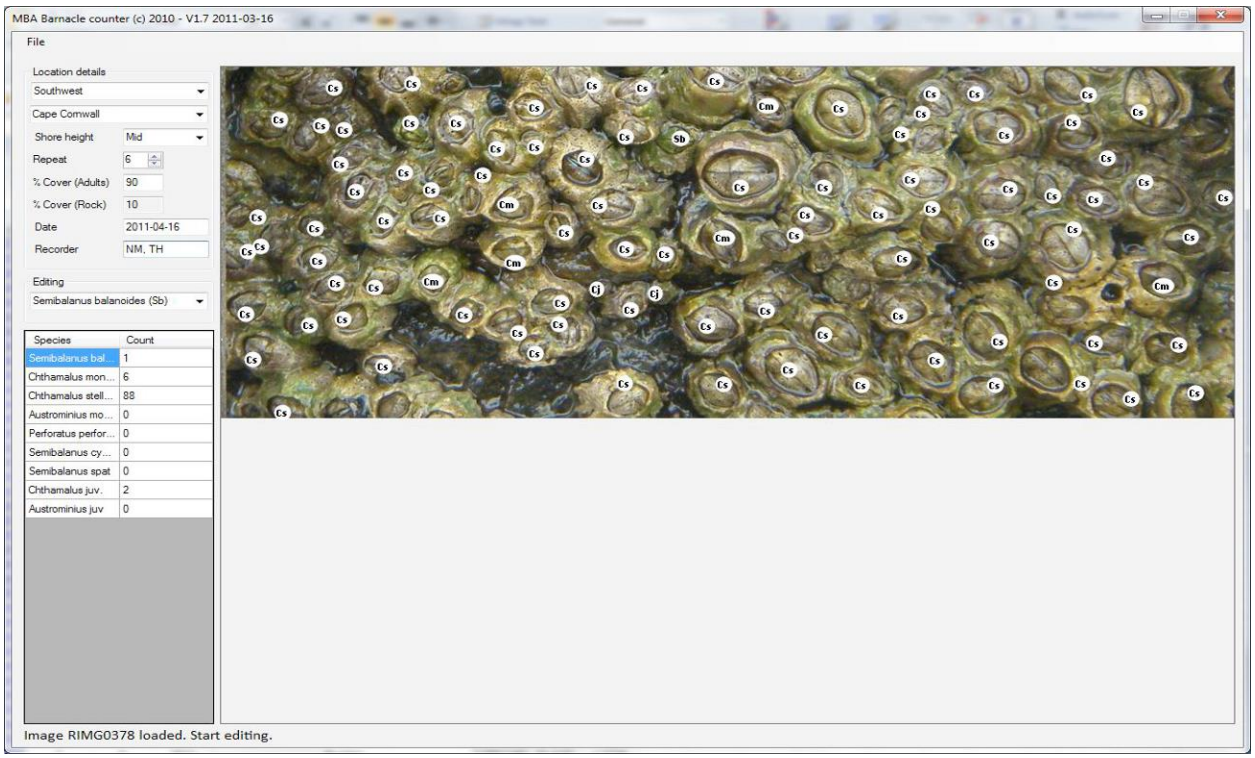

Figure 3. A 5cm x 2cm subsection of the 5x5cm barnacle quadrat images taken during MarClim surveys being analysed using MarClim digital image software. The species are identified and marked by a unique identifier code and the number of adult and juvenile barnacles for each species is recorded in a linked Access database.

Figure 4. MarClim limpet (left surveyor) and barnacle (right surveyor) quadrat surveys, Porth Ceiriad.

Table 1. MarClim Survey Site Locations 2014: NM: Nova Mieszkowska, HS: Heather Sugden, LF: Louise Firth, LA: Leoni Adams, BL: Barney Letheren, PB: Paul Brazier, GW: Gabe Wyn, KR: Kirsten Ramsay, BW: Ben Wray, EL: Emmer Litt, MB: Mark Burton, KL: Kate Lock, JJ: Jen Jones, JAT: John Archer-Thompson

Day	Month	Year	Site	Region	Recorder	Grid	Lat	Long
12	7	2014	Rhyl crescent sea wall & groynes	North Wales	NM, HS, LA	SJ021824	53.3299	-3.4715
12	7	2014	Llanddulas	North Wales	NM, HS, LA	SH906787	53.2933	-3.6296
12	7	2014	Rhos-on-sea	North Wales	NM, HS, LA	SH843805	53.3140	-3.7381
12	7	2014	Little Orme	North Wales	NM, HS, LA	SH812825	53.3260	-3.7852
13	7	2014	Penmaenmawr Natural	North Wales	HS, BL	SH704763	53.2683	-3.9440
13	7	2014	Penmaenmawr Artificial	North Wales	HS, BL	SH709763	53.1613	-3.9369
13	7	2014	Penmaenmawr Slipway	North Wales	HS, BL	SH699766	53.2712	-3.9521
13	7	2014	Great Orme Trwynygogarth	North Wales	NM, LA	SH749834	53.3327	-3.8801
13	7	2014	Great Orme East	North Wales	NM, HS, LA	SH782832	53.3321	-3.8297
13	7	2014	Menai Bridge	North Wales	NM, HS, LF, LA	SH555714	53.2207	-4.1643
13	7	2014	Trwyn Y Penrhyn	North Wales	NM, HS, LF, LA	SH629797	53.2971	-4.0575
13	7	2014	Great Orme East	North Wales	NM, HS, LA	SH782832	53.3321	-3.8297
13	7	2014	Trefor	North Wales	NM, HS, LA	SH376474	52.9992	-4.4215
13	7	2014	Caernarfon (Aber Foreshore Road)	North Wales	NM, HS, LA	SH521671	53.1374	-4.2897
13	7	2014	Great Orme Trwynygogarth	North Wales	NM, LA	SH749834	53.3327	-3.8801
13	7	2014	Penmon North	North Wales	NM, HS, LF, LA	SH641813	53.3111	-4.0413
14	7	2014	Martins Haven	South Wales	MB, KL	SM759091	51.7357	-5.2471
14	7	2014	Porth Eilian	North Wales	HS, LA	SH477929	53.4109	-4.2928
14	7	2014	Porth Swtan	North Wales	NM, HS, LF, LA	SH298891	53.3713	-4.5598
14	7	2014	Cemlyn	North Wales	NM, HS, LF, LA	SH337934	53.4111	-4.5035
14	7	2014	Cemaes	North Wales	NM, HS, LF, LA	SH372944	53.4219	-4.4502
14	7	2014	Point Lynas	North Wales	NM, LA	SH484929	53.4111	-4.2823
14	7	2014	Holyhead	North Wales	NM, HS, LF, LA, BW, EL	SH257825	53.3108	-4.6461
14	7	2014	Moelfre	North Wales	NM, HS, LF, LA, BW, EL	SH513859	53.3490	-4.2354
14	7	2014	Bull Bay	North Wales	NM, HS, LF, LA, BW, EL	SH427945	53.4238	-4.3688
15	7	2014	Porth Dafarch	North Wales	NM, LF	SH233798	53.2856	-4.6522
15	7	2014	Porth Oer	North Wales	NM, HS, LF, LA	SH163297	52.8343	-4.7279
15	7	2014	Nefyn	North Wales	NM, HS, LF, LA	SH274415	52.9430	-4.5702
15	7	2014	Aberffraw	North Wales	NM, LF	SH337674	53.1776	-4.4899
15	7	2014	Rhosneigr	North Wales	HS, LA, GW, KR	SH315725	53.2233	-4.5253
15	7	2014	Trearddur Bay	North Wales	HS, LA, GW, KR	SH252789	53.2790	-4.6231
16	7	2014	Llanbedrog	North Wales	NM, HS, LF, LA	SH335311	52.8516	-4.4742
16	7	2014	Aberdaron	North Wales	NM, HS, LF, LA	SH166260	52.8003	-4.7220
16	7	2014	Porth Neigwl	North Wales	NM, HS, LF, LA	SH288245	52.7908	-4.5404
17	7	2014	Porth Ceiriad	North Wales	NM, HS, LF, LA	SH308247	52.7938	-4.5094
17	7	2014	Abersoch Lifeboat Station	North Wales	NM, HS, LF, LA	SH323265	52.8107	-4.4881
17	7	2014	Criccieth East	North Wales	NM, HS, LF, LA, PB	SH494376	52.9146	-4.2412
17	7	2014	Criccieth Castle	North Wales	NM, HS, LF, LA, PB	SH494376	52.9146	-4.2412
11	8	2014	West Angle Bay	South Wales	MB	SM848038	51.6916	-5.1151
11	8	2014	Pembrokeshire Power Station	South Wales	MB, JJ	SM930032	51.6896	-4.9952
12	8	2014	Monkstone Point	South Wales	MB	SN150033	51.6978	-4.6784
26	8	2014	North Haven	South Wales	MB, LA	SM735093	51.7365	-5.2819
26	8	2014	South Haven	South Wales	MB, LA, JAT	SM733088	51.7319	-5.2845
27	8	2014	Broadhaven	South Wales	MB, LA, JJ	SM859144	51.7871	-5.1057

4. RESULTS

4.1. 2014 Findings

4.1.1. Recent changes in the global and regional climate

The latest findings from the IPCC 5th Assessment Working Group I Report on the Physical Science Basis of Climate Change http://www.ipcc.ch/report/ar5/wg1/#.Uwt9YvYzmlI reveal that the earth's climate has not warmed as rapidly over the last decade compared to the longer-term warming trend, which is tied to natural variability in the earth's climate system. This recent slowdown must be placed into context; each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 and the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years with 2014 globally being the warmest year on record http://www.bloomberg.com/graphics/2014-hottest-year-on-record/. 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.

Storm events are predicted to reach such severe wind speeds, wave heights and precipitation levels more often with continuing climate change, although changes in storm frequency cannot yet be predicted with high confidence. The IPCC 5th Assessment Working Group I Report documents an apparent increase in the proportion of very intense storms since 1970, although the frequency of extreme weather events appears to be less predictable. Whilst UK government funding has been promised to tackle the damage to agricultural and domestic sectors, the natural coastline and the defensive and economic implications from the catastrophic storm damage is not being addressed.

The 2013/14 winter was characterized by the Met Office as a 'very severe' period of storms and associated wave conditions, unmatched in terms of intensity and duration for over 50 years. These sea conditions resulted in the bulk of the ocean wave energy from the North Atlantic being driven onto the coastlines of Wales repeatedly between December 2013 and February 2014. The size and intensity of the storms generated some of the largest waves ever recorded to hit land in Western Europe, reaching 16 metres in height. These storms coincided with some of the highest spring tides of the year and record-breaking precipitation levels for the UK dating back 248 years, leading to saturated coastal ecosystems and an exacerbation of the physical impacts of storm wave forces.

Biological impacts of these storm events were surveyed at all 44 MarClim sites in Wales six months afterwards during the annual surveys in July 2014, details of which are reported below in Section 4.1.2.

Ongoing research led by Mieszkowska is looking to build new climate models that use physical data at a spatial and temporal resolution suitable to analyse the MarClim site-specific data and determine species and community level responses to recent change, then forecast future changes based on new IPCC and Met Office/Hadley Centre climate forecasts.

4.1.2. Storm impacts on Welsh rocky shores

Six months after the storm events of winter 2013/14, MarClim surveys around the Welsh coastline found little evidence of damage to intertidal rock habitat or to rocky intertidal communities. Only two sites had significant changes to the long-term community structure: Porth Neigwl and Aberdaron. Both shores are exposed rocky headlands on the southeast tip of the Llyn Peninsula where the prevailing Atlantic currents hit the land, and thus were

likely to have been subject to the highest wave forces during the storms around the north Wales coastline.

At Porth Neigwl, the main rocky reef and boulder field at the base of the cliff by Trwyn y Fostle (52.7908N, -4.5404E) showed no impacts, however, the boulder field situated approximately 100m east in the sandy beach that is usually approximately 100 m in horizontal length was far larger, showing that previously covered sections of this boulder field had been uncovered by removal of sand from this area (Figure 5). This extensive boulder field was completely covered in early colonizing ephemeral green *Ulva* spp. and red *Porphyra* spp. of algae (Figure 6). This boulder field is usually covered in *Mytilus* spp. and barnacles, but sediment scouring and movement thought to be the result of higher wave action during the storm events than usually occurs in this bay is thought to have removed these sessile invertebrates, clearing the rock surface. The presence of ephemeral algae six months after the event is indicative of the first stages of succession on rocky intertidal habitat. Surveys in 2015 will determine whether the species usually found on this boulder field have returned and colonized the area.

Figure 5. Ephemeral algae dominating the boulder shore at Porth Neigwl in July 2014.

Figure 6. *Ulva intestinalis* dominating the boulder shore at Porth Neigwl in July 2014.

The headland Aberdaron (52.8003N, -4.7220E) was also comprised of rocky cliff extending into the mid-eulittoral sandy beach, with small to large boulders. Again evidence sediment movement was observed, with the boulder field being far more extensive than in previous years (Figure 7). This boulder field was characterized by a band approximately 0.35 m in height above the beach level where only ephemeral green *Ulva intestinalis* was present, above which another band approximately 0.35 m in height was colonized by new recruits of the barnacle *S. balanoides* that had settled in the spring of 2014 (Figure 8). These observations are strongly indicative of large amounts of sediment movement and scour in the bay in excess of that seen in previous years.

No other major changes to habitat or community composition were recorded at the other 42 long-term MarClim sites. The data were used in the Natural Resources Wales report on storm damage.

Figure 7. Boulder field uncovered by large movement of sediment at Aberdaron.

Figure 8. Ephemeral algal coverage and barnacle new recruitment on boulders at Aberdaron.

4.1.3. Lusitanian 'warm water' species

Great Orme East still marks the northern range limit of *Phorcus* (*Osilinus*) *lineatus*, which was first recorded as a multi-age population (as opposed to isolated individuals) in 2010, with abundances increasing from Occasional (1 per minute search), 2011 (1.47 per minute search), to Frequent (7 per minute) in 2012 but decreasing back to Occasional (1.4 per minute search) in 2013. Fewer individuals were present on the west coastline of the Great Orme (0.67 per minute search, 2013) but abundances had increased again in 2014 (2.067 per minute search).

At Great Orme Trwynygogarth on the west side of the Orme, 0.93 individuals per minute search were found in 2014, showing that this very small population had not increased in size significantly since the first MarClim survey at this site in 2007. It is likely that these

small range edge populations at Great Orme are seeded by larvae from the Caernarfon and Anglesey populations.

Surveys at Llanddulas across the MarClim time-series showed how expansion of *Gibbula umbilicalis* from Rhos-on-Sea to this small cobble shore in 2008 marked the new most north eastern population in Wales (there being a habitat-mediated gap in the biogeographic range until southern Scotland, with MarClim surveys funded by SNH tracking the northern range limit at Murkle Bay, northeast Scotland). In 2008 *G. umbilicalis* was Frequent (1.75 individuals per minute search). This population had increased to Common in 2012, with an average of 10.67 individuals per minute search but declined to Frequent in 2013 with three individuals per minute search recorded. Similar abundances of 3.26 individuals per minute were also recorded in 2014.

Population abundances of Lusitanian warm water kelps and topshells around the UK increased throughout the 2000s in response to warming of the marine climate, but began to decline from 2010-2013 in likely response to the hiatus in global warming detected during the 2000s (Figure 9), (Mieszkowska (2013) Report to Natural England). Surveys at these long-term sites in 2014 showed that the recent declining trend had stopped, with increased numbers of individuals within populations from northern range limits in north Wales right around the Welsh and English coastlines and along the English Channel to the northeast range limit. Future annual surveys will be able to provide evidence of whether the long-term warming trend has resumed, or if the increase in population abundances was a short-term response to the milder winter thermal conditions experienced in 2013/14.

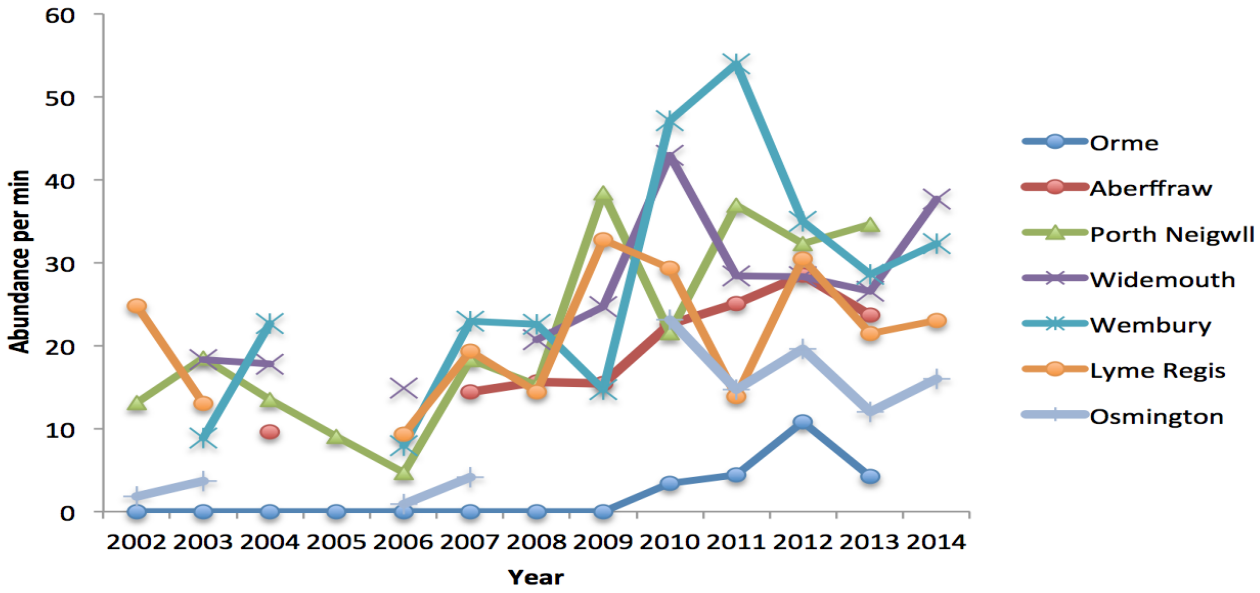

Figure 9. *P. lineatus* abundances at selected sites from the northern range edge at Great Orme East to the north eastern range edge in south England at Osmington.

The MarClim time-series has tracked the increase in abundance of the warm water kelp *Saccorhiza polyschides* around the UK coastline in line with warming temperatures during the early 2000s. Since 2009, intertidal populations in Wales have declined in abundance or disappeared, likely due to the colder winters experienced in recent years (Table 2). Observations from subtidal dive surveys carried out by the Skomer MNR team and MRes student projects in Plymouth supervised by Mieszkowska indicate that *S. polyschides* has been increasing in abundance far more rapidly in subtidal kelp beds along the Atlantic

coastline of France and the southern coastline of England during the 2000s. These observations suggest that the colonisation and dominance of kelp forests in the UK is driven by subtidal populations where environmental temperatures are more stable and do not approach lower lethal temperatures, whereas intertidal populations are subject to cold winter air temperatures likely to result in juvenile mortalities within the intertidal fringe.

Table 2. SACFOR abundance categories for *S. polyschides.*

Site	2007	2008	2009	2010	2011	2012	2013	2014
Cemaes Bay	NS	NS	NS	NS	R	NS	NS	NS
Porth Swtan	NS	NS	F	NS	NS	R	NS	NS
Rhosneigr	NS	C	C	NS	NS	NS	NS	NS
Aberffraw	NS	NS	O	R	NS	NS	NS	NS
Nefyn	NS	NS	A	NS	NS	NS	NS	NS
Porth Oer	NS	A	A	R	NS	R	R	O
Aberdaron	NS	NS	O	NS	NS	C	NS	NS
Porth Neigwl	NS	NS	F	NS	NS	O	NS	R
West Angle Bay	NS	NS	NS	NS	NS	NS	O	NS

4.1.4. Boreal 'cold water' species

Species of UK concern with respect to climate-driven declines in abundance and distribution include the kelp *Alaria esculenta*, fucoid *Pelvetia canaliculata* and the barnacle *Semibalanus balanoides*. None of these species have southern distributional limits currently in Wales and the Welsh MarClim sites show little variation in population abundance across the 2002-2014 time period.

4.1.5. Invasive Non-Native Species

MarClim survey sites are located at exposed or semi-exposed sites away from direct influences of human activities. Few records of INNS were found in 2014, similar to previous years. The invasive ascidian *Corella eumyota* was again found in low numbers on the undersides of boulders by Menai Bridge in 2014, but this population is not increasing in size.

The Japanese brown alga *Sargassum muticum* has been present in the UK since the 1970s. Analysis of MarClim sites where *S. muticum* was present across the 2002-2014 time-series show that this species has appeared at three sites for the first time in 2014: Cemlyn, Trearddur Bay and Aberffraw, and has increased in abundance in recent years at sites where it was previously established (Table 3). The solitary tunicate *Styela clava* is not on the MarClim list, but the surveyors found it to again be present in low densities on the concrete supports of the old lifeboat slipway at Abersoch in 2014.

Table 3. SACFOR abundances for the invasive *S. muticum.*

Site	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Penmon North	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cemlyn	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R
Trearddur Bay	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	A
Rhosneigr	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	C
Aberffraw	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	C
Porth Oer	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	A	A
Menai Bridge	NR	NR	NR	NR	NR	NS	NS	NS	R	R	R	NS	F
Broadhaven	A	C	NS	NR	NS	NS	NS	O	F	A	F	F	C
Dale	NR	NR	NR	NR	NR	O	NS	NS	NS	F	R	NS	NR
Martin's Haven	NS	NS	NS	NS	NS	NS	R	NS	R	NS	NS	NS	R
South Haven	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS	NS	NS
West Angle Bay	F	NS	O	NS	NS	O	NS	NS	F	NS	NS	NS	NS

A survey of sheltered boulder shores in Wales was carried out in July 2014 by MarineSeen, in tandem with the MarClim surveys.

4.2. Spatio-temporal trends

Multidimensional scaling analyses were performed for the macroalgal assemblages present at five sites around the Welsh coastline; Penmon North and Rhosneigr on Anglesey, Porth Oer and Porth Neigwl on the Llyn Peninsula in north Wales, Martin's Haven and West Angle Bay in Pembrokeshire in south Wales for the 2013 report (Mieszkowska 2014). These community assemblages had not changed significantly in 2014.

4.2.1. Northeast coastline

The abundance of *P. lineatus* and *G. umbilicalis* in recent years in north Wales at, and close to northern range limits has shown a slow-down in the increasing trend recorded across the previous decade, with the northern range edge for *P. lineatus* remaining at Great Orme East since the first record of a multi-age population in 2010. The regional decline in abundances recorded from 2010-2013 was not observed in 2014, with abundances increasing again (Figure 9).

Comparison with SST at these locations shows a drop in SST in 2008 that may be reflected in the reduction in densities of both *P. lineatus* and *G. umbilicalis*. This may be due to either individuals at these locations moving to more cryptic habitat in cracks and crevices further down the shore where they were not found during the standard searches, or a decline in recruitment, however, detailed analysis of the individual size data for the entire topshell datasets is beyond the scope of the current contract.

4.2.2. Anglesey

The blue mussel *Mytilus* spp. has declined at several sites including Penmon North, Moelfre, Porth Swtan and Porth Dafarch. Abundances of both Boreal and Lusitanian limpets and barnacles have remained at similar densities in 2014 to previous years in the 2010s.

4.2.3. Llyn Peninsula

Mytilus spp. has also declined at several sites on the Llyn over the past three years. Mussel beds are temporally variable and the recent decline may be part of a natural fluctuating cycle. Abundances of both Boreal and Lusitanian limpets and barnacles have remained at similar densities in 2014 to previous years in the 2010s.

4.2.4. Pembrokeshire

Most species have not fluctuated more than 1-2 SACFOR categories across the time-series indicating natural stochasticity but no acute impacts or pervasive changes. The warm water kelp *Saccorhiza polyschides* was recorded for the first time at West Angle Bay in 2013 as Occasional, but was not seen in 2014. *Mytilus* spp. appears sporadically at sites, remains for a few years and then disappears again. This is typical of mussel beds that are often the result of a single spatfall that does not successfully recruit in subsequent years.

A new survey station added at the new Pembroke power station in 2013 to monitor the potential impacts of warm water outflow on adjacent intertidal habitats was resurveyed in 2014. No unusual species were recorded.

4.3. Relevance to policy drivers and conservation objectives

Mieszkowska, with the MarClim modeller Burrows (SAMS) and MarClim surveyor Hawkins (University Southampton) have used the MarClim UK time-series to develop indicators designed to address the needs of the Marine Strategy Framework Directive (MSFD) (Burrows *et al*. 2014). The approach taken reflects discussions which took place at an expert workshop JNCC/Defra-led expert workshop (Birmingham, April 2011) that resulted in the proposals for UK MSFD targets and indicators presented to UK Government in Moffat *et al*. (2011). The MarClim indicators use species-level metrics to derive a score that can be compared to a numeric scale to determine the current status and changes between subsequent assessments. An indicator for Climate Change has been developed and tested using metrics based on abundances of warm water and cold water species to provide information on "prevailing physiographic, geographic and climatic conditions" around the UK and Ireland. Good Environmental Status for the MSFD relies on eleven descriptors of which four are relevant for these relatively undisturbed and unexploited habitats. The findings and final report have now been published and can be found at: http://jncc.defra.gov.uk/page-6813.

MarClim protocols have been cited as an example of best practice for time-series collection in the PEGASEAS Governance Guide for Policymakers in the EU https://www.pegaseas.eu/wp-content/uploads/2015/01/PEGASEAS-Compendium-English-Version.pdf. This EU Interreg Project aims to provide 'effective governance of the Channel Ecosystem' and the incorporation of MarClim protocols into this initiative is testament to the robust, widely applicable methodology and resultant data to a wide range of issues regarding status and governance of coastal ecosystems in Europe.

MarClim has been highlighted in a global scientific assessment of the need for scientific research to be appropriately designed to provide fit-for-purpose information at relevant spatial and temporal scales useful to managers of protected areas, statutory bodies and policymakers. This paper demonstrates how ground-breaking the MarClim project and the long-term collaboration with Natural Resources Wales and the Marine Biological Association of the UK has been in delivering relevant information on the Condition and Status of intertidal habitats in Wales against a backdrop of pervasive climate change http://www.biomedcentral.com/content/pdf/s40665-014-0006-0.pdf .

MarClim has also been selected as the test time-series for the INSHORE International Network for Research in Rocky Intertidal Systems http://rockyinshore.org/about/ demonstrating the global impact of this project.

5. SUMMARY

All 44 rocky shores surveyed by the MarClim team were considered to be in good condition in 2014. The community composition at the majority of long-term sites did not show major changes in abundance in 2014 compared to recent years. Coldwater macroalgae have not changed in abundance across the sites. Warm water topshells, limpets and barnacles have shown a slight slowdown in the decadal increasing trend, and this will be monitored in future years.

Technological advances in equipment to measure physiological parameters including heart rate, body temperature and respiration in the field will be trialled during MarClim surveys in 2015. New microclimate data at the scale of the individual site has now become available, and will be used for future temporal assessments of changes in species abundances in response to changes in environmental conditions at the shore and regional level that have not been previously possible with available satellite and weather station data and technology.

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APPENDIX 1. MarClim Sampling Protocols 2014

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

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

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

Species	S	A	C	F	O	R	Not seen	Comments
Codium spp.								
Laminaria hyperborea								
Laminaria digitata								
Saccharina latissima (L. saccharina)								
Laminaria ochroleuca								
Alaria esculenta								
Himanthalia elongata								
Sargassum (Bactrophycus) 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								
Calliblepharis jubata								
Chondracanthus acicularis								
Asparagopsis armata								
Colpomenia peregrina								
Sacchoriza polyschides								
Grateloupia turuturu								
Palmaria palmata								
Heterosiphonia japonica								
Halichondria panacea								
Hymeniacidon perlevis								
Anemonia viridis								
Aulactinia verrucosa								
Actinia fragacea								
Actinia equina								
Haliplanella lineata								
Sabellaria alveolata								
Chthamalus stellatus								
Chthamalus montagui								
Semibalanus balanoides								
Balanus crenatus								
Perforatus (Balanus) perforatus								
Austrominius (Elminius) modestus								
Pollicipes pollicipes								
Mytilus spp.								
Clibanarius erythropus								
Haliotis tuberculata								
Testudinalia (Tectura) testudinalis								
Patella vulgata								
Patella depressa								
Patella ulyssiponensis								
Patella (Ansates) pellucida								
Gibbula umbilicalis								
Gibbula pennanti								
Gibbula cineraria								
Phorcus (Osilinus) lineatus								
Calliostoma zizyphinum								
Littorina littorea								
Littorina saxatilis agg.								
Melarhaphe neritoides								
Nucella lapillus								
Onchidella celtica								
Crassostrea gigas								
Crepidula fornicata								
Botrylloides violaceus								
Corella eumyota								
Dendrodoa grossularia								
Asterocarpa humilis (cerea)								
Didemnum vexillum								
Asterias rubens								
Leptasterias mulleri								
Paracentrotus lividus								
Strongylocentrotus droebachiensis								
Watersipora subtorquata								
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	*Gibbula umbilicalis*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Notes:

APPENDIX 2: Data Archive

The report and data collected under Natural Resources Wales contract FC 73-02-359 is archived as Project No 443 Media No 1483 and is maintained on a backed-up server based storage at NRW headquarters.

The data archive consists of:

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

[B] Excel spreadsheets of species records

[C] Some site photographs from each location.

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

File Path for data:

Ffynnon – NRW-15-048211

File path for the report:

Ffynnon – NRW-15-048440

Metadata for this project is publicly accessible through the Natural Resources Wales Library Catalogue http://194.83.155.90/olibcgi/ by searching 'Dataset Titles'. The metadata is held as record no 109815.

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Further copies of this report are available from the library

Email: library@cyfoethnaturiolcymru.gov.uk