

# MarClim Annual Welsh Intertidal Climate Monitoring Survey 2017

Dr. N. Mieszowska

NRW Evidence Report No 256

Date: March 2018



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

03000 653000

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Report series: Natural Resources Wales Evidence Report  
Report number: 256  
Publication date: March 2018  
Contract number: MOA0070 (formerly M081 MFSG 10)  
Contractor: Nova Mieszkowska, Marine Biological Association  
Contract Manager: Paul Brazier  
Title: MarClim Annual Welsh Intertidal Climate Monitoring Survey 2017  
Author(s): Nova Mieszkowska  
Technical Editor: Paul Brazier  
Peer Reviewer(s) -  
Approved By: Mike Camplin  
Restrictions: None

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### Recommended citation for this volume:

Mieszkowska, N. 2018. MarClim Annual Welsh Intertidal Climate Monitoring Survey 2017. Natural Resources Wales Evidence Report No. 256 pp 22 + x, Natural Resources Wales, Bangor.

## Crynodeb Gweithredol

Mae'r adroddiad hwn yn crynhoi'r arolygon, y casglu data a'r dadansoddi a gwblhawyd ar safleoedd rhynglanwol creigiog o gwmpas arfordir Cymru o dan prosiect â'r teitl MarClim, fel y'i disgrifir yn Mieszkowska (2005) <http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm>. Mae'r arolwg blynyddol yng Nghymru yn ffurfio rhan o arolwg parhaus, cyson dros 15 mlynedd, sy'n cynnwys y DU gyfan, o dros 100 safle rhynglanwol creigiog sy'n destun arolygon. Mae ardal ddaearyddol yr arolwg yn cynnwys safleoedd ledled gogledd a de-orllewin Cymru lle mae data hanesyddol yn bodoli sy'n mynd yn ôl i'r 1950au, a safleoedd ychwanegol lle y rhagwelir y bydd ffin yr ardal yn ymestyn. Cafodd arolygon MarClim eu cynnal ar 41 safle yn 2017. Cynhaliwyd arolygon ar 32 safle yng ngogledd Cymru a naw safle yn ne Cymru.

Ychwanegwyd pedair rhywogaeth anffroddol at restr MarClim yn 2017: yr gwymon coch *Caulacanthus ustulatus* a *Pikea californica*, a'r tiwnigogion *Botrylloides diegensis* a *Perophora japonica*, ar ôl ymgynghori â Dr John Bishop a chronfa ddata Ysgrifenyddiaeth Rhywogaethau Anffroddol Prydain. Mae MarClim bellach yn cofnodi chwe rhywogaeth anffroddol o gwymon a 12 infertebrat fel rhan o arolygon MarClim.

Ychwanegwyd safle newydd yn Neyland (ar bwys Brunel Wall) yn Aberdaugleddau yn 2017, gan i'r môrwiail goresgynnol *Undaria pinnatifida* gael ei weld yno. Cynhelir arolwg arall o'r safle yn 2018. Cafodd yr gwymon goresgynnol *Caulacanthus ustulatus* ei ychwanegu at restr MarClim yn 2017 a chafodd ei gofnodi yng Nglanfa Dale Fort. Roedd yr asgidian goresgynnol *Corella eumyota* yn bresennol ar y safle MarClim ym Mhorthaethwy rhwng 2012 a 2016, ond ni chafwyd y rhywogaeth hon yno yn ystod 2017. Roedd yn 'Doreithiog' ar goesau'r llithrfa yng Ngorsaf Bad Achub Aber-soch ac yn 'Fynych' ar Draeth y Lanfa, Dale, yn 2017. Chwiliwyd am rywogaethau goresgynnol o'r gwymon *Asparagopsis armata* a *Heterosiphonia japonica*, yr anemoni goresgynnol *Diadumene lineata*, y tiwnigogion *Didemnum vexillum* ac *Asterocarpa humilis*, y molysgiaid *Magallana gigas* a *Crepidula fornicata*, y brysoad *Watersipora subtorquata*, a'r crancod *Hemigrapsus sanguineus* a *Hemigrapsus takanoi* i gyd, ond ni chafwyd unrhyw enghreifftiau o'r rhain ar unrhyw safle MarClim tymor hir yng Nghymru yn 2017.

Gwelwyd bod cyrhaeddiad a helaethrwydd cregyn crib dŵr cynnes Lwsitanaidd wedi cynyddu mewn poblogaethau sefydledig yng Nghymru trwy gydol y 2000au, mewn ymateb i'r hinsawdd yn cynhesu, a bod eu helaethrwydd wedi gostwng rhwng 2010 a 2013 o ganlyniad i'r blwch mewn cynhesu byd-eang a nodwyd yn ystod y 2000au. Yn 2016, cafwyd enghreifftiau unigol o *Phorcus lineatus* am y tro cyntaf yn Llanddulas, gan nodi estyniad arall i ffin cyrhaeddiad gogleddol arweiniol y rhywogaeth hon yng ngogledd Cymru. Roedd y boblogaeth fach hon yn dal i fod yn bresennol yn 2017.

Mae gwybodaeth am brosiect MarClim a'r data gwyddonol a gesglir ganddo'n cael eu trosglwyddo i sefydliadau llywodraethol, staff, asiantaethau cadwraeth, rheolwyr Ardaloedd Cadwraeth Arbennig (ACAau) a Safleoedd o Ddiddordeb Gwyddonol Arbennig (SoDdGAau) morol a'r cyhoedd er mwyn cynyddu gwybodaeth, dealltwriaeth ac adrodd ynghylch cwestiynau sy'n wyddonol, rheolaethol a chymdeithasol bwysig mewn perthynas â newid hinsawdd byd-eang, asideiddio'r cefnforoedd ac effeithiau dynol llai ar yr amgylchedd morol, gan gynnwys datblygu, anheddu ac ymelwa ar y parth morol, ecosystemau cydrannol a rhywogaethau.

Defnyddir MarClim i asesu a llywio polisiau a chyfarwyddbau'r DU a'r UE, gan gynnwys Cyfarwydeb Fframwaith Strategaeth Forol yr UE, Canllawiau Llywodraethu PEGASEAS, Asesiadau Cyflwr ar gyfer ACAau a SoDdGAau a Safleoedd Morol Ewropeaidd, ac fel data gwaelodlin ar gyfer proses dynodi Parthau Cadwraeth Morol y DU.

Cafodd set ddata cyfres-amser MarClim ei datblygu gan Mieszowska, Burrows a Hawkins (2013) o dîm MarClim fel Dangosyddion Statws Amgylcheddol Da ar gyfer Cyfarwydeb Fframwaith y Strategaeth Forol, gyda'r adroddiad cyntaf wedi'i gyhoeddi yn 2014: <http://jncc.defra.gov.uk/page-6813>. Datblygwyd ail gyfnod o waith – i ddatblygu cyfres-amser MarClim fel dangosyddion newid hinsawdd rhywogaethol (Mynegai Tymheredd Rhywogaethau) a chymunedol (Mynegai Tymheredd Cymunedau) fel rhan o broses datblygu dangosyddion Statws Ecolegol Da Cyfarwydeb Fframwaith y Strategaeth Forol – gan dîm MarClim yn 2017.

Mae prosiect MarClim a'r tîm ymchwil yn darparu monitro unigryw, hanfodol, tymor hir a data ymchwil ac arbenigedd gwyddonol. Mae'r rhain yn cael eu defnyddio gan adrannau Llywodraeth y DU i fynd i'r afael â chyfarwyddbau polisi cenedlaethol ac Ewropeaidd pwysig, gan gynnwys Cyfarwydeb Fframwaith Strategaeth Forol yr UE, Cyfarwydeb Cynefinoedd yr UE, Cyfarwydeb Fframwaith Dŵr yr UE, Asesiadau Comisiwn OSPAR, a phroses dynodi Parthau Cadwraeth Morol y DU fel rhan o Ddeddf y Môr a Mynediad i'r Arfordir.

## Executive Summary

This report summarizes the 2017 rocky intertidal survey work, data and analysis completed around the coastline of Wales under the project title of MarClim, as described in <http://www.mba.ac.uk/NMBL/publications/occpub/occasionalpub20.htm> Mieszkowska (2005). The annual survey in Wales forms part of a sustained, fifteen-year, continuous annual UK survey of over 100 long-term rocky intertidal survey sites. Geographical coverage includes sites throughout north and southwest Wales for which historical data dating back to the 1950s exist, and additional sites where range extensions have been predicted to occur. MarClim surveys were carried out at forty one sites in 2017. Thirty two sites were surveyed in north Wales and nine sites in south Wales.

Four Invasive Non-Native Species were added to the MarClim list in 2017; the red algae *Caulacanthus ustulatus* and *Pikea californica*, and the tunicates *Botrylloides diegensis*, and *Perophora japonica*, upon consultation with Dr. John Bishop and the GBNS secretariat database. MarClim now records six NIS of macroalgae and twelve invertebrates as part of the MarClim surveys.

A new site at Neyland (by Brunel Wall) in Milford Haven was added in 2017, as the invasive kelp *Undaria pinnatifida* was spotted there. This site will be resurveyed in 2018. The invasive red alga *Caulacanthus ustulatus* was added to the MarClim list in 2017 and was recorded at Dale Fort Jetty. The invasive ascidian *Corella eumyota* was present at the Menai Bridge MarClim site between 2012 and 2016, however, this species was not found there in 2017. It was Superabundant on the slipway legs at Abersoch lifeboat station and Frequent at Jetty Beach, Dale in 2017. Invasive species of macroalgae, *Asparagopsis armata*, *Heterosiphonia japonica*, the invasive anemone *Diadumene lineata*, tunicates *Didemnum vexillum* and *Asterocarpa humilis*, molluscs *Magallana gigas* and *Crepidula fornicata*, bryozoan *Watersipora subtorquata*, the crabs *Hemigrapsus sanguineus* and *Hemigrapsus takanoi* were all looked for, but not found at any MarClim Wales long-term site in 2017.

Lusitanian warm water topshells have shown increases in range and abundance at established populations in Wales throughout the 2000s in response to climate warming, and a reduction in abundance between 2010-2013 due to the hiatus in global warming detected during the 2000s. In 2016, individuals of *Phorcus lineatus* were found for the first time at Llanddulas, marking another extension of the northern, leading range edge for this species in north Wales. This small population was still present in 2017.

The MarClim project and scientific data collected by MarClim is communicated to government organisations, staff, conservation agencies, marine SAC and SSSI managers and the general public to increase the knowledge, understanding and reporting of scientifically, managerial and societally important questions relating to global climate change, ocean acidification and smaller-scale human impacts on the marine environment including development, habitation and exploitation of the coastal zone, component ecosystems and species. MarClim is used to assess and inform UK and EU policies and directives including the EU Marine Strategy Framework Directive, PEGASEAS Governance Guide, Condition Assessments for SACs, SSSIs and European Marine Sites and as baseline data for the UK Marine Conservation Zone designation process.

The MarClim time-series dataset was developed by Mieszkowska, Burrows and Hawkins (2013) of the MarClim team as Good Environmental Status Indicators for the MSFD, with the first report published in 2014: <http://jncc.defra.gov.uk/page-6813>. A second phase of work to develop the MarClim time-series as species (Species Temperature Index) and community indicators of climate change (Community Temperature Index) as part of the MSFD GES indicator development process was developed by the MarClim team in 2017.

The MarClim Project and research team provide unique, essential, long-term monitoring and scientific research data and expertise. This is used by the UK government departments to address major national and European policy directives including the EU Marine Strategy Framework Directive, EU Habitats Directive, EU Water Framework Directive, OSPAR Commission Assessments, and the UK Marine Conservation Zone designation process as part of the Marine and Coastal Access Act.



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## 1 INTRODUCTION

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

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

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

## 2 BACKGROUND

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

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

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

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

The project focuses on a robust set of temperature-sensitive, readily observed, intertidal climate indicator species of invertebrates and macroalgae for which long-term data sets and monitoring sites are available. The MarClim species list includes boreal cold-water and lusitanian warm-water origins, native to the UK intertidal ecosystems, and invasive non-native species (INNS) 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-native 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 INNS identified as posing a risk to native rocky intertidal communities. To ensure comparability with the historical data the original methodology was retained for ACFOR (now SACFOR) scoring of species abundances and barnacle quadrat counts. Additional quantitative methodology to facilitate robust statistical analysis and modelling has been incorporated since 2002 and is detailed in the Survey Protocols section below.

Climate-driven shifts in the biogeographic ranges of native and non-native species are also being tracked by Dr. Mieszkowska around the wider northern European coastline using the MarClim protocols. These surveys provide geographically extensive, contextual evidence on distributions, abundances, biological mechanisms by which intertidal species respond to large-scale climate related changes and allow Welsh data to be placed into a European context, with special relevance to the EU Marine Strategy Framework Directive 'Good Environmental Status' indicators (<http://jncc.defra.gov.uk/page-6813>).

### 3 METHODS

The MarClim protocols (Appendix 1) were used as the standard survey methodology at all survey sites. These protocols include additional INNS 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 thirty nine long-term sites in 2017 (Table 1, Figure 1). Thirty three sites were surveyed in north Wales and six sites in south Wales.

Rocky shores in north Wales were surveyed by Dr. Nova Mieszkowska from The Marine Biological Association, Heather Sugden from Newcastle University, Kathryn Birch and Laura Grant from Natural Resources Wales (Figure 2). Several NRW staff have been trained in MarClim methodology during previous annual surveys.

Six sites were surveyed in south Wales including two sites on the Skomer Island Marine Conservation Zone, five on the mainland and one on Skokholm Island. These surveys were carried out and cross-calibration exercises undertaken by Mark Burton of NRW. All surveyors have carried out cross-calibrations with Mieszkowska in several previous years including on-site training to ensure accurate continuation of sample methodologies and protocols. Data entry was completed by Leoni Adams with QA by Nova Mieszkowska and Paul Brazier.

Semi-quantitative SACFOR abundance scores were recorded for a suite of 77 species of invertebrates and macroalgae, including nine non-native invertebrate and nine macroalgal species.

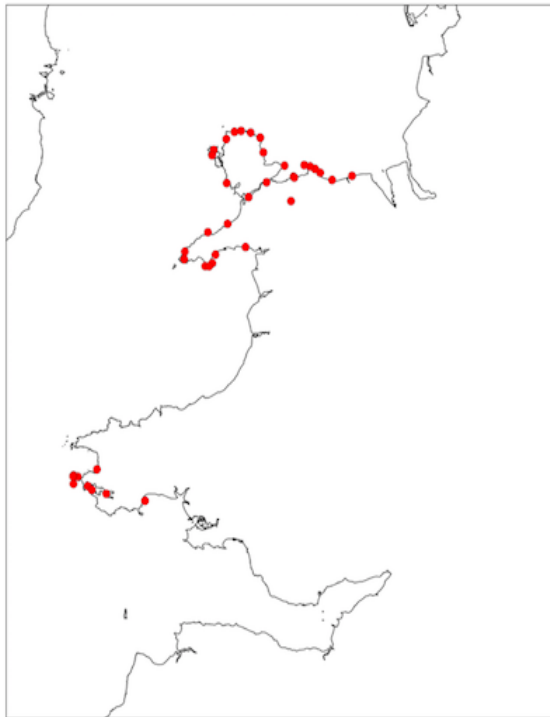
Replicate, quantitative quadrat counts were made for barnacles (0.0025 m<sup>2</sup>) (Figure 3) and population abundances for each species counted using bespoke digital image software. Ten replicate 0.25 m<sup>2</sup> quadrats that were counted at each site to record the abundance of limpet species, were randomly placed within the mid shore 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, each of three minutes duration were made separately for *Phorcus lineatus* and *Steromphala (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 every individual was measured in mm to 1 decimal place and population size frequencies calculated from the data.

All data have been submitted to NRW in electronic format. All surveyors had been trained in MarClim methodology and cross-calibrated in the field with Dr. Mieszkowska. An additional site at Holyhead was added to the MarClim Wales site network in 2010 and has been re-surveyed annually to track any potential spread of the non-native ascidian *Didemnum vexillum* which has been the subject of an intense eradication program by NRW inside [Holyhead marina](#). An additional site at Llanddulas, which has been sporadically checked for absence of indicator species has been added to the list after the appearance of a population of *Steromphala 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 in 2017, to ensure further range extensions of the topshells are accurately located.

## MarClim Annual Welsh Intertidal Climate Monitoring Survey 2017

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 labeled 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.



0 15 30 60 Miles

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Figure 1. MarClim sites surveyed in 2017

Figure 2. NRW staff doing MarClim

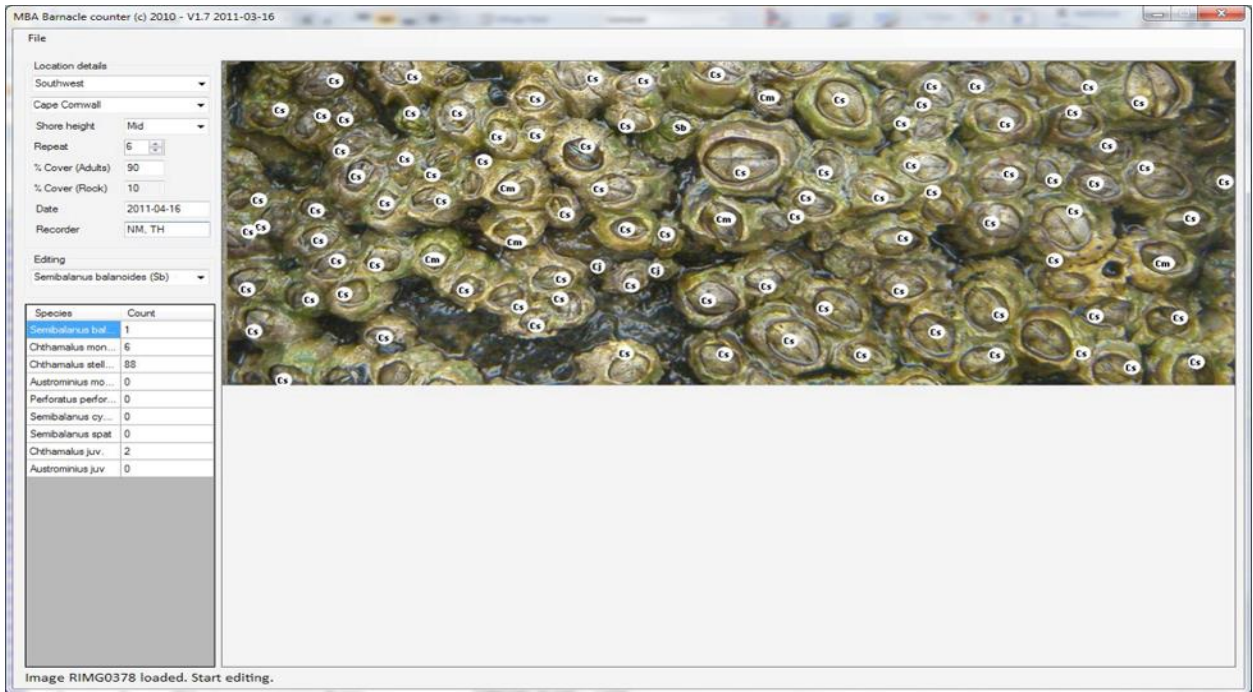


Figure 3. A 5 cm x 2 cm subsection of the 5 x 5 cm barnacle quadrat images taken during MarClim surveys being analysed using MarClim digital image software. The species are identified and marked by a unique identifier code and the number of adult and juvenile barnacles for each species is recorded in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



Figure 4. MarClim 0.25m<sup>2</sup> limpet quadrat used for surveys



Table 1. MarClim Survey Site Locations 2017

Day	Month	Year	Site	Grid	Lat (WGS84)	Long (WGS84)
20	7	2017	Rhyl crescent sea wall & groynes	SJ020824	53.3299	-3.4715
20	7	2017	Llanddulas	SH906787	53.2933	-3.6296
20	7	2017	Rhos-on-sea	SH843805	53.3140	-3.7381
20	7	2017	Little Orme	SH812825	53.3260	-3.7852
20	7	2017	Great Orme East	SH782832	53.3321	-3.8297
20	7	2017	Penmaenmawr Slipway	SH699766	53.2712	-3.9521
21	7	2017	Great Orme Trwynygarth	SH749834	53.3327	-3.8801
21	7	2017	Penmaenmawr Natural	SH704763	53.2683	-3.9440
21	7	2017	Penmaenmawr Artificial	SH709763	53.1613	-3.9369
21	7	2017	Trefor	SH376474	52.9992	-4.4215
21	7	2017	Caernarfon	SH521671	53.1374	-4.2897
21	7	2017	Penmon North	SH641813	53.3111	-4.0413
21	7	2017	Menai Bridge	SH555714	53.2207	-4.1643
22	7	2017	Bull Bay	SH427945	53.4238	-4.3688
22	7	2017	Moelfre	SH513859	53.3490	-4.2354
22	7	2017	Point Lynas	SH484929	53.4111	-4.2823
22	7	2017	Holyhead	SH257825	53.3108	-4.6461
22	7	2017	Porth Swtan	SH298891	53.3713	-4.5598
22	7	2017	Cemaes	SH372944	53.4219	-4.4502
22	7	2017	Cemlyn	SH337934	53.4111	-4.5035
23	7	2017	Aberffraw (Braich-Lwyd)	SH337674	53.1776	-4.4899
23	7	2017	Porth Dafarch	SH233798	53.2856	-4.6522
23	7	2017	Rhosneigr	SH315725	53.2233	-4.5253
24	7	2017	Nefyn	SH274415	52.9430	-4.5702
24	7	2017	Porth Neigwl	SH288245	52.7908	-4.5404
24	7	2017	Porth Oer B	SH163297	52.8343	-4.7279
25	7	2017	Aberdaron	SH166260	52.8003	-4.7220
25	7	2017	Abersoch Lifeboat Station	SH323265	52.8107	-4.4881
25	7	2017	Porth Ceiriad	SH308247	52.7938	-4.5094
25	7	2017	Llanbedrog	SH335311	52.8516	-4.4742
26	7	2017	Criccieth (East)	SH494376	52.9146	-4.2412
26	7	2017	Criccieth Castle	SH494376	52.9146	-4.2412
26	7	2017	Martin's Haven	SM759091	51.7356	-5.2470
21	8	2017	Skokholm South Haven	SM741051	51.6992	-5.2701
22	8	2017	North Haven	SM735093	51.7364	-5.2818
22	8	2017	South Haven	SM733088	51.7319	-5.2845
23	8	2017	Monkstone Point	SN150033	51.6978	-4.6784
23	8	2017	Neyland Natural (by Brunel Wall)	SM967047	51.7045	-4.9433
24	8	2017	Broadhaven	SM859144	51.7871	-5.1057
24	8	2017	Jetty Beach Dale	SM822053	51.7041	-5.1533
14	9	2017	West Angle Bay	SM859144	51.6916	-5.1151

## 4 RESULTS

### 4.1 2017 Findings

#### 4.1.1 Recent changes in the global and regional climate

The latest findings from the IPCC 5<sup>th</sup> Assessment Working Group I Report on the Physical Science Basis of Climate Change <http://www.ipcc.ch/report/ar5/wg1/#.Uwt9YvYzml> reveal that the earth's climate has not warmed as rapidly over the 2010s compared to the longer-term warming trend since the 1980s, due to non-anthropogenically mediated, natural variability in the earth's climate system. This recent slowdown must be placed into context; each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 and the northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years with 2016 being globally the warmest year on record <http://www.bloomberg.com/graphics/hottest-year-on-record/>, and the third warmest in the UK since 1910 <http://www.metoffice.gov.uk/news/releases/2016/2016-a-year-in-weather-statistics>.

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

The levels of carbon dioxide in the global atmosphere passed the 400ppm threshold permanently in 2016 (Figure 5). Increased CO<sub>2</sub> concentrations in the atmosphere raise the global temperature, and cause increased drawdown of CO<sub>2</sub> into the global oceans, exacerbating ocean acidification.

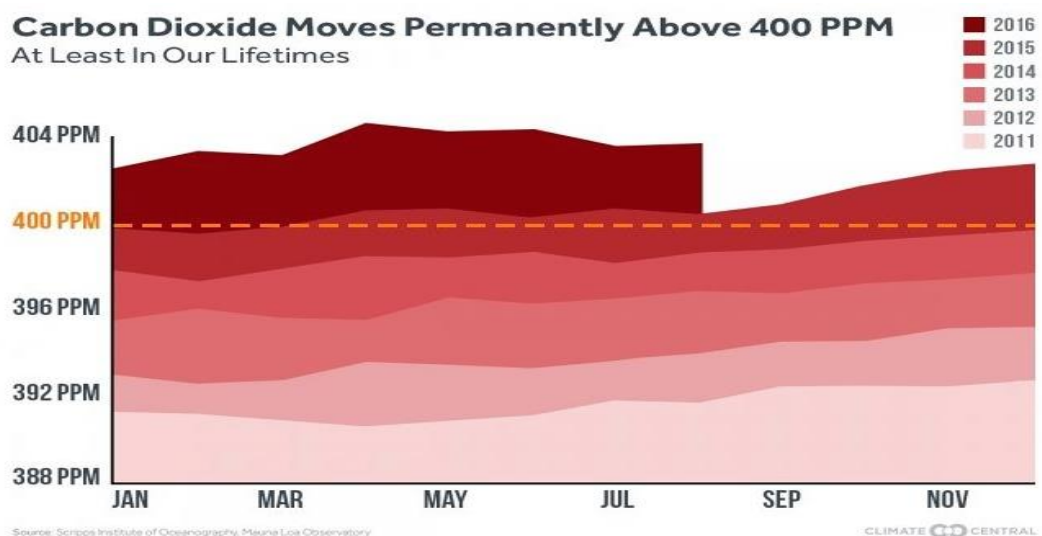


Figure 5. Atmospheric concentrations of carbon dioxide. Reproduced from Scripps Institute of Oceanography/Climate Central.

Storm events are predicted to reach 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 5<sup>th</sup> 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 characterised 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. Biological impacts of these storm events were surveyed at all 42 MarClim sites in Wales six months afterwards during the annual surveys in July 2014. Subsequent annual MarClim surveys have reassessed the effects on community structure following the 2013/14 storms after 18, 30 and 42 month periods via analysis of those species that have resisted storm damage, those species that were able to return after the extreme storm events and invasive non-native species that opportunistically occupied vacant habitat after storm-induced species loss, colonising those shores affected by storm damage. Details are reported below in Section 4.1.2.

#### 4.1.2 Storm impacts on Welsh rocky shores

An environmental audit was carried out by NRW after the 2014/14 storms (Duigan *et al.* 2014). Significant and highly variable impacts were recorded across a range of habitats and species, to the extent that ecosystem structure and functioning had changed, with algae, barnacles and molluscs being scoured from substrata or damaged and biogenic reefs were eroded in the intertidal zone. MarClim surveys around the Welsh coastline have tracked the changes in species and community composition annually since the 2013/14 storm event. The two sites that had significant changes in habitat structure were Porth Neigwl and Aberdaron, exposed rocky headlands on the southeast tip of the Llyn Peninsula where the prevailing Atlantic currents hit the land. These shores were subject to the highest wave forces during the storms around the north Wales coastline. At both shores, rocky habitat was uncovered by the storms and has remained uncovered since this time.

At Porth Neigwl, the main rocky reef and boulder-field at the base of the cliff by Trwyn y Ffosle (52.7908N, -4.5404E) showed no impacts, however, the boulder field situated approximately 100 m east in the sandy beach that is usually approximately 50 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 7). This boulder field was covered in blue mussel *Mytilus* spp. and barnacles previous to the storm event, 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. This extensive boulder field has shown successional stages of colonisation over the past three years, with ephemeral algae dominating in 2015 (Figure 6), with *Fucus vesiculosus* and *F. serratus* (both Superabundant) becoming the most dominant algae in 2016 (Figure 8). *Semibalanus balanoides* being Superabundant. Grazing gastropods *Littorina littorea* and *Phorcus lineatus* were also recorded in the boulder

field in 2016 and 2017, demonstrating additional trophic layers to the foodweb in this habitat and a species composition typical of a climax community present in 2017 (Figure 9).



Figure 6. Ephemeral algae dominating the boulder shore at Porth Neigwl in July 2014



Figure 7. Boulder shore at Porth Neigwl, July 2015



Figure 8. Boulder shore at Porth Neigwl, August 2016



Figure 9. Boulder shore at Porth Neigwl, August 2017



Figure 10. Boulder field uncovered by large movement of sediment at Aberdaron in July 2014



Figure 11. Boulder field at Aberdaron in July 2015



Figure 12. Boulder field at Aberdaron in August 2016



Figure 13. Boulder field at Aberdaron in July 2017

The headland at Aberdaron (52.8003N, -4.7220E) is also comprised of rocky cliff extending into the mid-eulittoral sandy beach, with small to large boulders. The boulder field was far more extensive in 2014 than in previous years, due to large movements of sediment within the bay (Figure 10). The boulder field remained uncovered in 2015 and 2016, without noticeable return of previously removed sediment and continued exposure. Succession to a *F. vesiculosus* and *S. balanoides* dominated community was recorded in 2014 (Figure 10), and has remained as a climax community to date (Figures 11-13), demonstrating a shift towards more stable, later stage colonising species.

The MarClim data collected on post-storm impacts in 2014 and 2015 were used in the Natural Resources Wales report on storm damage (Duigan, Rimington & Howe 2014) (<http://naturalresources.wales/media/1976/welsh-coastal-storms-december-2013-and-january-2014-an-assessment-of-environmental-change.pdf>).

#### 4.1.3 Changes in abundance across the time-series

The red alga *Mastocarpus stellatus* has shown declines in abundance at nineteen sites in the past few years, all of which are in north Wales (Aberdaron, Aberffraw, Abersoch, Bull Bay, Cemaes, Cemlyn, Criccieth East, Great Orme East, Great Orme Trwynyogarth, Little Orme, Menai Bridge, Moelfre, Nefyn, Penmaenmawr, Porth Ceiriad, Porth Dafarch, Porth Oer, Porth Swtan and Trearddur Bay). A regression analysis shows this declining trend (Figure 14). Abundances have not shown a

declining trend at Penmon, Porth Neigwl or Rhosneigr in north Wales, nor at any site with the exception of West Angle Bay in south Wales across the time-series. These changes are unlikely to be climate driven, as sea temperatures have been slightly cooling over the past decade. No other boreal species showed distinct changes in their abundance in 2017.

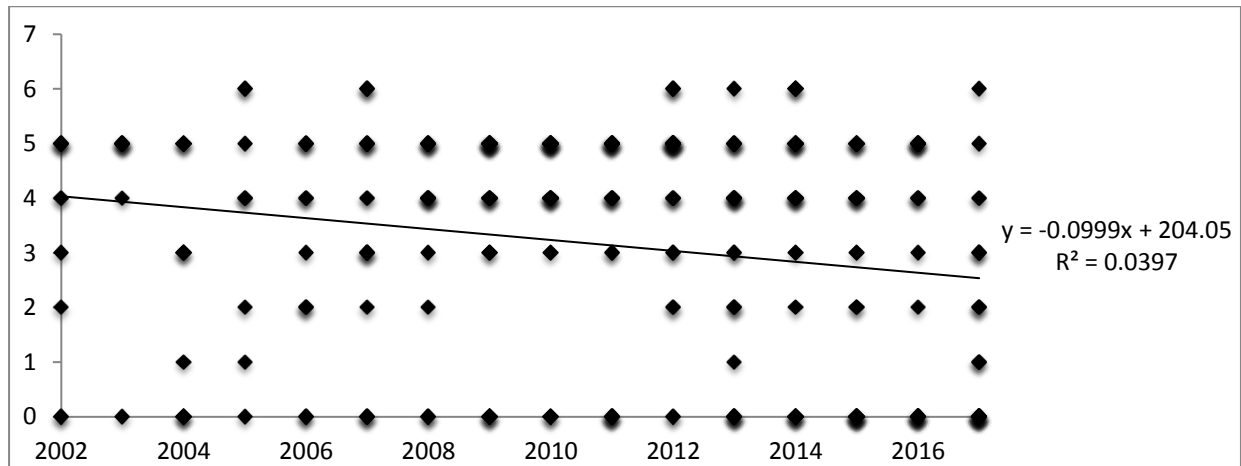


Figure 14. SACFOR scores for *M. stellatus* at all MarClim sites across the time-series

#### 4.1.4 Invasive Non-Native Species

The invasive red alga *Grateloupia turuturu* and the invasive brown alga *Undaria pinnatifida* were both recorded in 2017 at an opportunistic survey at Neyland (by Brunel Wall) in Milford Haven (Figures 15,16). *G. turuturu* has been recorded in Milford Haven marina both by NRW and by the MarClim team in the last few years. The record of *U. pinnatifida* is the first positive record at a MarClim site in the history of the time-series. *Caulacanthus ustulatus (okamurae)* has been added to the MarClim species list in 2017. It was found at Jetty Beach, Dale. *Sargassum muticum* was found at several sites in north and south Wales as in previous years, but has not spread to new locations in the MarClim site list. *Colpomenia peregrine* was Occasional at Holyhead, Rhosneigr and Trefor, but has not returned to Menai Bridge.



Figure 15. *Grateloupia turuturu* (left) and *Undaria pinnatifida* (right) at Neyland in 2017



**Figure 16. Neyland survey site, Milford Haven, south Wales**

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

## 4.2 Spatio-temporal trends

The MarClim time-series shows that many species recorded for the project have responded to both climate warming and cooling of the marine climate across this century. Lusitanian gastropods have shown the fastest range extensions around the north Wales coastline in response to warming of sea temperatures. The community composition and abundance of component species has not shown large shifts, as climate change impacts are species specific, and therefore the effects are more subtle than those caused by regime shifts upon ecosystem structure and functioning.

## 4.3 Relevance to policy drivers and conservation objectives

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



## 5 SUMMARY

All 39 rocky shores surveyed by the MarClim team were in good condition in 2017. The community composition at the majority of long-term sites did not show major changes in abundance in 2017 compared to recent years. Cold water macroalgae have not changed in abundance across the sites. Warm water topshells, limpets and barnacles prior to 2014 had shown a slight slowdown in the decadal increasing trend, 2014-2016 data indicate that abundances of these species may now be back on an upward trend with an extension of the northern, leading range edge of *P. lineatus* recorded in 2016. INNS have shown a decline in abundance at those MarClim sites where they have been previously recorded. One new record of *U. pinnatifida* at Milford Haven represents the first positive sighting of this species at a MarClim site in Wales.

## 6 REFERENCES

Duigan, CA, Rimington NA, Howe, MA (Eds). 2014. Coastal storms December 2013 & January 2014 – an assessment of environmental change. Natural Resources Wales Evidence Report No: 33, 122pp, Natural Resources Wales, Bangor.

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

Simkanin, C., Power, A., Myers, A., McGrath, D., Southward, A., Mieszkowska, N., Leaper, R., & O’Riordan, R. 2005. Using historical data to detect temporal changes in the abundances of intertidal species on Irish shores. *J. Mar. Biol. Ass. UK*: 85: 1329-1340.

## 7 ACKNOWLEDGEMENTS

MarClim thanks Paul Brazier for contract management and continued support of the MarClim project since 2002.

### **Surveyors:**

NM Nova Mieszkowska, MBA  
LA Leoni Adams, MBA  
KB Kathryn Birch, NRW  
LG Laura Grant, NRW  
MB Mark Burton, NRW Skomer MCZ  
HS Heather Sugden, Newcastle University

## APPENDIX 1. MarClim Sampling Protocols 2017

### 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

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

#### Recruits

*Semibalanus*  
  
*Chthamalus* (Total)  
*Austrominius modestus*

### 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<sup>2</sup> 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
<i>Codium</i> spp.								
<i>Laminaria hyperborea</i>								
<i>Laminaria digitata</i>								
<i>Saccharina latissima</i>								
<i>Laminaria ochroleuca</i>								
<i>Alaria esculenta</i>								
<i>Himantalia elongata</i>								
<i>Sargassum muticum</i>								
<i>Ascophyllum nodosum</i>								
<i>Pelvetia canaliculata</i>								
<i>Fucus spiralis</i>								
<i>Fucus vesiculosus</i>								
<i>Fucus serratus</i>								
<i>Fucus distichus</i>								
<i>Cystoseira</i> spp.								
<i>Halidrys siliquosa</i>								
<i>Bifurcaria bifurcata</i>								
<i>Mastocarpus stellatus</i>								
<i>Chondrus crispus</i>								
<i>Lichina pyramaea</i>								
<i>Undaria pinnatifida</i>								
<i>Dictyopteris polypodioides</i>								
<i>Dictyopteris cyanoloma</i>								
<i>Calliblepharis iubata</i>								
<i>Chondracanthus acicularis</i>								
<i>Asparagopsis armata</i>								
<i>Colobomenia peregrina</i>								
<i>Sacchoriza polyschides</i>								
<i>Grateloupia turuturu</i>								
<i>Palmaria palmata</i>								
<i>Heterosiphonia japonica</i>								
<i>Caulacanthus ustulatus (okamurae)</i>								
<i>Pikea californica</i>								
<i>Halichondria panacea</i>								
<i>Hymeniacidon perlevis</i>								
<i>Anemonia viridis</i>								
<i>Aulactinia verrucosa</i>								
<i>Actinia fragacea</i>								
<i>Actinia equina</i>								
<i>Diadumene (Haliolanella) lineata</i>								
<i>Sabellaria alveolata</i>								
<i>Chthamalus stellatus</i>								
<i>Chthamalus montagui</i>								
<i>Semibalanus balanoides</i>								
<i>Balanus crenatus</i>								
<i>Perforatus perforatus</i>								
<i>Austrominius modestus</i>								
<i>Pollicipes pollicipes</i>								
<i>Mytilus</i> spp.								
<i>Clibanarius erythropus</i>								
<i>Haliotis tuberculata</i>								
<i>Testudinalia testudinalis</i>								
<i>Patella vulgata</i>								
<i>Patella depressa</i>								
<i>Patella ulvssionensis</i>								
<i>Patella pellucida</i>								
<i>Steromphala umbilicalis</i>								
<i>Steromphala pennanti</i>								
<i>Steromphala cineraria</i>								
<i>Phorcus lineatus</i>								
<i>Calliostoma zizyphinum</i>								
<i>Littorina littorea</i>								
<i>Littorina saxatilis</i> agg.								
<i>Melanophloeus neritoides</i>								
<i>Nucella lapillus</i>								
<i>Onchidella celtica</i>								
<i>Macallana cincta</i>								
<i>Crepidula fornicata</i>								
<i>Botrylloides violaceus</i>								
<i>Botrylloides diegensis</i>								
<i>Perophora japonica</i>								
<i>Corella eumvota</i>								
<i>Dendrodoa grossularia</i>								
<i>Asterocarpa humilis</i>								
<i>Didemnum vexillum</i>								
<i>Asterias rubens</i>								
<i>Leptasterias mulleri</i>								
<i>Paracentrotus lividus</i>								
<i>Stronvlocentrotus droebachiensis</i>								
<i>Watersipora subatra</i>								
<i>Hemigrapsus sanguineus</i>								
<i>Hemigrapsus takanoi</i>								

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**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		
								<i>P. depressa</i>	<i>P. vulgata</i>	<i>P. ulysipp</i>
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	
		<i>Phorcus lineatus</i>	<i>Steromphala umbilicalis</i>
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 spreadsheet of species records

[C] Some site photographs from each location

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

File Path for data:

File path for the report:

File path for the archive:

Metadata for this project is publicly accessible through the Natural Resources Wales Library Catalogue <https://libcat.naturalresources.wales/webview/> by searching 'Dataset Titles'.

Date: 13<sup>th</sup> March 2018





**Cyfoeth  
Naturiol**  
Cymru  
**Natural  
Resources**  
Wales

Published by:  
Natural Resources Wales  
Maes y Ffynnon  
Ffordd Penrhos  
Bangor  
Gwynedd  
LL57 2DW

03000 653000

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