Cyfoeth Naturiol Cymru
Natural Resources Wales

Welsh Coastal Storms, December 2013 & January 2014 – an assessment of environmental change

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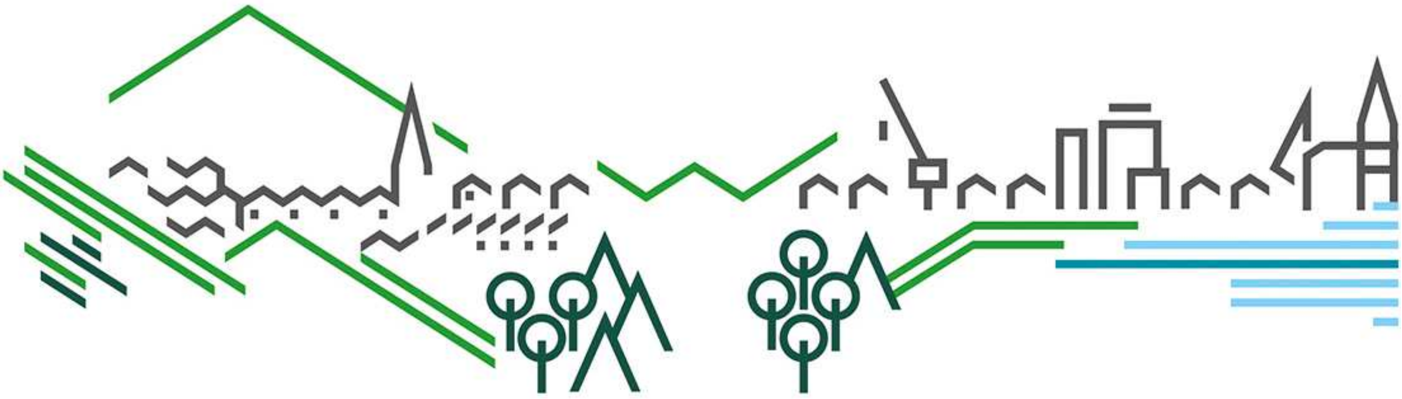

About Natural Resources Wales

We are a Welsh Government Sponsored Body. 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.

Evidence at Natural Resources Wales

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

We will secure this vision by:

Maintaining and developing the technical specialist skills of our staff;

Securing our data and information;-

Having a proactive programme of evidence work developed in collaboration with others;

Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and

Communicating our evidence in an open and transparent way.

This Evidence Report serves as a record of work carried out or commissioned by Natural Resources Wales. It also helps us to share and promote use of our evidence by others and develop future collaborations.

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1. Crynodeb Gweithredol

Yn Rhagfyr 2013 ac Ionawr 2014, yn dilyn cyfres o systemau gwasgedd isel dros Fôr Iwerydd, cynhyrchwyd ymchwyddau storm o faint sylweddol, a thonnau pur bwerus; pan gyfunwyd y rhain â phenllanw achoswyd trafferthion difrifol ar hyd arfordir Cymru. Rhoddwyd strwythurau a godwyd i amddiffyn yr arfordir rhag llifogydd dan bwysau mawr, ac fe'u difrodwyd; mewn rhai mannau bylchwyd yr amddiffynfeydd, gan achosi difrod i eiddo. Aethom ati i helpu'r cymunedau a ddioddefodd, ac ar yr un pryd rhoddwyd archwiliad amgylcheddol ar waith i astudio effaith y stormydd ar fywyd gwyllt ac ar ein safleoedd cadwraeth arfordirol. Cafwyd rhagor o stormydd yn gynnar ym mis Chwefror 2014, a gallai'r rhain fod wedi achosi rhagor o newidiadau amgylcheddol. Fodd bynnag, casglwyd y cofnodion cychwynnol at ei gilydd a'u bwydo i Gam 1 yr Arolwg Arfordirol (Cyfoeth Naturiol Cymru 2014a) ar ddiwedd Ionawr 2014. O'r herwydd, nid ydym wedi ymdrin yn benodol yma â stormydd mis Chwefror.

Mae'r adroddiad hwn yn ffurfio cofnod o'r canlynol: effeithiau'r achosion hynny o dywydd garw; graddfa'r newidiadau amgylcheddol oedd yn gysylltiedig â hwy yn nhermau'r amgylchedd ffisegol a'r biota; y gwersi a ddysgwyd; a'r goblygiadau ar gyfer rheoli'r amgylchedd a chadwraeth yng Nghymru. Cynhaliwyd yr archwiliad hwn ar sail yr adroddiadau a dderbyniwyd yn dilyn y stormydd, ond er bod dros 80 o gofnodion wedi dod i law ni ellir ei ystyried fel archwiliad trwyadl. Ni chafwyd digon o amser i gynnal adolygiad llenyddiaeth cynhwysfawr o effeithiau ecolegol y stormydd.

Mae'r adroddiad hefyd yn cyflawni argymhelliad 36 o Adroddiad Adolygiad Llifogydd Arfordirol Cymru, Cam 2 (Cyfoeth Naturiol Cymru 2014b, sef cwblhau'r diweddaru parhaus a wneir i Gam 1 yr asesiad 'cyflym' o'r newidiadau amgylcheddol a brofwyd yn ystod stormydd Rhagfyr 2013 ac Ionawr 2014.

Lleolwyd nifer o'r adroddiadau o newidiadau amgylcheddol a dderbyniwyd gan staff a chydweithwyr mewn safleoedd a ddynodwyd ar gyfer diddordebau gwarchod natur a/neu nodweddion daearegol. Yn wahanol i'r sefyllfa yn Lloegr, roedd Cymru'n ffodus i beidio â cholli unrhyw un o'i thirffurfiau daearegol mawr, statig; fodd bynnag, cafodd nifer o safleoedd lle dinoethir deunyddiau Cwaternaidd, mwy meddal, eu herydu'n sylweddol. Cafwyd rhai manteision wrth i nodweddion daearegol gael eu hamlygu, a chofnodwyd dinoethiadau newydd a gweithgaredd cynyddol yn y prosesau naturiol. Lledaenwyd nifer o hanesion o ddiddordeb i'r cyhoedd a gododd o ddarganfyddiadau palaeo-amgylcheddol ac archeolegol. Seiliwyd y sialensau parhaus sy'n ein hwynebu ar gofnodi a monitro'r nodweddion daearegol, ac adeiladu ar y diddordeb a gynhyrchwyd ymhlith y cyhoedd.

Mae'r gwir effaith ar ein cynefinoedd a'n rhywogaethau arfordirol yn dal i ddod i'r golwg, ac mewn rhai achosion ni fyddwn yn llawn werthfawrogi maint yr effaith am flynyddoedd lawer. Fodd bynnag, cofnodwyd effeithiau arwyddocaol a hynod amrywiol ar draws ystod o gynefinoedd a rhywogaethau, i'r graddau lle bydd strwythur a swyddogaeth yr ecosystem wedi newid. Er enghraifft, o fewn cyfnod byr yn y parth rhynglanwol, cafodd algâu, cregyn llong a molysgiaid eu sgwrio o is-haenau neu eu difrodi, ac erydwyd creigresi biogenig. Newidiwyd natur a siâp yr arfordir yn sylweddol mewn sawl man. Collwyd cyfeintiau mawr o dywod glan y môr, gan ddinoethi is-haenau o graig; cariwyd deunyddiau mwy garw i'r lan, a chafodd nodweddion naturiol, megis gwrymiau graean bras, eu hail-siapio. Er na chafwyd llifogydd difrifol yn y corsydd pori arfordirol, ac mai effeithiau ysgafn yn unig a gofnodwyd ar gyfer y morfeydd heli a'r traethellau llaid, effeithiwyd yn fawr ar dalcenni twyni tywod a chlogwyni meddal oherwydd erydiad, cylchlithro a bylchu.

Ar y systemau twyni tywod, credir fod colli cymaint o dywod glan y môr, traethlinau, cyn-dwyni a blaen-dwyni embryonig wedi cael effaith fawr – dros dro'n unig, gobeithir – ar y ffawna infertebrat cysylltiedig. Daeth asesiad risg ar gyfer rhywogaethau a chasgliadau infertebrat allweddol i'r casgliad fod y rhywogaethau sy'n gysylltiedig â chlogwyni meddal yn fregus hyd at ddifodiant lleol, o leiaf. Y rhywogaethau sy'n fwyaf tebygol o fod wedi dioddef yr effaith fwyaf yw'r rhai sy'n gysylltiedig â broc môr, y traethlinau a phlanhigion y traeth. Bydd angen mwy o arolygu a monitro yn ystod haf 2014 cyn gallu penderfynu beth fydd yn digwydd i infertebratau. Yn gyffredinol, mae'r effeithiau ar gynefinoedd a rhywogaethau wedi dangos bod ein hadnoddau bywyd gwyllt naturiol yn fregus mewn tywydd eithafol, a gall hynny achosi effeithiau cronnus, hir dymor, ar statws y boblogaeth ac ar gyflwr y safle.

Gweld cyrff adar y môr yn cael eu golchi i'r lan oedd y darlun mwyaf dramatig a gafwyd o'r effaith ar fywyd gwyllt; amcangyfrifir fod dros 30,000 o adar wedi trengi ar arfordiroedd Gorllewin Ewrop, gan gynnwys llawer o adar o'r cytrefi yng Nghymru. Roedd y digwyddiad hwn yn un eithriadol yng nghyd-destun Cymru, fel y gwelir yng nghanlyniadau Arolwg yr RSPB ar yr Adar a Olchwyd i'r Lan yng Nghymru (a gynhwysir yn Atodiad 1), ac mae'n bosibl yr adlewyrchir hyn yn niferoedd adar y môr am flynyddoedd lawer i ddod. Er eu bod yn fregus, ni welwyd unrhyw dystiolaeth o farwoldeb ar raddfa fawr mewn pysgod na mamaliaid y môr, ond gall fod morloi ifanc unigol a aned yng Nghymru wedi cael eu dadleoli, a bod eu cyflwr wedi dioddef oherwydd hynny.

Mae yna gonsensws eisoes fod sbwriel morol yn effeithio'n economaidd, yn amgylcheddol ac yn esthetig ar y Deyrnas Gyfunol. Daeth stormydd y gaeaf â'r mater hwn i sylw'r cyhoedd pan adawyd llawer iawn o sbwriel ar draethau Cymru. Rhoddwyd cyhoeddusrwydd eang i'r mater, a gwelwyd pobl yn dod at ei gilydd i glirio traethau ar ôl y difrod. Mae angen ystyried ymhellach y dewisiadau strategol deublyg – sef rheoli'r sbwriel yn y ffynhonnell, a chael gwared â'r deunyddiau ar ôl iddynt grynhoi – ac ystyried hefyd pa adnoddau fydd yn angenrheidiol i gyflawni hyn.

O safbwynt amgylcheddol, dysgwyd nifer o wersi yn sgil y stormydd enbyd - pa mor barod oeddem ni i baratoi ar eu cyfer, i ddeall eu heffaith, ac i ymateb iddynt. Mae'r adroddiad hwn, felly, yn cynnig argymhellion ynghylch gwella'r ymateb i ddigwyddiad o safbwynt amgylcheddol, yr angen am well cydweithio gyda sefydliadau partner, a'r angen am wella'r dulliau o fonitro a chofnodi newidiadau amgylcheddol. Nodwyd hefyd yr angen i asesu safleoedd o safbwynt eu breguster a'u gwytnwch. Bydd angen adolygu cynlluniau rheoli safleoedd dynodedig er mwyn penderfynu a yw effeithiau stormydd yn achosi newid sylweddol yn y nodweddion cadwraethol, neu'n gwneud hynny i'r fath raddau fel nad oes modd eu hadfer. Nodwyd eisoes rai ymyriadau adferol, neu ddulliau o atgyweirio, ond efallai y bydd angen rhagor ohonynt ar lefel safle, neu er mwyn cynnal y nodweddion o ddiddordeb mewn cyd-destun cenedlaethol neu ryngwladol. Rydym yn cydnabod bod y broses o gynllunio'r draethlin yn rhoi cyfle allweddol i ni gynllunio sut i weithredu yn y dyfodol, ac adnabod cyfleoedd i wneud arfordir Cymru'n fwy gwydn i achosion o dywydd gwael neu eithafol y disgwylir iddynt gynyddu yn y dyfodol o ran maint ac amlder.

Mae'r asesiad hwn yn nodi'r chwe maes allweddol isod fel meysydd y bydd angen rhagor o waith arnynt, gyda 15 o argymhellion unigol. Ni chyfyngwyd yr argymhellion gan argaeledd adnoddau, ond cydnabyddwn y bydd y rhain yn creu cryn sialens wrth fynd i'r afael â'r gwaith. Oherwydd hynny, bydd angen trafod yr argymhellion yn drwyadl, yn fewnol a chyda'n partneriaid, i sefydlu cynllun gweithredu realistig.

Y meysydd allweddol yw:

- Gwell gwybodaeth;
- Buddsoddiad parhaus;
- Cydweithio a gweithio mewn partneriaeth;
- Sgiliau a chynhwysedd;
- Gwell gwytnwch; a
- Gwell cynllunio ar gyfer addasu i newid yn yr hinsawdd.

2. Executive Summary

In December 2013 and January 2014 a series of Atlantic low pressure systems generated significant storm surges and relatively powerful waves, which in combination with high tides caused considerable disruption along the Welsh coast. Flood and coastal defence structures were damaged and severely tested, and in some locations defences were breached causing damage to property. At the same time as assisting the affected communities, we embarked on an environmental audit of the impact of the storms on wildlife and our coastal conservation sites. There was further storm activity in early February 2014 which may have caused further environmental change. However, initial records were collated to feed into the Phase 1 Coastal Review (Natural Resources Wales 2014a) at the end of January 2014. The February event has therefore not been explicitly covered here.

This report serves as a record of the effects of these severe weather events, the degree of associated environmental change in terms of the physical environment and the biota, the lessons learned and the implications for future environmental management and conservation in Wales. This audit was carried out on the basis of reports received following the storm events, and, whilst over 80 records were received, it cannot be considered as exhaustive. Time was not available to carry out a comprehensive literature review of the ecological impacts of storms.

The report also fulfils recommendation 36 in the Wales Coastal Flooding Review Phase 2 Report (Natural Resources Wales 2014b) – to complete the ongoing update to the Phase 1 'rapid' assessment of environmental changes experienced during the December 2013 and January 2014 storms.

Many of the reports of environmental change received from staff and collaborators were at sites designated for nature and/or geological conservation interests. Unlike England, Wales was fortunate not to lose any of its large scale, static geological landforms but many of the softer Quaternary exposure sites were significantly eroded. There were positive benefits in terms of increased visibility of geological features, records of new exposures and increased natural process activity. Public interest stories were generated around palaeo-environmental and archaeological discoveries. Our ongoing challenges are around recording and monitoring the geological features and building on the interest generated.

The true extent of the impact on our coastal habitats and species is still becoming apparent and in some cases will not be fully understood for several years. However significant and highly variable impacts were recorded across a range of habitats and species, to the extent that ecosystem structure and functioning will have changed. For example, within a short period in the intertidal zone, algae, barnacles and molluscs were scoured from substrata or damaged and biogenic reefs were eroded. The nature and shape of the coastline was markedly altered in several locations. Large volumes of beach sand were lost, exposing rock substrata, coarser material was driven inshore, and natural features, such as shingle ridges, were reshaped. Whilst coastal grazing marsh was not seriously inundated and only minor impacts were reported for saltmarsh and mudflats, frontal sand dunes and soft cliff were severely affected due to erosion, slumping and breaching.

On dune systems, the widespread loss of beach sand, strandlines, embryonic fore dunes and frontal dunes is thought to have had a major, although probably temporary, impact upon their associated invertebrate fauna. A risk assessment for key invertebrate species and assemblages concluded that species associated with soft cliff are vulnerable to at least localised extinctions. Species associated with driftwood, the strandline and beach flora are likely to have suffered the greatest impact. Further survey and monitoring over the summer 2014 will be needed to determine the outcome for invertebrates. In general, the impacts on habitats and species have demonstrated that our natural wildlife resources are vulnerable to the impacts of extreme weather events, which can have cumulative and long-term effects on population status and site condition.

The seabird wreck was the most dramatic illustration of the impact on wildlife, with over 30,000 birds estimated to have died on the Western European seaboard, including many birds from Welsh colonies. This event was exceptional in a Welsh context, as reflected in the results of the RSPB Welsh Beached Birds Survey (included in Annex 1), and it may be reflected in future seabird numbers for many years. Although vulnerable, there was no large scale evidence of fish or marine mammal mortality but individual Welsh born seal pups may have been displaced and suffered deterioration in condition.

There is already a consensus that marine litter has economic, environmental and aesthetic impacts in the UK. The winter storms raised awareness of this issue with large volumes of material being deposited on Welsh beaches. This generated considerable public interest and effort to clean the beaches after the events. Further consideration needs to be given to the dual strategic options of control at source and removal of material once accumulated, and the resourcing of these efforts.

From an environmental perspective we have learned a number of lessons about how ready we were to prepare for, understand the impact of, and respond to, major storm events. This report therefore makes recommendations about improving incident response from an environmental perspective, the need for improved collaboration with partner organisations and the need to improve the monitoring and recording of environmental change. A case for site vulnerability and resilience assessments was also identified. Designated site management plans will need to be reviewed to determine whether storm impacts significantly, or irreversibly, alter the conservation features. Some remedial interventions or restoration action have already been identified but more may be needed at a site level or to maintain the interest features in a national or international context. We recognise that the shoreline management planning process provides a key opportunity to plan future action and identify opportunities to make the Welsh coastline more resilient to severe or extreme weather events that are expected to increase in both magnitude and frequency in the future.

This assessment has identified the following six key areas for further work, with 15 individual recommendations. The recommendations have not been restricted by availability of resources, which we recognise will be a significant challenge to delivery. The recommendations will therefore require debate and discussion both internally and with our partners, to establish a realistic delivery plan.

The key areas are:

Improved information;
Sustained investment;

Collaboration & partnership working;
Skills & capacity;
Improved resilience; and
Improved planning for climate change adaptation.

3. Introduction

3.1 Background

If you imagine that you are flying along the coastline of Wales, you will see that the land margin can be divided into two distinct types – man made structures (e.g. sea defences, harbours, marinas and promenades) and natural habitat. It has been estimated that in Wales 28% of the coast has some form of artificial structure while sand dunes, saltmarsh and sea cliffs are the most extensive coastal margin habitats (Russell et al. 2011). Both types of coastline are equally important in terms of the protective services they deliver, but Wales' natural resources also deliver a number of additional benefits.

Welsh coastal habitats provide a wide range of ecosystem services (Russell *et al*. 2011). They include climate, hazard, soil and water quality regulation; the cultural services associated with seascapes, historical sites and biodiversity; and the provision of food. Jones *et al*. (2011) considered coastal defence to be the most important service delivered by our coastal margins, with all habitats contributing either directly, by dissipating or attenuating wave energy, or indirectly through regulating sediment movement.

Approximately 60% (1.9 million) of the population live on, or near to, the coast, and 77% of the coastline is designated for its environmental importance. The coastal and marine environment supports an estimated 93,000 jobs, with visits to the coast accounting for 40% of overnight stays in Wales (Visit Wales, the Tourism and Marketing Division of the Welsh Assembly Government 2008 cited in Natural Resources Wales 2014a,b). The coastal environment of Wales is a major attraction to visitors who are drawn by the wild and dramatic quality of the landscape, wildlife and sea, and its recreational opportunities, including the Wales Coast Path. In addition to the Pembrokeshire Coast National Park, the Snowdonia National Park also extends down to the north Wales and Cardigan Bay coast. The Anglesey, Pen Llŷn and Gower Areas of Outstanding Natural Beauty (AONB), 3 of our 5 AONBs, are predominantly coastal. Our highly valued coastline is very economically important for Wales and is vital to the tourism industry (Welsh Assembly Government 2008).

The coincidence between the occurrence of a series of severe winter storms in December 2013 and January 2014, and the creation of Natural Resources Wales provided us with the unique opportunity to carry out a holistic and integrated assessment of our coastline in terms of its environmental condition and protective capacity. This report is intended to complement and stand alongside the Coastal Review (Phase 1 & Phase 2) reports which we have already presented to the Minister for Natural Resources and Food (Natural Resources Wales 2014a; Natural Resources Wales 2014b), and delivers recommendation 36 of the Phase 2 Coastal Review (Natural Resources Wales 2014b). In addition, we recognise that these severe weather events could provide a valuable insight into the likely consequences of climate change in terms of the vulnerability and resilience of the coastal environment.

3.2 Report Objectives

The main objectives of this report are:

- To briefly describe the severity of the storm events of December 2013 and January 2014 and assess them in the context of both historical events and climate change;
- To produce a description of the environmental change that was initially witnessed around the coast of Wales as a consequence of the storms;
- To assess the implications of the change from a Welsh biodiversity, geodiversity and protected sites perspective;
- To indicate whether any remediation is appropriate or possible;
- To highlight the lessons learned and follow on action required from the weather events, with a view to future improvement and integration, for example in recording and reporting change and determining remedial action; and
- To make recommendations for ongoing or future research and monitoring needs, in order to ensure our designated sites and their biological and geological diversity are sustainably maintained, enhanced and used now and in the future.

Inevitably, there is still a lot that we do not know at this stage of the year because the growing season is still developing, and it is too early in the monitoring season to have collected the data. In some cases impacts may not be discernible for several years. We therefore need to aware of the possibility of further impacts becoming apparent, as well as recovery of habitats and species, as we did following the Sea Empress Disaster in 1996.

3.3 Storm Severity in December 2013 and Early January 2014

The Natural Resources Wales Coastal Review Phase 2 Report (Natural Resources Wales 2014b) included the following overview of the December 2013 and January 2014 storms.

On 5th December 2013 a deep low pressure system off the west coast of Scotland brought severe gale force winds to North Wales, specifically the Liverpool Bay area. These created a significant storm surge and large onshore waves that coincided with high tide and caused considerable disruption along the North Wales coastline.

During January 2014 a succession of low pressure systems, tracking from the Atlantic, generated significant storm surges and very large offshore waves which, combined with high astronomic tides, caused considerable disruption to the south and west coasts of Wales. Although the highest tide was on 3rd January, this event continued until the 6th January, as successive low pressure systems continued to bring gale force winds and very large waves, a considerable number of which were high energy swell waves.

The Phase 1 Report (Natural Resources Wales 2014a) also identified that the peak sea level experienced in December 2013 was the highest recorded in Liverpool Bay during the 21 years since the tidal gauge was established. The level exceeded the previous highest value by a considerable amount (300 mm).

In January 2014 the peak recorded level at:

Milford Haven was 4.51 m AOD. This was the highest level since at least February 1997 and exceeded the March 2008 tide (another notable event) by 0.14m.

Newport was 8.03 m AOD. This was the highest level since at least February 1997 and exceeded the February 1997 level by 200mm.

Barmouth was 3.92 m AOD. This is marginally higher than the February 1997 level.

Liverpool was 5.86 m AOD. Some 0.36 m lower than the peak level on 5th December 2013.

Note: Metres Above Ordnance Datum, (mAOD) is based on the mean sea level at Newlyn in Cornwall and is used as the reference point to calculate height above sea level in the UK.

Both of these storm incidents affected not only Wales, but also other parts of the UK, most notably the east coast of England in December and the south and south west coast of England in January.

There was further storm activity in early February 2014 which may have caused further environmental change. However, initial records were collated to feed into the Phase 1 Coastal Review (Natural Resources Wales 2014a) at the end of January 2014. The February event has therefore not been explicitly covered here.

3.4 Future Coastal Flood and Coastal Erosion Risks

We know that projections for the future of our coastal areas are of increasing risk, as a consequence of climate change and, in particular, sea level rise. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report estimates that global temperatures have risen 0.85°C from 1880-2012 (IPCC 2013). There has been an associated rise in global sea level which is now increasing at approximately 3.2 mm per year (Church *et al*. 2013).

The IPCC state that it is very likely that the 21st Century rate of sea level rise will exceed the 1971-2000 rate, for all modelled emissions scenarios. A central estimate of a 0.47 m increase by 2081-2100 is projected, relative to the 1986-2005 baseline. An increase of 0.5m is estimated to result in a 10-fold to 100-fold increase in the frequency of sea level extremes (relative to present day) in northern Europe by the end of the century (Church *et al*. 2013). This would mean a coastal flooding event that has a return period of 100 years at present will potentially occur on average between every year and every ten years by 2100.

Storminess and precipitation extremes are also important factors that will be exacerbated by climate change and will contribute to the increased flood and erosion risk. Already the Met Office has recorded an increase in days of heavy rain in the UK, such that a rain event with an average return period of 125 days in the 1970s now has a return period of 85 days (Met Office & Centre for Ecology and Hydrology (CEH) 2014). In terms of storminess the Met Office suggests that while there have been no significant changes in storm frequency in mid latitudes in the north Atlantic, the intensity of individual storms has increased (Met Office & CEH 2014). Future projections of storminess are still highly uncertain due in part to resolution limitations of climate models. However, the premise, founded on basic atmospheric physics, that a warmer world will lead to more intense daily and hourly heavy rainfall events, remains valid (Met Office 2014).

While the question of attribution of a weather event or a series of weather events to anthropogenic climate change will always be couched in terms of probability, it is possible to discern significant trends in climate data that are consistent with recent extreme events in Wales and the UK. Viewing these events collectively at a global scale, the IPCC suggest that it is likely that there has been an anthropogenic influence on increasing extreme coastal high water due to an increase in mean sea level (IPCC 2012).

We have significant evidence of the impact of historical storm events in Wales, with numerous examples cited by Davies & Jones (2014). These include reports of wrecks of the Great storm of 1859, which scattered wrecks along the whole of the Welsh coast, and a quote from Giraldus Cambrensis on the winter of 1171-2:

> *"The wind blew with such unprecedented violence that the shores of South Wales were completely denuded of sand….the seashore took on the appearance of a forest grove, cut down at the time of the flood….The tempest raged so fiercely that conger eels and many other fish were driven up on the high rocks…"*

Looking back over the longer term, the last 2000 years or so, we know from work by Bristow (2009, 2011) at Morfa Dinlle in north Wales that there is evidence of storm events. Bristow identified the presence of around 20 low-angle erosion surfaces, tentatively interpreted to have been formed during storm events. From dating information and the number of erosion surfaces, the evidence suggests that the storm erosion events which formed these may have occurred on a 100 year time scale.

It is important to recognise that the fundamental physics of global warming provides certainty that continuing (and historical) emissions will lead to further warming of both the atmosphere and consequently the oceans, making further significant sea level rise due to thermal expansion inevitable. Moreover in south and mid-Wales isostatic land subsidence will also inevitably exacerbate sea level rise.

The climate change risk assessment for Wales (UK 2012 Climate Change Risk Assessment) identified a number of most potentially significant threats for Wales from climate change including:

- Increases in flooding both on the coast and inland, affecting people, property and infrastructure;
- Changes in coastal evolution including erosion and coastal squeeze, affecting beaches, intertidal areas and other coastal features; and
- Changes in species including a decline in native species, changes in migration patterns and increases in invasive species.

In addition, under a natural environment theme, the assessment also included the following main potential threats:

- Changes in climate space and species migration patterns, which could result in significant changes in biodiversity;
- Changes in coastal and estuarine habitats and species, including a reduction in intertidal area; and
- Changes in the marine environment, including an increase in disease hosts and pathogens, harmful algal blooms and invasive species. The effects of ocean acidification include adverse impacts on shellfish.

Taken collectively and with a view to enhancing our resilience for the future, the question of attributing the events of last winter to climate change is really a technical aside. Given the considerable confidence around the projected increase in frequency of coastal flooding due to climate change during this century, the experience of winter 2013/2014 should serve as an invaluable insight for policy makers, planners and practitioners into what in the future may become commonplace for the coastal environment of Wales. Davies and Jones (2014) concluded that weather extremes have social, economic and emotional impacts on Welsh communities. This report seeks to make links across the socio-economic and environmental gradient.

3.5 Designated Sites

Many of the changes and impacts of the storms described in this report have affected sites which are subject to statutory conservation designations, including Sites of Special Scientific Interest (SSSIs), Natura 2000 sites (Special Areas of Conservation (SACs) & Special Protection Areas (SPAs) and National Nature Reserves (NNRs). A significant proportion of the Welsh coastline is included under one or more of these designations. For example more than 77% of the total length of the intertidal area in Wales lies within SSSIs (Countryside Council for Wales, 2006), with much of this percentage accounted for by large estuary SSSIs, such as the Dee, Severn and Carmarthen Bay estuaries (Figure 1). There are also over 800km of Heritage Coast, three coastal Areas of Outstanding Natural Beauty (AONBs) and two National Parks.

The focus for geological conservation is the Geological Conservation Review (GCR), a GB-wide review of geological and geomorphological sites (Ellis 2011). There are 480 GCR sites in Wales, 122 of which have part of the protected feature on the coast. Thirteen GCR sites have been selected purely for the coastal geomorphological feature.

The summary description of change in section 4, and more detailed descriptions in Annex 1 illustrate some of the sites and features which have been affected.

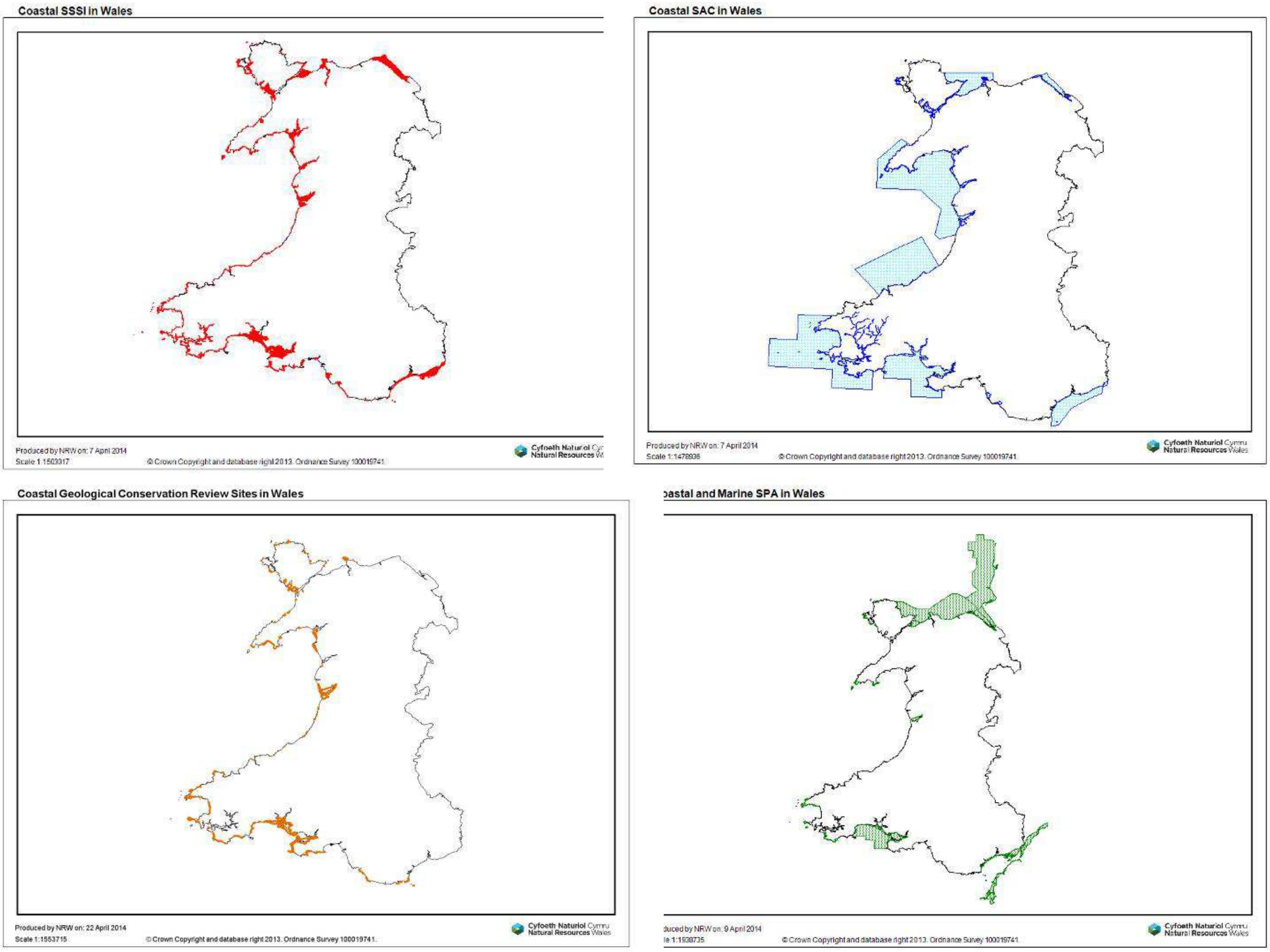


Figure 1. Maps showing Wales' Coastal designated sites: Sites of Special Scientific Interest (red), Special Areas of Conservation (blue), Geological Conservation Review sites (orange), Special Protection Areas (green).

3.6 The Environmental Audit

We carried out a rapid collation of records for environmental change on the coast during January 2014, which included data for change arising from both the December and January storms. Data were submitted from staff and a number of our partners, including the National Trust, Glamorgan Heritage Coast, Kenfig National Nature Reserve, and the North Wales Wildlife Trust, with over 80 records collated. Recorders were asked to submit records of the location of the reported change, including grid reference and Local Authority area; an indication of the habitat(s) or feature type(s) affected (e.g. beach, dune, saltmarsh mudflat, hard or soft cliff, shingle etc.); whether the change noted is within a designated site (NNR, SSSI, SAC etc); and a brief description of the change, along with photographs if available. A collated record is included at Annex 2 to this report. Unfortunately, time was not available to carry out a comprehensive literature review of the ecological impacts of storms but some key references have been included.

The main headlines from this early collation exercise were reported in the Phase 1 Coastal Review report to the Minister (Natural Resources Wales 2014a), and also in Natur Cymru (Duigan *et al.* 2014).

Since then, other impacts have come to light, most notably the seabird wreck indicating potentially significant impacts on some of our Welsh seabird colonies. In addition, Natural Resources Wales specialists have been able to consider the initial records in more detail, and in some instances it has been possible to gather some further data and information. Figure 2 shows the locations where change has been recorded, demonstrating that the impacts of these storm events were widespread, with the possible exception of the Severn Estuary which did not appear to experience significant change on this occasion.

Annex 1 consists of detailed descriptions of the main examples, as far as we are aware, of environmental changes that have occurred. This includes accounts for the physical environment (geology, geomorphology and coastal process), followed by coastal habitats and species. We also refer to other environmental impacts that have occurred, such as the accumulation of litter, and we discuss landscape implications and impacts on access, in particular the Wales Coast Path. All records received to date are included, for completeness, in Annex 2. Within the limited time period available we have also tried to present the information in a Welsh context and make reference to relevant scientific literature and other information sources. A summary of change is provided below.

We acknowledge that the records we have are not exhaustive. This report includes recommendations as to how we can improve the collation of data for our sites in the light of future events. Also, some changes or impacts may not yet be apparent. Furthermore we know that some changes will be temporary - part of a natural cycle of change in a dynamic coastal environment - and are likely to ‘repair’ naturally over various timescales. However, some changes, such as loss of soft cliff habitat or geological features, are permanent.

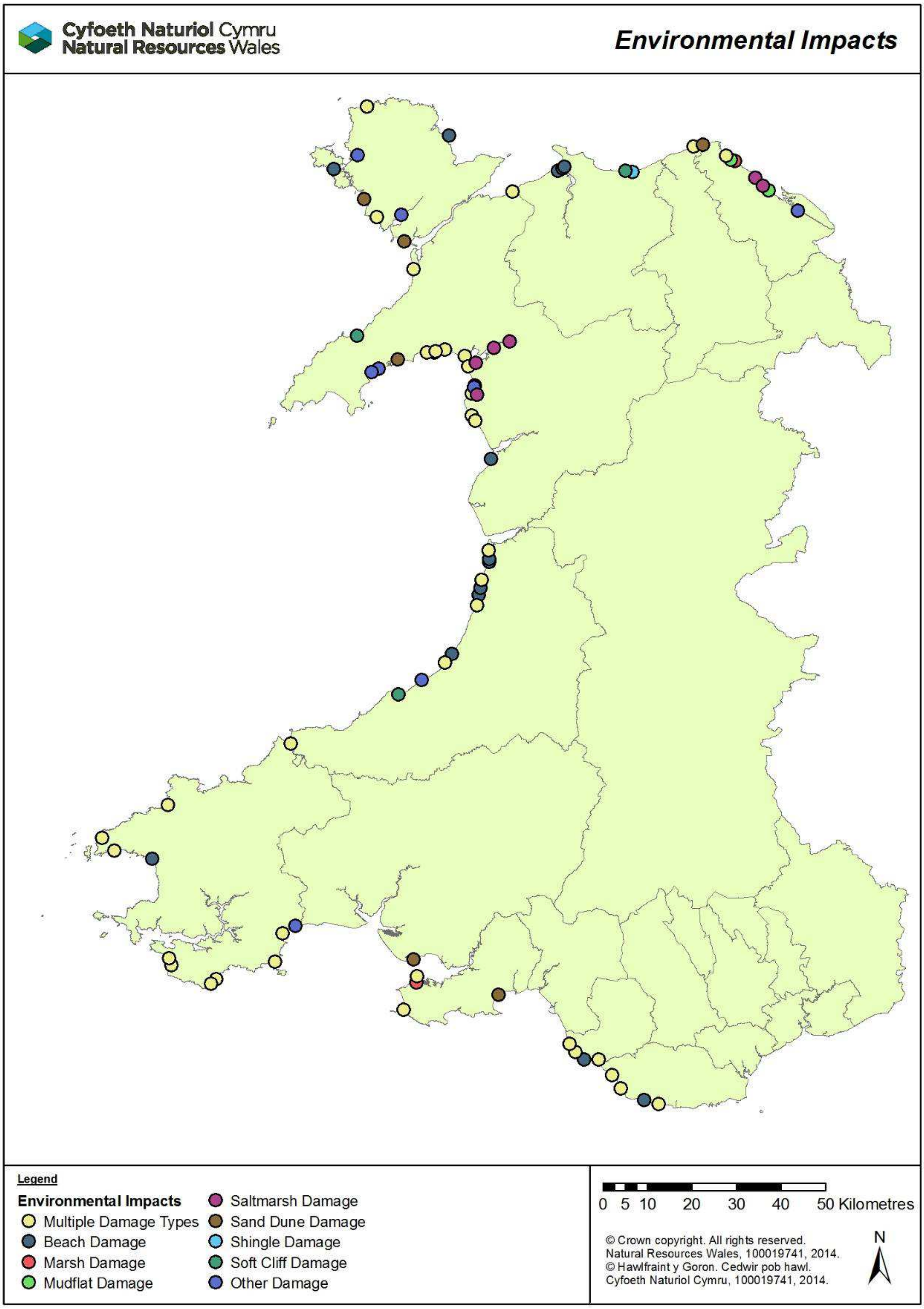


Figure 2. Locations of recorded environmental change as at 31st January 2014. All records shown here are listed in Annex 2 (section 8.2). Note that some sites described in Annex 1 (section 8.1) are not mapped as these records were submitted later.

4. Welsh Context and Assessments of Change

4.1 Geodiversity - Geology, geomorphology and coastal processes

Wales' geology is rich and diverse and is extremely important both scientifically and as a resource for people to use and enjoy. Geodiversity also plays a key role in shaping the landscape, underpinning biodiversity through influencing the distribution of habitats, and shapes the location of human settlement and infrastructure. Nowhere is this more evident than on the coast.

Nationally important geological and geomorphological sites are selected as part of the Geological Conservation Review (GCR) (Ellis et al. 1996, Ellis 2011). GCR sites are divided into three different types in a conservation context. 'Integrity' sites contain geomorphological features, such as static landforms that require holistic management. 'Finite' sites comprise features of limited extent which are often irreplaceable if destroyed or depleted and need to be protected as a whole. While 'exposure' sites reveal the features of often extensive subterranean geology, where the basic conservation principle is that erosion or removal will not damage the resource because freshly exposed material will be revealed.

In the context of the winter storms, and from monitoring data collected to date, Wales was fortunate not to lose any of its outstanding integrity sites and there was only minor loss of the resource in finite sites, such as the erosion of tufa at Cwm Nash, Vale of Glamorgan (Figure 3). However, they do remain vulnerable to damage in future extreme weather events. In contrast several well known large scale geological features were lost on the English Coast (e.g. Sea Arch Porthcothan, Cornwall; Pom Pom Rock Sea Stack, Portland, Dorset).

Many of the Quaternary exposure sites have seen significant erosion that has 'freshened' coastal cliff sections consequently improving visibility of the geological feature. The erosion and freshening up of sections has highlighted the need to monitor and record features exposed in coastal cliffs. In particular it is important to record exposed features before there is slumping or more erosion. The challenge for Natural Resources Wales is to continue the photo-monitoring of GCR sites and to also encourage academics to use this geological resource for their research.

Many of the Welsh coastal geomorphology sites have experienced increased activation of natural processes as a result of the storms. In particular, there has been very significant erosion of frontal dunes and movement of shingle and cobble ridges. Localised landslides have also occurred. While beach levels were eroded, there were new exposures of hard rock and Quaternary deposits.

Several press stories focused on the palaeo-environmental and archaeological history of these sites and new discoveries arising from storm erosion. For example, an Auroch's horn was found at Dinas Dinlle beach in Gwynedd; 800-year old bones, suspected to have belonged to a monk, or possibly a shipwreck victim, were found poking out of a cliff at Monknash. The renewed exposure of the prehistoric sunken forest at Borth was linked with the legends of the lost kingdom of Cantre'r Gwaelod and photographs of the area were included in newspapers around the world. A Bronze Age wooden walkway was found at Borth, while ancient peat cuttings were revealed near Tywyn. Wales already benefits from its acknowledged place in the history of the science of geology and archaeology, with large numbers of students and professionals visiting our famous sites. This professional network could be used as an awareness raising opportunity to generate further research and educational revenue in Wales, which would be compatible with Welsh Government's science ambitions.

From a geological ecosystem services perspective there are likely to have been trade-offs at several sites between the regulating service of coastal protection towards cultural services, such as landscape enhancement and educational opportunities. But equally, the eroded materials would act as a sediment supply for beaches and other geomorphological features and habitats.

Figure 3. Collapsed tufa at Cwm Nash, Vale of Glamorgan showing an example of a 'finite' geological deposit (Chris Byrne Natural Resources Wales, 9th Jan 2014) & 'freshened' Quaternary exposures at Dinas Dinlle already showing signs of slumping (Raymond Roberts, Natural Resources Wales, January 2014).

4.2 Habitats and species

As illustrated by the State of Nature report (2013), we have an incomplete picture of biodiversity trends in the UK, which in some cases are even more difficult to discern at a Wales level. It was concluded that we do not have sufficient information to make robust, quantitative assessment of the state of nature in Wales. In particular, no attempt was made to provide an overview of Welsh coastal or marine habitats in the report, whereas a scenario was more easily available for farmland, woodland, upland and lowland heathland. However, the severe weather events have highlighted some important implications for biodiversity conservation of coastal and marine habitats and species in Wales and our responsibility to report on biodiversity trends.

Within a short period of days and in some cases hours, there has been significant and highly variable local environmental change in intertidal biodiversity. The scale and degree of impact has altered site biodiversity and food web function. Algae have been scoured from their substratum, while shell-bearing molluscs have been physically damaged and biogenic reefs eroded. In these locations available rock substrata will have increased (Figure 4). According to Morris *et al.* (2010), marine species that are less well connected (i.e. present in isolated populations only) are likely to be more affected by storm events, as their ability to recover will be more limited if isolated populations within a coastal cell have been wiped out. We are not yet aware of any particular species that have been affected in this way as a result of the storms.

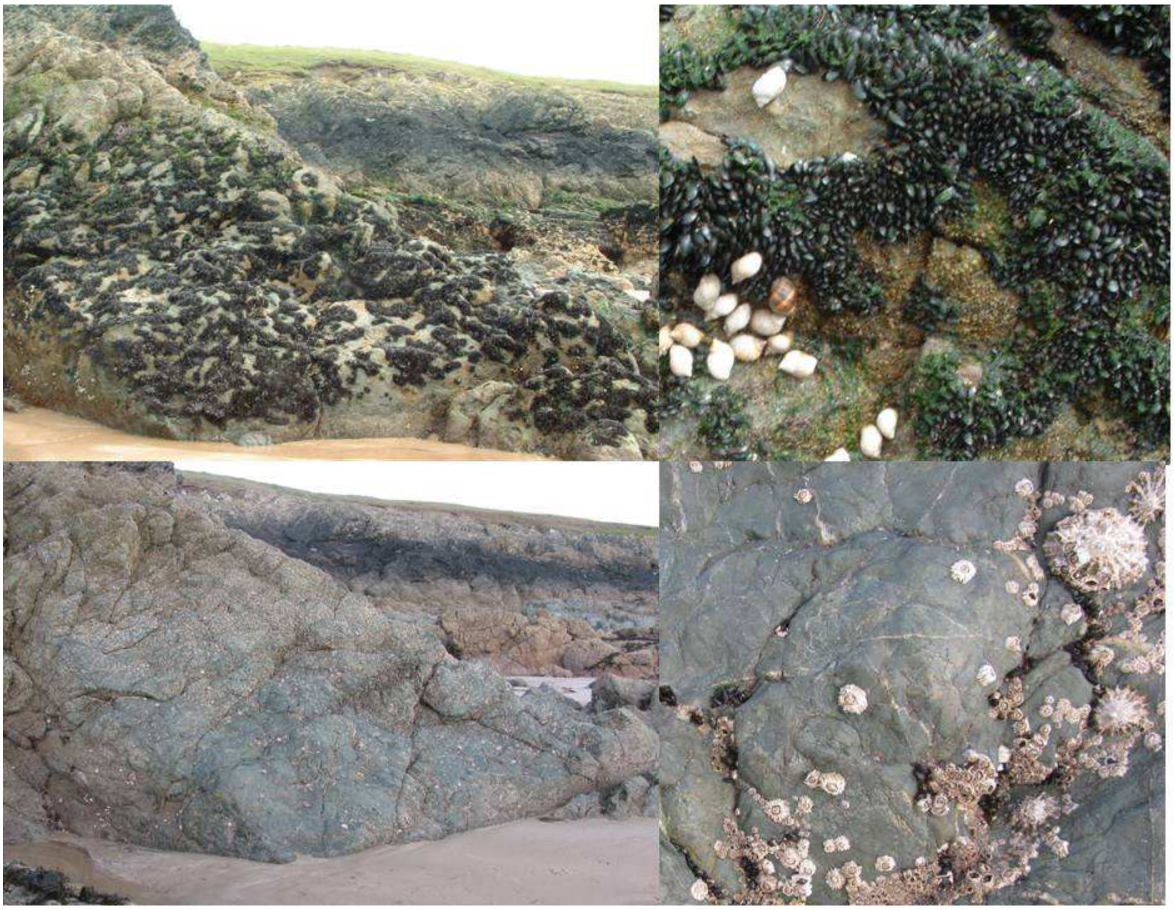


Figure 4. Rocky Shore at Aberffraw- before photos at top, after at the bottom, showing loss of mussels and dogwhelks and a reduction in barnacles (Photo provided by Ivor Rees).

Large volumes of beach sand have been lost from the intertidal zone, probably deposited offshore, with knock-on biological effects. Coarser material (cobbles and pebbles) has been both exposed due to the loss of sand and also driven inshore, with natural features (e.g. shingle ridges) being resculpted and realigned.

There is evidence of stranded subtidal biota but it is not possible to determine the degree of offshore change at this point in time. Diving, sonar surveys, dropdown video and sediment invertebrate surveys planned for the summer may reveal further evidence. However in the longer term Brodie *et al.* (2014) predict that the “combined impacts of seawater warming, ocean acidification, and increased storminess may replace structurally diverse seaweed canopies with associated calcified and noncalcified flora with simple habitats dominated by noncalcified, turf-forming seaweeds.”

There are reports of minor erosion of saltmarsh and mudflats, although this may be under-recorded in relation to these events. In addition, some grassland habitats, such as those at Cwm Ivy SSSI, were breached and inundated during the storms. The shoreline management policy here is no active intervention, meaning that it is very unlikely that work will be carried out to repair the sea wall, and the habitats will therefore gradually become more saline. Other grassland habitat types are vulnerable to both inundation and salt-spray, which may lead to shifts in the transition zones between maritime and terrestrial grassland, if this scale of event occurs more regularly in future.

Frontal sand dunes and soft cliff were severely affected due to erosion, causing slumping and breaching at a number of locations and exposing bedrocks and clay deposits at some sites (Figure 5). These changes may have had a significant impact on populations of rare or threatened invertebrates such as the Strandline Beetle *Eurynebria complanata* and the Large Mason Bee *Osmia xanthomelana* which are present in a restricted number of localities in Wales. Subsequent monitoring has shown that *O. xanthomelana* has survived the storm events at its two Welsh localities, but in much reduced numbers (see 8.1.3 In Annex 1).

Figure 5. Erosion of the dunes in action at Penally on 6th January 2014 (Sid Howells, Natural Resources Wales).

4.3 Marine fish, mammals and birds

Although there is no specific evidence of significant numbers of fish being killed or beached during the recent storms in Wales, there are numerous studies from other regions of the world to show marine fish populations are vulnerable to extreme weather events, with associated impacts on the fishing industry possible (Callaway *et al.* 2012, Cheung *et al.* 2012, Frost *et al.* 2012, Heath *et al.* 2012, IMCORE 2011, Munroe *et al.* 2013, Schaefer *et al.* 2006, Tilmant *et al.* 1994). Shellfish seem particularly vulnerable to displacement and beaching, while estuaries and their fish species could be subject to sudden environmental changes resulting in mortalities and changes in distribution. However the impacts of a particular storm on fish are likely to be very variable and difficult to predict.

Storms can also affect marine mammals (Evans *et al.* 2005), especially Grey Seals (*Halichoerus grypus*) during the pupping season (September to December), when coastal pupping sites are in use. In Wales, approximately 50% of the pupping sites are coastal caves (Stringell *et al.* 2013), which are typically inundated during storm surges.

There was no evidence, however, of increased storm related Grey Seal mortality in Welsh and UK waters based on stranding records (Rod Penrose 2014 in *litt.*; Cetacean Strandings Investigation Programme (CSIP) 2014 in *litt.*). However, further south, more juvenile Grey Seals than usual (30 versus ca. 8) were washed up in poor condition on the north Portugal and NW Spain coast during the winter storms. The juvenile seals found here are thought to originate from Ireland and SW Britain colonies (Gemma Hernandez-Milian, 2014 *in litt.*),and likely from Pembrokeshire – the largest colony in the region (Baines *et al.* 1995). There has also been no clear indication of increased cetacean (dolphins, porpoises and whales) strandings in Wales or the UK as a result of the recent winter storms (CSIP *pers. comm.*), but this, of course, might be due to reduced surveillance effort in poor weather conditions.

The most dramatic impact of the storms on Welsh wildlife was exemplified by the seabird wreck. It took several weeks for the scale of the event to emerge as the birds starved and lost condition offshore. This wreck is likely to be recorded as one of the most severe incidents of storm induced seabird mortalities which may be reflected in seabird numbers for several years. Auks (Razorbills, Guillemots, Puffins) were the most impacted. It is estimated that over 30,000 birds died on the Western European seaboard, including Welsh birds. More monitoring is required to determine the impact on our Pembrokeshire bird populations, especially on Skomer Island. Although a seabird wreck can be considered a one-off natural event, a scenario of increasing incidents associated with climate change has the capacity to disrupt with increasing regularity and ultimately diminish our internationally important seabird colonies which are also a valuable tourist attraction.

4.4 Litter and Access

Significant volumes of litter were deposited on the shore and further inland during the storm events ranging from small polystyrene beads and plastic fragments, to large plastic boxes and fishing nets (Figure 6). Litter can also be trapped and buried within dunes, and therefore may have been released through dune erosion. It is accepted that litter can cause harm to marine wildlife through entanglement and ingestion, and through movement across and smothering of the seabed. Fishing related debris was noted as a significant component of the 'litter' washed ashore. The fishing industry lost a significant amount of fishing gear at sea during the storms. As a result, Welsh Government has made compensation available to enable gear to be replaced. There is therefore a potential opportunity to assess the scale of this issue through assessing the compensation claims submitted.

Charting Progress 2 (UKMMAS 2010) reported that the coast of Wales has the highest volumes of marine litter in the UK, and that this level of marine litter is having a negative impact on achieving the vision of clean and safe seas. It also indicated the need to further monitor and assess the level of harm caused by litter in the marine environment. The environmental impact of marine litter will become more evident in the near future as it features as a descriptor which will be used for assessment of Good Environmental Status under the EU Marine Strategy Framework Directive. Severe weather events, such as those recently experienced and climate change, are expected to drive more litter onto beaches. While ongoing research is starting to highlight the potential impact of microplastic pollution in the marine environment (Ivar do Sul & Costa 2013).

Figure 6. Strand of litter at Afon Dwyfor (Paul Brazier, Natural Resources Wales, 12th Jan 2014)

Media reports following the Welsh storms suggest that significant efforts have been made by some Local Authorities and communities to remove beach litter from their local environment, with the support of the Marine Conservation Society and Keep Wales Tidy. However, we recognise that more could be done in future to support a co-ordinated effort, including guidance on disposal of litter and the natural materials that should not be removed. We also recognise that further consideration could be given to strategies to remove litter at source (e.g. a scheme to promote the recovery and disposal of old fishing gear) or as part of fishing efforts. Additional investment in diver-lead recovery of marine litter, may also be an effective means of combating this problem.

As reported in Natural Resources Wales' Coastal Review Phase 1 (Natural Resources Wales 2014a), there was significant damage to coastal defences, roads, street furniture, the rail network and hundreds of properties were flooded. There was also significant impact upon the Wales Coast Path, with damage recorded at over 70 locations along the 870 mile route and a repair bill of approximately £340,000. Significant effort has already gone into repairing and re-opening the path, but the impacts serve as a reminder of the challenges of maintaining such a route in the dynamic coastal environment. At the same time, it is this dynamic, dramatic and sometimes wild environment which makes the coast path such an important asset and attraction.

5. Discussion

The storm events of December 2013 and January 2014 have provided food for thought, especially given the multi-faceted role of Natural Resources Wales. From the perspective of recording and responding to environmental change and potential impacts, we could have been better prepared. We know that this view is mirrored in England, where better preparedness may have resulted in less livestock and infrastructure being left vulnerable to the storm. This section of our report discusses what has happened to date and what further steps may be required.

5.1 Future incident response

We have learned from these events that a more robust approach to incident management (preparedness, response and recovery) for environmental assets is required. For example, this would improve our ability to protect against the loss of, or injury to livestock that graze some of our coastal protected sites, and the evacuation of other assets. We should therefore review our existing incident arrangements for the estate that we own and manage to ensure that appropriate arrangements are in place with respect to flooding and coastal erosion.

We should also work in partnership with other organisations, such as the Local Authorities, National Trust and Wildlife Trusts, to share our approach and assist them with incident arrangements for flood and coastal erosion risk for the environmental assets that they manage. This partnership approach also needs to extend beyond Wales, especially since we have cross-border coastal interests around Liverpool Bay and the Severn Estuary. We have already made contact with Natural England and the Environment Agency and established an informal working group to discuss and compare the responses to the winter storms and future co-ordination of effort.

Natural England (2014) has identified over 48 SSSIs which were affected by the winter storms, with impacts including loss of infrastructure such as bird hides and signage, but also loss of livestock, as well as impacts to site features. A joint statement between the Environment Agency and Natural England (2014) sets out the approach to repair and restore sites, taking account of site requirements and shoreline management plan policies. It has been recognised that more could have been done to improve the systems of warning and planning for an event such as this and steps have already been taken to implement improvements (Tim Collins, Natural England, pers. comm.).

In the first instance we need to take account of the vulnerability and resilience of our coastal sites in the light of future climate change. Work to understand vulnerability better is already under way e.g. the Climate Vulnerability Assessment of Designated Sites in Wales (Wilson *et al.* 2013), the Marine Habitat Vulnerability Assessment of the Welsh Coast (Jolley *et al.* 2012), Conserving Geodiversity Sites in a Changing Climate: Management Challenges and Responses (Prosser *et al.* 2010), and also an in-house assessment of vulnerability of geological sites by Natural Resources Wales specialists, which identified 21 of the 122 coastal GCR sites as highly vulnerable.

We already anticipate that some sites and habitats will be able to adapt to change and should be allowed to do so, while other sites will be deemed important enough in a national or international context to require ongoing protection.

We have learned several lessons as part of our approach to gathering the data for this assessment. We are in the process of producing a definitive map and register of potentially vulnerable coastal sites with associated information on features and staff to contact within and outside Natural Resources Wales. Such a register would need long term maintenance and management. In relation to storm events, we have an ambition to develop a standard and semi-automated system for recording and reporting environmental change. This should be more comprehensive and not just reliant on *ad-hoc* staff visits. For example, we noted most respondents automatically used photographs to report and record the incidents of change and beached biota. This suggests that there may be an opportunity to develop a citizen science project in this area, with the public using mobile devices to submit records. We also picked up some of our information by monitoring Twitter and other social media which is being increasingly used to mine information on environmental incidents.

We know that measurement of physical change arising from such events is critical in underpinning the assessment of ecological implications. Ideally, good baseline (pre-storm) data are therefore required as well as post storm monitoring. Following these winter storms, we had limited physical data to inform analysis. It is hoped that the Wales Coastal Monitoring Centre will, in future, service this need. Also, monitoring of SSSIs is limited to our 5-yearly geological SSSI monitoring programme. Therefore, again, assessment of change and impact was restricted because of a lack of pre-storm information for many sites and features.

5.2 Implications for designated sites

Many of the impacts of the storms described in this report have affected sites which are subject to statutory conservation designations, including Sites of Special Scientific Interest (SSSIs), Natura 2000 sites and National Nature Reserves. A significant proportion of the Welsh coastline is included under one or more of these designations. For example more than 77% of the total length of the intertidal area in Wales lies within SSSIs, with much of this percentage accounted for by large estuary SSSIs such as the Dee, Severn and Carmarthen Bay estuaries.

Although the site designations all operate under different legislation and have differing objectives, the main common purpose of these designations is to contribute towards the conservation of biodiversity and geodiversity. They can also have other objectives such as to promote sustainable resource use and to provide opportunities for recreation, scientific study and education.

The conservation of habitats, species and geological features, including through the designation and management of protected areas, usually accommodates, and in many cases, encourages processes of natural change. Therefore the objectives for many of these protected sites, as set out for example in site management plans, specifically acknowledge the natural dynamism of many habitats and the role that natural processes play in maintaining biodiversity and geodiversity and the ecosystem services that the sites provide. The impacts of storm events such as those recently experienced around Wales need to be understood in this context, as well as in the wider context of shoreline management planning. In particular, case by case judgements are required as to whether the changes that have occurred to a given protected site should be considered as an adverse impact and, if so whether any steps should, or can, be taken to restore the site, or whether the changes should be considered as an inevitable and desirable part of natural environmental change. Even where damage has occurred, habitats can often be expected to recover naturally and the time taken for this can vary from weeks or months, to decades.

Some coastal habitats, for example sand dune systems are inherently dynamic and in a more or less continual state of transition, and the characteristic fauna and flora of sand dunes is largely a result of that variability. Periods of significant accretion can be interspersed with dramatic erosion events such as those seen in the recent storms. Likewise, the conservation value of many coastal geological sites is dependent on the continuation of the physical processes of erosion that removes debris at the foot of the cliffs and maintains clean and accessible exposures. Sites such as Dinas Dinlle and

Morannedd on the Pen Llŷn coast are particularly reliant on wave action to remove accumulated debris. Geodiversity sites notified for their coastal geomorphology by their very nature rely on active processes and minimum human intervention where possible.

In contrast, for some habitats and the species they support, their range, extent and quality has already been significantly reduced by the impacts of development, land use, habitat fragmentation or other anthropogenic factors. Designated sites can represent a significant proportion of the remaining occurrence. Populations of species that are already much reduced in size or range, and habitats which are already fragmented or hemmed in by coastal infrastructure or other land uses, are often less resilient to the effects of sudden environmental change. In these cases so-called 'natural' processes, including extreme weather events, are not necessarily benign in nature conservation terms. As noted earlier in this report, the natural range of a number of invertebrate species, such as the Strandline Beetle and Large Mason Bee, is restricted to a small number of localities around Wales. Extreme weather events at these locations can lead to loss of the species' particular habitat requirements, and can have significant long term effects on the populations and their ability to recover.

Some coastal habitat types are restricted in extent and/or poorly connected. Severe or extreme weather events can lead to long-term or possibly permanent loss of these features. For example Traeth Pensarn SSSI in Conwy is designated for the value of the plant communities on the shingle and boulders above high water mark, a habitat type now considered fragmented and vulnerable around the coast. Coastal defences and other developments that increase coastal stability upstream of the site have resulted in reduced flow of shingle material onto the site. These depleted levels of shingle and sand are at greater risk of being mobilised or lost from the system in severe weather events. In addition, remedial works to defence structures and built coastal assets can add further pressure to the natural environment and delay recovery. For example, repeated engineering works to re-profile shingle ridges as a 'natural' defence feature can delay or impede the recovery of associated biota.

Where damage to protected sites or vulnerable species populations has occurred, we may need, where practical, to look for opportunities to restore some sites in order to continue to meet national and international commitments to biodiversity conservation. Where site restoration or recovery is not possible, we need to look more strategically at the network of protected sites, and identify opportunities to bring new areas into appropriate conservation management, so as to increase the resilience of habitats and species to future environmental change. A decision framework that identifies and prioritises actions to increase the adaptive capacity of species has been published (Oliver *et al.* 2012). This framework classifies species according to their current distribution and projected future climate space, as a basis for selecting appropriate decision trees. These decisions rely primarily on expert opinion, with additional information from quantitative models, where data are available. The framework considers *in-situ* management, followed by interventions at the landscape scale and finally translocation or *ex-situ* conservation.

5.3 Monitoring and Recording

As described above, the data collated in this report were the result of ad-hoc site visits by our staff and our partners. There was limited pre-storm information for many of our sites and, particularly in the case of biological SSSIs, there is no monitoring programme in place. Therefore, without significant additional effort it will be difficult to monitor how some of the habitats and species respond to and recover from the storm events. After the Sea Empress Oil Spill in 1996 a substantial monitoring programme was undertaken to understand the full impacts of the disaster, and to see how habitats and species recovered over time. From this work we developed an appreciation of the ability of the marine and coastal environment to recover, and this improved understanding has helped to refine our response to oil spill incidents. To date we have very little post storm ecological recovery data, and therefore the aftermath of the recent storms presents an opportunity to develop a targeted monitoring programme with the aim of understanding vulnerability and resilience better, and informing future management.

Our geologists follow a five-yearly site condition and photo-monitoring programme of geological SSSIs. Many geological sites cover large areas with access difficulties. For example many of the sites along the Pembrokeshire coast require monitoring from the sea or air. Other sites such as cave or mineralogical sites may require specialist contractors to undertake the work. Although the geological photo-monitoring programme does record changes in site condition and allow a brief assessment of the new features, thorough recording and analysis of new geological sections relies on academics and researchers. Again the recent storm activity presents an opportunity to work with the academic community to promote the relevant scientific work.

5.4 Sustainable coastal management- Opportunities arising from the storms?

The management of the Welsh coast is complicated. It involves a wide range of individuals and organisations, and numerous interests: amenity, access, tourism, all of which support the economy; housing and transport next to the coast and require protection from erosion and flooding; a stunning landscape, wealth of wildlife and geological interest of national and international importance.

The challenges of managing the coast are set to become more complicated because of the pressures of climate change - sea-level rise, warming, acidification and the potential for increased storminess. Welsh Government's National Strategy for Flood and Coastal Erosion Risk Management in Wales (Welsh Government, 2011) recognises the need to consider '*sustainable and innovative approaches to ensure that in future we move beyond defence and drainage alone, and find ways to work with natural processes*.' Such an approach also provides an opportunity to improve the resilience of the coastal environment and the habitats and species it supports.

The shoreline management planning process provides a tool to enable all parties to work together to develop a long-term sustainable plan which takes account of sea-level rise. These plans set the strategic direction which underpins the more detailed planning. As witnessed by these storm events (Natural Resources Wales 2014a), there was significant impact to communities and infrastructure such as roads, railways and the coast path. The Phase 2 Coastal Review report (Natural Resources Wales 2014b) sets out a series of recommendations to help to reduce and manage that risk.

This report describes how the natural environment was affected, and plans for adaptation are needed here too. In a small number of specific instances we already know that intervention is required urgently. These examples include Traeth Pensarn SSSI on the north Wales coast which has suffered erosion of the vegetated shingle over a number of years, with coastal defence works updrift of the site interrupting the supply of shingle to this section of coast. The recent storms have exacerbated the erosion and the remaining shingle habitat is now under significant threat. We are working with Conwy County Borough Council on repairing the defences and importing a significant amount of quarried material to replenish the shingle resource to allow the habitat to recover.

We also know that the sea wall at Cwm Ivy SSSI on the Gower Peninsula was breached during the storms allowing saline water to penetrate the freshwater grassland. We know that it is not sustainable to continue to defend this site in the long–term, but the decision about what we would do in the event of a breach has now been brought forward. In this instance the site will become more resilient if change is allowed and managed than if we were to continue to attempt to defend. We are therefore working with our partners to develop a programme of adaptation and managed realignment.

The need to improve the resilience of the natural coastal environment is high on the social, political and environmental agenda. This could include:

- Reducing habitat fragmentation for species which are susceptible to storms;
- Carefully managing the sediment supply at the coast, so that places such as Traeth Pensarn are not sediment starved;
- Delivering managed realignment to maintain or increase the areas of coastal and intertidal habitat;
- Restoring estuary form and function; and
- Improving the natural defence function these habitats provide.

Implementation of shoreline management plans, which includes development of more detailed planning where needed, and is delivered at a pace which matches the changes in forcing factors as a result of climate change should also support these aims.

The post-storm accumulations of litter on our beaches provide an opportunity for removal of waste from the marine ecosystem, whilst ensuring that the beneficial natural material which forms the strandline remains in place. We could work with Local Authorities, Keep Wales Tidy, the Marine Conservation Society and communities to consider how resources can be made available to encourage and support those who are willing to organise clean-up events of their local areas. This could include disposal facilities and guidance on the natural material which should remain on site. In addition there are implications for larger Reduce and Recycle Campaigns and opportunities to involve other marine stakeholders, such as the fishing industry.

6. Conclusions

This report shows that the Welsh coast is vulnerable to severe weather events and demonstrates the sorts of impacts and associated ecosystem service consequences that can be expected to become more frequent in the future. These events have the capacity to drive physical processes with significant consequences for our natural resources and ecosystem service delivery. Ultimately we hope this report generates a better understanding of the potential environmental consequences of such events.

Some of the environmental change recorded is likely to be permanent, and the start or reactivation of natural processes. In addition, the events may be responsible for long-term species population declines and local extinctions. This situation has implications for Natural Resources Wales' implementation of *The Ecosystem Approach* and natural resource management.

This audit demonstrates that there is a core network of personnel within and outside Natural Resources Wales which has some (limited) capacity to respond to and report on the implications of severe weather events. This network could be further developed to be more effective. There are obvious parallels to be drawn with contingency planning for other scenarios. In addition this experience should also inform the development of collaborative adaptation and restoration strategies at a regional and local level.

We hope this report will stimulate and attract further interest and research in this area, as topics such as natural hazards, societal challenges and climate change become increasingly prominent issues in Wales and the UK.

Current climate change scenarios indicate that coastal flooding, erosion risk and other consequences of severe weather events are set to increase in both magnitude and frequency. This will bring distinct challenges when ensuring that the environment and natural resources of Wales are sustainably maintained, sustainably enhanced and sustainably used now and in the future.

7. Recommendations

This report fulfils Recommendation 36 of the Wales Coastal Flooding Review Phase 2 (Natural Resources Wales 2014b) to '*Complete the ongoing update to the Phase 1 'rapid' assessment of environmental changes experienced during the December 2013 and January 2014 storms*.' In addition it provides further evidence for the need to pursue the majority of the recommendations in the Wales Coastal Flooding Review Phase 2 Report (Natural Resources Wales 2014b), and provides further clarity on 15 specific recommendations, under six priority areas for the Natural Environment **(NE)**, as set out below. These recommendations will require debate and discussion both internally and with our partners to establish a realistic delivery plan. This plan should be fully integrated with delivery of the 47 recommendations which aim to improve management of flood and coastal erosion described in the Wales Coastal Flooding Review Phase 2 (Natural Resources Wales 2014b).

IMPROVED INFORMATION:

There needs to be improved Information on coastal flood defence and erosion management systems, including areas where natural features are delivering this ecosystem service (coastal defence).

Rec. NE 1	**This report illustrates the wider environmental implications of severe weather events. We reiterate Recommendation 31 in the Wales Coastal Flooding Review Phase 2 Report on needing improved information on the status of coastal flood defence systems, *including* natural habitats that perform a defence function.**
Rec. NE 2	**Improve our knowledge of the condition of designated site features to help inform pre-storm baselines and trends, to enable assessment of storm implications and appropriate management**

	measures.
Rec. NE 3	Continue to work with partners to review and formalise the *ad hoc* response to the recent storm events. This should involve co-ownership, co-design, co-funding and co-delivery of a comprehensive approach to data gathering (register of sites/contacts, use of citizen science etc) in the event of a storm. Options for a targeted and prioritised monitoring programme to enable future reporting on post-storm behaviour of habitats, species and geomorphological features should also be explored.
Rec. NE 4	All relevant bodies should recognise the importance of long-term physical and ecological monitoring in a changing environment and work together to consider the need for secure long-term funding of this area of work. This is linked with Recommendation 40 of the Wales Coastal Flooding Review Phase 2 Report which seeks business case approval for the Wales Coastal Monitoring Centre.

SUSTAINED INVESTMENT:

Sustained investment in emergency planning and preparedness for incidents, which includes the wider environment; and investment in coastal biodiversity is needed.

Rec. NE 5	Invest in coastal flood forecasting, warning, awareness, response and recovery, as set out in Recommendation 27 of the Wales Coastal Flooding Review Phase 2 Report. This investment should also include improved preparedness, response and recovery for incidents from an environmental perspective.
Rec. NE 6	Review the existing vulnerability assessment for coastal environmental interests to identify whether vulnerable sites have been correctly identified, and carry out an assessment of resilience. Further develop the assessment so that in future, appropriate remedial action can be quickly identified and delivered in a planned way.
Rec. NE 7	Invest in adaptation measures for the natural environment as well as the built environment (linked with Recommendations 41 & 42 of the Wales Coastal Flooding Review Phase 2 Report). Deliver coastal realignment and/or habitat creation/restoration schemes required to meet the legislative requirements for designated sites, but also to improve the resilience of the coast to climate change.

COLLABORATION & PARTNERSHIP WORKING:

Greater networking of agencies and authorities is required to develop strong delivery partnerships.

Rec. NE 8	Increase levels of collaboration between the relevant response agencies in Wales to support improved incident response and the delivery of adaptation measures. This should include risk management authorities, such as Natural Resources Wales and Local Authorities, but also key partners, such as Network Rail who manage significant assets at the coast.

SKILLS AND CAPACITY:

To determine what gaps exist, so these can be addressed to ensure effective delivery of coastal flood and erosion risk management including consideration of wider environmental implications.

Rec. NE 9	Review skills and capacity to deliver the recommendations described here including robust long-term monitoring, assessments of vulnerability and resilience, development of detailed adaptation plans and their subsequent implementation.
Rec. NE 10	Work with the academic community and non-Government organisations to raise awareness of and encourage post-storm recording and analysis of fresh geological exposures - this could also generate further research and educational revenue in Wales, which would be compatible with Welsh Government science ambitions.

IMPROVED RESILIENCE:

There should be more support for land owners and site managers to deliver actions to improve resilience

Rec. NE 11	Government policies and programmes for delivery of environmental resilience are prepared for, and are responsive to, severe weather events. For example, vulnerability and resilience assessments for coastal sites, habitats and species are in place and inform planning & preparedness. Mechanisms are in place to support post-storm environmental monitoring and recording, and delivery of remedial action if required.
Rec. NE 12	Encourage provision of support and guidance to carry out post-storm litter collection activities.
Rec. NE 13	Natural Resources Wales should continue to review the

	implications from the winter 2013/14 storms for coastal designated sites over the 2014 summer survey period and further clarify any remedial actions which may be required.

IMPROVED PLANNING FOR CLIMATE CHANGE ADAPTATION:

Integration of locally developed plans which take full account of climate change, and work with the natural environment to increase resilience is needed

Rec. NE 14	Integrate implementation of Shoreline Management Plan policies (as per Recommendation 41 of the Wales Coastal Flooding Review Phase 2 Report) as a means to deliver appropriate adaptation of the natural environment as well as the human environment, and to improve resilience to severe/extreme weather and climate change.
Rec. NE 15	Integrate local delivery plans (as per Recommendations 41 of the Wales Coastal Flooding Review Phase 2 Report), ensuring that consideration of the wider environment and ecosystem services is built in at the detailed level to help improve sustainability and resilience to climate change.

8. Annexes

8.1 Annex 1- Description of Environmental Change

8.1.1 Geology, Geomorphology & Coastal Processes (Raymond Roberts, Natural Resources Wales)

The underlying geology strongly influences the topography and the outline of Wales' coast. Rocks that are erosion-resistant generally form headlands whereas rocks that are susceptible to erosion tend to form bays and inlets. Overprinted onto this is the influence of geological structures such as faulting, bedding and folding which can have an important role in shaping the coast. The underlying geology will also have an important bearing on the cliff profile and its susceptibility to landslides. For example, weaker rocks are more likely to fail more readily to form sloping cliffs, whereas erosion-resistant rocks are more likely to yield near-vertical cliffs. Many of the beaches in Wales are also backed by Quaternary sediments such as glacial till, sands and gravels which are particularly susceptible to erosion.

Geological Conservation Review sites

At a statutory level the focus for geological conservation is the Geological Conservation Review (GCR) which is a GB-wide review of geological and geomorphological sites. There are 480 GCR sites in Wales, 122 of which have part of the protected features on the coast. The sites comprise hard rock sites (Tenby Cliffs, Great Orme), soft cliffs (Morannedd, Abermawr), static geomorphological processes (Borth, Glanllynnau), and active processes (Morfa Dinlle, Morfa Harlech). Sites of Special Scientific Interest (SSSIs) may have a single GCR site or combination of overlapping features. Thirteen GCR sites have been selected purely for their coastal geomorphological feature. In addition to the statutory protected GCR sites, there is also a network of Regionally Important Geodiversity Sites (RIGS).

Management of GCR sites

GCR sites can be classified in three main types, namely Integrity, Finite or Exposure sites. Integrity sites contain landforms which are irreplaceable if destroyed. Examples include previously active geomorphological sites, caves and karst. Finite sites comprise features of limited extent that would be damaged or depleted if removed or lost, such as unique mineral, fossil or geological feature sites, and some stratotypes. Exposure sites provide exposures of a feature which is extensive or also well developed below the ground. Exposure sites are numerically the more common type and may include exposures in disused and active quarries, road cuttings and pits, exposures in coastal and river cliffs, foreshore exposure, mines and tunnels, inland outcrops and stream sections.

The broad conservation principle for these types of site is different. Integrity and Finite sites are, by definition, finite and irreplaceable. To conserve them, a 'protectionism' approach must be adopted. In contrast, the principle for Exposure sites depends on the maintenance of an exposure, the precise location of which is not always critical. Marine erosion is often vital in creating fresh exposure, particularly in softer rock formations. Similarly, quarrying may be welcomed under some circumstances because it creates a fresh exposure and progressively reveals new rock surfaces enabling a rock body to be analysed in three dimensions.

Accessibility and visibility are important factors in the management of geological and geomorphological SSSIs.

Coastal geodiversity

The majority of coastal GCR sites are either active geomorphological sites or include features exposed in coastal cliffs and on the foreshore. The main conservation objective for geological features in coastal cliffs is the maintenance of natural processes that allow erosion to proceed unimpeded and thereby maintain the degree and quality of exposure of the geological features. Any development that directly or indirectly affects the amount or quality of the exposure of the feature constitutes a threat to the site.

Active geomorphological sites encompass mass movement, coastal and fluvial sites in which processes are active and the range of landforms associated with these processes, for example dunes, spits and saltmarsh. Conservation objectives focus on allowing the processes and features that they create to evolve naturally, unimpeded by human intervention, although almost every site will be affected by some degree of land management. The principal target will be that there are no artificial developments or modifications of any kind that affect the evolution of the natural geomorphological systems.

Impact of storms

GCR sites are monitored by geologists from Natural Resources Wales on a 5-year cycle and, although a number of coastal sites have been monitored recently, there has not been a strategic assessment of the impact of the 2013-2014 winter storms. However, from monitoring and other site visits examples of changes have been noted as described below.

A number of GCR sites also underpin important habitats such as sand dunes, soft cliffs and intertidal habitats and further examples of changes at these sites are recorded in following sections of the Annex.

Erosion of Quaternary sites

Many Quaternary sites contain areas of glacial sands and gravels that are particularly susceptible to coastal erosion. The GCR site at Glanllynnau on the Llŷn Peninsula has two individual components separated by a mainline railway. The coastal cliffs comprise glacial, late-glacial and Holocene sediments while inland of the railway a landform assemblage comprises kettle holes and associated sediments. Both features require different management. The coastal ‘exposure’ feature needs to be kept visible and accessible and is kept fresh by wave action. The morphology of the inland ‘integrity’ feature needs to be kept intact. The recent storms have caused significant erosion at the western end of the site (Figure 7) and there is likely to be discussion on what measures are needed to protect the railway. Rock armouring put in place to protect the railway has already begun to encroach on the GCR interest. At Abermawr in Pembrokeshire, there has been significant erosion of the Quaternary interest (Figure 8). Photo-monitoring by geologists from Natural Resources Wales helps gives a measure of the rate of coastal erosion and an example of the effect on a particular GCR feature.

Figure 7. Erosion at Glanllynnau is likely to lead to casework with Network Rail (Stewart Campbell, Natural Resources Wales).

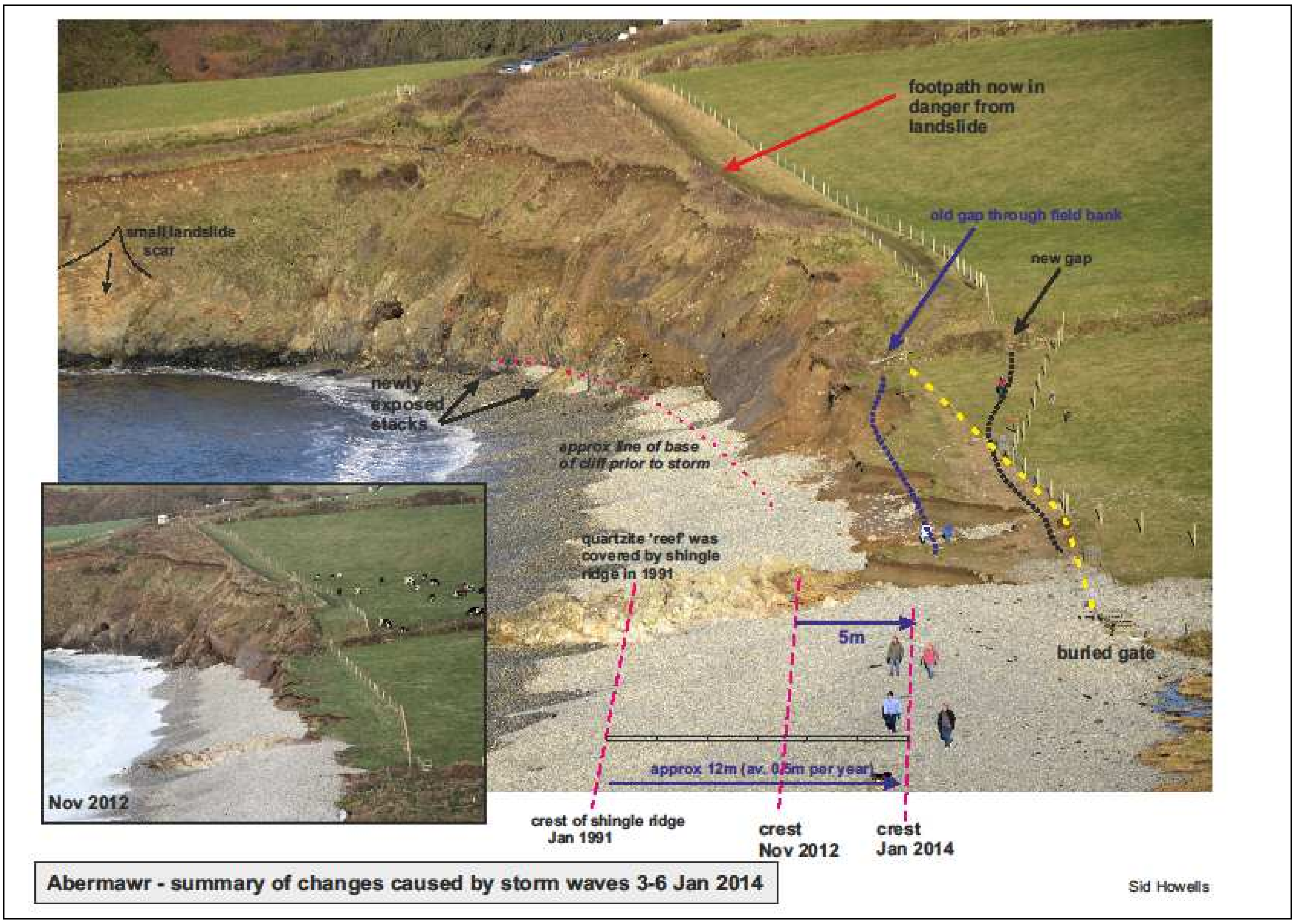


Figure 8. Erosion of Quaternary geological features at Abermawr, Pembrokeshire (Sid Howells, Natural Resources Wales).

Removal of sediment at the foot of cliffs and freshening of faces

Soft cliff sites, such as many coastal Quaternary sites, often suffer from slumping and have debris obscuring exposures at the base of the cliff. Winter storms with high tides periodically remove this material re-exposing the feature. Examples include Dinas

Dinlle, Moranedd (Figure 9) and Glanllynnau. Although removal of the debris is beneficial to the site interest, this is often only for the short-term as many of these cliffs will slump again.

Figure 9. The susceptibility of Quaternary sites to erosion varies depending on the material. Dinas Dinlle (left) illustrates glacial sands and gravel and Morannedd (right) shows glacial till forming the lower part of the cliff.

Erosion of sand dunes

There has been significant erosion in a number of active geomorphological GCR sites such as Newborough Warren, Morfa Harlech and Morfa Dyffryn. The main change has been erosion and truncation of frontal dunes leaving steep faces at the back of the beaches. There have also been numerous examples of shingle and cobbles deposited in the upper parts of the beach.

Landslides

Although the main examples of change in geological and geomorphological sites have been on Quaternary sites, there have been examples of landslides on hard rock sites, for example, Wig Bach near Aberdaron.

Scouring and drop in beach level

Some beaches have seen a fall in beach levels. In many sites, this has exposed large areas of glacial till and numerous examples of submerged forests.

Coastal processes (Ceri Seaton & Emmer Litt, Natural Resources Wales)

The series of storm events has eroded coastal features and transported sediment offshore, often forming nearshore and offshore bars. In the longer-term following a period of calmer conditions, it is likely that the sediment transported offshore will be transported back onshore to replenish the coastal zone. Coastal processes are cyclical in nature, and dynamic features such as beaches are continually changing morphology in response to forcing factors such as wind and waves, with the aim of establishing a dynamic equilibrium.

A barrier system like Whiteford Burrows exhibits dynamic shoreline features and has undergone phases of erosion and accretion over the last century (see Figure 10; from Pye & Blott 2012). At Newborough Warren, the National Coastal Erosion Risk Maps (NCERM) predict approximately 4-8m of erosion in the next 20 years, 10-20m erosion over the next 50 years, and 20-40m over the next 100 years. Pye and Saye (2005) estimate, through expert geomorphological assessment, an erosion rate of approximately 70-100m by 2100, double that predicted in NCERM. The storm events of December 2013 and January 2014 resulted in the erosion of 10m along a significant length of dune frontage, with erosion up to 15-20 m in places. Whilst some recovery is expected, it is clear that these events were significant in the context of longer-term predicted change, and demonstrates the degree of dynamism which can be experienced at these sites.

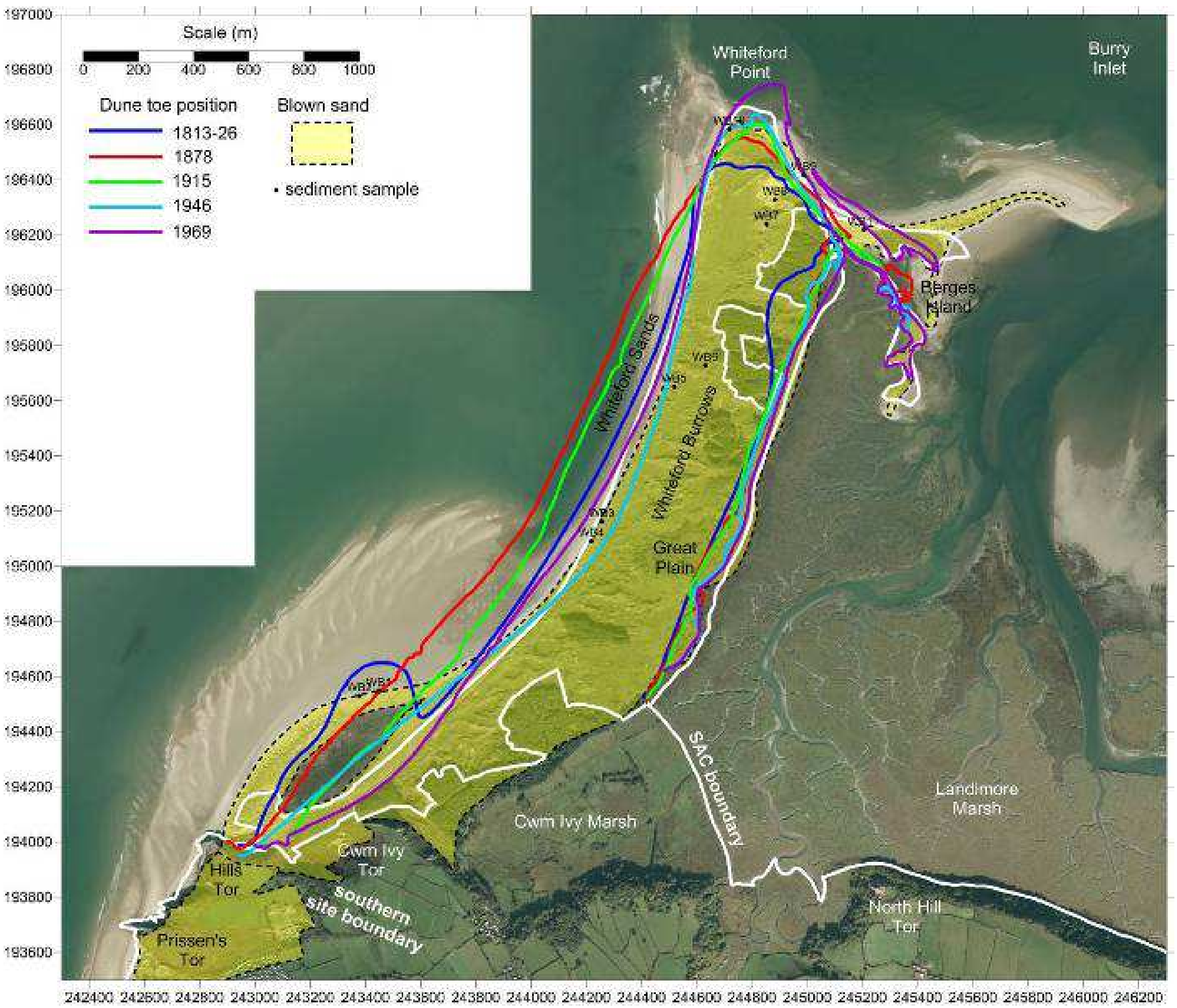


Figure 10. The extent of blown sand in relation to SAC boundaries at Whiteford Burrows. Also shown are the positions of the dune toe inferred from historical maps and aerial photographs (from Pye & Blott 2012).

8.1.2 Habitats

Intertidal Rock Habitats (Paul Brazier, Natural Resources Wales)

No major topographic changes on rocky shorelines, other than cliff falls at the top of the shore, have been recorded, but the most wave-exposed rocky headlands are largely inaccessible and therefore go unrecorded. Arguably, the full extent of available rocky substratum has increased as a result of the storms, due to drops in sediment levels across Wales. The sediments are likely to work their way back into the shallow subtidal and intertidal zones but, until then, the new substratum provides opportunities for colonisation, including opportunities for fast growing non-native species to become established.

At a number of sites where Honeycomb reef (a Section 42 habitat and Special Area of Conservation [SAC] biogenic reef) covers the mid and lower shore (Criccieth, Cei Bach, Dunraven Bay), the sand that this worm relies on to form tubes has been removed from the shore, although the very high levels of suspended material resulting from the storm has so far been supplying the necessary material for tube rebuilding. The sustained biogenic reef will depend on the return of sand onto the beaches during the spring and summer in order to permit tube growth. In some locations, the wave action has broken holes into the reef forming rock mills which gradually widen the area of damage (Figure 11). High river levels can also compromise the resilience of the reef by applying physiological stress on individual worms (Figure 12).

Figure 11. Damage to the integrity of Honeycomb *Sabellaria alveolata* reef at Cei Bach (Paul Brazier, 31st Jan 2014).

Figure 12. Flooding across the biogenic honeycomb reef at Cei Bach (Paul Brazier, 31st Jan 2014).

Where the extreme low shore and subtidal rock lies adjacent to sandy bays, there has been loss of algal cover and mussels *Mytilus edulis*, resulting in areas of bare rock - an unusual sight in the marine environment. The succession of fast-growing opportunist algae through to the development of a more stable community of algae, grazers and other primary consumers and predators will be evident over the coming months and years.

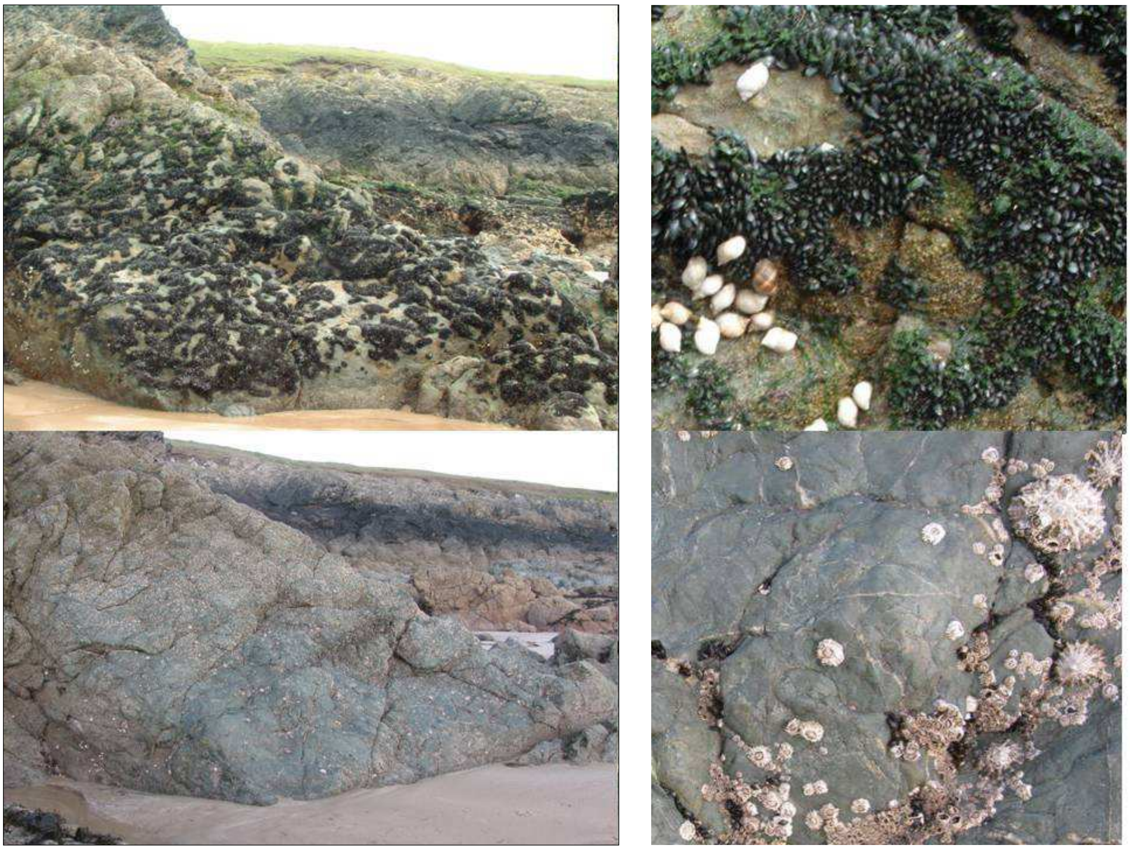


Figure 13. Loss of intertidal rock fauna on scoured bedrock at Aberffraw (Ivor Rees, 2nd April 2014).

Site account

Cardigan Bay (Aberaeron and Cei Bach) - Honeycomb reef

Repeat monitoring of 'Reef' features in Cardigan Bay SAC identified a number of effects from the storms. The Honeycomb reef was clearly broken up in places, revealing ancient peat and boulder clay under the surface of the boulders and cobbles that are normally bound together by the *Sabellaria alveolata* sand tubes along this stretch of coast. Typically, hollows were formed along the periphery of the reef, where loose cobbles act as grind stones, eroding away at the edges, during periods of wave action (Figure 14).

Figure 14. Mid shore at Aberaeron, clay and wood remains exposed beneath the cobble layer (Paul Brazier, 28th April 2014).

On the lower shore at Aberaeron, the wave action from the storms move a large number of boulders and cobbles from the sublittoral fringe (near subtidal) zone, higher onto the beach. The pink coralline algal crusts have subsequently bleached to show an expanse of whitened cobbles. Numerous remains of broken Kelp *Laminaria hyperborea* were also evident on the lower shore, washed up from a few metres depth (Figure 15).

Figure 15. Extreme low shore at Aberaeron, showing bleached algal crusts and stumps of kelp plant stipes (Paul Brazier, 28th April 2014).

Certain of the rockpools that are part of a long term monitoring programme at Aberporth suffered severe scour and also possibly subsequent siltation. The fauna and flora were substantially impoverished where this occurred (Figure 16).

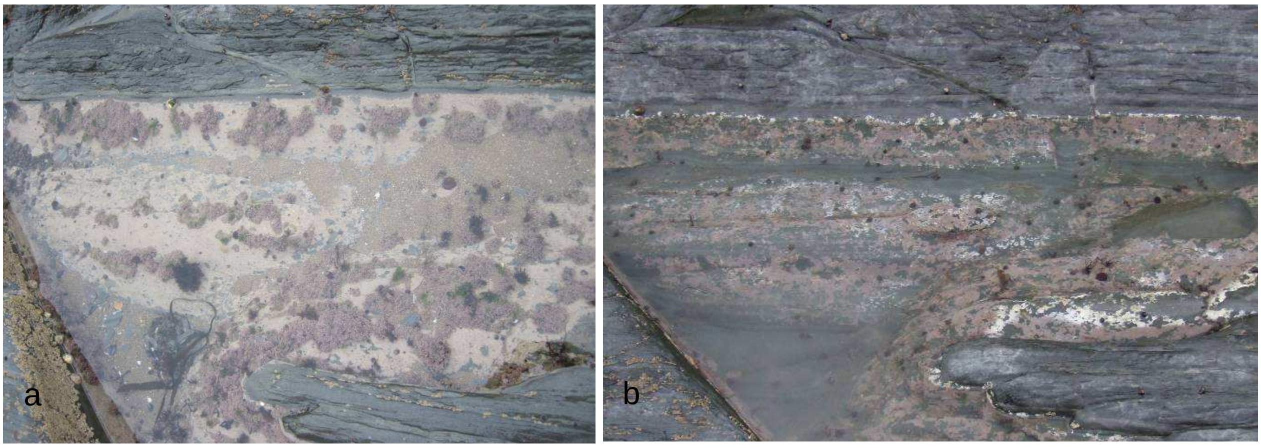


Figure 16. Upper shore pool at Aberporth, showing scoured bedrock; a) 2012, b) 2014 (Paul Brazier. 29th April 2014).

Intertidal Sediment Habitats (Paul Brazier, Natural Resources Wales)

Mudflats

Mudflats are a Section 42 priority habitat due to persistent losses of habitat to developments in estuaries and other inlets. Mudflats are part of the SAC feature *Mudflats and Sandflats not covered by Seawater at Low Tide.* During the December storms, high tides in conjunction with a more northerly wind resulted in the south side of the Dee estuary experiencing higher than usual erosion from wave action. Damage to the Network Rail retaining wall at Ffynnongroyw resulted in emergency construction works being placed 7m out onto intertidal mudflats and saltmarsh at five breached locations. The loss of sediment habitat, acknowledged as an important bird feeding and roosting area, is small but part of the accumulated losses that the Dee estuary suffers from through coastal development. Some further loss of habitat was recorded adjacent to the Mostyn breakwater and around Flint Point, where the mud, clinker and other old industrial waste were eroded out from the steep shoreline. The greater impact is likely to be from the freeing up of old industrial debris into the estuarine system.

Sandflats

Sandflats are part of the SAC feature *Mudflats and Sandflats not covered by Seawater at Low Tide*. They range from species-rich, sheltered sediment flats to open coast, steep and wave-exposed sandy beaches. The latter were in direct line of the effects of the storm. In many parts of the coast, large volumes of beach sand were lost from the intertidal zone, seemingly to be deposited in the shallow sublittoral zone, just offshore. This has resulted in ancient forest material (peat and wood) being exposed at numerous beaches (Freshwater West, Newgale, Borth/Ynyslâs, Tywyn, Fairbourne and Porth Neigwl) and bedrock at Marloes Sands and Merthyr Mawr (Figure 17). At other locations, such as Criccieth and Trearddur Bay, the stripping of sediments from sandy and cobbly beaches has resulted in boulder clay being exposed and eroded by subsequent wave action (Figure 18). Many of the infaunal species that characterise the sediment community are highly mobile and able to re-bury, but whether they survived the wholesale movement of the sediments is unknown. The sediments will quickly become recolonised by amphipods, isopods and polychaete worms.

Figure 17. Exposed submerged forest at Borth (Ian Medcalf, Natural Resources Wales. 28th Feb 2014).

Figure 18. Exposed underlying boulder clay at Llanystumdwy (Rowland Sharp, Natural Resources Wales. 11th Jan 2014).

Coarse materials (cobbles and pebbles) have also been thrown above the high water mark, resulting in loss of material from the upper intertidal zone. Numerous urban areas have been inundated (Aberystwyth, Porthcawl), coastal infrastructure smothered (Newgale, Dunraven Bay, Gwbert Aberteifi) and natural features realigned (Tanybwlch Aberystwyth, Ysgethin Morfa Dyffryn, Wallog). The geographically-restricted biotope that is characterised by the crustacean *Pectenogammarus planicrurus* may have been hard hit by the changing levels in gravels and pebbles at Aberystwyth and Pwllheli.

Subtidal Habitats

Reports on the effects of the storms on subtidal habitats are sparse, due to them being out of sight and inaccessible. There were numerous strandings of live sea cucumbers *Thyone fusus*, Otter Shells *Lutraria lutraria* and whelks *Buccinum undatus*, particularly at Morfa Dyffryn, Dinas Dinlle, Newborough Bay, Aberffraw and Gronant (Figure 19).

The sediments (sand, pebbles, cobbles) that have been lost from most of the beaches around the Welsh coast have ended up in the shallow subtidal. These will largely be covering other sediment areas. Many infaunal animals will be active burrowers that will be able to reach the surface in these open coast sediments, but there may be other species that are less able to reach the surface, such as seagrass *Zostera marina*, large bivalves and epibiota on hard substrata. Preliminary observations of the subtidal seagrass beds at Borthwen (near Rhoscolyn) suggest that the extent of the bed is smaller and also less dense. This may be as a consequence of movement of the sandy sediments in this bay.

Figure 19. Stranded sea cucumber *Thyone fusus* at Dinas Dinlle (Bryn Jones, Natural Resources Wales. 14th Feb 2014).

Brackish / saline lagoons

Lagoons are an unusual and rare habitat, both in the UK and elsewhere, and are classed as SAC priority features, SSSI features and Section 42 habitats. The characteristic lagoon community includes species almost or entirely restricted to lagoonal habitats, where they represent some of our rarest plants and animals. They are highly vulnerable to high sea levels and flood events. On one hand, the increased freshwater flow can force the salinity down, whilst excessive over-topping (isolated, silled, sluiced lagoons) or percolation (percolation lagoons) of seawater can raise the salinity. From reports around the Welsh coast, the impact of wave action and incursion of seawater are the main effects noted during the storms.

At Morfa Madryn, the lagoons that are managed as freshwater features for birds were flooded from overtopping seawater. The flood banks were breached and eroded, resulting in successive tides entering the area of the lagoons. Although salinity measurements have not been taken, this is likely to have partially increased the salinity of some of the pools, which will affect the feeding opportunities for certain bird species (Figure 20).

Figure 20. Overtopping of the floodbanks at Morfa Madryn, Llanfairfechan (John Ratcliffe, Natural Resources Wales. 5th Dec 2013).

At Cemlyn Lagoon, Anglesey (Figure 21), wave action pushed shingle to the top and over the crest of the shingle ridge, resulting in the crest being lowered (by up to 50cm) and moved landward (Figure 22), and changes to water levels and salinity. Shingle also moved westwards, influencing the area of the sluice and some has been lost to the road and car park. Previous storms have had similar effects, with gradual evolution of the lagoon. Remedial work to the topography of the lagoon each time maintains the tern nesting sites.

Figure 21. Cemlyn Lagoon aerial image (Rohan Holt, Joint Nature Conservation Committee. circa 1996).

Figure 22. Cemlyn Lagoon shingle accumulating in the lagoon (Ivor Rees, 7th Dec 2013).

Saltmarsh

The high spring tides and storm surges have resulted in flooding of estuary saltmarsh, leading to large strandings of organic material mixed in with litter and some incidences of damage to sluices (Figure 23). Where tides and waves have overtopped the floodbanks, flooding has accessed low-lying grazing fields, causing welfare issues for farm animals and damaged swards. In the Dee estuary, overtopping of the southern, mid-estuary shoreline may have caused minor erosion of the saltmarsh edge. The presence of organic debris on the upper saltmarsh is considered to be a naturally occurring event and part of the cycle of nutrients in a saltmarsh system.

Figure 23. Litter debris at Afon Dwyfor (Paul Brazier, 12th Jan 2014).

Shingle

At Cemlyn Bay, the shingle ridge was lowered and the crest moved inland as a result of wave action. Parts of the ridge appear to be up to 50cm lower than sections either side, whilst the roots of Sea-kale *Crambe maritima*, some up to 20cm long, have been left exposed on the crest of the ridge, indicating a local reduction in the crest height (Figure 24). At the west end of the ridge, more stable cobbles have been undercut and material lost from the area (Figure 25).

Figure 24. Vegetated shingle ridge at Cemlyn showing eroded sea kale on the ridge front (Ivor Rees, 7th Dec 2013).

Figure 25. Vegetated shingle ridge at Cemlyn showing erosion at the west end (Ivor Rees, 7th Dec 2013).

Between Llanddulas and Pensarn (Traeth Pensarn SSSI), the vegetated shingle ridge has suffered further erosion, with loss of material at the westernmost point, reducing the width to less than 10m from the seawall. Over recent years, there has been limited natural shingle feed from the west here, compromising the long-term existence of this feature. Recent storms have exacerbated the need for beach feeding to protect the SSSI feature and the amenity beach, and to ensure the long-term integrity of the coastal protection. At Aber Dysynni (Broadwater), reshaping of the coastline may have mobilised the vegetated shingle that lies to the south of the estuary mouth. Remedial work is likely to maintain the mouth of the Afon Dysynni and so reconstruct the shingle bank.

Elsewhere, mobile shingle on upper shores and storm beaches have been moved landward by the wave action. At some of these locations, it is part of the natural evolution of the shoreline (Ysgethin on Morfa Dyffryn, Kenfig and Rest Bay). In other locations, such as Newgale, the shingle is pushed back to the top of the beach to clear highways and other infrastructure, whilst at Tanybwlch, Aberystwyth, the partial breach and lowering of the height of the storm beach may ultimately lead to an entire breach and a re-routing of the Afon Ystwyth.

Sand Dunes (Mike Howe, Natural Resources Wales)

Coastal sand dunes are dynamic habitats which undergo periods of accretion and erosion as a consequence of climatic conditions. In the absence of anthropogenic influences, natural erosion events are critical to the healthy functioning of dune systems with the periodic movements of sand into the dunefield promoting pioneer conditions and checking succession to more fixed habitats. Unless there is significant down-wind drift, most sand lost to the sea during such events will help to replenish offshore sand deposits which will feed back into the dune systems at times of dune accretion. The erosion events witnessed in winter 2013-14 should therefore be viewed as change rather than damage.

Nevertheless, Welsh sand dunes certainly took a dramatic pounding as a consequence of high spring tides, gale-force winds and storm surges from December 2013 to February 2014. Storm surges in early December were from a north-easterly direction and had most impact upon Gronant Dunes and Talacre Warren. The frontal dunes at Talacre eroded back by c.3m and were breached in one or two places. As they play a strategic role in the coastal defences for the village of Talacre and Presthaven Sands Holiday Park, the breaches were infilled and parts of the frontal dunes were bulldozed to provide banks for increased protection from high tides. Storms from late December to February were overridingly from a more typical south-westerly direction and impacted upon most of the Welsh dune systems, to a greater or lesser effect. The most significant changes have occurred at Newborough Warren and Pembrey Burrows where frontal dunes have eroded back by up to 20m. On most systems, the frontal dunes are now truncated and vertically-inclined, although these will naturally erode quickly to a more typically-sloped frontage.

The impact upon dune systems in more sheltered locations has been less marked. At the most sheltered system, Merthyr Mawr Warren, frontal dunes have eroded back to a maximum of 3 to 4.5m. The major impact has been the loss of large volumes of sand from the beach, exposing bedrock and clay deposits. There was little change to the dune rejuvenation areas in the inland dune field, with only small-scale sand movements.

The most obvious biological impact is the (temporary) loss of fore dune habitats on many Welsh dune systems. Two Annex I habitats have borne the brunt of the storm surges, and a major part of *Embryonic Shifting Dunes* and a significant proportion of *Shifting Dunes with Marram Grass* will have been lost. Whilst natural processes will restore these over time, the plant and invertebrate species associated with these habitats may have been lost, at least locally. The more widespread elements of the beach flora such as Sea Rocket *Cakile maritima*, Sea Beet *Beta vulgaris maritima* and dune-forming grasses such as Marram *Ammophila arenaria*, Lyme-grass *Leymus arenarius* and Sand Couch *Elytrigia juncea* will rapidly re-colonize and arguably flourish in the newly-created pioneer conditions, but more localized species such as Sea Stock *Matthiola sinuata*, already declining at its few remaining Welsh localities, may not have fared so well at least locally. Although adapted to living in such harsh and ever-changing environments, invertebrates with fragmented distributions such as the Sandhill Rustic *Luperina nickerlii* may also have been adversely affected, particularly if beach profiles have been reduced by as much as 2m at some systems (see Annex 1, 8.1.3).

Site accounts

Gronant Dunes & Talacre Warren (Paul Day & Mike Howe, Natural Resources Wales)

Loss of frontal dune habitat varies from 1m at western end to more than 10m at Point of Ayr as a consequence of storm surges in early December 2013. Frontal dunes at Point of Ayr were breached in about four locations, allowing saline intrusion into an area between two ridges. Whilst water could access this area through an existing route, recent changes will increase the risk of more frequent flooding. The breaches were repaired for coastal defence purposes, and areas of truncated fore dunes in front of Presthaven Sands Holiday Park were bulldozed to provide a higher barrier to further erosion. The erosion of frontal dunes has exposed old fencing posts and wiring, creating a health and safety hazard.

Figure 26. The impact of December storms on Talacre Warren (Mike Howe, December 2013).

Morfa Conwy (Neil Smith & Mike Howe, Natural Resources Wales)

Frontal dunes towards the western end of the system have retreated by up to 10m, although typically 3 to 5m and are now steep and truncated. Erosion of the former tip on the fore dunes in front of the caravan park has exposed waste which may require further (shingle) protection. The fencing to exclude access to the remnant belted beauty moth population was damaged and has since been repaired.

Tywyn Trewan and Tywyn Llydan

The frontal dunes have eroded back several metres.

Tywyn Aberffraw (John Ratcliffe, Natural Resources Wales)

The frontal dunes have eroded by c.10m resulting in the removal of embryonic dunes and creation of 2 to 3m vertical sand cliffs. Sand dunes have been pushed back at the river mouth by a number of metres.

Newborough Warren (Graham Williams & John Ratcliffe, Natural Resources Wales)

Storm surges from late December 2013 to February 2014 resulted in lowering of the beach and the loss of 10m of frontal dune along much of the shoreline, with a maximum retreat of 15 to 20m. Losses of frontal dune are estimated at 3.5ha, with loss of approximately 85,000 m^3 of sand. The viewing platform constructed in March 2013 was undermined in December 2013 and collapsed in early January 2014 and there were significant losses of conifers onto the beach as the sea undermined the plantation. Dune frontage retreat is in line with that forecast by Pye & Saye (2005). Extensive salt-burn of the conifer plantation is becoming apparent.






Figure 27. Impact of winter storms at Newborough Warren (Mike Howe & John Ratcliffe, Jan 2014).

Figure 28. Retreat of frontal dunes at Newborough Warren after the winter storms. Red line indicates current line of frontal dunes compared to the situation in 2009.

Morfa Abererch (Molly Lovatt & Lucy Kay, Natural Resources Wales)

Frontal dunes have been eroded, endangering a caravan park and railway line. Repair works are proposed to protect both the remaining dune frontage (previously protected by coastal works) and the caravan park – these works need to be implemented due to the flood risk to parts of Pwllheli if there is a complete breach. However, the SMP2 policy for epoch 2 is managed retreat and it is recognised that the imminent repair works need to acknowledge this and that discussion needs to be started now about moving from the current position of Hold The Line to plan for a programme of Managed Retreat.

Morfa Bychan (National Trust observer)

Fore dune ridges have been truncated but no breaches have resulted in inundation of low-lying land.

Morfa Harlech (Rhodri Dafydd, Natural Resources Wales)

Frontal dunes eroded and truncated along their entire length (c.3.5km), with 3 to 5m cliffing and slumping, and embryo dunes temporarily lost in south and central sections. Further north, a shorter section (c.1km) with a lesser degree of erosion (1 to 2m cliffs), and no erosion at Harlech Point.

Figure 29. Impact of winter storms on frontal dunes at Morfa Harlech (Rhodri Dafydd, Jan 2014).

Morfa Llandanwg (Rhodri Dafydd & Lucy Kay, Natural Resources Wales)

There has been severe erosion of this small dune system which is part of Natural Resources Wales' coastal defences. A key issue is nature of any future works in this area in line with the Shoreline Management Plan 2 (SMP2) draft policies. There is local interest in retaining the dunes, but this is unsustainable in the longer term and the SMP2 report advocates an integrated Artro estuary-wide project to look at this whole section of coast in terms of its future management and implementing options that are more self-sustaining in the future.

Figure 30. Frontal dunes at Morfa Llandanwg (Rhodri Dafydd, Jan 2014).

Morfa Dyffryn (Rhodri Dafydd, Natural Resources Wales)

Storm surges have resulted in a northward migration of shingle along beach, the movement of shingle ridge inland and breached at some locations into dune blowouts. Movement of shingle has closed off the lagoon at the mouth of the Afon Ysgethin which has cut a new course through the beach. Frontal dunes have eroded and become truncated along their entire length (c.3.5km). None of the dunes have been breached to such an extent to cause inundation of low-lying land.

Figure 31. Changes to the frontal dunes at Morfa Dyffryn following winter storms (Rhodri Dafydd, Jan 2014).

Aberdyfi Dunes

The loss of frontal dunes may have resulted in the loss of (some of) the sand lizard population. There has been a request from Aberdyfi golf club for re-instatement of the dunes and it is unclear what options will be pursued in the short and medium term. As with other sections of eroding coast, specific focus needs to be given to developing and implementing options that improve the sustainability of the coastal defences.

Ynyslâs Dunes (Mike Bailey & Jill Bullen, Natural Resources Wales)

Storm surges have pushed the upper shore shingle (cobbles) into the dunefield and caused widespread flooding. There has been a considerable drop in sand levels in the intertidal zone, resulting in exposures of peat.

Figure 32. Changes to the dune frontage at Ynyslâs Dunes (Mike Bailey & Jill Bullen, Jan 2014).

The Bennett, Newport (Jon Hudson, Natural Resources Wales)

The frontal dunes have eroded back beyond the old (dune stabilisation) fence line and vary from 1 to 2m in height, with vertical faces. Accreting embryo and yellow dunes have been lost, leaving a truncated dune face. On the estuary side of the dunes, the sand gradient down to the river has increased suggesting that the river has moved closer to the dune system.

Whitesands Burrows (Jon Hudson, Natural Resources Wales)

A small area (c.20 m) of frontal dunes has been eroded. Several metres of sand have been scoured from the beach, temporarily exposing a submerged forest and glacial clays.

Broomhill Burrows (Jon Hudson, Natural Resources Wales & National Trust observers)

Frontal dunes have been truncated, but none of the dunes has been breached to such an extent to cause inundation of low-lying land.

Brownslade & Linney Burrows (Jon Hudson, Natural Resources Wales)

The frontal dunes have receded by a few metres, with dunes left undercut and likely to erode further. Large driftwood (tree trunks) has been carried up to 20m inland. Some of these timber debris piles supported a rich fauna of deadwood-nesting bees and wasps (see Knight & Howe, 2006) which may have been at least temporarily lost.

Stackpole Warren (Paul Culyer, Natural Resources Wales & National Trust observers)

The fore dunes at Barafundle Bay and Broad Haven have been truncated, but none has been breached to such an extent to cause inundation of low-lying land.

Tenby Dunes (Sid Howells, Natural Resources Wales)

Around 1500m of foredunes have been eroded back by several metres, forming steep sand cliffs which will erode further.

Coppet Hall beach, Saundersfoot

Small dunes along half the length of beach (south), approximately 2.5m high and 3 to 4m deep, have been completely lost.

Pembrey Burrows (Ruth Harding, Mike Howe, James Moon, Natural Resources Wales & Simeon Jones, Carmarthenshire County Council)

The frontal dunes have been truncated along their entire length, eroding back by up to 20m, including at Tywyn Point. This has resulted in steep, vertical cliffing, in places up to 15m in height. Beach access points have eroded away, leaving high vertical drops to the beach. Subsequent access has resulted in sand slippages. Some stands of sea buckthorn growing on the immediate dune frontage have fallen onto the beach. A large blow-out and sand flat at the eastern end of the dune system, created by a sea incursion in winter 2012-13, has remained open.

Tall sand cliffs are in a dangerous condition and may need bull-dozing to make safe for the public.

Figure 33. Frontal dunes at Pembrey Burrows (Mike Howe, Jan 2014).

Whiteford Burrows (Nick Edwards, Natural Resources Wales & Alan Kearsley-Evans, National Trust)

Frontal dunes have been truncated and eroded back by up to 10m. Peat shelves and submerged trees are now visible as a result of the beach profile being significantly lowered. No significant breaches but the embryo slack developing in the SW corner of the system was inundated by sea water.

Swansea Bay Dunes (Becky Wright, Natural Resources Wales)

Some erosion of foredunes in Swansea Bay, with erosion of dunes within Blackpill SSSI.

Crymlyn Burrows (Mike Howe, Natural Resources Wales)

Frontal dunes have receded by 3 to 5m along the entire length of the system and are now truncated and cliffed.

Baglan Burrows (Ken Pye, Ken Pye Associates)

Incursion of sand into former ragworm farm in December 2013.

Figure 34. Incursion of sand into former ragworm farm (Ken Pye, Jan 2014).

Kenfig Burrows (David Carrington, Bridgend County Council & Scott Hand, Natural Resources Wales)

General loss of sand and shingle along upper beach and erosion back of dunes from 2 to 8m, with an average loss of c.2m of frontal dunes. Appears to have helped maintain sand mobility within the dune rejuvenation areas.

Figure 35. Frontal dunes at Kenfig (David Carrington & Scott Hand, Jan 2014).

Merthyr Mawr Warren (Duncan Ludlow, Natural Resources Wales)

Large volumes of sand were removed from the beach, with bedrock exposed in many places together with clay deposits towards the top of the beach in places. The strandline was noticeably reduced, with much of the organic and inorganic material washed away. The retreat of the dune frontage was variable across the site, with a maximum loss of 3 to 4.5m. This has exposed former beach profiles and a number of World War 2 artefacts, such as barbed wire posts and sand ladders. The retreat of the frontal dunes has resulted in the formation of small, vertical dune cliffs in many places, ranging in height from 1 to 4.5m, with the highest cliffs formed between the shingle bank at the western end of the beach and Black Rocks. Small notches were created into the frontal dunes by wave action. Most were quickly re-filled with wind blown sand. The remaining contained a large volume of strandline debris which may prevent any further wind erosion. There appeared to be little change to the dune rejuvenation areas despite the prolonged periods of high winds. Some sand movement was evident but nothing too extreme in scale. It is assumed that the high winds had little effect as the sand was also constantly wet due to the heavy rain and therefore less mobile.

Figure 36. Frontal dunes at Merthyr Mawr following the winter storms (Duncan Ludlow, Jan 2014).

Soft Cliff (Mike Howe, Natural Resources Wales)

Coastal soft cliffs are composed of poorly-consolidated rocks such as glacial till, sand, clays, shales and head deposits, which are subject to frequent slumping and landslips caused by rain, tidal and storm surges and percolating groundwater. They are a significant but highly localised component of the Welsh coast, with their total length of c.100km comprising less than 7% of the coastline (Howe 2003). As well as their geomorphological importance and significance in terms of coastal processes, Welsh soft cliffs also support invertebrate species and faunas of national importance. These are associated with areas of bare ground and pioneer and ruderal plant communities promoted by regular landslips, and with seepages, pools and other hydrological features (Howe 2003, in prep.; Howe *et al*. 2008). Whilst landslips are required to maintain the biological interest of soft cliffs, the rapid rates of erosion experienced during the recent winter storms may have had an adverse impact upon the invertebrates fauna - this is discussed in more detail in the Annex 1, 8.1.3.

The impact of the winter storms has been most pronounced on the south Llŷn coast, where cliffs have receded by up to 5m. At the eastern end of Porth Neigwl, where annual rates of regression are about 0.5m, much of the vegetation has been stripped off the cliff slopes leaving bare glacial till and sand, and seepages on the slopes have been temporarily effaced. Sandy faces are likely to be further eroded by high winds and tides during the remaining winter period. In the central section, which supports cliffs of sand and till, the cliffs have been truncated and faces are now vertically inclined. At Porth Ceiriad, there have been several cliff slippages, including a major slump towards the western end, the cliff face seepages have been temporarily effaced.

A major slump occurred on the cliffs in Rhossili Bay in February, with a section eroding to bare ground and cliff seepages here were temporarily effaced. The beach profile has been lowered by 1 to 1.5m. This has occurred elsewhere on the south Gower coast (e.g. at Fall Bay and Mewslade Bay), but the soft cliffs on this stretch of the coastline is protected from erosion to a greater degree by wave-cut platform and impacts have been minimal.

Other soft cliff slippages have been widespread but appear to have been relatively minor, impacting mostly on the Wales Coast Path.

Site accounts

Morfa Madryn (John Ratcliffe, Natural Resources Wales)

Low bank overwashed, with 1 to 2m of soft cliff removed.

Beaumaris Cliffs (Jean Matthews, Natural Resources Wales)

Some erosion of the cliff face.

Figure 37. Soft cliffs at Beaumaris (Jean Matthews, Jan 2014).

Dinas Dinlle

Previously slumped material has been largely washed away leaving clean faces. However, there has been some undercutting, and towards the southern end of the site there has been some new slumping.

Porth Nefyn

Landslip of soft cliff.

Porth Neigwl (Mike Howe, Natural Resources Wales)

Retreating at an annual rate of 0.5m (Harrop 1994), the soft cliffs at Porth Neigwl have eroded back significantly this winter. At the eastern end of the bay, much of the vegetation has been stripped off the cliff slopes leaving bare glacial till and sand, and seepages on the slopes have been temporarily effaced. Sandy faces are likely to be further eroded by high winds and tides during the remaining winter period. This will have had an impact upon key invertebrates associated with soft cliff habitats (see Annex 1, 8.1.3).






Figure 38. Erosion of the cliff faces at Porth Neigwl (Mike Howe, Feb 2014).

Porth Ceiriad (Mike Howe, Natural Resources Wales)

Porth Ceiriad has experienced major slippages along its entire length, these being particularly pronounced at the western end. Sand lenses have been lost from the cliff slope and seepages have been temporarily effaced. This will have had an impact upon key invertebrates associated with soft cliff habitats (see Annex 1, 8.1.3).

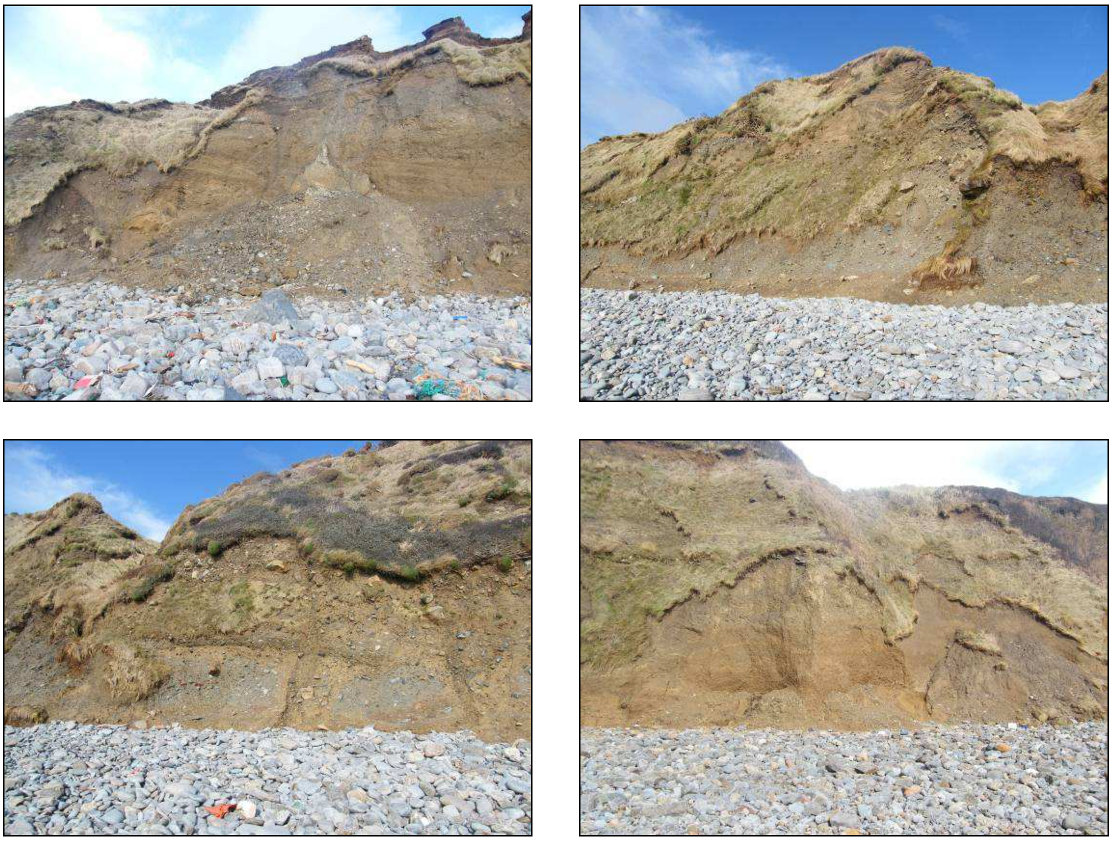


Figure 39. Erosion of soft cliffs at Porth Ceiriad (Mike Howe, Feb 2014).

Afon Dwyfor & Afon Wen (Paul Brazier & Rowland Sharp, Natural Resources Wales)

Soft boulder clay cliffs have eroded and slumped in a number of places. Upper-shore shingle (cobbles) and mid- and upper-shore sand have been removed from the site. The material has gradually washed down shore, seriously affecting the turbidity of the seawater along adjacent stretches of the coast.

Figure 40. Changes at Afon Dwyfor & Afon Wen (Paul Brazier & Rowland Sharp, Jan 2014).

Moranedd (Lucy Kay, Natural Resources Wales)

Eroding boulder clay cliff, with slumped material in front of cliff washed away and new vertical face of erosion. Increased sand levels around boulders at base of cliff.

Monk Point, Criccieth (Paul Brazier, Natural Resources Wales)

Eroded material has smothered the upper shore habitats.

Wallog (Bob Mathews, Natural Resources Wales)

Total failure of stone defences below Wallog house, 2km north of Clarach. Erosion of these defences has revealed an unconsolidated cliff composed of backfill overlying glacial deposits. The section of the Wales Coast Path here, which lies directly above the area of erosion, is now in imminent danger of collapse.

Llanon (Bob Mathews, Natural Resources Wales)

Erosion and retreat of coastal cliffs within Traeth Llanon SSSI and partial failure of private coastal defences seaward of Plas Morfa Hotel. Debris, including building material, has been placed onto the beach behind the defences.

New Quay – Llannina Point

Sections of soft cliff have slumped, with piles of clay at base of cliff.

Abermawr (Sid Howells, Natural Resources Wales)

Shingle ridge has been pushed back several metres, with erosion of the soft cliff and destruction of parts of geological SSSI feature.

Caerfai Bay

A small-scale landslip has undermined the coast path where it goes down to a popular tourist beach, leaving it inaccessible.

Rhossili Bay (Alan Kearsley-Evans, National Trust)

The soft cliffs have slumped as a result of the storm surge and high levels of rainfall, with a section eroding to a bare substrate, and the beach profile has been lowered by 1 to 1.5m.

Figure 41. Changes at Rhossili Bay. 13th January 2014 & 26th February 2014 (Alan Kearsley-Evans).

Horton Cliff (Mike Howe, Natural Resources Wales)

Small-scale erosion of head deposits and sand, with large boulders removed from cliff face and displaced onto wavecut platform.

Figure 42. Small-scale erosion at Horton Cliff (Mike Howe, June 2014).

Cwm Nash (Paul Dunn, Glamorgan Heritage Coast & Chris Byrne, Natural Resources Wales)

Cliff falls to tufa cliffs to west of stream outfall (Cwm Nash SS904700).

Figure 43. Tufa cliff collapse, 7th - 9th January 2014 (Chris Byrne).

Hard Cliffs (Mike Howe, Natural Resources Wales)

Coastal hard cliffs in Wales have a varied geology and include igneous rock strata in Pembrokeshire and on Anglesey and the Llŷn Peninsula, sedimentary Silurian and Ordovician rocks in Cardigan Bay, Carboniferous limestone on Gower, Anglesey and the Creuddyn peninsula in north Wales, and Jurassic limestone in the Vale of Glamorgan. By their very nature, hard cliffs are resistant to erosion and, as a consequence, have not experienced the same erosion events as have occurred on soft cliffs as a result of the winter storms. Whilst there have been rock falls on some sections of the Vale of Glamorgan Heritage Coast, most notably at Dunraven Bay, the stacks and arches which are a feature of the limestone coast on the Castlemartin peninsula have remained intact. This is in contrast with impacts upon similar landform features at Portland, Dorset and Porthcothan Bay in Cornwall.

Site account

Glamorgan Heritage Coast (Paul Dunn, Glamorgan Heritage Coast & Chris Byrne, Natural Resources Wales)

On the Glamorgan Heritage Coast, the limestone cliffs can erode at similar rates to soft deposits. Slippages of these limestone cliffs at Dunraven Bay have occurred as a consequence of wave action and rainfall, and may have impacted upon the population of Shore Dock *Rumex rupestris*, a Habitats Directive Annex II species and a Qualifying feature of the SSSI.

Figure 44. Three views of Dunraven Bay (Paul Dunn, Jan 2014).

Lowland Grassland (Stuart Smith, Natural Resources Wales)

Note that only terrestrial grassland habitats are covered in this report. Maritime grasslands (and maritime heaths) have not been thoroughly covered due to an absence of specialist knowledge in Natural Resources Wales at the time of writing this report.

Species-rich terrestrial grassland habitats are moderately frequent along the Welsh coastline, both within and outwith statutory sites. A few localities are at risk from extreme and prolonged storm conditions through salt-water inundation or erosion/collapse of maritime cliffs and slopes. A larger number are vulnerable to the effects of greatly increased levels of salt-spray, although these effects are generally less severe. Many areas of coastal grazing marsh, which although not necessarily botanically rich may be of conservation value for uncommon fauna, are at particular risk of inundation.

Species-rich terrestrial lowland grasslands fall within five broad categories: neutral, acid, calcareous, marshy and Calaminarian grasslands. Each of these groupings is covered by a Biodiversity Action Plan Priority Habitat and at least a portion of each includes Habitats Directive Annex I habitat. Examples of all of the broad grassland habitats are present by the coast, although for Calaminarian grasslands there is only one small example known in a maritime setting.

Lowland grassland independently qualifying SSSI features are potentially at risk from storm damage on 22 SSSIs, either through being situated immediately adjacent to the coast or through attachment to tidal river systems; these are shown in Figure 45. Nine of these are also within or partly within SACs, in five cases forming all or part of SAC features. A number of additional high value grassland sites, including some pSSSIs, are similarly at risk.

Thus far, there have been very few reports of actual damage to terrestrial grassland due to the storms of winter 2013/14. However, only some of the potentially vulnerable sites have so far been visited, and more gradual change in plant communities due to increased soil salinity (causing displacement of terrestrial grassland by maritime habitats) will take longer to become clear in any case.

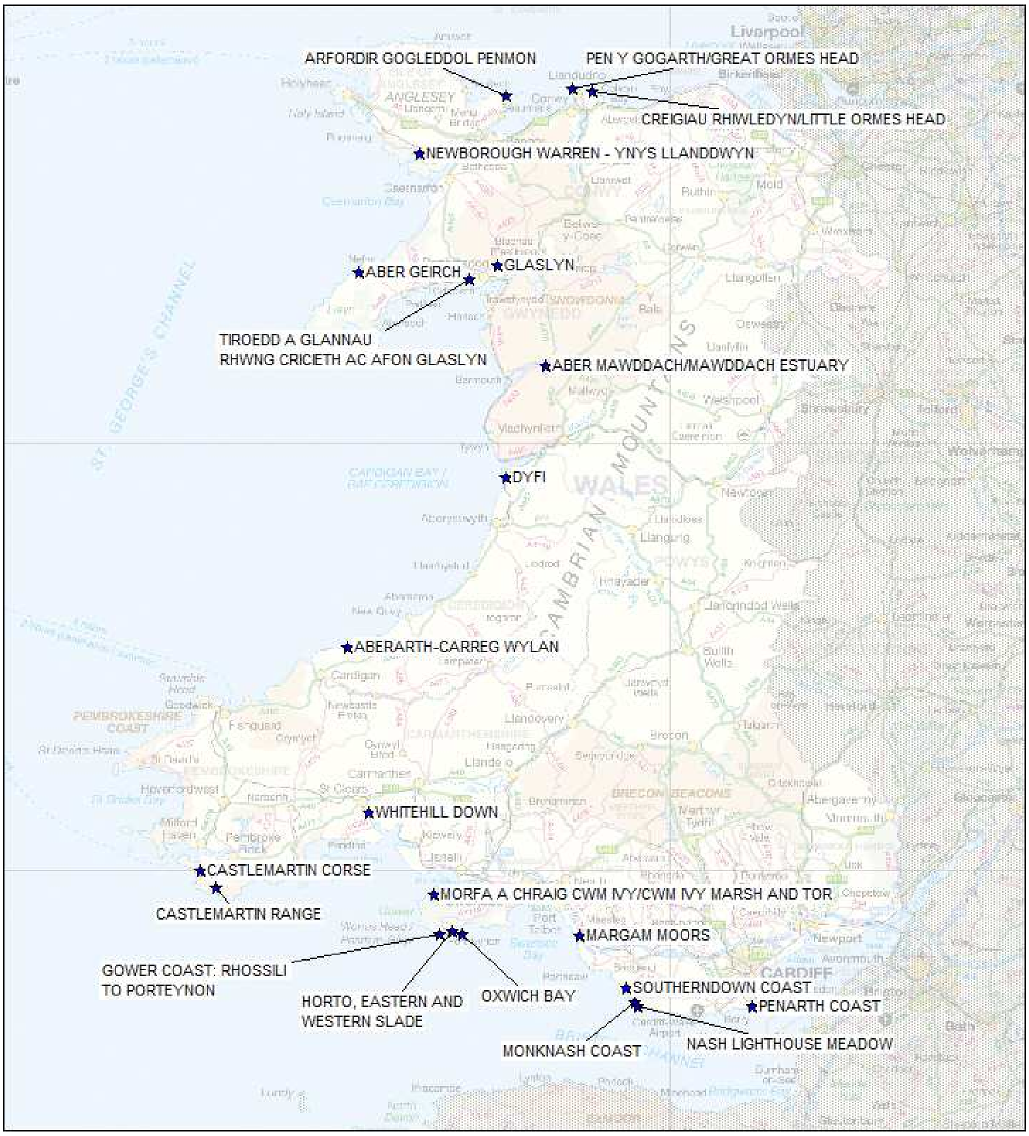


Figure 45. Coastal lowland grassland SSSIs with terrestrial grassland features at risk from storm damage. OS miniscale 1:1,000,000 raster with 100km grid, no relief. © Crown Copyright. All rights reserved. Natural Resources Wales Licence No. 100019741.

Calcareous grassland

Calcareous grasslands are disproportionally well represented close to the coast, due largely to the fact that much of the Carboniferous and other hard limestone bedrock in Wales is coastal. At most sites, the calcareous grassland habitat closest to the sea is situated on high cliff tops or slopes, as for example is largely the case at Great Orme's Head (Pen y Gogarth/Great Ormes Head SSSI) in Conwy. In some cases, however, stands of the habitat are distributed right up to the cliff edge and are therefore vulnerable to loss through cliff erosion e.g. at Castlemartin Range SSSI in Pembrokeshire (Figure 46). There have been no reports of this having occurred so far however.

Transitions from maritime grassland to terrestrial lowland grassland are particularly well-established on some of the Gower coast SSSI (Figure 47). There is a long-term risk here of expansion of the maritime grassland at the expense of highly valued terrestrial grassland should violent storm events become more frequent in the future (compounded by any rise in sea level). This could potentially be assessed during

SAC/SSSI monitoring, perhaps with more focus on transitional zones. It should be noted, however, that such transitions are dynamic by nature, and the effects of one year's storm events may not be significant. Any significant shifts in broad habitat patterning will need time to become clear.

Figure 46.Lowland grassland reaching cliff edge, Castlemartin Range SSSI, Pembrokeshire (Stuart Smith).

Figure 47. Terrestrial to maritime grassland transitions, Gower coast, West Glamorgan (Stuart Smith).

Neutral grassland

Only a very small proportion of unimproved neutral grasslands in Wales are located close to the coast, although some particularly uncommon forms of the habitat are at risk. For example, the largest known area (in Wales) of the National Vegetation Classification (NVC) community *Cynosurus cristatus – Caltha palustris grassland* (MG8) occurs just beyond the sea wall at Malltraeth Cob on Anglesey (Newborough Warren – Ynys Llanddwyn SSSI) (Figure 48) and would be vulnerable to any breach.

Some examples of the scarce MG5b sub-community (*Cynosurus cristatus – Centaurea nigra palustris grassland, Galium verum sub-community*) are located on cliff tops at Castlemartin Range SSSI (Figure 46) and on coastal slopes on a few SSSIs in South Glamorgan, among them Monknash Coast SSSI. With an estimated loss of between 1 and 2m of tufa and limestone cliff at Cwm Nash (part of Monknash Coast SSSI; Figure 49), there has been a loss of maritime grassland here, but it is yet unclear whether adjacent stands of MG5b have been affected.

Figure 48. MG8 grassland behind sea wall at Malltraeth, Anglesey (Stuart Smith**).**

Figure 49. Cliff erosion in winter 2013/14 threatening MG5b sub-community of vegetation at Cwm Nash, South Glamorgan (Christina Byrne, Natural Resources Wales)

Acid grassland

A fairly small proportion of sites are by chance located such that they are potentially vulnerable to floristic change caused by to increased levels of salt-spray e.g. stands of NVC *Festuca ovina – Agrostis capillaris – Rumex acetosella grassland* (U1) at Mwnt, Ceredigion (Aberarth – Carreg Wylan SSSI) (Figure 50). There have been no reports of damage so far.

Marshy grassland

This is the most widespread of the species-rich grassland habitats on the coast, rush-dominated forms in particular often forming a component of coastal grazing marsh. Some examples are at risk of inundation by sea water e.g. within Glaslyn SSSI, where leakage of saline water through the sea wall over the years has led to the formation of transitions between maritime vegetation and terrestrial marshy grassland which is partly referable to the Habitats Directive Annex I habitat *Molinia Meadows on calcareous, peaty or clay-silt-laden soils (Molinion caeruleae).*

Significant damage to the sea wall, resulting in salt-water inundation, occurred at Cwm Ivy Marsh SSSI on Gower in winter 2013/14. This site supports a small marshy grassland and a much larger area of botanically less rich grazing marsh. The site is currently being considered for coastal realignment and it is as yet unclear if the breach will be repaired.

The sea protection at Newgale in Pembrokeshire was breached by sea water on at least three occasions in winter 2013/14 (Figure 51), notably in early February when the stranding of a bus hit the national news. Although not notified as a SSSI, the hinterland marshland is of high conservation value and is clearly very likely to have been adversely affected by the inundation.

Figure 50. Acid (U1) grassland vulnerable to salt spray at Mwnt, Ceredigion (Sarah Mellor, National Trust).

Figure 51. Inundation of terrestrial grassland habitat at Newgale, Pembrokeshire (Jon Hudson, Natural Resources Wales).

Coastal grazing marsh

There does not appear to have been widespread saltwater inundation of coastal grazing marshland in Wales, with only a few reports of significant breaches, including Cwm Ivy (above). Other areas of grazing marsh flooded include: Mostyn Dock to Greenfield in Flintshire (partly in Dee Estuary SSSI) and Morfa Madryn (see Figure 20) in Gwynedd, the latter in an area already planned for future coastal realignment.

8.1.3 Species

Marine Invertebrates (Paul Brazier, Natural Resources Wales)

Effects on marine species have largely been recognised in the section on the effects on marine (intertidal and subtidal) habitats.

At Nash Point, there is evidence of limpets being fractured and damaged by stones thrown around during the storm (Figure 52). It is quite possible that this has happened in many places, but post-storm observations of topshells and winkles suggest that they have held their position on the rocky shores and have not been swept off their preferred habitat. At Aberffraw however, rocky promontories adjacent to the sandy bay have been scoured of limpets, barnacles and mussels, leaving areas of bare rock.

Figure 52. Damaged limpet *Patella vulgata* at Nash Point (Dave Johnston, Natural Resources Wales.15th Jan 2014).

The geographically-restricted biotope that is characterised by the amphipod crustacean *Pectenogammarus planicrurus* may have been hard hit by the changing levels in gravels and pebbles at Aberystwyth and Pwllheli.

A very limited view of the effects on the subtidal species is given by the various reports on the content of the strandline in days after the storm. There were numerous strandings of live sea cucumbers *Thyone fusus*, otter shells *Lutraria lutraria* and whelks *Buccinum undatus*, particularly at Morfa Dyffryn, Dinas Dinlle, Newborough Bay, Aberffraw and Gronant (Figure 19).

Summer surveys at a regular monitoring site on Sarn Badrig (St Patrick's Causeway) have discovered considerable changes to the communities on the boulders, cobbles and pebbles, giving the impression that the seabed has been harrowed. Large boulders still maintain the turf of seaweeds, sponges, hydroids and bryozoans, but the perennial species are largely absent from the smaller substrata, as a result of the scouring effect of being moved by wave action. The substrata appear to be less embedded into the sand and gravel matrix, and might therefore take some time to settle down. Some patches of the sarn appear to have elevated sand levels, with some of the seaweeds sticking out from within the sand and patches of anoxia that form where the seaweeds are buried and dying.

Terrestrial invertebrates (Mike Howe, Natural Resources Wales)

Terrestrial and freshwater invertebrates associated with sand dunes, coastal soft cliff and shingle beaches have evolved to cope with these dynamic and often inhospitable habitats. Indeed, most of the specialist species on sand dunes (70%; Howe *et al*. 2012) and soft cliffs (86%; Howe in prep.) are associated with pioneer conditions (Tables 1 & 2) and are highly dependent upon periodic erosion events. However, as the extent of these habitats has declined and the remaining resource has become increasingly fragmented, populations of these specialists have experienced concomitant declines and are becoming increasingly isolated. This makes them particularly vulnerable to large-scale events and less able to re-colonise after experiencing local extinctions.

Table 1. Habitats utilized by Welsh dune invertebrate specialist species. Text in blue indicates pioneer habitats and species numbers. From Howe *et al*. 2012.

Dune Habitat	No. of Species
Strandline & Driftwood	26
Beach Flora (*Cakile, Beta, Agropyron*)	7
Marram	35
Bare & Sparsely-vegetated Sand	194
Pioneer Dune Slacks	33
Mature Dune Slacks	18
Dune Grassland	65
Dung & Fungi	24
Ruderals & Bramble	7
Scrub & Carr	15
TOTAL	424 (295)

Table 2. Habitats utilized by UK invertebrate species restricted to coastal soft cliffs. Text in blue indicates pioneer habitats and species numbers (Howe in prep).

Habitat	No. of Species
Bare ground	5
Tallus	1
Pioneer vegetation	12
Rank vegetation	1
Seepages	4
Pools	3
Reedbeds	2
Fen	1
TOTAL	29 (25)

On dune systems, the widespread loss of beach sand, strandlines, embryonic fore dunes and frontal dunes will have had a major, if hopefully temporary, impact upon their associated invertebrate faunas. The deposition of cobble and other coarse materials at the beach heads may hinder, or even prevent, the successful emergence of adults over-wintering under the substrate that have survived the more immediate loss of habitats. Species associated with large accumulations of driftwood may be lost to the inadvertent clearing up of materials taken inland and deposited within the dunefield. On coastal soft cliffs, large-scale erosion has resulted in the loss of pioneer vegetation and temporarily effaced hydrological features such as seepages and pools.

Key species and assemblages at risk are given in Table 3 and short accounts for the most seriously threatened are given below. Many other invertebrates, either components of assemblages on SSSIS or not subject to any protection or management measures, will also be at risk. Soft cliff associates such as the craneflies

Idiocera bradleyi (Creigiau Gwbert, Porth Nefyn, Traeth y Mwnt) and *Symplecta chosenensis* (Great Orme, Gwydir Bay, Porth Ceiriad, Porth Nefyn, Porth Neigwl, Porth Pistyll, Traeth y Mwnt), the beetles *Ochthebius poweri* (Cwm Col-Huw, Ffontygari Cliffs, Whitesands Bay) and *Tachys micros* (Porth Neigwl), and the Black Headed Potter Wasp *Odynerus melanocephalus* (Porth Ceiriad, Porth Neigwl, Porth Pistyll, Porthkerry) are vulnerable to at least localized extinctions. Species associated with driftwood, the strandline (the spiders *Argena patula* and *Haplodrassus minor*) and beach flora (e.g. Sand Dart *Agrotis ripae*, the flea beetle *Psylliodes marcida*) are likely to have suffered the greatest impact.

Table 3. SSSI Qualifying features at risk from large-scale changes to the coastline in Wales. Species in blue are highlighted in the accompanying text.

Species/Assemblage	Vernacular Name	No. SSSIs as Q feature	SSSIs/Sites at risk	Remarks
Agroeca dentigera	a spider	1	Ynys-las Dunes	Only UK population
Chrysolina sanguinolenta	a leaf beetle	1	Poppit Dunes	Only Welsh population
Eurynebria complanata	Strandline Beetle	5	Castlemartin Range, Crymlyn Burrows, Merthyr Mawr Warren, Pembrey Coast, Whiteford Burrows.	In UK, confined to Severn Estuary & Bristol Channel. Associated with the strandline.
Luperina nickerlii gueneei	Sandhill Rustic	3	Dee Estuary, Gronant Dunes & Talacre Warren, Newborough Warren.	*L. nickerlii gueneei* mostly confined to dunes in north Wales. Associated with *Elytrigia juncea* in embryo dunes.
Lycia zonaria	Belted Beauty	1	Morfa Conwy	
Osmia xanthomelana	Large Mason Bee	1	Porth Ceiriad & Porth Neigwl	
Paludinella littorina	Lagoon Snail	2	Lydstep Head to Tenby, Stackpole	Restricted distribution in the UK
Panagaeus crux-major	Crucifix Ground Beetle	1	Pembrey Coast	Not recorded since 1998
Podalonia affinis	a sand wasp		Gronant Dunes & Talacre Warren	Only Welsh population
Pseudomogoplistes vicentae	Scaly Cricket	1	Marloes Sands	Only Welsh population
Sitona gemellatus	a weevil	1	Porth Dinllaen i Borth Pistyll	Only Welsh population
Vertigo angustior	Narrow-mouthed Whorl Snail		Oxwich Bay, Pembrey Coast, Whiteford Burrows	
Coastal Assemblage		9		
Dune Assemblage		15		
Saltmarsh Assemblage		1		
Soft Cliff Assemblage		2		

Sandhill Rustic

The Sandhill Rustic moth *Luperina nickelii gueneei* (Figure 53) is associated with coastal dunes in north Wales, the Wirral and south Lancashire (Sefton and Fylde) where larvae feed on the rhizomes of Sand Couch *Elytrigia juncea* growing in pioneer dune habitats in the fore dunes, on shingle ridges and in transition zones between saltmarsh and dune (Figure 54). This habitat is dynamic in nature and prone to periodic losses and gains from coastal erosion and accretion. Severe winter storms can destroy significant areas of breeding habitat but such losses are typically offset by the development of new areas of habitat as new ridges and areas of embryo dune are created. Optimum habitat is a flat-topped, low mound dominated by a stand of Sand Couch, which is normally, but not essentially, inundated by the highest tides and where Sand Couch is the dominant plant species and bare, loose, unsaturated sand predominates underneath, sometimes with significant amounts of shingle. Eggs are laid in groups in the leaf sheaths in August/September, and caterpillars hatch soon afterwards and mine down the stem. If they survive the winter, larvae emerge from the bottom of the stem in spring and start feeding on the root crown, later moving out along the nutritious rhizomes. They pupate in July and emerge as adults from mid-August to early September.

Figure 53. Sandhill Rustic *Luperina nickerlii* © Adrian Spalding.

With significant losses of beach sand and embryo dune habitat, and the localized deposition of cobble and shingle at the beach heads and into the frontal dunes, this species may have suffered severe losses as a consequence of the winter storms.


Figure 54. Sites at Newborough Warren supporting breeding populations of Sandhill Rustic in 2010 (see Wallace, 2011). These areas have been lost during the winter storm surges.

Belted Beauty

The Belted Beauty moth *Lycia zonaria* (Figure 55) is restricted to Morfa Conwy in Wales, with only two populations in England (Wirral and Lancashire). The Welsh population has been declining steadily over the last 15 years as pioneer dune grassland has developed into a ranker sward, causing the build-up of a humic layer and a reduction in the preferred foodplants of the larvae, Common Bird's-foot-trefoil *Lotus corniculatus* and Yarrow A*chillea millefolium*. Small-scale management interventions (excavations to expose sand) have failed to arrest declines and counts of adult moths have been in single figures since 2006 with the last record, of a single male, in 2012. Attempts to establish populations on Kinmel Dunes and Newborough Warren have been unsuccessful.

Previous observations at The Meols on the Wirral (where the population has recently been lost) demonstrated that adult emergence was encouraged by seawater incursion onto the dunes. Tidal surges and incursions onto the fore dunes at Morfa Conwy in winter 2013-14 may have been expected to elicit a similar response from any remnant population but no adults were found during the flight period in 2014. Worryingly, the loss of frontal dunes and areas of pioneer dune grassland and the deposition of cobble, brick and concrete over one of the last breeding sites (Figure 56) significantly reduces the remaining areas of suitable habitat.

Figure 55. Male of Belted Beauty *Lycia zonaria* © Adrian Fowles, Natural Resources Wales.



Figure 56. The loss of frontal dunes and deposition of cobble at Morfa Conwy, March 2014 (Mike Howe).

Strandline Beetle

The UK distribution of the beetle *Eurynebria complanata* (Figure 57) is restricted to the Severn Estuary and the Bristol Channel where it it associated with strandlines on sandy beaches backed by dunes. Whilst adults are nocturnal and are thought to feed exclusively on sand hoppers, little is known of the life cycle of this species and its ovewintering stage and localities are unknown, although Hyman (1992) suggests that “adults move inland into dune areas”. If the species overwinters under sand at the head of sandy beaches, the loss of beach sand and embryo fore dunes will have had an adverse impact upon populations at all its Welsh stations.


Figure 57. Adult of the Strandline Beetle *Eurynebria complanata* (Mike Howe).

Crucifix Ground Beetle

The beetle *Panagaeus cruxmajor* has been recorded from two Welsh localities, Llanrhidian Marsh on Gower in 1915 and Tywyn Burrows (part of Pembrey Burrows) in Carmarthenshire from 1985 to 1998 (Entotax Consultants 2000). The Tywyn Burrows population was centred on a relatively new dune slack, supporting a suggestion that the beetle is an early colonizer, prefering sites in an early establishment phase and utilizing them for a limited period of time unless disturbance arrests or delays natural succession. Overwintering adults are probably prone to flooding. Since the last record, much of the dune slack has been lost, with a 25 to 30% reduction in September 1998 when the sea breached the dunes and inundated the southern section of the dune slack. A retreat of the dunes of up to 20m in winter 2013-14 will have resulted in the loss of any remnant slack and a reduction in beach levels may have impacted upon any remaining adult population.

Large Mason Bee

Until its discovery at Porth Ceiriad and Porth Neigwl in 1998 and 1999 respectively, *Osmia xanthomelana* (Figure 58) was thought to be extinct in the UK after its last breeding locality on the Isle of Wight was lost to a landslip in 1994. The Welsh localities support small populations (maximum counts of 40 females at Porth Neigwl and 20 at Porth Ceiriad), which are associated with cliffs of glacial sand & till and perched dunes, nesting in sandy banks, lining the nests with fine muds collected from cliff seepages and foraging on Common Bird's-foot-trefoil *Lotus corniculatus*. Whilst periodic erosion helps to maintain breeding sites and a trefoil sward, the populations are at risk from large-scale erosion events. Because of the vulnerability of the population at Porth Neigwl, with the majority of nests occurring in a very small landslip near the cliff edge, 16 sand banks were excavated in the perched dunes further inland in January 2011 and these now support small numbers of breeding females (Clee 2011).

The collapse of a large section of the soft cliff at the western end of Porth Ceiriad this winter will have resulted in the loss of a large proportion of the population. At Porth Neigwl, the loss of large areas of forage on eroded cliff faces, the temporary loss of seepages and the near collapse of the main breeding locality (Figure 59) may have had a long-term impact upon the population. Surveys in summer 2014 have revealed that the bee has survived at both sites, although in reduced numbers with maximum counts of adult females of five and 20 at Porth Ceiriad and Porth Neigwl respectively (Carl Clee pers. comm.).

Figure 58. Large Mason Bee *Osmia xanthomelana* © Mike Hammett

Figure 59. The further collapse of the main breeding area for the Large Mason Bee at Porth Neigwl. This small area (at the bottom of the picture) has supported more than 50% of the breeding females and is now precariously perched on the cliff top (Mike Howe).

Scaly Cricket

Following its discovery on the shingle beach below the cliffs at Marloes Sands, Pembrokeshire in 1999, *Pseudomogoplistes vicentae* is known to occur here in reasonable numbers although suitable habitat is restricted to 0.6km of beach (Hudson 2007). Wider searches have failed to locate additional Welsh populations. Scaly crickets usually occur above the high tide mark of shingle beaches, among shingle and under rocks and strandline debris. There is little available information on the ecology of this species but it must over-winter under the shingle substrate at the head of beaches. If there has been a significant loss of beach sand and substrate, then its continued presence at Marloes Sands may have been affected.

Fish & Shellfish (Catherine Duigan, Natural Resources Wales)

For offshore fish, it seems to be assumed from literature sources that the effects of storms are minimal, although no definitive evidence has been identified. However in shallower coastal waters and estuaries, storm conditions are likely to compete with natural currents and flows, and have an increased impact. These impacts have been most dramatically illustrated in hurricane conditions and a number of specific examples were reported after Hurricane Sandy which hit the north-east coast of the US (Midway 2010).

Critical fish habitat for feeding and breeding, such as floodplain habitat, marshes and estuaries, experienced inundation by flood waters, with sea water intrusions during the storm, often followed by rapid freshwater flushing as rainfall inland reached the coastal areas. Under these conditions, fish at different life stages will experience sudden changes in salinity which is likely to have physiological effects or cause the fish to be displaced upstream or downstream. In addition high volumes of freshwater entering coastal habitats can be particularly threatening to estuarine fish as the less dense freshwater floats on top of the denser salt water. Midway (2010) suggested that this stratification essentially restricts estuarine and saltwater species, often in conditions of low oxygen as minimal mixing between the two water bodies takes place. In one of the small number of studies on hurricane effects on fish, Houde *et al*. (2005) documented notable distributional shifts in species in Chesapeake Bay after Hurricane Isabel in

2003. A large number of freshwater species, including *Alosa* sp., were documented in the main stem of the bay after the hurricane, likely the result of high flows, while high abundances of Bay Anchovy and Atlantic Croaker observed in the lower portion of the bay can be explained storm surge. Large fish kills were reported in Everglades National Park following Hurricane Andrew and the Pascagoula River after Hurricane Katrina with depleted oxygen levels in coastal waters implicated as the possible cause (Schaefer *et al*. 2006, Tilmant *et al*. 1994). Hurricane Irene and Tropical Storm Lee generated extreme flooding in the Delaware River watershed that produced prolonged bay-wide low salinity and consequent historically-high mortalities for the oyster stock in the upper reaches of Delaware Bay (Munroe *et al*. 2013).

In the longer term, Calloway *et al*. (2012) predicted that changes in rainfall patterns will increase the turbidity and nutrient loading of rivers, potentially triggering harmful algal blooms and negatively affecting bivalve farming, and presumably natural shellfish beds, such as mussels and cockles. Estuarine fish communities would also experience sudden changes in salinity. In addition, ocean acidification may disrupt the early developmental stages of shellfish.

There were no reports of significant number of fish being killed during the Welsh storms but it could be suggested that we need to remain vigilant in the context of experiences from other regions. However there are photographic records of individual fish being beached. The 12lb cod found on the 3rd green of the Porthcawl Golf course featured in the media (Daily Mail news article 2535183). While an individual Pearlside *Maurolicus muelleri* (Figure 60) found in January on the beach at Llanystumdwy represents the second Welsh record; the first record was one stranded alive on the Gann Flats, Dale, Pembs. in April 1969 (Doug Herdman, pers. comm.). They are considered to be a mesopelagic fish normally found between 100 and 500m and reasonably common in deeper water. There were some reports of mass strandings in NE Scotland and near Yarmouth in the 19th century, then very little until 2006-2009 when a number were found in the Isles of Scilly and adjacent Cornish coast. Individuals have also turned up in Ireland and Scotland (Doug Herdman, pers. comm.). However, the recording of a number of them on the cooling water intakes at Hinkley Point some way up the Severn Estuary suggest that they probably occur in South Wales waters.

Callaway *et al*. (2012) concluded that, at the moment, there is sparse evidence to indicate that climate change is affecting aquaculture in the UK and Ireland. However, they recognised that marine aquaculture relies on coastal habitats that will be affected by climate change in the future. For example, changes in the frequency and strength of storms pose a risk to aquaculture infrastructure, such as salmon cages. This impact is comparable to the claims of Welsh fisherman of damage to fishing gear, especially pots for catching lobsters, whelks, prawns and crabs, during the recent storms. In response, the Welsh Government has announced the establishment of a gear replacement scheme. It was also reported that the Welsh inshore fishing industry lost income because boats were unable to go to sea during the bad weather. It is not possible to predict if such extreme weather situations could amount to a significant change in seasonal fishing pressures on fish stocks. The IMCORE (Innovative Management of Europe's Changing Coastal Resource) Project (2011) recognised that extreme events can impact on commercial fishing. The main conclusions were that small fishing vessels will be most affected as they will be unable to travel and that damage to fishing gears leading to ghost fishing could be anticipated. The potential biological effects were mixed in terms of benefits and impacts on fish breeding cycles and breeding habitat.

Shellfish, such as crabs and lobsters, seem particularly vulnerable to displacement and beaching during storms. Following a storm on the east coast of England in late March 2013, crabs and lobsters, most of which were dead, were found along the beach between Barmston and Fraisthorpe. There are also some anecdotal reports that Welsh lobster catches are reduced since the storm, with beaching of associated sub-tidal fauna recorded. In the longer term, Calloway *et al*. (2012) predicted that sea-level rise will shift shoreline morphology, reducing the extent of some habitats that are suitable for the industry, and by implication specific fish species. Other sections of this report will illustrate how extreme weather events are capable of being agents of this change. It is possible that storms may also play a role in the translocation of fish diseases, parasites and pathogens, and the spread of nuisance and non-native species.

In the context of the Welsh storm, it can be concluded that:

i. estuaries and their fish species may become a particular environmental pressure point under storm conditions;
ii. there are components of our fish populations which are likely to be sensitive to the impacts of storms, especially migratory species such as shad and salmon which have to pass through estuaries, and shellfish which are vulnerable to beaching;
iii. fishing gear is likely to be damaged and this will have knock-on effects on fishing activity and increase the incidents of ghost fishing.

Accepting that severe weather is likely to be an expression of climate change, these observations and considerations after the Welsh storms show that there are potential implications for fish, including their survival, distribution and behaviour. Ultimately, the effects of a specific storm on fish species are likely to vary considerably and be determined by factors such as storm strength and storm timing, location, fish population status, water quality and habitat type and condition.

It is worth noting that the larger and long-term effects of climate change on fish (fin and shellfish), fisheries and aquaculture were the subject of a Marine Climate Change Impacts Partnership report card (2012) with the supporting evidence base published in the scientific literature (Callaway *et al*. 2012, Cheung *et al*. 2012, Frost *et al*. 2012, Heath *et al*. 2012). The key messages from these sources should form the basis for the future consideration of the potential effects of coastal storms on fish populations. The report card stated with high confidence that 1.) there are clear changes in the depth and latitudinal distributions, and migration and spawning behaviours of fish, many of which can be related to warming sea temperatures; and 2.) for fisheries and aquaculture there will be both opportunities and threats. Medium confidence was associated with the impact on the integrity of marine food webs if key species are disrupted. Increased frequencies of storms and severe weather are likely to contribute to these scenarios and add to the challenges associated with the management of fisheries and aquaculture resources and any restoration efforts, such as oyster bed reinstatement.

Figure 60. Pearlside *Maurolicus muelleri* (Rowland Sharp, Natural Resources Wales).

Mammals (Tom Stringell, Natural Resources Wales)

For the purposes of this report, we consulted the UK Cetacean Strandings Investigation Programme (CSIP) and concluded that there is no clear evidence of increased strandings in Wales of any marine mammal species as a result of the recent winter storms.

However further south, young grey seals regularly arrive on the shores of North Portugal and NW of Spain when big storms occur in winter, but usually numbers are about 8, and they arrive exhausted. This year around 30 have been found on the Basque coast to South Portugal coast. The young seals found on the Basque coast are assumed to come from French colonies, but Galician (NW of Spain) and Portuguese seals are thought to originate from Ireland, Wales and SW England colonies (Gemma Hernandez-Milian 2014 in litt). In addition, Evans *et al*. (2005) suggest that large-scale climatic events provide a powerful distal influence on the propensity for whales to strand in southeast Australia, so it could be useful to analyse mammal strandings in the context of storm indices and changing weather patterns.

Birds (Gareth Cunningham, RSPB & Tim Birkhead, University of Sheffield)

Our assessment of the impact of the storm events on birds was compiled from two special submissions from Gareth Cunningham of the Royal Society for the Protection of Birds (RSPB) derived from a recent beached birds survey and an assessment of the bird wreck by Tim Birkhead, University of Sheffield.

Beached Birds Survey (Gareth Cunningham, RSPB)

On 24th February 2014, the RSPB undertook its annual beached bird survey, with data also collected a week either side of this date too. The beached bird survey is an international scheme to monitor bird mortality around the coast. 700 RSPB volunteers cover more than 1500 miles of coastline around the British Isles, with many others performing similar surveys on North Sea coasts in other countries.

Whilst the records gathered so far indicate this is potentially one of the most severe winters on record, it is unlikely that the full impact will be reflected within the Welsh populations for a number of years. The annual nesting bird counts will help give an indication of whether the mortalities were predominately adult birds or more recent fledglings.

The results from Wales for the 2014 beached bird survey are recorded in Column 1 in Table 4. In addition, RSPB collated a number of records from members of the public and other coastal organisations, such as staff at Kenfig NNR and The National Trust on Gower. These records are shown in column 2 and were combined to give an overall impression of the species most impacted (column 3 and Figure 61).

Table 4. 2014 Beached bird survey and public records combined.

Species	Survey Record Totals	Public Record Totals	Combined Totals
Black Headed Hull	4	0	4
Common Gull	5	3	8
Cormorant	1	0	1
Curlew	1	0	1
Fulmar	1	2	3
Gannet	1	2	3
Great Crested Grebe	1	0	1
Great Northern Diver	1	0	1
Greater Black Back Gull	1	0	1
Guillemot	222	264	486
Herring Gull	9	1	10
Kittiwake	52	16	68
Manx Shearwater	0	1	1
Oystercatcher	5	0	5
Puffin	13	16	29
Red Breasted Merganser	1	0	1
Razorbill	288	665	953
Shag	3	5	8
small wader	1	0	1
unidentified gull	4	17	21
Totals	614	992	1606

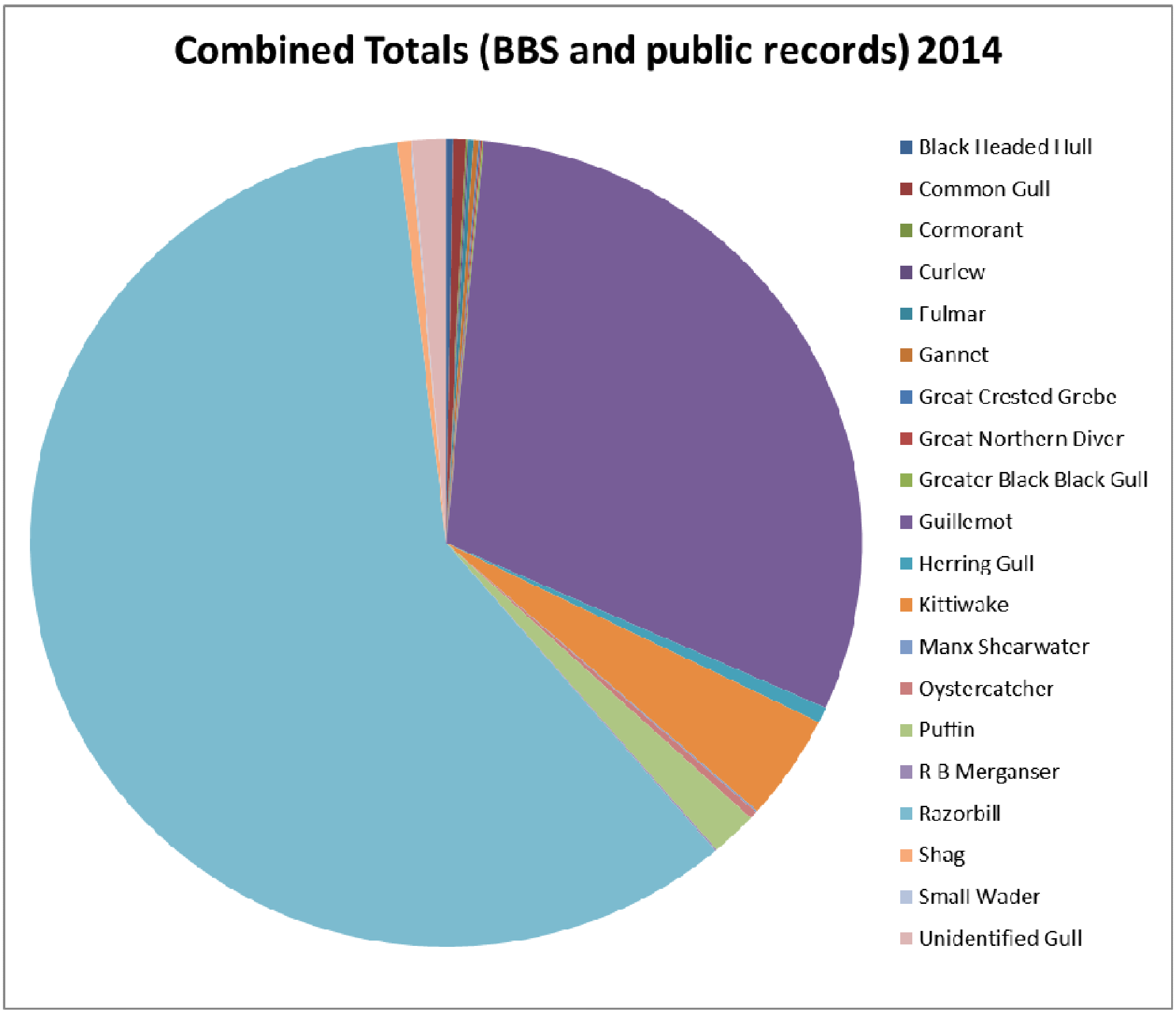


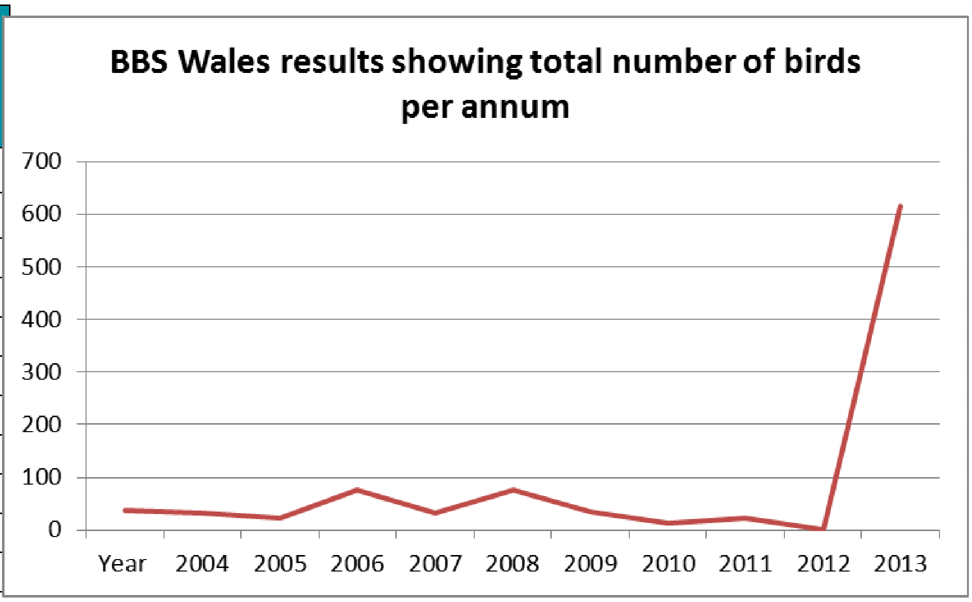
Figure 61. 2014 BBS and public records combined.

As the results demonstrate, species of auk and Razorbill *Alca torda* in particular, were most impacted by the winter storms, with Guillemot *Uria aalge* the next most impacted. A similar trend has been observed across the UK where auks were the most impacted taxon. A number of ringed birds were also recovered; we are awaiting results on the individual records to gain a better picture of their age and nesting location.

Finally, we compared this year's record (Welsh beached bird survey results only) with beached bird survey results from previous years (Table 5. Please note that this does not differentiate between species but compares the total numbers (of all species) found within a survey year.

Table 5. Beached bird survey results in Wales since 2004 & Chart 2: Beached bird survey Wales results showing total number of birds per annum.

Year	Total numbers beached birds (Wales only)
2004	37
2005	31
2006	23
2007	75
2008	32
2009	76
2010	34
2011	12
2012	22
2013	0
2014	614



The results indicate that, for Wales, the 2014 numbers are higher than the combined totals for all previous years, giving an impression of the severity of the storms and the impacts on Welsh seabirds.

Seabird Wreck (Tim Birkhead, University of Sheffield)

The persistent storms, comprising high winds, high seas and heavy rain during January and February 2014, were exceptional in their severity. The consequences for seabirds wintering on the western European seaboard have been severe, with a minimum of 32,000 dead birds recorded. Of these around 16,000 are Atlantic Puffins *Fratercula arctica*, and about 10,000 are Common Guillemots *Uria aalge*. The remainder include Razorbills *Alca torda* and a number of other seabird species. As the RSPB's 2014 report makes clear, dead birds were washed up along the coast from Iberia, France and western Britain. Autopsies confirmed that almost all birds were grossly underweight, suggesting that they had starved to death. Such massive mortalities of seabirds are rare, but not unknown, and are usually associated with extreme weather conditions (Newton 2014). The link between poor weather and poor body condition suggests that persistent bad weather makes the birds' prey (small fish and invertebrates) more difficult to locate and catch, and/or that seabirds have difficulty maintaining their energy balance under such conditions. Some of the birds found dead had evidence of oiling, but this was not the main cause of death for most birds.

The largest previous wreck in the Irish Sea occurred in September 1969 when around 12,000 Guillemots were found dead. As in 2014, there was no obvious sign of death, and autopsy of these birds suggested that PCBs might have been implicated (Holdgate 1971). However, it now seems more likely that the cause of the 1969 wreck was extreme weather and starvation associated with the fact that many birds were moulting (and hence flightless), and that the PCBs were released into the body as the birds metabolised their fat stores in the absence of sufficient food. Another major wreck occurred on the east coast of Britain in February 1983 following bad weather. Around 34,000 seabirds were affected, mainly Razorbills (16,000) and Guillemots (12,200) (Underwood & Stowe 1984). In February-March 1994 following stormy conditions, 50,000 birds, mainly Guillemots (20,000-50,000) and Shags (3000-5000) were washed up on the east coast of Britain (Harris & Wanless 1996).

In one sense, a ‘wreck’ caused by bad weather is a ‘natural disaster’, unlike an oiling incident. Yet the meterological predictions are that severe weather conditions – which result in wrecks - are part of climate change, and are likely to become more frequent.

The 2014 wreck was over by early April and the full effects on the breeding populations of the Pembrokeshire seabirds will not become apparent until the birds are back at the colony and breeding. However, there are early indications of the likely effects. The clearest of these is the very high number of recoveries of ringed birds found dead during the wreck (reported to the British Trust for Ornithology). There is also direct evidence from ringing recoveries that both Guillemots and Puffins ringed on Skomer have been killed in the wreck and again, for both species, the numbers of ringing recoveries are very high. Indeed, for the Guillemot, they are higher than any figure for the last forty years. We also know that the recoveries include birds of both pre-breeding and breeding age, so all age classes are involved. Some of the recovered Guillemots from Skomer had been ringed last year and were therefore less than one year old, but others were breeding adults (including one 28 year old bird).

Autopsies of 160 Guillemots from the wreck revealed that 80% were female: this could be because females are slightly smaller than males and therefore slightly more vulnerable to food shortage. This in turn may have unusual consequences at the colony if there are large numbers of unpaired male guillemots at the colony.

The ringing recovery data indicate that we will see a reduction in the breeding populations of both Guillemots and Puffins at Skomer in the 2014 breeding season. However, because Puffins are much more difficult to census than Guillemots, assessing the magnitude of the effect of the wreck will be more difficult than it is for Guillemots. A 40-year long database of Guillemot numbers, survival and breeding success and our understanding of how the population ‘works’ will enable us to assess the impact of the wreck on the population in considerable detail (Meade *et al*. 2012).

Counts of Guillemots are the most basic form of monitoring and will provide one form of assessment of the effect of the wreck. Those counts will be conducted in June 2014. However, on the basis of our previous work on Skomer, counts are much less sensitive measures of the effect of wrecks and oil spills than survival data (Votier *et al*. 2005). Once the birds start breeding (usually in early May) we will – using the population of marked individuals - be able to assess the overall reduction in survival as a result of the wreck. Based on past decades, average adult survival (from one year to the next) has been 95%. It is almost certain to be lower this year and it is important to recognize that even small a reduction in survival – for example down to 80% - can have a disproportionately large impact on average longevity. Our prediction is that with increased mortality from the wreck, many birds will have lost their partner. Guillemots are long-lived with an average breeding life of 20 years, but up to 35 years. They also retain their partner throughout their lives. This means than many birds will have to find a new partner. This may take one or more seasons and breeding success is almost always reduced when birds change partner; it then gradually improves as they get to know each other's idiosyncrasies. We therefore predict that Guillemot breeding success will be lower in 2014 (at least) than the average of 0.80 chicks/ pair that we have recorded over previous years.

Breeding success is partly determined by the timing of breeding, being greater with earlier breeding. Climate change has resulted in earlier breeding of Guillemots on Skomer, but the last few years have also seen much greater variation in the timing of breeding, with both the earliest and latest seasons ever in 40 years. Climatically, the spring of 2014 is an 'early' one so far, but it is difficult to predict whether Guillemots will breed earlier or later than normal. The effect of the severe weather conditions on the birds' body condition may result in later breeding as the birds take longer to build up their reserves.

One effect we expect to see as a result of the increased mortality, is a reduction in the age of first breeding. Most Guillemots breed for the first time at age 7. However, with many birds losing their partner, there may be opportunities for young birds to start breeding sooner than they otherwise would do. However, if most of the mortality has occurred among the pre-breeding guillemots, that is, those aged between 1 and 6, there may not be sufficient young birds for this to happen. If this is the case, it may take five years for the full impact of the wreck to be ascertained.

In brief, on the basis of our long term Guillemot study we can - at this stage of the season -make a number of informed predictions about how the increased mortality will play out at the colony. In addition, we can also collect the data to test those predictions, and provide a comprehensive report on the breeding season.

Postscript from Tim Birkhead 29/07/2014 - Guillemot data for breeding season 2014

This year's work suggest two types of effect: (i) the aftermath of the spring storms, but possibly also (ii) a longer term effect. Although 2014 was not a disastrous season in any sense for guillemots, the list of effects (below) together gives cause for concern.

This year:
(i) breeding was very late;
(ii) breeding success was lower than in many other years;
(iii) adult survival was very low - as predicted, because of the very large numbers of Skomer guillemots birds killed in the wreck (higher than in any previous year);
(iv) chick-feeding rates were very low (and the chicks were small at ringing), and;
(v) chick diet was relatively poor.

The study plot counts do not indicate any great loss of birds as a result of the wreck, but there are two possible reasons for this. First the margin of error on the counts is now quite high, and second, we suspect that young birds on detecting 'gaps' in the population (as a result of (iii) above,) spend more time on the breeding ledges. This reinforces my point that counts alone constitute a rather blunt monitoring tool.

8.1.4 Other Environmental issues- Litter and Access

Litter (Catherine Duigan, Natural Resources Wales)

Significant volumes of litter were deposited on the shore and further inland during the storm events ranging from small polystyrene beads and plastic fragments, to large plastic boxes and fishing nets. Litter can also be trapped and buried within dunes, and therefore may have been released through dune erosion. It is accepted that litter can cause harm to marine wildlife through entanglement and ingestion, and through movement across and smothering of the seabed. Fishing related debris was noted as a significant component of the 'litter' washed ashore. The fishing industry lost a significant amount of fishing gear into the environment during the storms. As a result, Welsh Government has made compensation available to enable gear to be replaced. There is therefore a potential opportunity to assess the scale of this issue through assessing the compensation claims submitted.

The most recent overview of marine litter in the UK was reported in Charting Progress 2 (CP2) – The state of UK seas (UKMMAS 2010). CP2 reported that an average of over 2000 items of litter per kilometre of UK beach surveyed was found over the period 2003 to 2007. There is evidence that there has been a considerable rise in the amount of litter. In 1994, 1045 items/ km surveyed were recorded and by 2007 this had risen to 2054 items/km surveyed. This equates to an increase of 96.5%. Most of this litter seems to come from the general public either through direct littering on beaches or through land-based litter being swept or blown onto beaches. Over the whole of the UK, fishing is consistently the second major identified source of beach litter, followed by sewage-related debris, shipping, fly tipping and medical uses. Plastic litter items remain the highest material source of litter in all UK sea regions.

Exposed Welsh waters and coastal areas seem to be accumulating a relatively high litter load. The Western Channel and Celtic Sea region (which includes Severn Estuary) shows the highest beach litter densities for the whole of the UK; with an average of just over 4600 items/km, well above the UK average. As well as high levels of public litter (average 1506 items/km) this region has extremely high levels of fishing and shipping litter (averages of 885 and 79 items/km, respectively). The reason for the high litter load on these beaches may be due to the high rates of tourism and fishing in this region, and increased input of shipping litter from the Channel through prevailing winds and currents. The Irish Sea beach litter densities (circa. 2500 items/km) are also higher than the UK average but exhibits little variation.

Offshore litter is ubiquitous in UK waters, but at generally low levels; 0-16.81 items/ha with densities of <1 items/ha found at the majority of sites. The significantly higher densities of litter found in Carmarthen Bay (16.81 items/ha), north Cardigan Bay (11.06 items/ha), Celtic Deep and Rye Bay, would suggest that these are areas of accumulation, i.e. litter sinks. In the period 2003-2008, Carmarthen Bay and north Cardigan Bay were considered the most impacted sites in the UK. However the data also suggest that weather conditions may play an important role in the accumulation of litter, particularly at the litter sinks where the sea is shallow and can scour out the accumulated litter. Maximum litter density is usually recorded after strong winds and gales, indicating that seabed litter is moved and washed ashore. The most frequent types of offshore litter recorded were polythene sheeting and bags, rope and polythene twine, followed by hard plastic and metal.

CP2 concludes that this level of marine litter is having a negative impact on achieving the vision of clean and safe seas. CP2 also recognises a need to further monitor and assess the level of harm caused by litter in the marine environment. Ongoing research is also starting to highlight the potential impact of microplastic pollution in the marine environment (Ivar do Sul & Costa 2013).

The environmental impact of marine litter will become more evident in the near future as it features as a descriptor which will be used for assessment of Good Environmental Status under the EU Marine Strategy Framework Directive. There is already a consensus that litter has economic, environmental and aesthetic impacts. Severe weather events, such as those recently experienced, exacerbated by the effects of climate change, are expected to drive more litter onto beaches.

Two different strategies are advocated as responses to marine litter – control at source and removal of material which has built up over the past 60 years since plastic has become expendable. The recent storms could be considered an opportunity to remove litter from the marine ecosystem.

Campaigns to Refuse, Reduce and Recycle plastics are part of international strategies to manage this type of waste. The carrier bag charging scheme in Wales could be seen as a proactive initiative to address source issues but there are additional options worth considering. In particular the KIMO Fishing for Litter Project has been operating in Scotland and South West England. With stakeholder buy-in litter which has been trawled up from the seabed is landed onshore with disposal facilities provided in port. This reduces the volume of debris which will be deposited on beaches and saves time for fishermen who have to untangling their nets. In addition the quantities of litter landed by region are reported.

Media reports following the Welsh storms suggest that significant efforts have been made by some Local Authorities and communities to remove beach litter from their local environment, with the support of the Marine Conservation Society and Keep Wales Tidy. However, we recognise that more could be done in future to support a co-ordinated effort, including guidance on disposal of litter and the natural materials that should not be removed. We also recognise that further consideration could be given to strategies to remove litter at source (e.g. a scheme to promote the recovery and disposal of old fishing gear) or as part of fishing efforts. Additional investment in diver-lead recovery of marine litter may also be an effective means of combating this problem.

Figure 62. Natural Resources Wales volunteers collect litter at Merthyr Mawr beach and dunes, 8th July 2014 (Duncan Ludlow, Natural Resources Wales).

Access

As reported in Natural Resources Wales' Coastal Review Phase 1 (Natural Resources Wales 2014a), there was significant damage to coastal defences, roads, street furniture, the rail network and hundreds of properties were flooded. There was also significant impact upon the Wales Coast Path, with damage recorded at over 70 locations along the 870 mile route and a repair bill of approximately £340,000. Significant effort has already gone into repairing and re-opening the path, but the impacts serve as a reminder of the challenges of maintaining such a route in the dynamic coastal environment. At the same time, it is this dynamic, dramatic and sometimes wild environment which makes the coast path such an important asset and attraction.

8.2 Annex 2- Records of Environmental Change

In January 2014, Natural Resources Wales staff and our partners were asked to submit records of known environmental change arising from the storm events of December 2013 and January 2014. The records received are listed in Table 6 below. The records included location, features affected, whether the change had occurred within a designated site and a brief description. This method of data collection was not exhaustive in terms of checking all designated sites around the Welsh coast and relied on *ad hoc* site visits.

Annex 1 provides a more detailed description of many of these records, as well as some additional records which have been received since 31st January 2014.

Table 6. Records of environmental change arising from the storm events of December 2013 and January 2014, which were submitted to NRW by 31st January 2014. These are illustrated in Figure 2 (main report). Designations: SAC - Special Area of Conservation; SPA - Special Protection Area, Ramsar - Wetland of International Importance, SSSI – Site of Special Scientific Interest. Other sites: NNR – National Nature Reserve, AONB – Area of Outstanding Natural Beauty, LNR – Local Nature Reserve.

			Features affected									Designations affected							
Location	OS Grid Ref.	Local Authority	Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site	Litter present	Comment	Source
Summer-house Point	SS990666	Vale of Glamorgan								X	X							Two small sections of coast path lost due to large cliff fall. Liassic cliffs affected.	Paul Dunn Glamorgan Heritage Coast
Col Huw	SS956675	Vale of Glamorgan	X															Beach pebble thrown up onto car park and surroundings.	Paul Dunn Glamorgan Heritage Coast
Cwm Nash	SS904701	Vale of Glamorgan	X					X		X					X			Cliff falls to tufa cliffs to west of stream outfall. Eroded eastern side of bridge. Damage and destruction	Paul Dunn Glamorgan Heritage Coast

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		to limpets on the shore.	
Dunraven Bay	SS884732	Vale of Glamorgan	X							X		X			X			Pebble beach thrown up onto car park exposing underlying clay beds, and damaging listed deer park wall, and car park. Slumping of cliff fall in shore dock area due to wave action and rainfall.	Paul Dunn Glamorgan Heritage Coast
Merthyr Mawr Warren	SS854768	Bridgend	X			X	X					X			X	NNR		Beach denuded of sand exposing bedrock in may places(approx 3km in length).Estimated 5m retreat of sand dunes across 2km resulting in dune cliffs approx 12' in height. Some cliffing of dunes along edge of saltmarsh.	Duncan Ludlow Natural Resources Wales
Porthcawl	SS82147672	Bridgend	X															Shingle storm beach pushed over the sea defence and defences partially undermined.	
Kenfig NNR	SS7880, SS7881 and SS7782	Bridgend	X		X		X					X			X	NNR		General loss of sand and shingle along upper beach and erosion back of dunes from 2 to 8 metres. Average loss about 2 metres of coastline. Track at Sker at SS78988017 washed away.	David Carrington Kenfig Nature Reserve
Rest Bay to Pink Bay, Porthcawl	SS80177838 to SS 79627927	Bridgend	X		X													Damage to coastal path boardwalk and fence to Royal Porthcawl Golf Club. Gravel and sand under boardwalk washed away in less	David Carrington Kenfig Nature Reserve

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		than 5 places undermining footing to boardwalk.	
Swansea Bay	SS628914	Swansea					X								X			Erosion of fore-dunes in Swansea Bay noted, Blackpill SSSI possibly affected but not designated for dune feature.	Becky Wright Natural Resources Wales
Rhossili Beach	SS414881	Swansea	X					X		X		X			X			The soft cliffs have slumped as a result of the storm surge and high levels of rainfall. The coast path has fallen on to the beach at this point and has been temporarily re-routed.	National Trust
Whiteford Burrows	SS480950	Swansea	X				X					X	X	X	X	NNR		Fore-dune ridges have been truncated at this sand dune systems. None of the dunes have been breached to such an extent to cause inundation of low lying land.	National Trust
Cwm Ivy	SS441933	Swansea							X		X				X			Damage to a medieval sea wall resulting in a temporary closure of the Wales Coast path. The wall is undergoing assessment to determine the suitability for repair or otherwise. Fences damaged and fields flooded.	National Trust
Pembrey	SS436994	Carmarthen					X					X	X	X	X			Fore-dunes have been eroded back to a former line, 2009-10.	Emmer Litt Natural Resources

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																			Wales
Amroth	SN16940714	Pembroke-shire									X	X			X			Small area of the road (approx 20mx5m) collapsed and a hole has been exposed where the sub-base (pebbles) of the road has been undermined and washed out immediately behind defences which have been displaced. Undermining of road mainly caused by damaged water main. Flooded fields.	Natural Resources Wales Pembrokeshire Team
Coppet Hall Beach	SN14030535	Pembroke-shire	X				X					X			X			Small dunes along approx 1/2 the length of beach (south) completely eroded. Dunes were approx 2.5m high and approx 3-4m deep. Landowner now applying for consent for new defences. Car park recently upgraded and landscaped and now at risk of being undermined	Natural Resources Wales Pembrokeshire Team
Tenby South Beach	SS124991	Pembroke-shire	X				X								X			Around 1500 m long of fore-dunes have been eroded back by several metres forming steep sand cliffs which will erode further.	Natural Resources Wales Pembrokeshire Team
Barafundle	SR976937	Pembroke-shire	X				X					X	X		X			Fore-dune ridges have been truncated at all of these sand dune systems. None of the dunes have been breached to such an extent to cause inundation of low lying land.	National Trust

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		Steps to beach destroyed and foot path needs to be re-routed.	
Broad Haven	SR976937	Pembroke-shire	X				X					X	X		X			Fore-dune ridges have been truncated at all of these sand dune systems. None of the dunes have been breached to such an extent to cause inundation of low lying land.	National Trust
Brownslade Burrows	SR889982	Pembroke-shire	X				X					X	X		X			Dune frontage receded by a few metres, dunes left undercut and will erode further. Large driftwood (tree trunks) carried 20m inland.	Natural Resources Wales Pembrokeshire Team
Freshwater West	SR884997	Pembroke-shire	X				X					X	X		X			Fore-dune ridges have been truncated at these sand dune systems. None of the dunes have been breached to such an extent to cause inundation of low lying land.	National Trust
Newgale	SM849214	Pembroke-shire	X								X							Pebble beach head moved inland by 5-10m. Shingle ridge pushed back several metres across A road. Impounding of flood water in Newgale Marsh river channel through shingle shifted and erosion to small area of soft cliff. Council have restored shingle and river to original position. Several metres of sand scoured from beach. Submerged forest temporarily exposed. Wood Farm fields	Natural Resources Wales Pembrokeshire Team

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		flooded. Tenant's campsite (not National Trust) flooded, presumed damage to drainage / WC block.	
Carfai Bay	SM760242	Pembroke-shire	X					X				X	X		X			Small scale landslip has undermined coast path where it goes down to a popular tourist beach leaving it inaccessible.	Natural Resources Wales Pembrokeshire Team
Whitesands	SM733271	Pembroke-shire	X				X					X						Small area (c.20 m) of dune front eroded. Several metres of sand scoured from beach. Submerged forest and glacial clays temporarily exposed.	Natural Resources Wales Pembrokeshire Team
Abermawr	SM882346	Pembroke-shire	X							X					X			Shingle ridge pushed back several metres and erosion to soft cliff (destruction of parts of Geological SSSI feature).	Natural Resources Wales Pembrokeshire Team
Gwbert spit	SN159485	Ceredigion	X				X					X			X			The overtopping has caused large valleys to form on the lee side of the spit with steep unstable tips. On the seaward side the spit has been smoothed out and the incipient steep "cliff" at the crest have been eliminated. At the root of the spit there has been as usual a hollowing out where the spit meets the groin. As the caravan park	Jenny Higgins Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		begins there has been a substantial overtopping and material has been moved inland lowering the height of the spit in this important area (vulnerable because it is largely old dune). The whole spit seems to have moved inland by 2 to 3 metres and possibly shortened. Procedures agreed (Countryside Council for Wales) for remedial actions to safeguard access to Cardigan Harbour. Base of paths leading down to foreshore - possible damage to steps associated with Ceredigion section of coast path, below Quay West caravan park.	
New Quay - Llanina Point	SN402596	Ceredigion						X				X			X			Sections of soft cliff have slumped with piles of clay at base of cliff. Not sure of the extent of the slumping and how much can be attributed to the January storms.	Jenny Higgins Natural Resources Wales
Aberaeron Harbour	SN455629	Ceredigion																Overtopping of both inner and outer harbour walls. Some local properties and businesses affected.	Jenny Higgins Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Llanon	SN250710 to SN266870	Ceredigion	X					X		X					X		X	Erosion to coastal cliff and partial failure of private coastal defences seaward of Plas Morfa Hotel which has spread rubbish (building material etc.) on to the beach. Building material/telegraph poles used by landowner to construct the coastal defence structure now on the beach.	Bob Mathews Jenny Higgins Natural Resources Wales
Llanrhystud	SN523689	Ceredigion	X															Storm surge removed large amounts of shingle south of Llanrhystud, lowering beach level. Revealed old roadway on foreshore. Reported to and investigated by Dyfed Archaeological Trust.	Jenny Higgins Natural Resources Wales
Tanybwlch	SN580796	Ceredigion	X		X										X			Overtopping and erosion at back of beach. Coast path affected.	Jenny Higgins Natural Resources Wales
Aberyst-wyth	SN583823	Ceredigion	X															Significant damage to promenade. Overtopping resulting in flooding of road and some beach front properties.	Jenny Higgins Natural Resources Wales
Clarach	SN587838	Ceredigion	X												X			Defences failed, overtopping, local flooding in caravan park.	Jenny Higgins Natural Resources Wales
Wallog	SN590857	Ceredigion	X					X				X			X			Loss of coast path. Beach moved	Jenny Higgins

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		back approx 8m.	Natural Resources Wales
Borth	SN607904	Ceredigion	X														X	Sand scoured from the beach leaving exposed peat layer.	Natural Resources Wales
Borth	SN607904	Ceredigion	X															Beach levels dropped. Overtopping.	Jenny Higgins Natural Resources Wales
Ynyslas	SN605924	Ceredigion	X				X			X		X		X	X			Damage of the wooden structure running north - south (alongshore), allowing upper shore shingle (cobbles) to flow into dune habitats and widespread flooding. A considerable drop in sand levels in the intertidal zone, resulting in exposures of peat.	Jill Bullen & Jenny Higgins Natural Resources Wales
Fairbourne	SH61051316	Gwynedd	X									X			X			Sand scoured from the beach leaving exposed peat layer. Old peat cuttings exposed. Coastal defence undermined.	Natural Resources Wales
Morfa Dyffryn - mouth of Ysgethin	SH516218	Gwynedd	X		X					X		X			X		X	Northward migration of shingle spit, closing off lagoon. River cut own new course out to sea. Caravan sites to south of river inundated.	Rhodri Dafydd Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Morfa Dyffryn - Talybont-Benar	SH516218 to SH568230	Gwynedd	X		X		X			X		X			X		X	Northward migration of shingle along beach, movement of shingle ridge inland, breached at some locations into dune blowouts. Boardwalks damaged, old fences uncovered.	Rhodri Dafydd Natural Resources Wales
Morfa Dyffryn - Benar - Shell Island	SH568230 to SH550260	Gwynedd	X				X			X		X			X	NNR	X	Natural erosion of dune along whole frontage (3.4km+). Subtidal bivalve *Lutraria* washed out in high numbers. Dead juvenile seal. Boardwalks damaged, old fences uncovered.	Rhodri Dafydd Natural Resources Wales
Morfa Dyffryn - Pensarn/ Llanbedr	SH579277	Gwynedd				X						X			X		X	Flood bank breached, agricultural land behind flooded.	Dafydd Roberts/James West Natural Resources Wales
Morfa Dyffryn - Llandanwg	SH568280	Gwynedd	X				X					X			X		X	Fore-dune ridges have been truncated at all of these sand dune systems. None of the dunes have been breached to such an extent to cause inundation of low lying land. Natural erosion of dune along whole frontage (600m+/-). Old fences uncovered	National Trust & Rhodri Dafydd Natural Resources Wales

			Features affected									Designations affected							
Location	OS Grid Ref.	Local Authority	Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site	Litter present	Comment	Source
Harlech	SH573296	Gwynedd										X			X			Concrete steps onto beach unsafe, Network Rail responsible, problem reported to them.	Molly Lovatt Natural Resources Wales
Morfa Harlech - beach frontage	SH574298 to SH557346	Gwynedd	X				X			X		X			X	NNR	X	Natural erosion of dune along whole frontage (3.4km+ with 10-15ft cliffing/slumping foredunes). Embryo dunes temporarily lost in this section. Further North, a shorter section (+/- 1.1km) with lesser degree of erosion (4-6ft cliffs, decreasing further north to no erosion at point).	Rhodri Dafydd Natural Resources Wales
Morfa Harlech - point	SH559342	Gwynedd	X				X			X		X			X	NNR	X	Accumulation of large amounts of seaweed, flotsam/jetsam etc where point curves towards estuary mouth. Otherwise dune formation/saltmarsh formation not thought to be impeded.	Rhodri Dafydd Natural Resources Wales
Morfa Harlech - Glan y Mor	SH577349	Gwynedd							X			X			X		X	Old wartime flood bank overtopped, sluices damaged. No damage to site features.	Rhodri Dafydd Natural Resources Wales
Morfa Harlech - Pont Briwet	SH618384	Gwynedd				X						X			X		X	Saltmarsh erosion accelerated (compounded by new bridge works and constriction of channel).	Natural Resources Wales & Hochtief Consultants

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Morfa Harlech - Maentwrog	SH6539	Gwynedd				X						X			X		X	Flood bank breached, agricultural land flooded.	Ian Hugheston Roberts Natural Resources Wales
Morfa Bychan – Porth-madog	SH562381	Gwynedd	X				X					X			X			Fore-dune ridges have been truncated at all of these sand dune systems. None of the dunes have been breached to such an extent to cause inundation of low lying land.	National Trust
East Criccieth, Morannedd area	SH507380	Gwynedd	X					X		X		X			X		X	Eroding boulder clay cliff - slumped material in front of cliff washed away and new vertical face of erosion. Increased sand levels around boulders at base of cliff.	Lucy Kay Natural Resources Wales
Criccieth	SH48583753	Gwynedd						X		X		X			X	AONB		Cliff eroded. To avoid large drop in path due to recent erosion the path has been redirected into field, two new gates installed, path fenced off and vegetation cut back.	Molly Lovatt Natural Resources Wales
Afon Dwyfor	SH483373	Gwynedd	X					X		X ?		X			X		X	Soft boulder clay cliff eroded and slumped in a number of places. Upper shore shingle (cobbles) and mid and upper shore sand removed from the site. Some loss of honeycomb reef (BAP habitat) from mid-shore. Coastal path compromised and closed for safety.	Paul Brazier Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Llany-stumdwy	SH46693734	Gwynedd	X					X		X ?		X			X		X	West of Afon Dwyfor towards Afon Wen. Soft boulder clay cliff eroded and slumped in a number of places. Fences and fence posts are suspended in mid-air. Large boulders (sea defence) for a property have been moved and house now closer to the sea. At least 10-12ft loss of garden/field at the side of the house. Pipe running through bank above high water now exposed and broken (running to property?). Some loss of honeycomb reef (BAP habitat) from mid-shore. A number of Guillemots washed up along the stretch of beach. Photos available.	Rowland Sharp Natural Resources Wales
Abererch	SH401358	Gwynedd					X					X			X	AONB		Sand-dunes eroded. Sand ladder in mid air, repair work needed to be re-installed. In locality of one of Pwllheli Flood Defence Strategy managed re-alignment options.	Molly Lovatt Natural Resources Wales
Pwllheli	SH357337	Gwynedd									X	X			X			Existing rock armour defence - wash out of sand behind. Temporary repairs implemented by Gwynedd Council. In locality of one of Pwllheli Flood Defence Strategy managed realignment options	Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Carreg y Defaid (west of Pwllheli)	SH34173287	Gwynedd									X	X			X			Existing rock armour defence - wash out of sand behind. Repairs implemented by Natural Resources Wales. In locality of one of Pwllheli Flood Defence Strategy managed realignment options.	Natural Resources Wales
Nefyn	SH30874117	Gwynedd						X				X			X	AONB		Landslip of soft cliff, this is a regular occurrence, we are looking at moving the path inland here.	Molly Lovatt Natural Resources Wales
Dinas Dinlle	SH43605626	Gwynedd						X		X					X			Previously slumped material has been largely washed away leaving clean faces. However, there has been some undercutting, and towards the southern end of the site there has been some new slumping.	Raymond Roberts Natural Resources Wales
New-borough	SH41536254	Ynys Môn					X					X			X	AONB		Approx 10m retreat of dunes along much of the shoreline. Loss of viewing platform constructed 2013 on area of dunes which had formed over past 15 years since sea last threatened beach car park. Some loss of conifers on to beach.	John Ratcliffe Natural Resources Wales
New-borough	SH41536254	Ynys Môn	X									X			X	AONB		Strand of sea cucumber *Thyone fusus* from near shore sediment flats in Caernarfon Bay.	Mo Gash via Paul Brazier Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Malltraeth	SH40806866	Ynys Môn									X	X			X	AONB		Seaward face of Malltraeth Cob embankment damaged - vegetation and surface sediments removed and bank cut in to adjacent to Telford doors.	Rob Jones via Sally Ellis Natural Resources Wales
Aberffraw	SH35306808	Ynys Môn	X				X			X		X			X	AONB	X	Approx 10m removed from dune frontage; 2 - 3m sand cliff remains. Likely to recover later in season. Sand dunes have been pushed back at the river mouth by a number of metres. Strand of live sea cucumber *Thyone fusus* and live otter shells *Lutraria lutraria.*	John Ratcliffe, Jacques Sisson via Paul Brazier Natural Resources Wales
Rhosneigr	SH32457219	Ynys Môn					X									AONB		Several metres of dunes eroded.	Sioned Jones via Sally Ellis Natural Resources Wales
Trearddur Bay	SH25577940	Ynys Môn	X															"the vertical wall of the promenade has caused a lot of sand to wash off the beach exposing more of the submerged forest etc. Aberystwyth on a small scale. Wales Coastal Path damaged."	Ivor Rees via John Ratcliffe Natural Resources Wales
Aber Alaw	SH31008217	Ynys Môn									X				X	AONB		Bank has eroded, requires some work to safely connect bridge to bank. Wales Coastal path affected.	Molly Lovatt Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Cemlyn Bay	SH33069324	Ynys Môn	X		X						X	X	X		X	AONB		Shingle pushed up the top of the ridge towards the lagoon; at the western end tongues of shingle just reach the edge of the lagoon and near the weir and footbridge there are new shingle deposits. At western end, shingle pushed inland in December 13 appears to have been washed over and further eroded by waves in Jan 14. Parts of the ridge now appear to be up to 50cm lower than sections either side. c 20 cm of Seakale roots on top of the ridge in this area have been exposed, indicating local reduction in ridge height. Eastern car park and end of approach road covered in shingle (Dec 13). Peak of shingle ridge has moved landward impacting on the salinity and water levels within the lagoon. The site is leased to the WWT.	Ivor Rees via North Wales Wildlife Trust and John Ratcliffe; also Sally Ellis, C Lindenbaum Natural Resources Wales & National Trust
Y Swnt, Moelfre	SH516866 to SH516867	Ynys Môn	X									X				AONB		Section of coast path running along edge of pasture adjacent to coast lost due to erosion of soft sediments. Owner has attempted some coastal defence here in the past and is keen to replace/reinforce defences.	Sioned Jones Isle of Anglesey County Council via Sally Ellis Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Morfa Madryn	SH65997380	Gwynedd / Conwy						X	X				X		X	LNR		Low bank over-washed, flooding into lagoons and wet meadows. Wales Coastal path severely damaged; 1-2 m of soft cliff removed. This area is planned for National Habitat Creation Project saltmarsh project; in time, requiring relocation of Wales Coastal Path, new protection to Network Rail line and probably compensatory Lapwing habitat. Pressure now to reinstate bank to maintain Wales Coastal Path link in interim.	John Ratcliffe Natural Resources Wales
Morfa Conwy	SH7614 7862	Conwy	X												X		X	Former tip exposed at base, may require further (shingle) protection - within SSSI.	Neil Smith Natural Resources Wales
Morfa Conwy	SH77287918	Conwy	X												X			Storm damage to fenced area protecting Belted Beauty Moth, implication for Wales Coastal Path, within SSSI.	Neil Smith Natural Resources Wales
Deganwy promenade	SH77617955	Conwy	X								X				X			May require stabilisation works within SSSI.	Neil Smith Natural Resources Wales
Llanddulas Tip	SH91477854	Conwy						X									X	May have implications for Traeth Pensarn SSSI in terms of what form of protection is used to protect toe of cliff, preferred long term	Neil Smith Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		solution is shingle beach feeding in respect of adjacent SSSI.	
Traeth Pensarn SSSI	SH93017828	Conwy			X										X			Additional erosion to vegetated shingle ridge - long term solution requires shingle beach feeding.	Neil Smith Natural Resources Wales
Barkby Beach Prestatyn to Prestatyn Gutter	SJ06798406 to SJ08988428	Flintshire			X	X	X					X	X	X	X	LNR		Damage to frontal dunes along most of frontage including to rock armour protection at Barkby Beach end. Loss of frontal dune habitat throughout most of section. Where dunes unprotected by shingle or hard protection more significant losses; Wales Coastal Path, boardwalk, fences, viewing platform affected.	Paul Day Natural Resources Wales
Prestatyn Gutter to Point of Ayr	SJ08988428 to SJ12708496	Flintshire					X					X	X	X	X			Loss of frontal dune habitat varies from 1m at western end to 10m+ at Point of Ayr. Frontal dunes at Point of Ayr now breached in about 4 locations allowing saline intrusion into area between two ridges. However water could access these areas through an existing route. Risk of more frequent flooding to these areas in future. Rear dunes regarded as main coastal defence.	Paul Day Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
																		Boardwalk, fencing, signs, lifebuoys affected.	
Ffynnon-groyw to Mostyn Dock	SJ14128198 to SJ15288111	Flintshire		X	X	X						X	X	X	X			Railway wall damaged and rail line closed. After first event Network Rail repaired their seawall by placing rock on the foreshore in front of the wall building up to the height of the former wall and placing sandbags behind where the wall has been lost. Loss of intertidal habitat and cockle shingle to rock armour. Fortunately the major bird roost on the cockle shingle has not been lost and birds seen roosting 16 January 2014.	Paul Day Natural Resources Wales
Mostyn Dock	SJ15288111 To SJ16088174	Flintshire		X							X	X	X	X	X			Loss of slag wastes along the Mostyn breakwater and hence erosion of this groyne structure.	Paul Day Natural Resources Wales
Mostyn Dock to Greenfield	SJ16188081 to SJ19987801	Flintshire							X		X	X	X	X	X			Coastal fields inundated including both in and outside SSSI. Rock armour on top of wall moved around. Wales Coastal Path affected.	Paul Day Natural Resources Wales

Location	OS Grid Ref.	Local Authority	Features affected									Designations affected					Litter present	Comment	Source
			Beach	Mudflat	Vegetated shingle	Saltmarsh	Sand dune	Soft cliff	Coastal grazing marsh	Geological	Other	SAC	SPA	Ramsar	SSSI	Other Site			
Greenfield to Bettisfield Colliery Bagillt	SJ20757704 to SJ21887597	Flintshire				X						X	X	X	X		X	Earth bank breached in three locations. Glass etc.; debris exposed at the former Clinks landfill. Erosion at upstream end of Bettisfield Colliery tip. Wales Coastal Path/fences affected.	Paul Day Natural Resources Wales
Panton Kop/ Lord Vivian's Embank-ment	SJ22427513 to SJ23797416	Flintshire				X						X	X	X	X			Seawall overtopped by wave action-stone protection on wall frontage largely intact but overtopping has washed out material behind leading to holes (3/4). Overtopping may cause death of Hawthorn bushes forming visual screen from walkers on Wales Coastal Path along this wall and bird populations on adjacent fields inland. Wales Coastal Path/fences affected.	Paul Day Natural Resources Wales
Castle Works Flint & Flint Point	SJ23797416 to SJ24627401	Flintshire		X							X	X	X	X	X		X	Likely loss of Leblanc waste into estuary as all weathered material has been scoured from faces. Flint Point (also Leblanc waste) important in maintaining position of main river channel.	Paul Day Natural Resources Wales
Wepre Gutter	SJ30316948 To SJ31576892	Flintshire									X	X	X	X	X			Flood bank behind saltmarsh breached and/or likely to breach but main embankment intact behind. Public Right of way affected in part.	Paul Day Natural Resources Wales

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