Cyfoeth Naturiol Cymru
Natural Resources Wales

Marine Ecosystem Resilience:

A review of the current understanding and opportunities for enhancement in Wales.

Report No: 520

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Mae ein cefnforoedd yn cynnal bywyd ac yn uno cymunedau mewn ffordd ddwys ac, eto, yn wynebu mwy o fygythiadau heddiw nag erioed o'r blaen mewn hanes. Maent yn dirywio o safbwynt iechyd yn sgil ôl troed cynyddol defnydd dynol a'r newid yn yr hinsawdd, ac er gwaethaf mwy o weithredu byd-eang yn ystod y blynyddoedd diwethaf i amddiffyn y cefnfor, nid yw hyn yn digwydd ar raddfa ddigonol (Laffoley ac eraill, 2020).

Arweiniodd galwad frys i weithredu'r Panel Rhynglywodraethol ar y Newid yn yr Hinsawdd y Cenhedloedd Unedig yn 2018, i fynd i'r afael â'r newid yn yr hinsawdd, at fudiad argyfwng hinsawdd cynyddol. Ymatebodd Llywodraeth Cymru a Senedd y DU gyda datganiad argyfwng hinsawdd yn 2019. Dilynwyd hyn gan adroddiad pwysig a gyhoeddwyd gan y Platfform Polisi Gwyddoniaeth Rhynglywodraethol ar Wasanaethau Bioamrywiaeth ac Ecosystemau (IPBES, 2019) a ddatganodd "argyfwng natur" gyda'r angen brys i amddiffyn ac adfer natur a'i chyfraniadau hanfodol i gymdeithas.

Roedd amcanion trosfwaol yr adolygiad hwn fel a ganlyn:
1. Darparu gwell dealltwriaeth i CNC o gysyniad a mecaneg cydnerthedd morol i gefnogi gwaith rheoli effeithiol o ecosystemau morol sy'n seiliedig ar gydnerthedd.
2. Adolygu dulliau presennol ar gyfer asesu cydnerthedd ecosystemau yng Nghymru, gan gynnwys rhaglenni morol sy'n cyfrannu at asesu cydnerthedd ar hyn o bryd.
3. Archwilio cyfleoedd ar gyfer gwella cydnerthedd morol yng Nghymru i adeiladu ecosystemau morol cynaliadwy.

Mae effeithiau'r newid yn yr hinsawdd ynghyd â phwysau anthropogenig cynyddol (e.e. dŵr ffo amaethyddiaeth, dŵr gwastraff, halogion, gorfaethu/ewtroffigedd, sbwriel môr) yn bygwth bioamrywiaeth forol, gan effeithio ar statws cydnerthedd ecosystemau morol a pheryglu gwasanaethau ecosystemau. Mae cyfleoedd yn bodoli i reoli'r pwysau amgylcheddol hyn yn well, a'u lleihau, wrth ailadeiladu cydnerthedd naturiol ein hecosystemau morol i wrthsefyll ac addasu i aflonyddwch a newid. Cefnogir y gwaith o reoli ein hadnoddau morol naturiol yn gynaliadwy yng Nghymru gan gyfres o ddeddfwriaeth gyda'r nod o adeiladu cydnerthedd ecosystemau.

Cyflwynodd y fframwaith deddfwriaethol yng Nghymru, wedi'i ysgogi gan Ddeddf Llesiant Cenedlaethau'r Dyfodol (Cymru) 2015 a Deddf yr Amgylchedd (Cymru) 2016, ymrwymiad Llywodraeth Cymru i reoli adnoddau naturiol yn gynaliadwy a'i hymgyrch i atal a gwrthdroi'r dirywiad mewn bioamrywiaeth. Mae Deddf yr Amgylchedd (Cymru) 2016 yn darparu fframwaith cyfreithiol i gymhwyso'r dull rheoli ar lefel yr ecosystem yng Nghymru er mwyn sicrhau cynaliadwyedd ac i gynnal a gwella cydnerthedd ecosystemau. Nod Deddf Llesiant Cenedlaethau'r Dyfodol (Cymru) 2015 yw gwella llesiant cymdeithasol, economaidd, amgylcheddol a diwylliannol Cymru ac mae'n cydnabod pwysigrwydd ecosystemau gwydn wrth gyflawni hyn.

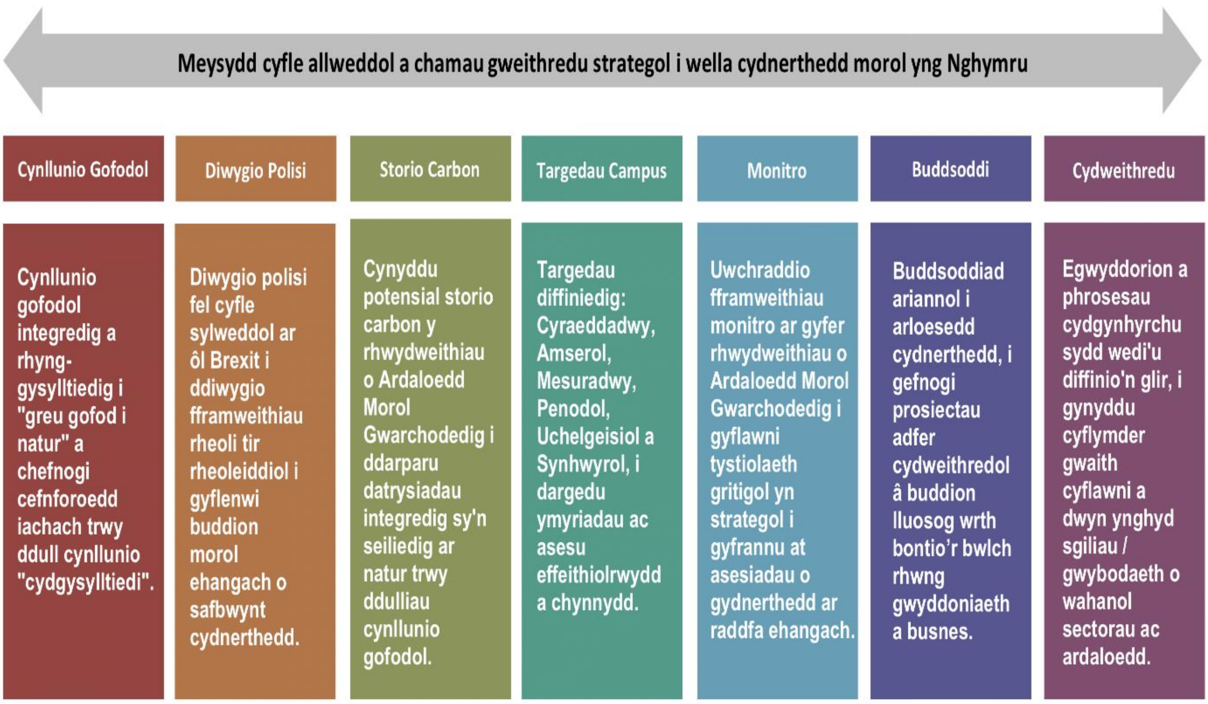
Nid yw'r cysyniad o 'gydnerthedd ecosystemau' yn syml, fel y dangosir gan y llu o ddiffiniadau a gyhoeddwyd dros y degawdau diwethaf. Fodd bynnag, yn y bôn, mae cydnerthedd yn ymwneud â gallu systemau i wrthsefyll a/neu addasu i aflonyddwch ac adfer ar ei ôl. Mae cydnerthedd ecosystemau wedi'i ddiffinio yng Nghymru fel a ganlyn: *"gallu ecosystemau i ymdopi ag aflonyddwch, naill ai drwy ei wrthsefyll, gwella ar ei ôl, neu addasu iddo, wrth gadw eu gallu i gyflenwi gwasanaethau a buddion yn awr ac yn y dyfodol" (Adroddiad ar Sefyllfa Adnoddau Naturiol, 2016)*

Mae ecosystemau yn systemau cymhleth, ymaddasol. Er mwyn adeiladu ecosystemau morol gwydn yng Nghymru ac atal newidiadau cyfundrefn anadferadwy i gyflyrau annymunol o gydnerthedd isel mewn ecosystemau, mae angen dealltwriaeth o'r mecanweithiau swyddogaethol sy'n strwythuro'r mathau o gynefinoedd morol amrywiol. Mae deall dynameg cydnerthedd morol yn hanfodol ar gyfer cyflwyno strategaethau rheoli cynaliadwy. Er mwyn i gydnerthedd ecosystemau symud o fod yn gysyniad damcaniaethol i un ymarferol, mae angen rhyw fath o asesu cydnerthedd er mwyn arwain gwaith rheoli a llywio penderfyniadau polisi (Pimm ac eraill, 2019).

Cyflwynodd Deddf yr Amgylchedd bum priodoledd cydnerthedd (amrywiaeth, maint, cysylltedd, cyflwr a gallu i addasu – a elwir yn agweddau erbyn hyn) fel dull o asesu ac adeiladu cydnerthedd ecosystemau trwy fframwaith DECCA (Latham ac eraill, 2013, Deddf yr Amgylchedd (Cymru) 2016). Mae ymyriadau wedi'u targedu sy'n defnyddio'r priodoleddau rhyng-gysylltiedig hyn o gydnerthedd ecosystemau yn debygol o wella cydnerthedd a lleihau nifer yr achosion o fynd dros drothwyon ecosystemau. Fodd bynnag, mae asesu cydnerthedd morol yn parhau i fod yn heriol dros ben, yn enwedig cysylltedd, yn sgil yr amrywiaeth ofodol ac amserol uchel mewn amgylcheddau morol.

Mae'r ddau Adroddiad ar Sefyllfa Adnoddau Naturiol gan CNC (SoNaRR, 2016 a 2020) wedi gwneud y camau cyntaf tuag at asesu cydnerthedd ecosystemau'r dirwedd genedlaethol. Aseswyd pob math o ecosystem forol yng Nghymru gan ddefnyddio priodoleddau cydnerthedd DECCA trwy ddull cyfun sy'n seiliedig ar dystiolaeth ynghyd â barn arbenigol ar gyfer categorïau ecosystemau, er mwyn nodi patrymau, statws a thueddiadau sy'n dod i'r amlwg o ran cydnerthedd. Fodd bynnag, mae asesiadau cywir wedi'u cyfyngu ar hyn o bryd gan y bylchau sylweddol mewn tystiolaeth ar gyfer cynefinoedd morol ledled Cymru.

Mae'r adroddiad hwn wedi nodi a thrafod meysydd cyfle a chamau gweithredu strategol allweddol i gefnogi ein her genedlaethol o adeiladu cydnerthedd ecosystemau morol yn y tymor hir.



Executive summary

Our oceans support life and unite communities in a profound way and yet, face more threats today than ever before in history. They are in declining health due to an increasing footprint of human use and climate change, and despite increased global action in recent years to protect the ocean, the scale is simply not sufficient (Laffoley *et al.*, 2020).

The United Nations' IPCC urgent call for action in 2018, to address climate change gave rise to a growing climate emergency movement. Both the Welsh Government and UK Parliament responded with a Climate Emergency declaration in 2019. This was followed by a landmark report published by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) that declared a "Nature Emergency" with the urgent need to protect and restore nature and it's vital contributions to society.

The overarching objectives of this review were to:
1. Provide NRW with a better understanding of the concept and mechanics of marine resilience to support effective resilience-based management of marine ecosystems.
2. Review current approaches for assessing ecosystem resilience in Wales, including marine programmes currently contributing to resilience assessment.
3. Explore opportunities for enhancing marine resilience in Wales to build sustainable marine ecosystems.

Climate change impacts coupled with increasing anthropogenic pressures (e.g. agriculture run-off, waste-water, contaminants, nutrient enrichment-eutrophication, marine litter) are threatening marine biodiversity, impacting the resilience status of marine ecosystems and compromising ecosystem services. Opportunities exist to better manage and reduce these environmental pressures whilst rebuilding the natural resilience of our marine ecosystems to withstand and adapt to disturbances and change. The sustainable management of our natural marine resources in Wales is underpinned by a suite of legislation that aims to build ecosystem resilience.

The legislative framework in Wales, driven by the Well-being of Future Generations Act (2015) and the Environment (Wales) Act (2016), introduced Welsh Government's commitment to the sustainable management of natural resources (SMNR) and their drive to halt and reverse the decline in biodiversity. The Environment (Wales) Act (2016) provides a legal framework to apply the ecosystems approach in Wales to ensure sustainability and to maintain and enhance the resilience of ecosystems. The Well-being of Future Generations Act (2015) aims to improve the social, economic, environmental and cultural well-being of Wales and recognises the importance of resilient ecosystems in achieving this.

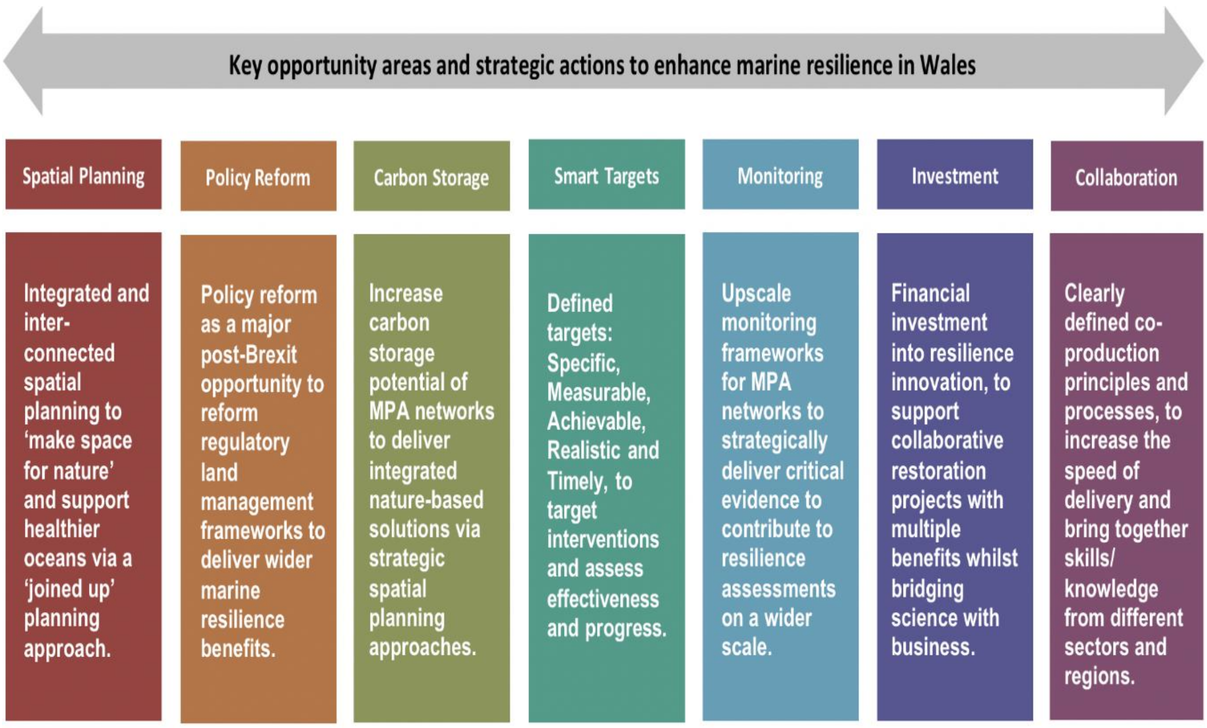
The concept of 'ecosystem resilience' is not straightforward, as evidenced by the multitude of definitions published over the last decades, But essentially, resilience relates to the capacity of systems to resist and/or adapt and recover from disturbance. Ecosystem Resilience has been defined in Wales as: *"the capacity of ecosystems to deal with disturbances, either by resisting them, recovering from them, or adapting to them, whilst retaining their ability to deliver services and benefits now and in the future" (SoNaRR, 2016).*

Ecosystems are complex, adaptive systems. To build resilient marine ecosystems in Wales and prevent irreversible regime shifts to undesirable ecosystem states of low resilience, requires an understanding of the functional mechanisms structuring the diverse marine habitat types. Understanding the dynamics of marine resilience is critical for delivering sustainable management strategies. For ecosystem resilience to move from being a theoretical concept to one in practice, some form of resilience assessment is required to guide management and inform policy decisions (Pimm, *et al.*, 2019).

The Environment Act introduced the five attributes of resilience (diversity, extent, connectivity, condition and adaptability- now aspects) as an approach to assess and building the resilience of ecosystems via the DECCA framework (Latham *et al*., 2013, Environment (Wales) Act 2016). Targeted interventions using these interconnected attributes of ecosystem resilience, are likely to improve resilience and reduce ecosystem thresholds being exceeded. However, assessing marine resilience remains extremely challenging, especially connectivity due to the high spatial and temporal variability in marine environments.

The two NRW State of Natural Resources Reports (SoNaRR, 2016 and 2020) have made first strides towards assessing the ecosystem resilience of the national landscape. All marine ecosystem types in Wales have been assessed using the resilience DECCA attributes via a combined evidence-based plus expert judgement approach for ecosystem categories, to identify emerging patterns, status and trends of resilience. However, accurate assessments are currently limited by the significant evidence gaps for marine habitats across Wales.

This Report has identified and discussed key opportunity areas and strategic actions to support our national challenge of building long-term marine ecosystem resilience.



1. Introduction: Ecosystem Resilience

Image source: John Briggs (NRW)

1.1 Ecosystem resilience: global and national context

Our oceans support life and unite communities in a profound way and yet, face more threats today than ever before in history. They are in declining health due to an increasing footprint of human use and climate change, and despite increased global action in recent years to protect the ocean, the scale is simply not sufficient (Laffoley *et al.,* 2020).

There is political and scientific agreement on the need for a wide range and immediate mitigation actions to avoid the devastating environmental impacts of climate change (UNEP, 2017, IPCC, 2018, ICPP., 2019).

The United Nations' IPCC urgent call for action in 2018, to address climate change gave rise to a growing climate emergency movement. Both the Welsh Government and UK Parliament responded with a Climate Emergency declaration in 2019. This was followed by a landmark report published by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) that described the loss of biodiversity as a "natural and human emergency' - a threat of equal magnitude to the Climate Emergency and a "Nature Emergency" was declared. The report highlights the urgent need to protect and restore nature and it's vital contributions to society. NRW's interim State of Natural Resources Report (2019) supports this international position.

The IPBES Report (2019) describes the declines in global biodiversity occurring at rates unprecedented in human history, with species extinction rates also rapidly accelerating: "The health of ecosystems on which we and all other species depend is deteriorating more rapidly than ever. We are eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide.” However, the IPBEs report (2019) also offers a glimmer of hope: “it is not too late to make a difference, but only if we start now at every level from local to global. Through transformative change, nature can still be conserved, restored and used sustainably. By transformative change, we mean a fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values.”

In 2015, The Nature Recovery Action Plan (NRAP) for Wales set out a framework of actions to address the UNs Environment Programme’s Convention on Biological Diversity’s (CBD) Strategic Plan for Biodiversity and the associated Aichi Biodiversity Targets for 2011-20 in Wales. The Plan communicated commitment to reversing the loss of biodiversity in Wales, with the ambition by 2020: ‘*To reverse the decline in biodiversity, for its intrinsic value, and to ensure lasting benefits to society*’ and objectives for action to:

1: Engage and support participation and understanding to embed biodiversity throughout decision making at all levels.
2: Safeguard species and habitats of principal importance and improve their management
3: Increase the resilience of our natural environment by restoring degraded habitats and habitat creation
4: Tackle key pressures on species and habitats
5: Improve our evidence, understanding and monitoring
6: Put in place a framework of governance and support for delivery

It has been acknowledged that very few of the 2020 Aichi targets have been achieved in Wales and that biodiversity is still in decline. The 2015 Strategy has been updated as a 2020 framework: *The Nature Recovery Action Plan for Wales 2020–21* to provide renewed focus and prioritisation within a fast changing policy context and the emerging ecological crisis.

Environmental pressures are causing global biodiversity declines at rates not previously encountered in history and rates of species extinctions are accelerating both globally and in our natural habitats in Wales. Significant and bold changes in the way we manage the natural environment in Wales are now required to halt the biodiversity loss and build ecosystem resilience, protecting nature’s benefits to people.

In December 2020, NRW published a second State of Natural Resources Report (SoNaRR2), describing these two interconnected global challenges: climate change and biodiversity loss, resulting in the climate and nature emergency. The State of Nature (2019) report documents this declining biodiversity across the Wales:

Figure 1. The decline in biodiversity in Wales (State of Nature Report, 2019)

In responding to both the Climate Emergency and Nature Emergency, the NRW Business Plan (2020-21) identified Strategic Priority areas of work with key deliverables. A number of these deliverables relate directly to building 'Ecosystem Resilience':

Putting nature at the centre:
• Progress the priorities of 'Vital Nature', NRW's strategy for nature, *embedding consideration of biodiversity and ecosystem resilience across all NRW's functions* and helping other public bodies do the same.
• Audit biodiversity action across NRW and develop, then roll out guidance for our staff on *what ecosystem resilience means in practice*, with mapping and tools to help delivery.

Managing the sea sustainably:
• Deliver the *marine ecosystem resilience programme*, including implementation of the Marine Strategy Framework Directive.

To achieve these marine resilience and sustainability goals requires:

- A coherent understanding of the concept of marine ecosystem resilience,
- An understanding of the mechanistic drivers influencing resilience across different ecosystems and landscape scales.
- A consistent approach for assessing ecosystem resilience across 'Land to Sea' catchments, to monitor change and effectively manage our environment.

1.2 Changing the mindset, scale and pace of marine ecosystem resilience delivery in Wales

Our biodiversity and habitats from 'Land to Sea' are facing significant challenges in Wales, however recent research shows that it is not too late to "bend the curve" on biodiversity loss and build ecosystem resilience (IPBES, 2019, Leclere *et al*., 2020). "*To meet the challenge, Wales needs to immediately raise its ambition and work at a broader landscape scale at a much faster pace commensurate with the transformative changes needed*" (SoNaRR, Aim2, 2020).

Current understanding of the marine environment in Wales provides indications of how local resilience can possibly be built by focusing on traditional single species approaches, but this will not be enough to support ecosystem resilience in the longer term or broader scale. Furthermore, there are substantial national gaps in evidence that need to be filled to support understanding of the thresholds beyond which ecosystem functioning cannot be maintained, particularly where responses are uncertain such as to climate change pressures.

To deliver sustainability agendas in Wales requires action involving:

- SMART targets (Specific, Measurable, Achievable, Realistic and Timely) to deliver interventions, assess effectiveness and progress. This includes a robust and comprehensive monitoring strategy across all scales: keystone species, ecosystem community structure/function and a wider lens 'land-to-sea' catchment basin scale.

- Fast track action via a wider-scale holistic and integrated approach consistent with the broader sustainability agenda is now critical in order to understand the multiple marine pressures, interactions and to manage these via an integrated approach. An integrated catchment scale resilience-based approach is key to building marine resilience and managing marine environments sustainably, enabling local communities to continue to benefit from our valuable ocean resources.

- Clearly defined co-production principles and processes to increase the speed of delivery, bringing together a wider set of skills and knowledge from different sectors, institutions and geographical areas. This action supports the SMNR principle for collaboration and engagement : '*to promote and engage in collaboration and cooperation*'.

SoNaRR, Aim2 (2020) recognises that such action requires significant behavioural change at a personal, local and national level and that the current climate of increased environmental awareness issues provides a timely opportunity to promote and incorporate *ways to 'close the gap'* between policy and action.

Key message

To meet our national challenge of building marine ecosystem resilience, consideration should be given to developing and implementing SMART targets, managing through a 'catchment-wide' lens and at a faster pace to deliver our national sustainability agenda.

1.3 Review of marine ecosystem resilience

The overarching objectives of this review are to:

1. Provide NRW with a better understanding of the concept and mechanics of marine resilience to support effective management of marine ecosystems.
2. Review current approaches for assessing ecosystem resilience in Wales, including marine programmes currently contributing to resilience assessment.
3. Explore opportunities for enhancing marine resilience in Wales to build sustainable marine ecosystems.

The approach used for the literature review evidence involved:

- A review of Global, UK and Welsh Government Strategies, Plans and Policies related to ecosystem resilience, with a focus on the marine environment.
- A review of NRW documents, Evidence Reports and National Frameworks related to biodiversity assessments, building ecosystem resilience, Marine Protected Areas and nature-based solutions to restore marine habitats.
- A systematic review of the scientific literature to inform the report objectives. This involved keyword searches of scientific journal databases to systematically identify the most relevant scientific literature, in addition to reviewing international Government reports, conference papers, grey literature and reports published by organisations globally.

2. Our changing oceans: marine resilience

Kelp beds

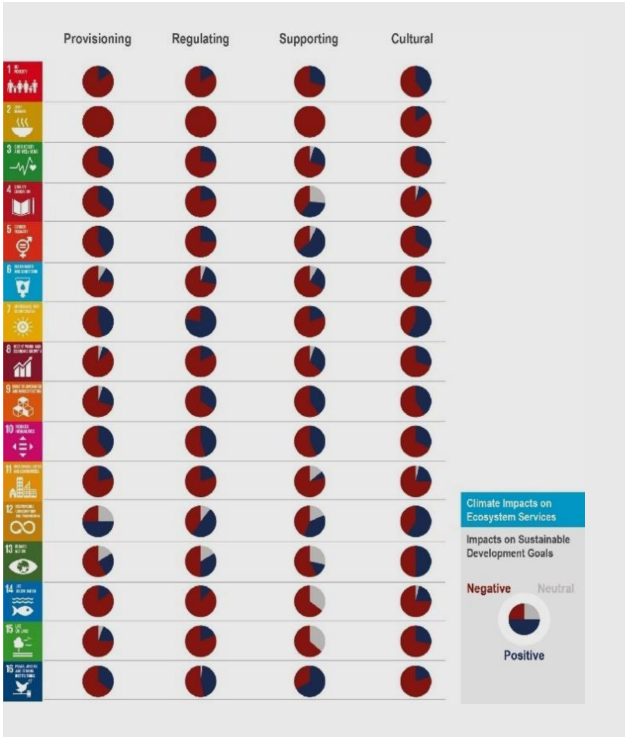
Our marine ecosystems are under growing pressure from a range of influences that include climate change, anthropogenic activities, non-native species and a myriad of environmental impacts from the wider catchment area. These environmental pressures impact the status and resilience of our marine ecosystem resilience capacity i.e. diversity, extent, condition and connectivity. Opportunities exist to better manage and reduce these environmental pressures whilst rebuilding the natural resilience of Welsh marine ecosystems to withstand and/or adapt to disturbances and change. The sustainable management of our natural marine resources in Wales is underpinned by a suite of legislation, policy and regulations outlined in Chapter 3.

2.1 Global climate-related trends, impacts and adaptation

The Intergovernmental Panel on Climate Change Special Report on the Oceans and Cryosphere in a Changing Climate reported in 2019 that warming seas, ice melt, reduced oxygen, ocean acidification, and sea-level rise are already significantly affecting ecosystems and society across the globe (IPCC, 2019). The warming, acidification and oxygen loss in the ocean is changing the structure and functioning of our oceans (species composition, diversity, nutrient cycling and primary production, food web structure) affecting marine organisms across trophic levels and significantly impacting marine services such as fisheries with implications for food production and human communities globally.

Impacts of our Changing Ocean on UN Sustainable Development Goals and Marine Ecosystem Services:

Figure 2. Summary diagram of relationships between impacted marine ecosystem services and the Sustainable Development Goals (SDGs) (Singh, *et al.* 2019).



The IPCC Special Report (2019) assessed how climate change impacts on marine ecosystems challenge sustainable development, using the United Nations SDGs as a framework to assess linkages between issues. Climate impacts on marine ecosystems affect their ability to provide seafood and raw materials, and to support biodiversity, habitats and other regulating processes. These impacts on the ocean affect people both directly and indirectly. SDG 14 is the goal that is most directly relevant to this review: "Life below water": indicators for marine pollution, habitat restoration and protected areas, ocean acidification, fisheries, and coastal development.

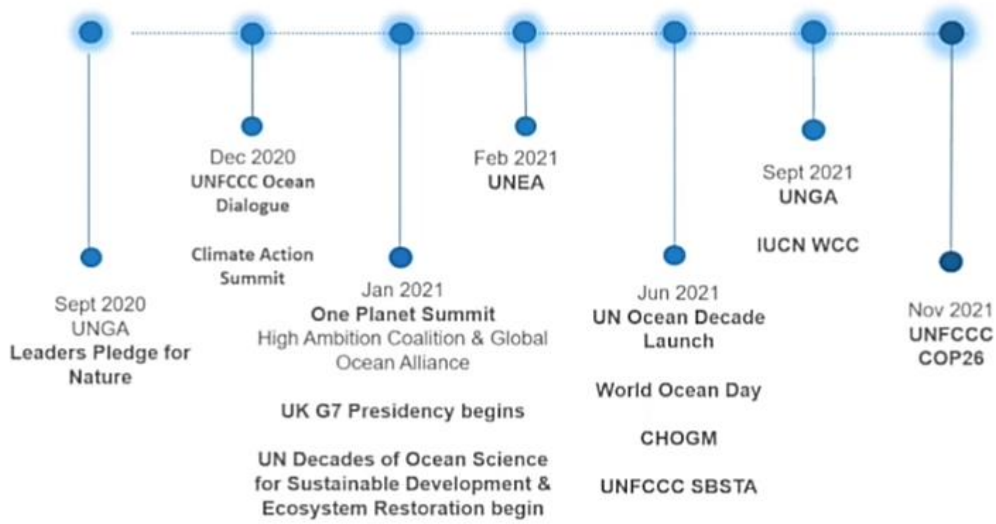
Table 1. Summary of marine ecosystem services.

Provisioning Services	Regulating Services	Supporting Services	Cultural Services
Fisheries are important marine *provisioning service,* providing food, nutrition, income and livelihoods for people around the world. Most global fisheries are considered to be fully to over-exploited (FAO, 2018). In addition to capture fisheries, mariculture is an important marine ecosystem provisioning service, contributing about 27.7 million tonnes of seafood in 2016 (FAO, 2018). Projections of climate change impacts, suggest an overall decline in mariculture potential by 2100 (Froehlich *et al.*, 2018)	*Regulating services* are ecosystem functions, such as climate regulation, that allow the environment to be in conditions conducive to human well-being and development (Costanza et al., 2017). A major regulating service provided by marine ecosystems is carbon sequestration. In coastal ecosystems, carbon is biologically sequestered in coastal sediments, commonly known as 'blue carbon'. Coastal blue carbon ecosystems provide climate regulatory services through their carbon removal and storage.	*Supporting services* are structures and processes, such as habitats, biodiversity and productivity, that maintain the ecosystem functions that deliver other services (Costanza *et al.,* 2017). Marine supporting services include: primary and secondary production; habitat provision for feeding, spawning or nursery grounds and biodiversity. These provide essential support for provisioning, regulating or cultural services (Fitter, 2010, Biggs *et al*., 2012)).	*Cultural Services* include recreation, tourism, aesthetic and spiritual experiences. These services are a product of humans experiencing nature and the availability of nature to provide the experiences (Chan *et al.,* 2012). However, the role of Cultural Services for enhancing the sustainability of human interactions with nature has remained largely unexplored (Garcia Rodrigues, *et al.,* 2017). Cultural values are diverse and include education, stewardship activities and network building.

2.2 Global and UK action for building ocean resilience and recovery

Implementing holistic and integrated strategies with targeted actions are essential for Ocean recovery. The recent timeline of global initiatives, targets and summits (Figure 3), demonstrates the global commitment towards ocean recovery; with this year being referred to as the 'Ocean-Climate-Nature Super Year 2021 for ambition and action'.

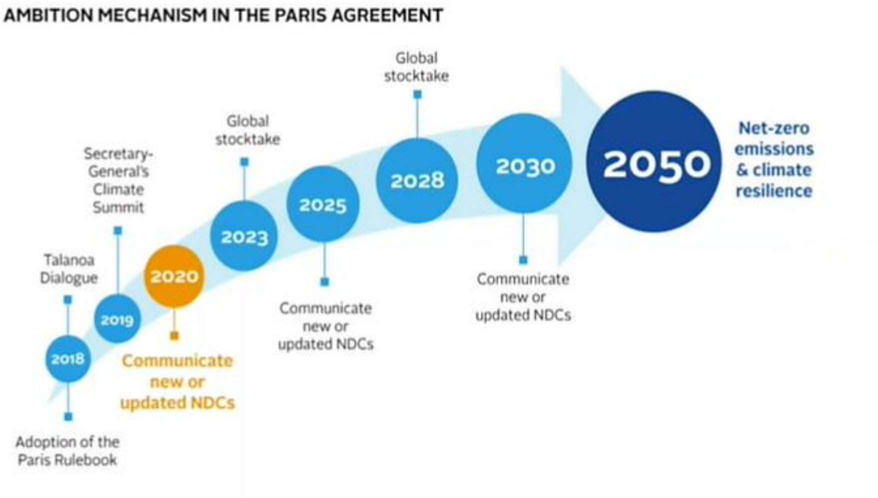
Figure 3. Timeline of global initiatives, targets and summits. Coastal Futures Conference (2021): S.Ockenden presentation (Defra): 'UK Government: Ocean & Climate':



International	Domestic UK
Convention on Biological Diversity & Post-2020 Global Biodiversity Framework UN Decade of Ocean Science for Sustainable Development & Ecosystem Restoration (2021-30) MPAs 30by30 Global Ocean Alliance & the High Ambition Coalition International Climate Fund & Blue Planet Fund	 UK Government vision for 'clean, healthy, safe, productive and biologically diverse oceans and seas' and Net Zero MPAs and Review of MPAs Coastal habitat restoration initiatives 'Green Recovery Challenge Fund' for conservation projects

Table 2. Key international and domestic UK actions for Ocean Recovery (Coastal Futures Conference, 2021).

Figure 4. The Nationally Determined Contributions (NDCs) ambition mechanism, with milestones for net-zero emissions and resilience by 2050 (Paris Agreement). From the World Resource Institute (2017).



2.3 Environmental impacts and trends on UK seas

The changing climate is having physical, ecological, social, and economic impacts on UK coasts and seas. There is clear evidence that warming seas, reduced oxygen, ocean acidification, and sea-level rise are significantly reducing marine ecosystem resilience - with further impacts are predicted (SoNaRR 2020).

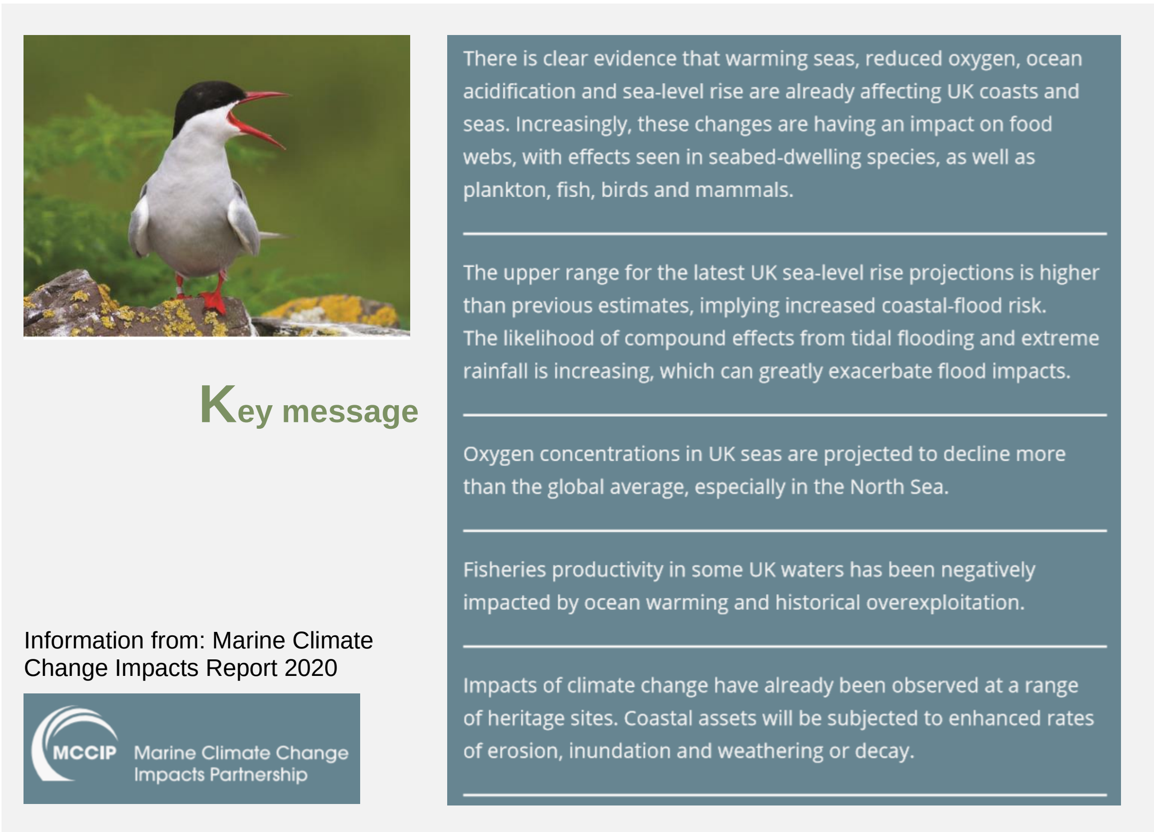


Figure 5. Climate change impacts on UK Seas (MCCIP, 2020)

The Marine Climate Change Impacts Partnership Report (MCCIP, 2020) documents the climate change impacts and trends:

- The upper range for the latest UK sea-level rise projections is higher than previous estimates, implying increased coastal-flood risk.
- Projected increases in sea-level rise are larger for England and Wales than Scotland and Ireland. The estimate for Cardiff by 2100 is 0.43–0.76m.
- Average projected sea temperature increases of 3°C by 2100 in the Irish and Celtic Seas will directly lead to a decrease in dissolved oxygen.
- Increases in stratification due to sea warming are likely to drive declines in oxygen concentrations.
- Many important habitats along the Welsh coastline, some of which are found within Marine Protected Areas (including salt marsh, maerl beds, horse mussel beds, and seagrass), are vulnerable to climate impacts. These include sea-level rise, sea warming, ocean acidification, and changes in storminess.
- At the North Atlantic Ocean Basin scale, long-term datasets show that changes in plankton species and communities have been influenced by climate over multidecadal periods, and strongly correlate with temperature change.
- Commercial fish populations in the North Sea and Celtic-Biscay shelf are reportedly among the most negatively impacted worldwide, due to intense and prolonged overfishing and rapid warming in recent decades (>0.2°C per decade).
- Impacts of ocean acidification on shellfish fisheries may be more pronounced in Wales than other regions of the UK due to their relative importance to the industry.
- Climate change could affect storms and waves in the North Atlantic, but natural variability will continue to dominate in the near future. Predicting future changes to the strength, frequency and track of storms is difficult, and there is still uncertainty as to what could happen within the Irish Sea region.

2.4 The concept of resilience

Resilience defines the ability of a system to recover from disturbance by either absorbing disturbance or using it as an opportunity for change - reorganising whilst essentially retaining the same function, structure, and feedbacks i.e. the same “identity”. Resilience science provides strategic thinking tools based on ‘complex adaptive systems’ models. Resilience thinking is now promoted as a broad socio-ecological approach (Walker & Salt, 2006, 2012; Pisano, 2012) which, in its linkage of environmental management, sustainability and society, mirrors the philosophy of the Ecosystem Approach.

Over the past decades, few concepts have received such prominence as ‘resilience’ - the capacity of a system to deal with change and continue to thrive. Coupled with theoretical discussions, has been an explosion of research into ways to assess, enhance and increase resilience of diverse system types and across all scales. This has resulted in an abundance of factors reported as influencing resilience, leading to a somewhat fragmented global understanding of the key drivers of resilience.

A resilience-based management approach to sustainability focuses on how to build capacity to deal with unexpected change. At the heart of this approach is understanding how people interact with the biosphere (air, water and land) within socio-ecological systems, rather than being external drivers of ecosystem dynamics. This sustainable approach helps support the essential ecosystem services that communities rely on.

The 7 principles of Resilience

- Maintain diversity and redundancy
- Manage connectivity
- Manage slow variables and feedbacks
- Foster complex adaptive systems thinking
- Encourage learning
- Broaden participation
- Promote polycentric governance systems.

Figure 6. Seven principles for building resilience in social-ecological systems (Biggs *et al.*, 2015).

Diversity, in all its forms: biological, ecological, landscape, social and economic, is seen as a key to the resilience of systems. An ecosystem will be more resilient if a critical function is performed by two rather one species, almost as an 'insurance policy' protecting the ecosystem against passing a critical undesirable threshold or tipping point. This beneficial effect of diversity is known as redundancy and has interesting consequences as it implies that systems (ecological or economic) maximised for efficiency may actually have reduced resilience (Latham *et al.,* 2013).

Key message

Systems with many different components (e.g. species) with increased diversity are generally more resilient than systems with few components. Redundancy provides 'insurance' within a system by allowing some components to compensate for the loss or failure of others. Redundancy is even more valuable if the components providing the redundancy also react differently to change and disturbance (response diversity).

Other important concepts within resilience theory include:

- **Thresholds:** An important part of resilience theory is the existence of thresholds (or limits) beyond which the ecosystem 'flips' to an alternative stable state. Thresholds are points at which a system cannot recover, transform or adapt to an alternative state. These have been demonstrated in a variety of marine ecosystems for example, coral reefs (Nystrom *et al*., 2000) and marine fisheries (Collie, *et al*., 2004).
- **Slow variables:** These control the movement towards thresholds and the effects accumulate over time. Slow variables are not easily measured but have overwhelming impact at the threshold point.
- **Adaptive cycles:** All systems are dynamic and often follow relatively predictable phases of rapid growth, conservation, release or breakdown and finally reorganisation. Adaptive cycles operate at numerous scales superimposed on one another, within a complex system that has been termed *panarchy (named after Pan – the God of Nature and unpredictable change)*. This appreciation of dynamics and the capacity to survive disturbance is vital for any approach to managing ecosystems, and relationships to wider sustainability issues. (Latham *et al.,* 2013).

2.5 Defining marine resilience

The concept of ecosystem resilience is not straightforward and multitudes of definitions have been published over the last decades, but essentially 'Ecosystem Resilience' relates to the capacity of systems to resist and/or adapt and recover from disturbance.

A basic distinction is often made between resilience as a measure of the speed of return to original conditions - termed 'engineering resilience', and resilience as the capacity of a system to absorb disturbance and retain its original structure and function - termed 'ecological resilience' (Holling, 1996). The term originally gained prominence through Holling (1973), who used it to describe specific aspects of ecological interactions.

Key message

'Ecosystem resilience' has been defined in Wales as:

"the capacity of ecosystems to deal with disturbances, either by resisting them, recovering from them, or adapting to them, whilst retaining their ability to deliver services and benefits now and in the future" (SoNaRR, 2016).

Definitions of resilience generally contain any combination of 3 major principles (Folke *et al*. 2004, Bernhardt & Leslie 2013):

- The magnitude of shock or pressure that a system can absorb while remaining within a given state.
- The degree to which the system is capable of self-organisation in light of the shock or pressure.
- The degree to which the system can build capacity for learning and adaptation.

At the core of any definition of resilience is the capacity of a marine ecosystem to keep functioning even when disturbed (Levin & Lubchenco, 2008) with the maintenance of the ecosystem services. The maintenance of resilience is driven by essential ecosystem components: the adaptive capacity of individual organisms, the timescale at which changes in their environments are occurring and the spatial scale at which both disturbance and resilience operate (Hughes *et al.,* 2005). Improving resilience at small scales might, ultimately, be little defence against pressures that operate at larger scales. For example, climate change is a global pressure with the potential to overcome resilience built at the local scale. The high connectivity of the marine environment means that additional remote pressures, including invasive species, marine debris and coastal run-off, also have the potential to threaten local resilience.

Reviewing and drawing conclusions on marine ecosystem resilience from global literature presents some formidable challenges, four of which were identified by O'Leary *et al.* (2017) in their review '*The resilience of marine ecosystems to climatic disturbances*':

1. A single, agreed-on definition of 'Ecosystem Resilience' does not exist (Table 3), and different studies have quantified responses in different ways.

2. Terms such as persistence, resistance, recovery, and resilience are often used interchangeably, and persistence, resistance, and recovery are sometimes defined as components of resilience (Table 3).

3. The relative use of these terms has changed through time. Frequency of the use of the term resilience has increased significantly over the past decades, with an average increase of 7.46% per year between 1984 and 2014. Resistance and recovery decrease over time by –1.01% and –0.86% per year respectively.

4. A final challenge is that publications often report the lack of resilience rather than a demonstration of resilience (e.g., Fraser *et al*. 2014, Koch *et al*. 2014).

Table 3. Definitions of ecological resilience (from O'Leary *et al.,* 2017).

Elton (1958): The possibility that communities are resistant to some perturbations and undergo no changes in structure on being perturbed.
Holling (1973)*: The measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables.
Weston (1978)*: The degree, manner, and pace of restoration of the initial system function and structure following a disturbance.
Connell and Sousa (1983)*: A system can be considered stable in the face of a disturbance if (a) it retains a similar structure ("resistance") or (b) it returns to a similar predisturbance structure after an initial deviation ("resilience").
Pimm (1984): The ability of a system to resist disturbance and the rate at which it returns to equilibrium following disturbance.
Holling (1996), Gunderson (2000): The magnitude of disturbance that can be absorbed before the system changes its structure by changing the variable processes that control the behavior.
Folke and colleagues (2002): Resilience, for social–ecological systems, is related to the magnitude of shock that the system can absorb and remain within a given state, the degree to which the system is capable of self-organization, and the degree to which the system can build capacity for learning and adaptation.
Walker and colleagues (2004)*: The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedback.
Desjardins and colleagues (2015): The capacity of a system to absorb change but maintain identity and a certain degree of integrity.
Operational definition used in this study: The persistence, throu gh either fast recovery or strong resistance, of the major habitat-forming taxa that define the structure of an ecosystem.

Key message

Reviewing and drawing conclusions on marine ecosystem resilience from global literature presents some formidable challenges, including: the lack of a common consistent definition for 'Ecosystem Resilience'; resilience terms that are used interchangeably in the literature leading to difficulties in developing consistent and objective approaches to operationalise the concept, and a lack of studies that have demonstrated marine resilience.

2.6 The mechanics of ecosystem resilience

Heraclitus of Ephesus (ca.544–483BC) - the first influential philosopher of change, viewed 'nature as change', in a constant state of flux and famously stated that: '*nothing endures but change*' (Mueller-Merbach, 2006). All evidence in the natural world, indeed indicates that the biological world is now changing at unprecedented rates.

The speed and magnitude of these environmental changes support the suggested new designation for this period in Earth history - the Anthropocene (Crutzen & Stoemer, 2000). An epoch, where human activity is changing the planet's climate and ecosystems (Barnosky *et al.* 2012, Steffen *et al.,* 2015, Millennium Ecosystem Assessment, 2005). While some of these changes have been gradual, many others have led to significant ecological regime shifts (Marten Scheffer *et al*., 2003).

Ecosystems are complex, adaptive systems characterised by historical dependency, non-linear dynamics and multiple basins of attraction (Levin, 1998). Nonequilibrium ecology and resilience theory have transformed and challenged the traditional assumptions of ecological stability and linear successional dynamics. These alternative interpretations indicate that ecosystem dynamics are strongly influenced by disturbance, heterogeneity, and existence of multiple stable states (Elmqvist *et al*., 2003).

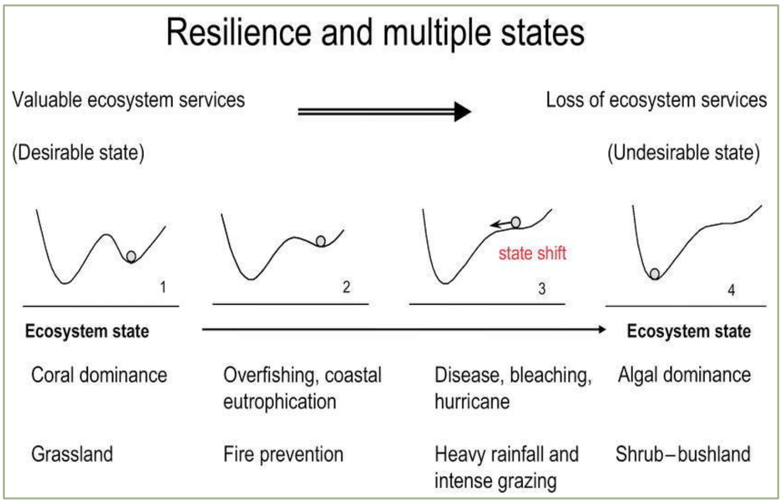


Figure 7. Resilience mechanics, multiple states and regime shifts (Elmqvist *et al*., 2003).

From the 1960's, ecologists started questioning the accepted view that ecological systems tended toward a unique climax state and instead raised the possibility that systems might have multiple potential equilibria (Holling, 1973). Following disturbance, the new conditions create a new feedback loops hence preventing a return to pre-disturbance equilibrium. In a multiple equilibria scenario, system conditions determine movement towards a particular equilibrium - with potential for the system to cross critical thresholds and flip between equilibria (Figure 7). Resilience essentially refers to the ability of the system to resist or absorb disturbance without crossing that critical threshold with ability to return to the original equilibrium state (Carpenter *et al.,* 2001, Gunderson, 2000, Holling, 1973, 2001). A 'regime-shift' occurs however, if the critical threshold is crossed, and in such cases reversal back into the original state may be difficult or impossible. Scheffer *et al.* (2001) proposed that by simple removal of environmental stress pivotal in a regime shift may be sufficient to return to the original state. This is essentially the strategy used when building ecosystem resilience – reducing environmental pressures whilst supporting Nature-based Solutions (NbS) to reinstate and regenerate natural ecosystem structure and processes.

Biological diversity appears to enhance the resilience of desirable ecosystem states, which is required to secure the production of essential ecosystem services. The diversity of responses to environmental change among species contributing to the same ecosystem function, which is referred to as 'response diversity', is critical to resilience. Response diversity is particularly important for ecosystem renewal and reorganisation following change and provides adaptive capacity in complex systems, uncertainty, and human-dominated environments. Response diversity is particularly important when planning ecosystem management and restoration, since it may contribute considerably to the resilience of desired ecosystem states against disturbance, mismanagement, and degradation (Elmqvist, 2003).

Ecosystem change or stress, even if it influences the performance and fitness of organisms, is not inherently bad. It is part of life and a motor of evolution. Disturbances in environmental conditions at certain levels and frequencies (e.g. intermediate disturbance hypothesis, Connell & Sousa, 1983) can set positive impulses, but in most other cases the outcome for the resident species and communities will be negative (e.g. Pearson and Rosenberg, 1978, Harley *et al.,* 2006, Halpern *et al.,* 2008).

Key message

- As humanity has altered the capacity of ecosystems to buffer disturbance, we can no longer take for granted a sustained flow of ecosystem services essential to our well-being.
- Resilience is necessary to sustain desirable ecosystem states in variable environments and uncertain futures.
- Response diversity, defined as the range of reactions to environmental change among species contributing to the same ecosystem function, is critical to resilience, particularly during periods of reorganisation.
- Management of both functional and response diversity at large scales and across scales, will be required to sustain and enhance the flow of ecosystem services. (Thomas Elmqvist *et al.* (2003).

3. Building resilient ecosystems in Wales

Peatland in Wales

To build and improve ecosystem resilience requires an assessment of the current resilience status. However, quantifying ecosystem resilience is complex, and involves profound understanding of the functional mechanisms structuring the diverse ecosystem types, such as disturbance capacity of ecosystem types, ecosystem thresholds and alternative states and the recovery state or condition. The development of resilience models also relies on the input of robust evidence metrics to ensure reliable model outcomes.

An alternative approach has been developed in Wales to overcome the extreme complexities and challenges of quantifying ecosystem resilience (Latham *et al.,* 2013, Environment (Wales) Act, 2016). The applied tool, the DECCA framework, assesses ecosystem resilience via environmental proxies that naturally integrate environmental variance. The framework does not attempt to measure ecosystem resilience attribute properties, rather assesses them as a suite of interconnected attributes and examines the interplay between them (Section 3.2).

Simple definitions of resilience imply that ‘disturbance’ is a discrete system event - a sudden and irreversible change, examples include land use change and intertidal habitat loss through coastal squeeze. However, environmental disturbance in Wales often results from long-term and continuous anthropogenic environmental pressures that affect complete land to sea catchments, examples include diffuse pollution from environmental contaminants (e.g. fertilisers, pesticides), eutrophication, unsustainable fishing, competition for land leading to loss of habitat and fragmentation, air pollution and introduction of invasive species. Climate change is an overarching pressure, interacting with all of these.

An obvious challenge for ecosystems in Wales is that following centuries of environmental exploitation, very few natural Welsh ecosystems are undisturbed from anthropogenic pressures. Therefore, the natural ecosystem baseline for recovery is difficult to assess and an expectation to return the environment to pristine natural baseline conditions is unrealistic.

Marine ecosystems and their attributes are dynamic and constantly changing. Both biotic and abiotic changes occur across varying temporal scales, from long evolutionary timescales to much shorter timescales of months to years. Given this continuous and ongoing change, definitions of the terms ‘natural’, ‘historical’ and ‘altered’ become blurred, and our ability to compare the current state of ecosystems with some potentially unknown historical ideal becomes ambiguous and arbitrary (Hobbs *et al.,* 2009). Therefore, reference to *favourable environmental conditions* that could potentially be maintained to enhance or restore ecosystems is a preferred management approach. To achieve this requires: changes in the environment to be assessed and monitored, drivers of change to be understood, thresholds identified (below which the environment becomes compromised) and measures identified for maintenance of ecosystem functioning.

3.1 Resilient ecosystems: legislation in Wales

The new legislative framework in Wales, driven by the Well-being of Future Generations Act 2015 and the Environment (Wales) Act 2016, introduced Welsh Government’s commitment to the sustainable management of natural resources (SMNR) and their drive to halt and reverse the decline in biodiversity.

The Well-being of Future Generations Act 2015 aims to improve the social, economic, environmental and cultural well-being of Wales, and recognises the importance of resilient ecosystems in achieving this via 7 Well-being goals (Figure 8) - one of which is a ‘Resilient Wales’: “*A nation which maintains and enhances a biodiverse natural environment with healthy functioning ecosystems that support social, economic and ecological resilience and the capacity to adapt to change*.”

The Environment (Wales) Act published in 2016, provided a legal framework to protect and enhance the resilience of ecosystems whilst applying the ecosystems approach in Wales to ensure sustainability. The Act puts in place nine principles for the sustainable management of natural resources (Figure 9), that are closely aligned to the UN SDGs. Environment (Wales) Act recognises the essential contribution biodiversity makes to SMNR and our well-being, by putting in place the section 6 Biodiversity and Ecosystem Resilience duty. This duty requires public authorities to seek to maintain and enhance biodiversity in the exercise of functions in relation to Wales, and in doing so promote the resilience of ecosystems, so far as consistent with the proper exercise of those functions.

Figure 8. National Well-being goals (WFGA, 2015) and National priorities NRP (2017).

Figure 9. The Environment (Wales) Act 2016 puts in place nine principles for SMNR.

The Environment (Wales) Act introduced the five attributes of resilience (Diversity, Extent, Connectivity, Condition and Adaptability (now replaced by Aspects) as an approach to assess and build ecosystem resilience. This DECCA tool was developed in NRW to assess and improve resilience in terrestrial systems (Latham *et al.,* 2013). The Act sets out an adaptive delivery framework for embedding the ecosystem approach through SMNR, with the State of Natural Resources Report (SoNaRR) setting out the national evidence base. The first State of Natural Resources Report (SoNaRR), published in 2016 used the five DECCA attributes to assess resilience and the direction of change. Findings suggested that no ecosystem in Wales was showing all the attributes of resilience, hence impacting the ability of our ecosystems to provide biodiversity and well-being benefits.

Welsh Government developed the Natural Resources Policy (2017) that outlined the national priorities for the sustainable management of natural resources and key ways the natural resources contribute across all Well-being goals. The Area Statements delivered by NRW contribute to implementing the Natural Resources Policy (NRP) in a local context, taking a collaborative place-based approach. The NRP national priorities for SMNR focus on delivering resilient ecological networks by:

- Delivering nature-based solutions
- Increasing resource efficiency and renewable energy
- Taking a place-based approach

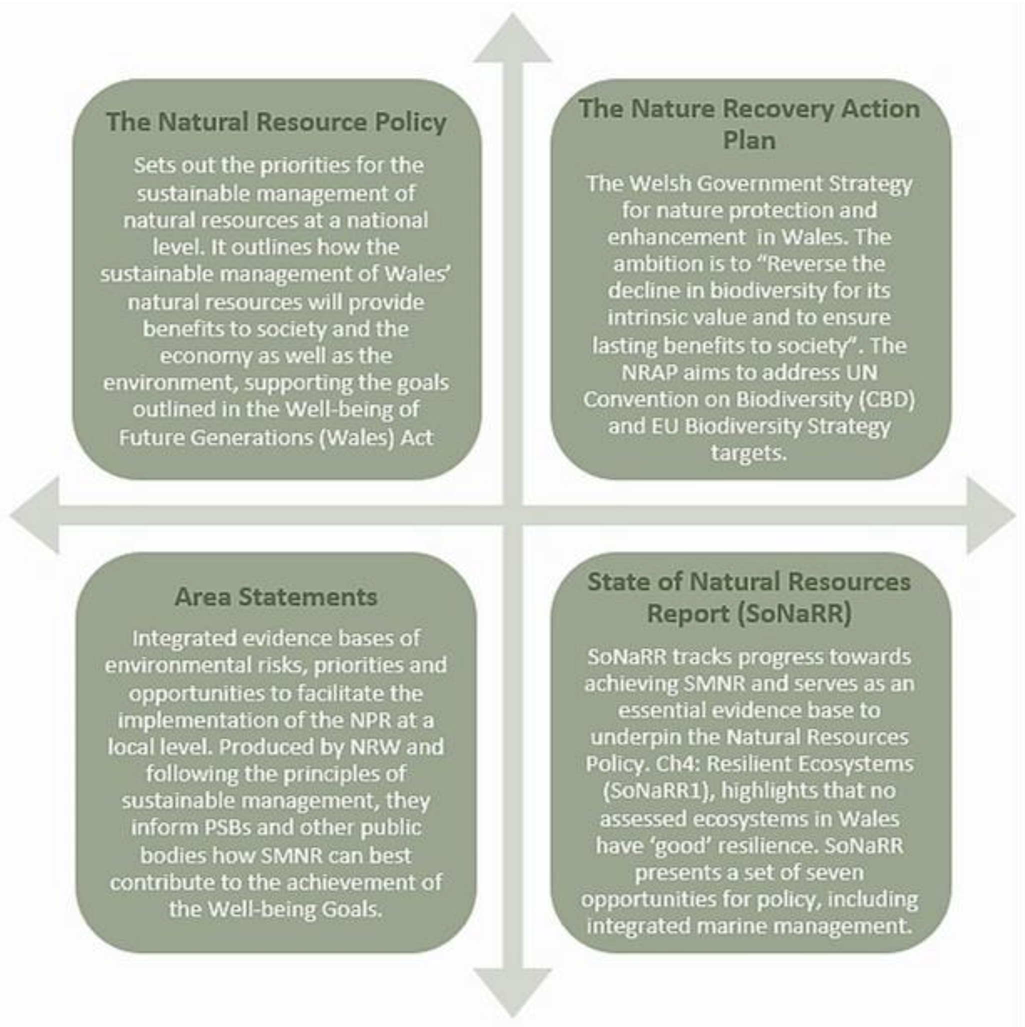


Figure 10. Ecosystem resilience at the heart of the Welsh sustainability agenda supported by a suite of policy frameworks.

The Environment (Wales) Act (2016) approach to ecosystem resilience and delivering SMNR has been developed from the 12 principles of the Convention on Biological Diversity (CBD) Ecosystem Approach, including the following directly related to ecosystem resilience:

Principle 5: 'Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach'. This states that 'Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6: 'Ecosystems must be managed within the limits of their functioning. In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning *may be affected to different degrees by temporary, unpredictable or artificially maintained conditions and, accordingly, management should be appropriately cautious'.*

The State of Natural Resources Report (SoNaRR) (2016) defines Ecosystem Resilience as: 'the capacity of ecosystems to deal with disturbances, either by resisting them, recovering from them, or adapting to them, whilst retaining their ability to deliver services and benefits now and in the *future'* – and recognises the complexities of quantifying ecosystem resilience. These relate to the dynamic and complex nature of ecosystems and the very poor current understanding of thresholds (defined as limits beyond which significant and perhaps catastrophic consequences follow) and lack of associated evidence. Environmental disturbances are discussed, with significant variations in terms of scale and duration – from one-off 'shock' events to long term, continuous pressures, that may result from natural or management processes or anthropogenic sources.

The Report outlines the pragmatic approach of the Environment Act (2016) in the assessment of environmental resilience via the interplay of the five DECCA attributes, considered as resilience building blocks: Diversity, Extent, Condition, Connectivity, Adaptability (now revised to Aspect). Targeted interventions using this suite of ecosystem resilience attributes in unison, are likely to improve resilience and reduce thresholds being exceeded. The suite of interconnected DECCA attributes as proxies for resilience is key, and sets this resilience assessment approach aside from more traditional approaches of natural resource management:

'It is important to recognise that these attributes are proxies for resilience (although 'adaptability' is partly synonymous with resilience); the actual processes of recovery, resistance and adaptation that comprise resilience are likely to arise from the interplay between the attributes, rather than from any one attribute in isolation.'

The Wales Marine Plan (2019) guides the sustainable development of our marine environments, by setting out how proposals will be considered by decision makers and contains general cross-cutting and sector-specific policies. Recognition of the value and benefits of a biodiverse and resilient marine environment is made within the 'Living within Environmental Limits' section of the Plan. Policies in this section of the Plan promote the protection and enhancement of the marine environment to deliver resilient marine ecosystems to meet needs of future generations.

The Plan acknowledges that MPAs are fundamental to the conservation of marine biodiversity, contributing to the health and resilience of the marine ecosystem, as recognised by the MPS. A well-designed, well-managed network of MPAs can provide greater benefits to biodiversity compared to individual unrelated sites. Welsh Government is committed to safeguarding MPAs to deliver a well-managed, ecologically coherent network of MPAs that is connected and represents a diverse range of habitats and species.

In Wales, our network of MPAs make a significant contribution towards the protection of biodiversity and resilience of the wider marine environment. MPAs in Wales, currently cover approximately 75% of our coastline and 69% of the inshore Plan area. Our MPAs are of various types, reflecting the specifics of their management and governance. These include Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), collectively known as European sites, Marine Conservation Zones (MCZs), Sites of Special Scientific Interest (SSSIs) and Ramsar sites that have marine components. When taken together these MPAs form a network that contributes to UK and international networks of MPAs.

Key message

Quantifying ecosystem resilience requires a profound understanding of functional mechanisms e.g. disturbance capacity, thresholds and recovery states, that structure diverse ecosystem types. Such extreme complexities and challenges, have been overcome in Wales by development and application of the DECCA framework (Environment Act (Wales) 2016), to assess ecosystem resilience via environmental proxies that naturally integrate environmental variance. The framework does not attempt to measure ecosystem resilience attribute properties, rather assesses them as a suite of interconnected attributes and examines the interplay between them. Targeted interventions using this approach, are likely to improve resilience and reduce ecosystem thresholds being exceeded.

3.2 Current NRW approaches and tools for assessing ecosystem resilience in Wales

Understanding the explicit links between ecosystem components and resilience of disturbance across multiple scales is needed to operationalise the concept of ecosystem resilience. The complexity of marine ecosystem structure and dynamics is based on the interactions of the component species, the food web connections across trophic levels and the landscape modifications induced by biotic-abiotic interactions on both a temporal and spatial scale.

As complex adaptive systems, marine ecosystems are composed of interacting individuals producing collective effects - integrating scales from individual behaviours to the dynamics of whole systems. Small changes are magnified through nonlinear interactions in the ecosystem, facilitating regime shifts and collapses. It is therefore critical that an integrated approach to resilience-based assessments is applied - at the appropriate system-level scale to protect essential ecosystem services. Biodiversity conservation over the past decades, has focused on targeted lower level (species/habitat) protection, but there is now an urgent need to assess and manage marine ecosystem structure/function through a much wider ‘Land to Sea’ lens at a catchment-wide scale.

To effectively manage the environment, ecosystem resilience must be either be quantified by complex models underpinned by robust evidence metrics or alternatively assessed via environmental proxies that naturally integrate environmental variance.

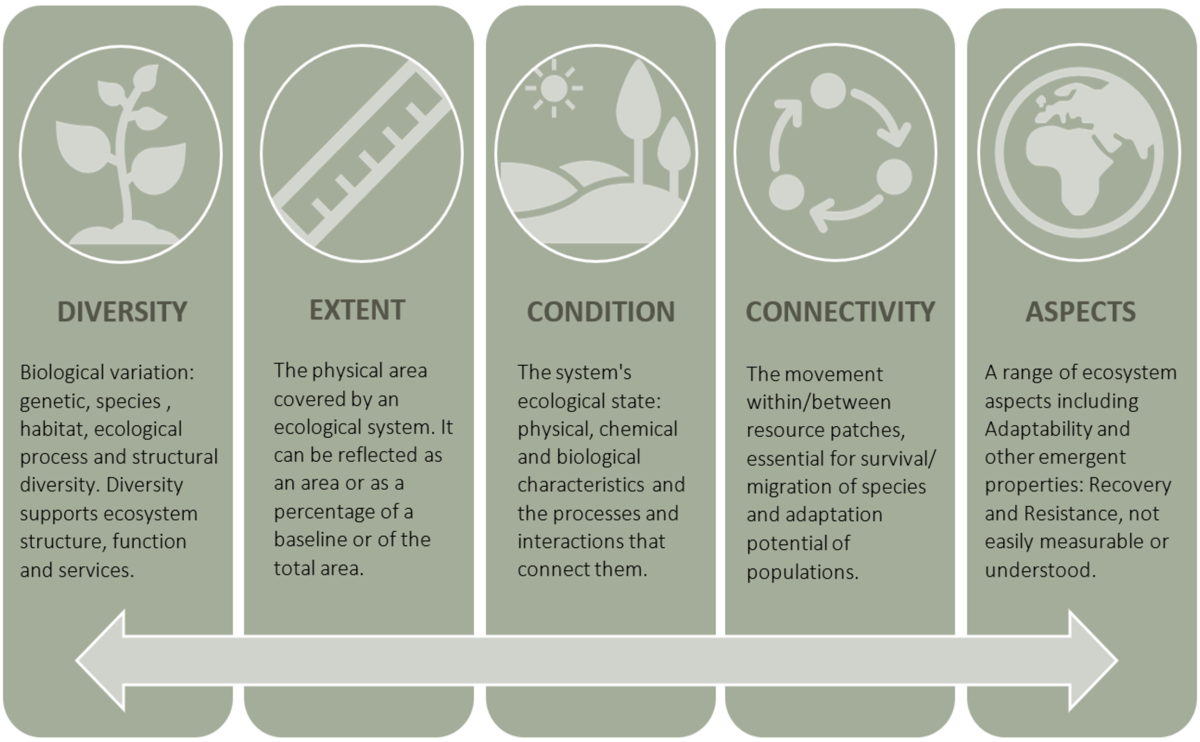
3.2.1 The ecosystem resilience DECCA framework

The DECCA framework (Latham et al. 2013, Environment (Wales) Act, 2016), was developed as an applied tool in NRW to overcome the extreme complexities and challenges of assessing ‘ecosystem resilience’ – including significant evidence gaps.

The DECCA framework involves assessment of five interconnected ecosystem attributes (Diversity, Extent, Condition, Connectivity, Adaptation - now Aspects), that in unison, function as a proxy for ecosystem resilience. In the updated version of the DECCA framework (2020), 'A'daptability has been expanded to 'A'spects, and now includes a range of emergent ecosystem properties that are less well understood, such as adaptability, recovery and resistance. Resilient ecosystems result from an interplay between these attributes. The framework does not seek to measure these ecosystem resilience attribute properties, but rather to assess them as a suite of interconnected attributes and examine the relationship between them. The flexible and comprehensive application of this approach, supports resilience-based management across *all* scales, including larger, interlinked functional ecological units such as river-basin catchments, coastal zones, habitat networks, and landscape formations.

Assessment of ecosystem resilience is complex, and tools need further development. The framework is currently being applied to design and prioritise actions to assess and enhance ecosystem resilience across Wales. Garrett (2020) recently reviewed the general concept of 'Ecosystem Resilience' from a terrestrial perspective and ecosystem resilience assessment tools via a literature review to support further development of the approach.

Figure 11. The five attributes of the DECCA framework describing ecosystem resilience.



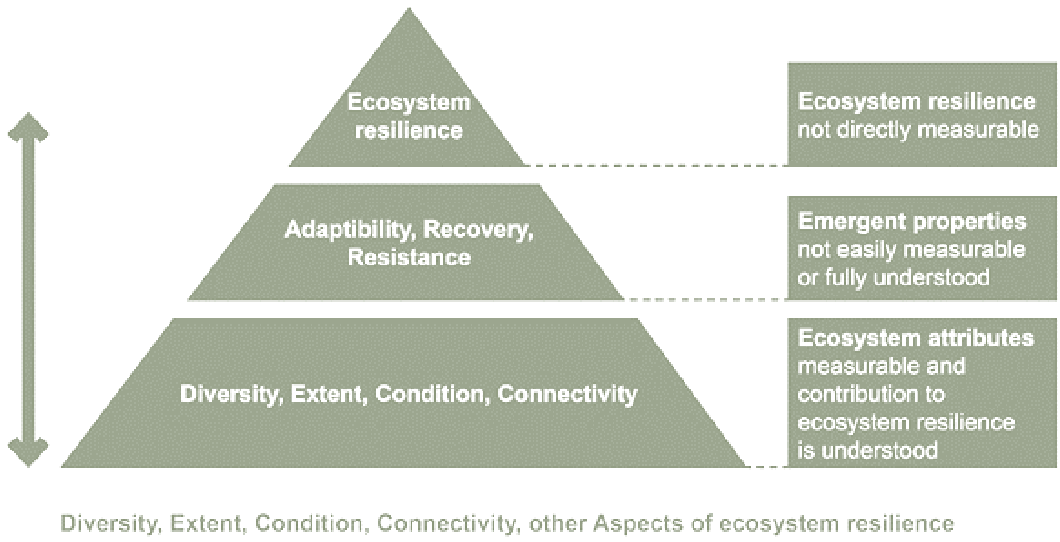


Figure 12. The relationship between the DECCA attributes (adapted from SoNaRR Aims2, 2020).

3.2.2 CuRVe (Current Relative Value) mapping tool

CuRVe mapping is a strategic tool currently under development in NRW for terrestrial ecosystems, to represent and assess resilience information spatially, and inform targeted interventions for building ecosystem resilience across Wales.

Fundamental challenges of developing such a spatial mapping tool for resilience include:

- Resilience being an emergent ecosystem property that is complex and incompletely understood.
- Quantifying resilience would require a defined baseline reference state, that is not described in Wales.
- Incorporating proxy attributes for resilience that can be potentially be quantified but non-comparable.

At a strategic level, the theory behind the CuRVe model tool is to use relative values of resilience attributes as a proportion of the highest current values in Wales. These values are then transformed to provide a pragmatic and consistent value range that combines to an average value for different attribute factors. This enables attribute types to be compared to provide a broad indication of resilience performance and underpin targeted actions and interventions to build resilience. CuRVe mapping is a strategic assessment tool rather than an absolute valuation approach and complements more specific detailed localised spatial habitat mapping.

A trial study for CuRVe mapping application in 2020 involved the five broad DECCA attributes for resilience being used as ‘measurable’ ecosystem resilience proxies (Naumann & Medcalf, 2020). Factors (n=16) informing the five attributes were selected based on their attribute importance in addition to data availability. Each of these factors were mapped by interpreting and combining existing datasets to inform a relative resilience value for the 1 km reporting squares. Factors informing each attribute were combined to create an 'attribute map' to spatially represent relative resilience of the five attributes, and then combined into one resilience map. Data availability and knowledge gaps were significant drivers for factor selection and scale consistency was emphasised.

3.3 Challenges of applying the DECCA attributes to marine ecosystems

Ecological processes in the marine environment are highly spatially and temporally variable. They are often specific to habitats, communities and biogeographic regions, and incorporate highly complex interactions between biophysical parameters and species groups. Accurate measurements of many marine system processes are therefore challenging due to both this complexity and dynamic nature of systems (Griffith & Fulton, 2014, Kool & Nichol, 2015).

A particular challenge is in accurate assessment of *connectivity* in marine populations since it is intrinsically dependent on system processes. The concept of connectivity relates to the rates, scale and spatial structure of exchange between populations (Cowen *et al.*, 2006).

Connectivity, the extent to which spatially distinct populations, communities, ecosystems, or habitats are linked, by the exchange of genes, organisms of all life stages, nutrients, and energy, is considered an important ecological criterion in the design of MPA networks, where the whole is more than the sum of its parts (Botsford *et al*., 2009; Cowen *et al.*,2000). However, the use of connectivity in designing MPAs globally has been limited (Leslie, 2005, Magris *et al.,* 2014) due to the challenges of estimating and predicting connectivity patterns (Thorrold *et al.,* 2002; Botsford *et al.,* 2009; Burgess *et al.* 2014; Bryan-Brown *et al.,* 2017).

Connectivity within the marine environment is primarily driven by the dispersal of larval stages of species by physical processes (winds, waves, tides and currents) and modified by relatively small larval movements and behaviours (Kool & Nichol, 2015). In addition, an increase or decrease in connectivity may not be directly indicative of a better or worse state, and the consequences are dependent on the system and processes within the relevant ecosystem. For example, high connectivity can have positive or negative influences on ecosystem components, depending on the circumstances, as can low connectivity (i.e. high retention). This is evidenced in processes related to the transport of eggs and larvae from spawning grounds to nursery areas, that could either be critical to successful survival or alternatively, contribute to the spread of harmful species and/or diseases.

There remains a significant gap between the increasing volume in scientific research on connectivity and its integration into marine spatial planning. Despite importance of this ecological attribute being recognised (Margules & Pressey, 2000; Roberts *et al*., 2003; Steneck, 2006), access to tools and operational frameworks that facilitates collaboration between sectors, has been limited. Additionally, connectivity is not an area-based target as many other ecological attributes hence making it difficult to develop quantitative objectives for marine spatial planning (Balbar *et al.*, 2019).

O’Leary *et al.* (2017) undertook an expert survey on marine resilience to understand factors that contributed to or prevent resilience across ecosystems. They reviewed published articles (n = 129) suggested by global marine experts as the most important publications relevant to resilience to climatic impacts across a diverse range of marine ecosystems. This review identified key factors important in promoting and preventing marine resilience from a management perspective (Figure 13, Table A and B respectively).

By surveying marine experts, the study accessed decades of experience on climatic stress and the response of biogenic habitats and elicit data scarcely published. The survey indicated that *bright spots of ecosystem resilience* were surprisingly common across six major coastal marine ecosystems - with resilience found across a wide range of climatic disturbance types and lengths, indicating that ecosystems can be resilient to even long-term chronic climatic stress. These bright spots represent opportunities for identifying and evaluating factors that support the resilience of coastal ecosystems undergoing climatic stress, thereby providing important information for the conservation and management of current and likely future conditions. These positive results provide some optimism that it is possible to identify and manage our marine environment for conditions that facilitate marine resilience (O’Leary *et al.,* 2017).

Although various factors were identified as important in promoting resilience to climatic impacts, *recruitment/connectivity* and *remaining biogenic habitat* (extent) were ranked most commonly as very important across expert opinion and literature – in addition to physical setting and management. This indicates that the protection of habitat and populations at locations where conditions may promote resilience, such as designated and well-managed Marine Protected Areas, may be the most effective approach to supporting marine resilience. The high frequency with which local stressors (both anthropogenic and biotic) were cited as important in preventing resilience in both the expert opinion and literature supports the importance of targeted action to reduce anthropogenic pressures in MPA networks as part of a coherent, integrated resilience-building management strategy.

Figure 13. Factors that increase (A) and decrease (B) the resilience and recovery of coastal biogenic ecosystems (from O'Leary *et al*, 2017):

Table A.

Survey response option	Description and examples
Adequate recruitment or connectivity	Supply of new recruits and connectivity with adjacent sites via larval or propagule dispersal (e.g., Thrush et al. 2013)
High levels of beneficial species interactions	Intact trophic structure facilitating key processes such as herbivory and predation or mutualisms can help maintain biogenic habitat and increase resistance to climatic stressors (e.g., Mumby et al. 2007)
Physical setting	Favorable temperature, currents, isolation, or position relative to sediment source can provide increased resistance to climatic stressors by ameliorating their effects (e.g., Alongi 2008)
Adequate remaining biogenic habitat	High amount of biogenic habitat maintained after disturbance (e.g., Guzman and Cortés 2007)
Genetic diversity or adaptation	Amount of existing genetic diversity prior to a disturbance that enables some proportion of biogenic habitat to survive disturbance (e.g., Hughes and Stachowicz 2004)
Functional diversity or redundancy	Multiple species that play similar roles in an ecosystem prevent system collapse if some species are lost (e.g., Palumbi et al. 2008)
Remoteness or low human accessibility	Level of isolation from any human disturbance (e.g., Gilmour et al. 2013)
Conservation and management measures	Active management to preserve an ecosystem or reduce nonclimatic forms of stress (e.g., fisheries restrictions or marine protected areas; Micheli et al. 2012)

Table B.

Survey response option	Description and examples
Space preemption preventing recovery	Phase shifts to alternative stable states caused by disturbance that then prevent recovery of the original habitat-forming species (e.g., Perkol-Finkel and Airoldi 2010)
Additional chronic (biotic) disturbance	Disease, invasive species, predator, or grazer outbreaks that reduce the ability of a system to withstand climatic stress (e.g., Hughes et al. 2003)
Additional local anthropogenic stressors	Local harvesting, nutrient input, or other localized human disturbance that reduces the resilience of systems to climate disturbance (e.g., Strain et al. 2015)
Additional global climatic stressors	Global stressors (such as ocean acidification) that reduce ecosystem resilience (e.g., Hoegh-Guldberg et al. 2007)
Lack of adequate management	Inadequate protection of ecosystems or habitats leading to reduced resilience (e.g., Beck et al. 2011)

3.4 Complexities in quantifying marine resilience

For ecosystem resilience to move from being a theoretical concept to one in practice, that helps guide management and inform policy decisions for the environment, some form of quantification is required (Pimm, *et al.,* 2019). Understanding and comparing differences in resilience across environments is critical for informing coastal management and policy, but the lack of simple, effective tools is currently a significant barrier such analysis and assessments (Masselink & Lazarus, 2019).

Quantifying resilience is not straightforward and remains extremely challenging - caution is advised in avoiding assumptions. Salt marshes, for example, have been found to be extremely vulnerable, with large salt marsh losses documented worldwide, and particularly in developed coastal zones (Lotze *et al.*, 2006, Kirwan *et al.*, 2019). However, estimates of critical rates of sea level rise for coastal salt marshes around the world indicate relatively high resilience at many salt marsh sites (Kirwan *et al*., 2016) with assessments highlighting that the *available sediment supply* is a key factor for marsh resilience to sea level rise (Ganju *et al.,* 2017, Thorne *et al.*, 2018). Salt marshes in microtidal regimes are particularly sensitive to a reduction in sediment supply under increasing rates of sea level rise, but salt marshes in macrotidal regimes are more resilient to high rates of sea level rise and/or reduced sediment supply. Resilience may be an intrinsic property of system structure and interactions, but is strongly related to, if not controlled by site-specific geographical, functioning dynamics and geomorphological processes hence further complicating any categorical statements about resilience in coastal ecosystems (Phillips *et al.,* 2018, Kirwan *et al.,* 2016, Masselink & Lazarus, 2019).

The concept of resilience is often closely linked to dynamical stability, however resilient coasts are not necessarily stable coasts. Given that resilience in geomorphic systems is sensitive to local geography, system dynamics and historical legacies (Lazarus *et al.,* 2019), blanket conclusions about the relative resilience of particular types of coastal habitats such as salt marshes, seagrass meadows, sand dunes becomes problematic. Until a better understanding of the multiple stable states of such coastal habitats is synthesised, managing coastal resilience in anthropogenically dominated contexts will remain a moving target. Also building resilience in coastal human–environmental systems requires a trade-off and balance between the needs to increase both the socioeconomic and natural coastal resilience for the future.

This highlights the need to view 'Ecosystem Resilience' as a property of complex adaptive systems, and as a consequence does not lend itself to be measured easily. Measuring and monitoring a narrow set of indicators or reducing resilience to a single unit of measurement is likely to block the deeper understanding of system dynamics needed to apply resilience thinking and inform management actions. Integrated resilience assessment approaches - such as the DECCA Framework in Wales (Latham *et al.,* 2013, Environment Act 2016) attempt to focus on a deeper understanding of system dynamics and resilience assessments, to capture resilience in a rigorous and repeatable way.

4. Marine programmes building ecosystem resilience in Wales

Seal pup, Skomer Marine Conservation Zone

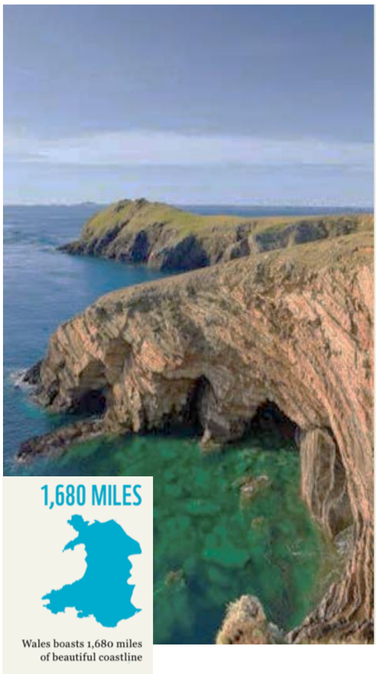
Managing for a resilient ocean must recognise that marine ecosystems can function in many different states, characterised by different species, community structures, and ecosystem processes - that can either be resilient or susceptible to change. These different ecosystem states deliver varying levels of ecosystem services. The point at which the system transitions from more desirable to undesirable states, known as the threshold or tipping point, often occurs relatively rapidly and is often unidirectional (Hoegh-Guldberg *et al*., 2007).

These state changes are well published in scientific literature for kelp forest ecosystems and illustrate how changes in biotic and abiotic drivers can result in state changes. Kelp forests can support productive fisheries, kelp harvesting, recreational opportunities, and shoreline protection through wave reduction - the desirable state. However, if predators known to structure kelp forest communities and contribute to its resilience (e.g. urchin-eating fish, or lobsters) are reduced to low levels, the resilience of this desirable state decreases and the system tips into a less desirable state characterised by a high abundance of urchins and overgrazed kelp, resulting in fewer ecosystem services (Steneck *et al.*, 2002).

A major challenge for assessing ecosystem resilience in marine ecosystems in Wales relates to significant evidence gaps. Fujita *et al*. (2013) proposed, that in the absence of quantitative metrics of resilience and thresholds between ecosystem states for a specific ecosystems, a marine management framework is recommended focussed on maintaining ecosystem attributes contributing to resilience and keeping drivers of ecosystem change within ranges that prevent ecosystems from transitioning to less desirable states. This proposed approach aligns with the DECCA Framework for resilience assessment in Wales, improving resilience goals for Marine Protected Areas, marine spatial planning, water quality control programmes, and fisheries management.

Understanding the dynamics of marine resilience is critical to achieving sustainable human interactions with their supporting ecosystems and hence implementing sustainable management strategies. An ecosystem with high ecological resilience requires a substantial amount of energy to transition to an alternative state, whereas a low resilience system would transition with a relatively small amount of energy (Angeler & Allen, 2016).

4.1 Marine ecosystem management in Wales



Wales boasts 1,680 miles (2,740km) of coastline and is home to Britain's only coastal national park in Pembrokeshire. At around 32,000 km², the Welsh marine area is 35% larger than the Welsh land mass - with an area of approximately 21,000 km².

Approximately 60% of the Welsh population live at or near the coast, with marine ecosystems supporting local and national economies. Marine industries contribute over £2.5 billion to the Welsh economy every year, support recreation and tourism for the well-being of communities and represent irreplaceable national biodiversity assets (WWF Cymru, 2012). With 75% of the coastline designated for environmental importance, our coastal and marine habitats are irreplaceable natural resources that deserve and require the appropriate sustainable management to ensure benefits now and into the future.

Healthy seas contribute to the provision of food, essential goods/services and also importantly, to the well-being of local communities. The extreme effects of climate change coupled with the increasing intensity of anthropogenic coastal pressures, are triggering habitat and biodiversity loss. Managing individual sectors in isolation is not sufficient to protect and conserve marine ecosystems. Integrated ecosystem-based management is essential to ensuring healthy functioning ecosystems that can continue to support and deliver valuable goods and services (Defra, 2009).

The NRW Marine programme delivers a plan-led, evidence-based and integrated approach to the sustainable management of marine natural resource through implementation of the Wales National Marine Plan (WNMP) and Area Statements - marine and coastal environment.

Marine ecosystem resilience and marine biodiversity protection/enhancement in Wales is managed by NRW Marine programmes through the delivery of Environment Act principles for the marine environment, the Wales Marine Plan and the UK Marine Strategy (MSFD) and key associated legislation such as the Water Framework Directive, Habitats Directive and Birds Directives. This is currently achieved through:

- An ecologically coherent and well-managed network of Marine Protected Areas (MPAs) guided by the MPA Network Management Framework and Action Plan.
- Sustainable management of marine activities and realisation of opportunities for Blue Growth, including renewable energy and fisheries.
- Integrated coastal management to ensure coordination and consistency in management of coastal natural resources and opportunities for managed realignment.

To enable targeted actions and interventions to improve marine resilience in Wales, a better understanding of both the concept of 'marine resilience' and its assessment metrics is required. Applying the DECCA resilience approach (Chapter 3) alone to manage the marine environment currently poses some challenges due to the current evidence gaps in Wales. Therefore, the current focus in NRW is on management of the ecosystem pressures to support a natural recovery of system functions.

Key regimes, both current and planned that will support effective marine resilience management include:

- Implementation of the Welsh National Marine Plan and Activity Regulation
- New Marine Protected Areas
- MPA Network and Management
- MPA Network Condition Improvement Project
- Fisheries Management
- Water quality
- Habitat restoration initiatives

These regimes support the health and resilience of marine natural resources, such as water quality, intertidal and subtidal habitats, and hydrological conditions, which in turn will have a strong influence on the security of ecosystem services and benefits to well-being (SoNaRR, 2020).

4.2 The health of the marine ecosystems in Wales: impacts and trends

The Welsh inshore marine area extends from the mean high-water mark to 12 nautical miles, covering almost 15,000 km^2 or 41% of the territory of Wales. Our marine ecosystems are rich and diverse with 69% of inshore waters designated as part of the network of 139 Marine Protected Areas (MPAs) that contain a variety of diverse marine habitats, benthic and pelagic communities: marine micro/macroalgae, benthic invertebrates, fish marine mammals and birds.

Our marine environment delivers a wide range of important ecosystem services that contribute to the well-being and economy of local communities. Benefits include: aquaculture and fishing, marine renewable energy, carbon storage/sequestration, aggregate extraction, shipping and natural flood defence. The intrinsic value of the marine environment also links directly to social opportunities and well-being benefits from recreation, tourism, and other activities.

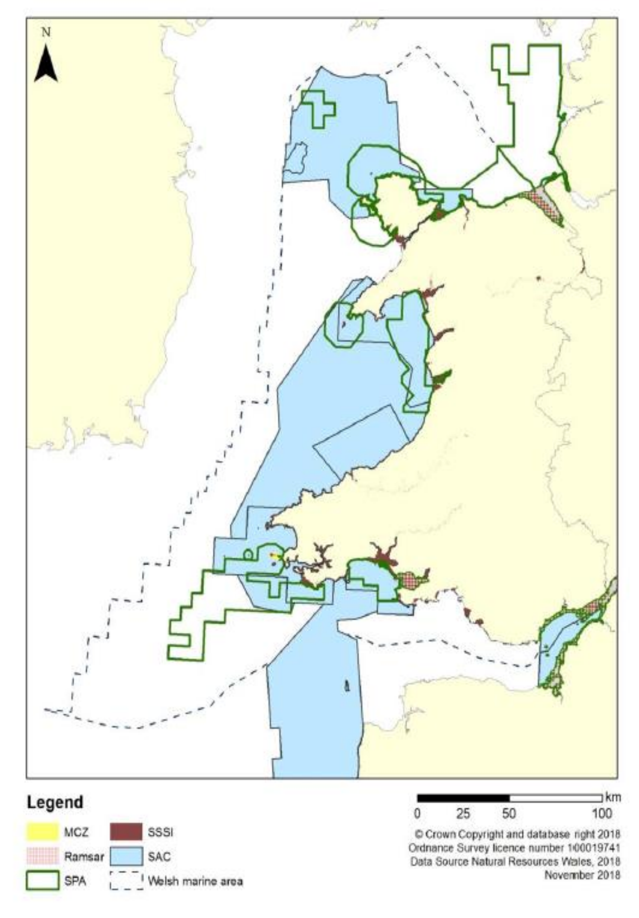


Figure 14. MPAs network in Wales.

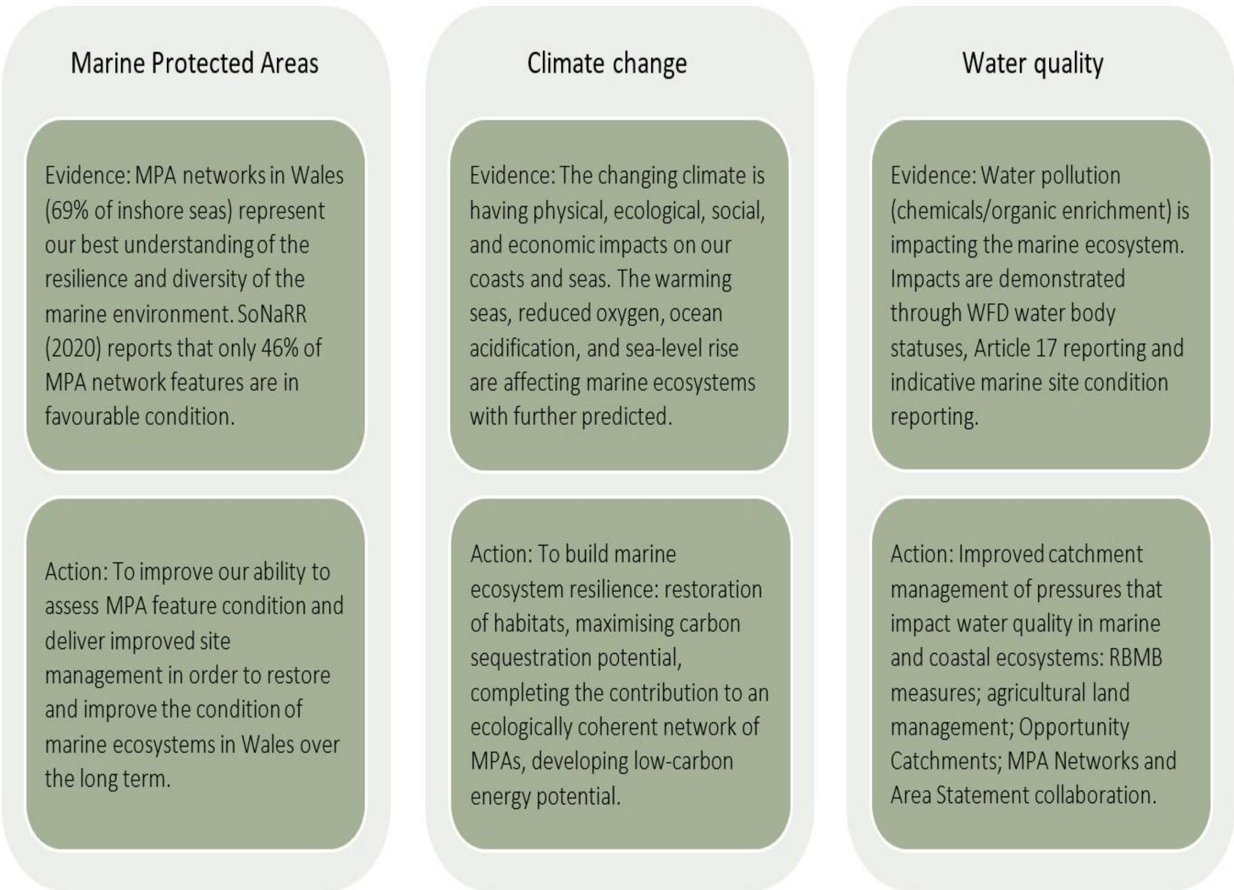
There is clear evidence that warming seas, reduced oxygen, ocean acidification, and sea-level rise are already affecting marine ecosystems, and further impacts are predicted. The SoNaRR2 (2020) report highlight the main pressures and challenges impacting the marine environment in Wales:

- The changing climate is having physical, ecological, social, and economic impacts on the marine environment in Wales.
- Increases in sea-level rise and coastal erosion driven by climate change expected.
- Changing shorelines will significantly impact coastal communities.
- Coastal defences such as sea walls currently inhibit the dynamic coastal habitat functions, essential for maintaining ecosystem resilience: extent and condition.
- Water pollution (nutrient levels and chemicals) is impacting the structure and function of marine ecosystems and compromising marine resilience.
- Air pollution is impacting the condition of the coastal margins ecosystem.

- Less than half (46%) of the Welsh MPA network features are in favourable condition. More needs to be done to secure effective and consistent MPA management.
- There are various evidence gaps across social, economic (including development) and environmental uses of the marine environment that restrict our ability to ensure sustainable management of marine natural resources.

Key message

Developing broader seascape scale ('Land to Sea') initiatives should be actioned to restore and enhance marine ecosystem resilience. A summary of key impacts, trends and proposed action for the marine environment in Wales is presented in the figure below with information from SoNaRR2 2020:

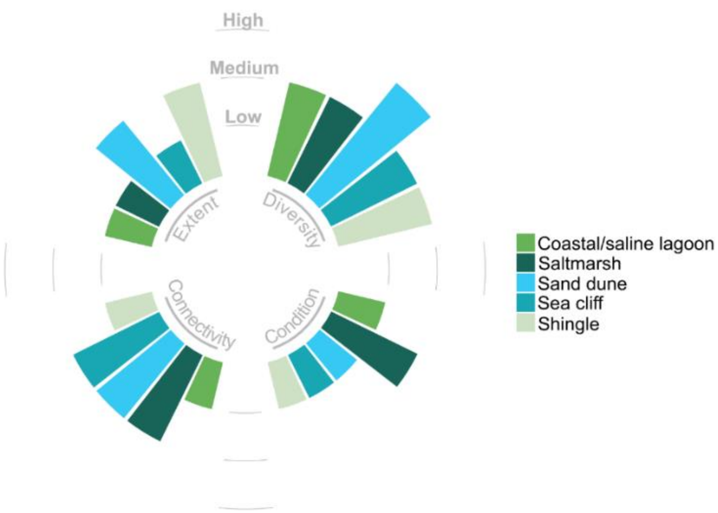


4.3 Marine ecosystems status in Wales assessed via the ecosystem resilience DECCA framework

The two NRW State of Natural Resources Reports (SoNaRR, 2016, SoNaRR2, 2020), have made first strides in assessing the ecosystem resilience of the national landscape. All ecosystem types in Wales have been assessed using the resilience DECCA attributes via an evidence-based plus expert judgement approach for ecosystem categories, to identify emerging patterns, status and trends of resilience.

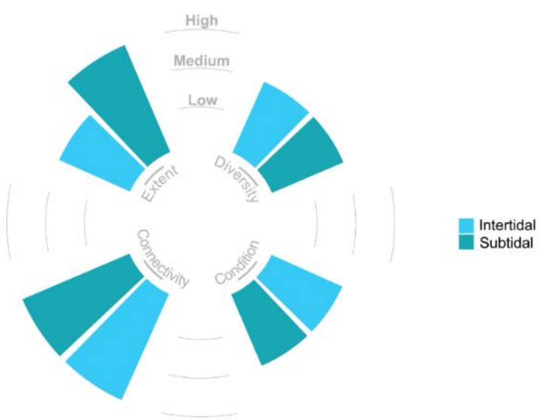
SoNaRR2 (2020) reported resilience assessment status for all ecosystem types (terrestrial, freshwater and marine) across Wales at a national scale. Resilience attributes were assessed and categorised as Low, Medium or High using evidence-based expert judgement, allowing inferences about the overall state of the resilience of different ecosystem types.

Figure 15. Coastal margin and marine habitat DECCA assessments (SoNaRR, 2020):



Coastal margin habitats:

- Moderate level of diversity with all types medium or high.
- Extent and condition are predominantly low
- Connectivity is low to medium



Marine habitats:

- Intertidal habitats have medium diversity and extent, with low condition and high connectivity.
- Sub-tidal habitat has high extent and connectivity but medium diversity and condition.

4.4 Building marine ecosystem resilience in Marine Protected Areas (MPAs) in Wales

A healthy, vibrant ocean supports healthy communities (Rao, 2015) and healthy ecosystems (Hoegh-Guldberg *et al.*, 2019). This connection is made in the United Nations Sustainable Development Goal for the ocean, SDG 14: Life Below Water. SDG 14 has seven main targets that aim to "*conserve and sustainably use oceans, seas and marine resources for sustainable development*." This connection is echoed by the Environment Act (2016) for Wales to achieve healthy ecosystems and sustainable fisheries.

SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development (United Nations).

Marine protected areas (MPAs) are one of the most widely utilised tools to preserve biodiversity, protect ecosystem services and build marine resilience to achieve ocean sustainability. Effectively managed MPAs, are vital for protecting biodiversity, the health of marine ecosystems and help safeguard ecosystem goods and services. They provide sanctuary for species and help restore healthy populations within and beyond their borders. These areas also build essential resilience against threats such as climate change and pollution by maintaining natural processes, storing carbon, and buffering coastlines as well as ensuring sustainable food supplies for coastal communities (The Marine Protection Atlas).

The past decade has seen a marked increase in the establishment of MPAs throughout the world (Watson *et al*., 2014, Lubchenco & Grorud-Colvert, 2015). This global response was motivated by the International Union for the Conservation of Nature's (IUCN) agreement to establish 10% of marine waters in MPAs by 2020 - formally adopted as Aichi Target 11 by the Convention on Biological Diversity and under the United Nations' Sustainable Development Goal 14 ('*Life Under Water'*). The increase in MPA development globally also reflects a growing number of scientific studies that have shown how MPAs can achieve a variety of conservation roles.

Global Ocean Alliance is a UK led initiative to champion an international commitment for a minimum 30% of the global ocean to be protected through Marine Protected Areas by 2030. This target is called the 30 by 30 initiative (30x30) with the ambition of halting biodiversity loss, ensuring global fish and food supplies and maintain a healthy ocean resilient to climate change. (UK Government Press Release, 2020).

MPAs, protecting ocean habitats by restricting specific activities, have been in existence for many decades (Solandt *et al.,* 2020) and exist in all shapes and sizes. An overarching emerging theme in the scientific literature is that the MPA quality is of equal importance to quantity. MPAs are not all equal and they offer varying degrees of protection: from minimum protection at the lower end of the scale with only a small conservation benefit up to highly protected that limits destructive activities and to fully protected status with no destructive activities and with full biodiversity protection (IUCN, 2019). Highly or fully protected areas are documented globally for contributing to biodiversity protection and conservation targets (Sala *et al.,* 2018).


a) FULLY PROTECTED: no extractive or destructive activities are allowed, and all impacts are minimized.

b) HIGHLY PROTECTED: only light extractive activities are allowed, and other impacts are minimized to the extent possible.

c) LIGHTLY PROTECTED: some protection exists but moderate to significant extraction and impacts are allowed.

d) MINIMALLY PROTECTED: extensive extraction and other impacts are allowed while still providing some conservation benefit to the area.

The MPA Guide recognizes four levels of protection of biodiversity from: IUCN World Commission on Protected Areas, Marine Conservation Institute, National Geographic Society, and UNEP World Conservation Monitoring Centre (2019)

Figure 16. MPA protection levels (IUCN, 2019)

https://www.youtube.com/watch?v=JgI_2MtdKYo

Key message

A well-managed ecologically coherent and resilient network of MPAs in Wales will help restore, protect and enhance the marine environment. Holistic approaches involving Marine Protected Areas, make marine management more effective and improve environmental governance.

4.4.1 Management of MPAs in Wales to build marine resilience

Marine ecosystems in Wales are rich and diverse, with approximately 69% of inshore waters designated within the network of 139 Marine Protected Areas (MPAs). These sites protect diverse marine habitats, benthic and pelagic communities: marine micro/macroalgae, benthic invertebrates, fish marine mammals and birds.

The MPAs in Wales form part of a network of sites throughout UK waters, and in Wales, are managed as a network to help achieve good environmental status under the Marine Strategy Framework Directive. The 139 Marine Protected Areas in Welsh waters are made up of:

- 13 Special Protection Areas (SPAs)
- 15 Special Areas of Conservation (SACs)
- 1 Marine Conservation Zone (MCZs)
- 107 Sites of Special Scientific Interest (SSSIs)
- 3 Ramsar sites

In 2017, Welsh Government committed to developing an ecologically coherent, well-managed network of MPAs. This work is currently being taken forward through the Welsh MPA network completion project, with support from NRW and JNCC.

The MPA Network Management Framework for Wales developed by the MPA Management Steering Group sets out the structure for improving the management and condition of the network of MPAs in Wales for the period 2018–2023. The Framework is supported by an annual Action Plan, which sets out the priority network-level actions to improve MPA management of the MPA network in Wales. The MPA Framework and Action Plan provide a steer for Management Authorities to guide delivery of the long-term vision for the management of the network:

"The Welsh MPA network is under effective and consistent management which safeguards the marine wildlife and habitats of sites and leads to site features achieving or maintaining favourable condition. Network management supports resilient marine ecosystems which in turn help to achieve clean, safe, healthy, sustainable, productive, and biologically diverse Welsh seas. MPAs are valued for the long-term benefits they provide to the people of Wales through the protection of their rich natural and cultural heritage."

The MPA Management Steering Group has developed five management principles to guide delivery of the vision of the network. The management principles are:

1. **Strategic planning.**
2. **Regulation, development consenting and assessment processes.**
3. **Management advice and guidance.**
4. **Understanding the condition of, and pressures and threats on, sites and their features to inform management.**
5. **Wider management.**

In 2016, NRW started work with partners on the MPA Network Condition Improvement Project (CIP) to address the recognised threats and pressures impacting MPA features. This is now part of the MPA Network Management Framework with the following priority work areas:

- Access and Recreation – e.g. damage to habitats or disturbance of species
- Water management and issues – e.g. coastal squeeze, flood, and coastal erosion risk management
- Pollution and waste – e.g. marine litter and diffuse water pollution
- Agriculture and land management
- Marine fisheries

4.4.2 MPA assessment, status and trends for marine resilience

In 2014, Welsh Government requested an analysis of progress towards the development of an ecologically coherent network of MPAs in waters around Wales. JNCC and NRW processed available data to enable Welsh Government to demonstrate the level of progress and Wales' contribution to the wider network of MPAs in the UK (JNCC Evidence Report, 2016) to seek the following information:

- How do existing MPAs in Wales contribute to the ecologically coherent network of MPAs in the UK?
- Are there any shortfalls in the network of MPAs in Welsh waters?
- Advice on potential options for filling any gaps.

The MPA designation types included in this JNCC assessment were: Special Areas of Conservation (SACs) with marine components, Marine Conservation Zones (MCZs) and Nature Conservation MPAs (NCMPAs).

MPA management assessment

The degree to which management actions are effectively achieving the agreed MPA goals and objectives in Wales is assessed via OSPAR. The OSPAR approach reviews the implementation of management actions, recognising that the management success of the MPA network will be linked to the achievement of the conservation objectives for the features of individual MPAs. OSPAR assessments for all MPAs are undertaken via a questionnaire approach to review the implementation of the MPA management cycle and whether MPAs are meeting defined conservation objectives.

The overall conclusion from the OSPAR assessment for Welsh sites in 2018 is that sites are being *partially* managed, without improvement from 2016. However, the

2018 feature level condition assessments were updated to include additional indicative condition assessments.

Figure 17. Five main OSPAR principles

Features: *Sites should represent the range of species, habitats and ecological processes in the area. The proportion of features included in the MPA network should be determined on a feature-by-feature basis, considering whether features that are in decline, at risk or particularly sensitive are of a higher priority and would benefit from a higher proportion being protected by MPAs.*

Representativity: *To support the sustainable use, protection and conservation of marine biological diversity and ecosystems, areas which best represent the range of species, habitats and ecological processes.*

Connectivity: *This may be approximated by ensuring the MPA network is well distributed in space and takes into account the linkages between marine ecosystems.*

Resilience: *Adequate replication of habitats, species and ecological processes in separate MPAs in each biogeographic area is desirable where possible. The size of the site should be sufficient to maintain the integrity of the feature for which it is being selected.*

Management: *MPAs should be managed to ensure the protection of the features for which they were selected and to support the functioning of an ecologically coherent network."*

Indicative feature assessments

Since 2018, NRW have undertaken indicative condition assessments to assess features in Wales' European marine sites i.e. Marine Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) that are designated for features of European and international importance. These assessments monitor the indicative condition of features in key sites in Wales' network of MPAs. The process to produce indicative feature condition assessments at the site level uses a workshop approach that applies available evidence and expert judgement to provide an indication of feature conditions. The evidence *quality* is an integral part of the indicative assessment and is assigned via confidence levels (Low/Medium/High) associated with the feature assessments. A permanent, sustainable, site-level feature condition reporting process is currently being developed, that will facilitate more effective and frequent delivery of assessments.

The European Maritime and Fisheries Fund (2014-2020, EMFF) project 'Improving Marine Site Level Condition reporting', is currently developing indicators and a process for reporting on the condition of features protected in Wales' network of Marine Protected Areas (MPAs), that will improve both the quantity and quality of MPA evidence to support marine resilience assessments. The indicators and targets will then be piloted in MPA sites throughout Wales. This work aims to develop condition indicators for MPA features leading to a better understanding and enhanced resilience-based management strategy and protection for the MPA network in Wales.

In 2018, NRW published indicative condition assessments for the 128 features (the protected habitats and species) of marine Special Area of Conservation (SAC) and Special Protection Area (SPA) (NRW, 2019). Results reported 46% of marine features assessed were in favourable condition, 45% in unfavourable condition and 9% unknown.

Table 4. The indicative feature condition assessment reports indicate the current marine resilience status of the EMS in Welsh Seas.

Dee Estuary SAC	**Dee Estuary SAC** Indicative feature condition assessment report
Menai Strait and Conwy Bay SAC	**Menai Strait and Conwy Bay SAC** Indicative feature condition assessment report
Anglesey Coast: Saltmarsh SAC	**Anglesey Coast: Saltmarsh SAC** Indicative feature condition assessment report
Cemlyn Bay SAC	**Cemlyn Bay SAC** Indicative feature condition assessment report (November 2018)
Llyn Peninsula and the Sarnau SAC	**Lleyn Peninsula and the Sarnau SAC** Indicative feature condition assessment report
Cardigan Bay SAC	**Cardigan Bay SAC** Indicative feature condition assessment report
Limestone Coast of South West Wales SAC	**Limestone Coast of South West Wales SAC** Indicative feature condition assessment report
Pembrokeshire Marine SAC	**Pembrokeshire Marine SAC** Indicative feature condition assessment report
Carmarthen Bay and Estuaries EMS	**Carmarthen Bay and Estuaries EMS** Indicative feature condition assessment report
Kenfig SAC	**Kenfig SAC** Indicative feature condition assessment report
Severn Estuary SAC	**Severn Estuary SAC** Indicative condition assessment report
Marine SPAs in Welsh waters	Indicative condition assessment report on marine features of **Welsh SPAs**

Marine resilience status and trends in MPA networks in Wales

The JNCC Evidence Report: '*Assessing the contribution of Welsh MPAs towards an ecologically coherent MPA network*' (2016), concluded the substantial contribution MPAs in Welsh territorial waters make a towards an ecologically coherent network but acknowledged significant evidence gaps and some 'shortfalls' in the protection of habitats and species of conservation.

Broad scale assessment of marine ecosystem resilience in the Welsh MPA network is currently being achieved via the suite of ecosystem resilience attributes (DECCA framework): diversity, extent, condition and connectivity (Environment Act Wales, 2016). This approach supports sustainable environmental management for assessment, monitoring and targeted interventions. However, current evidence gaps are significant for marine ecosystems in Wales and hence an evidence-based expert judgement approach has been used to support resilience assessments where necessary.

SoNaRR2 (2020) has recently reported resilience assessment status for all coastal and marine ecosystem types across Wales at a national scale using information from the 2018 indicative site-level feature condition assessments, 2018 interim WFD water body classification, and 2019 Article 17 reporting for intertidal and subtidal habitats. Resilience attributes were assessed and categorised as Low, Medium or High using evidence-based expert judgement, allowing inferences about the overall state of the resilience of different ecosystem types. The SoNaRR2 (2020) status results for coastal margin and marine habitats are outlined in Chapter 4 of this Report.

Resilience assessment of marine resilience reported ‘stable’ or ‘good’ overall for the extent and connectivity of intertidal and subtidal habitats. However, environmental pressures such as nutrient enrichment, contaminants, invasive non-native species (INNS), coastal squeeze, and infrastructure developments have impacted biodiversity and condition of some habitats (SoNaRR2, 2020).

Resilience assessment of coastal margin habitats impacted by climate change and anthropogenic pressures, reported a moderate level of diversity with all types being scored as either medium or high. However, the extent and condition of these habitats are predominantly low in resilience although their connectivity is medium to low. Coastal and saline lagoons appear to be the least resilient of ecosystems (SoNaRR2, 2020).

Key message

Action is required to improve protection of our MPA networks by building marine ecosystem resilience and harnessing their climate mitigation potential. This can be achieved by reducing environmental pressures within MPA networks and supporting the natural ecological recovery. Carbon storage and sequestration potential of MPA network has potential to be significantly unleashed via strategic spatial planning and a wider scale integrated approach. This will help to transform and restore the ocean, maximise nature benefits, rebuild the intrinsic values of the ocean and provide societal benefits through Ecosystem Services.

5. Nature-based solutions (NbS) as a valuable tool for building marine resilience

Seagrass meadow

How do we meet the 3 major challenges of the Anthropocene?

1. Mitigating and adapting to climate change
2. Protecting biodiversity
3. Ensuring human wellbeing

Addressing these interdependent challenges together is the ethos of the United Nations Sustainable Development Agenda - one of connectivity, inclusivity and partnership. It acknowledges interdependencies of the 17 defined social, environmental and economic goals that encourages actions (SDG) (United Nations, 2015). However, despite the importance of taking account of synergies and trade-offs between these goals there is little evidence that this is happening in practice (Smith, 2013, Set *et al.,* 2018, Moyer & Bohl, 2019).

There is increasing global recognition that when managed sustainably, natural ecosystems that deliver essential ecosystem services for communities, are society's most important defence against the harmful impacts of climate change and anthropogenic pressures by providing long-term ecosystem resilience and adaptation capacity (IIED Briefing, 2018).

The approach provided for in Environment (Wales) Act 2016, describes the sustainable management of natural resources (SMNR) as a key mechanism for dealing with climate change and anthropogenic pressures. This approach for mitigation and adaptation addresses economic, social and environmental aspects with a focus on delivering multiple benefits that is well aligned with the UN approach to environmental sustainability. Nature-based solutions (NbS) are recognised as a valuable tool in building ecosystem resilience to tackle both climate change and support the sustainable management of our natural resources (Natural Resource Policy (NRP, 2017) and NbS should now be at the heart of our sustainable development effort in Wales.

It is against this backdrop that nature-based solutions that work with natural ecosystem processes to provide sustainable solutions, are emerging as an integrated approach to build ecosystem resilience (Stein *et al.,* 2013, Seddon *et al.,* 2019, Seddon *et al.,* 2020). NbS have the potential to tackle both climate mitigation and adaptation challenges simultaneously at relatively low-cost while delivering multiple additional benefits for people and nature (Seddon *et al.,* 2020).

5.1 Defining 'Nature-based Solutions' (NbS)

At the 2016 World Conservation Congress, the International Union For Conservation of Nature (IUCN) adopted a resolution (WCC-2016-Res-069) that defined NbS.

Nature-based Solutions (NbS) defined by IUCN as:

"actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

This definition is from an IUCN publication that outlines the NbS framework (Cohen-Shacham, 2016), and a set of eight best practice principles. The IUCN later identified the core principles for successfully implementing and upscaling NbS (Cohen-Shacham, 2019).

NbS involve working with nature and harnessing the functioning of healthy ecosystems to provide benefits to both the environment and society. NbS target major challenges like climate change, disaster risk reduction, food and water security, health and are critical to economic development. Solutions often enhance existing natural or man-made infrastructure and inject long-term economic, social and environmental benefits.

In contrast to engineered approaches, NbS often offer multiple benefits. When applied strategically and equitably, NbS are a key tool in safeguarding ecosystem services and building ecosystem resilience through protecting biodiversity. For example, protecting and restoring natural habitats along coasts or in river catchments can protect communities and infrastructure from flooding and erosion, whilst enhancing/protecting biodiversity and delivering additional benefits such as increased carbon storage as demonstrated in the Case Studies illustrated in this report (Section 5.3.2) (Maloney *et al.,* 2019).

The IUCN Global Standard (IUCN, 2020) provides clear parameters for defining NbS and a common framework to help benchmark progress. Such a framework is essential to increase the scale and impact of the NbS approach, prevent unanticipated negative outcomes or misuse, and help policy makers and other stakeholders assess the effectiveness of interventions.

For NbS to be effectively implemented at the scale needed to reverse ecosystem degradation trends, clear and coordinated principles are required to inform development of evidence-based standards and guidelines for practitioners and decision-makers. Without clear principles and standards, activities undertaken to improve ecosystem integrity and human wellbeing may have unintended consequences (Gann *et al.,* 2018). The new IUCN Global Standard (2020) enables consistent designs, assessments and scale-up of Nature-based Solutions.

Figure 18. Nature-based solutions (NbS) to protect and sustainably manage ecosystems in ways that address societal challenges both effectively and adaptively to provide well-being and biodiversity benefits (IUCN, 2020).

5.2 Delivering NbS for marine environments in Wales

NbS offer low-risk and cost-effective strategies to address the current climate and biodiversity crises and build marine ecosystem resilience. Four principles, endorsed by 20 environmental and academic organisations, ensure that NbS deliver sustainable, equitable benefits for climate change adaptation, mitigation, and other societal challenges. (https://nbsguidelines.info/).

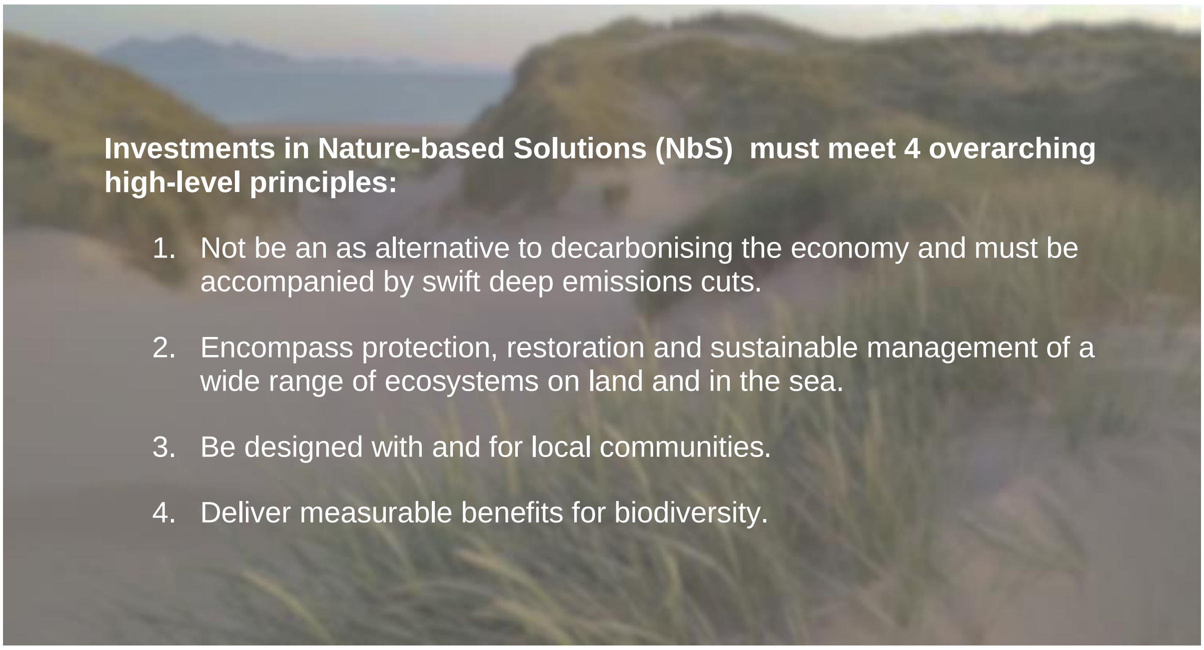


Image source: Newborough dune habitat (Sands of LIFE project), NRW.

Figure 19. The four overarching principles for Nature-based Solutions (NbS)

Protecting and restoring natural ecosystems is central to the climate change ambition of many countries, yet there is often a disconnect between vision and application (Seddon *et al.*, 2020). To address the mismatch between ambition and action, the science, practitioner and policy, communities must work together to:

- Clarify and properly disseminate information on what makes NbS effective
- Build practitioners' capacity to develop robust adaptation plans, fine-tuned to local socio-ecological contexts
- Access suitable levels of adaptation finance and/or technical support
- Ultimately implement effective NbS for the benefit of communities and the ecosystems on which they depend.

Figure 20. Important factors underpinning robust NbS design/approaches to deliver cost-effective solutions that effectively build resilience and deliver multiple benefits to natural ecosystems and communities (information from *Seddon et al.,* 2020).

The key role of NbS for cost effective adaptation to climate change needs to be recognised with a significant '*step-change'* in pace to scale up and deliver national Welsh NbS programmes. NbS can often improve upon engineered approaches at lower costs, delivering multiple benefits for climate change adaptation, mitigation, biodiversity, health, and the economy, supporting a fair and resilient economic recovery from the Covid crisis with significant potential for creating green jobs.

5.3 Realising NbS potential in MPA networks to build resilience in Wales

The marine environment plays a crucial role in climate regulation by acting as a sink for carbon in living tissue and oceans, and the longer-term sequestration of carbon in sediments. Seagrass beds and saltmarsh are good examples of 'blue carbon' sinks (Armstrong *et al.,* 2020).

5.3.1 Marine NbS: Blue carbon storage and carbon sequestration

The term 'blue carbon' refers to caron captured and stored by plants in coastal vegetated ecosystems, for example: seagrass meadows, salt marshes, kelp forests, rockweed beds and mangrove forests. The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019) describes the significant role of blue carbon in contributing to climate adaptation in addition to climate regulation. Blue carbon ecosystems provide a wide range of ecosystem services to both the marine environment and society, including benefits to fisheries, biodiversity protection/enhancement, storm protection and improvement to water quality.

Perhaps the most important ecosystem function is the ability of blue carbon ecosystems to sequester CO2 from the atmosphere and store it either as plant biomass or in the sediment as net sinks of carbon, and hence an important tool in climate change mitigation. More than half of the occurrence of natural carbon is taken up by the ocean, and blue carbon ecosystems are well documented as extremely effective for carbon capture despite their limited distribution across the globe. It is estimated that blue carbon ecosystems store five times more carbon per unit area than a tropical rainforest, a service that has now been recognised by the United Nations Intergovernmental Panel on Climate Change (IPCC).

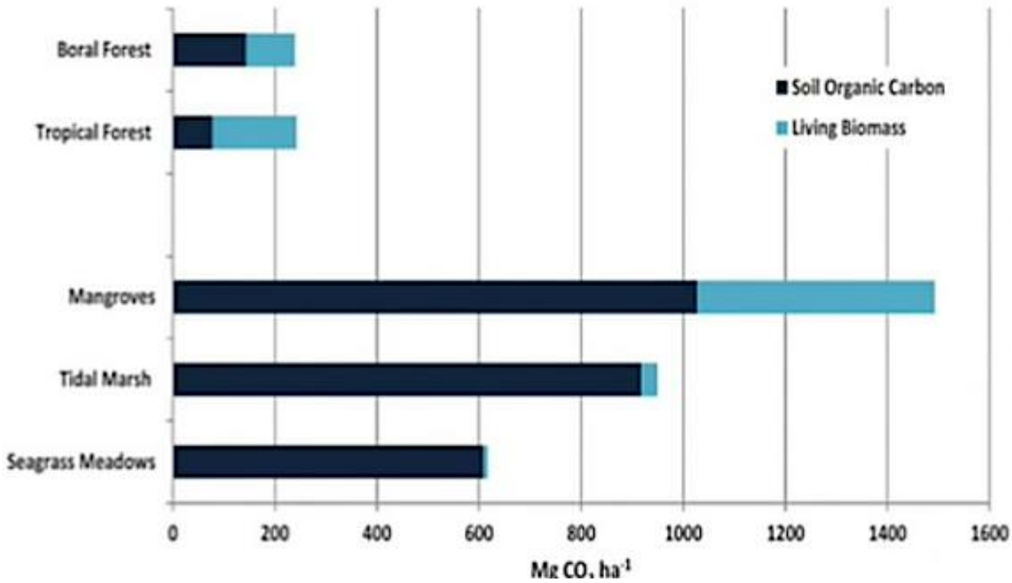


Figure 21. Mean Carbon storage above and below ground in coastal ecosystems versus terrestrial forests (Foururean *et al.,* 2012; Pan *et al.,* 2011; Pendleton *et al.,* 2012)

Blue carbon ecosystems are being degraded or destroyed as a result of human activities. Protection, restoration and sustainable use need to be key elements in the policy, management and use of these ecosystems. Protection and restoration of coastal blue carbon habitats provide wide ranging societal benefits in addition to climate regulation including benefits to fisheries, enhanced biodiversity, storm protection, reduced coastal erosion, water quality improvements and support to local communities ICPP (2019).

Coastal blue carbon investments can also be considered a cost-effective, *'no regrets'* mitigation strategy at the national MPA network level (Windham-Myers *et al.,* 2019). Additional research is however, needed to improve knowledge and understanding of the complex carbon dynamics of coastal vegetation and associated systems. Although the contribution of seagrasses to global oceanic carbon storage has been quantitatively acknowledged, most estimates come from just a few sites and seagrass species.

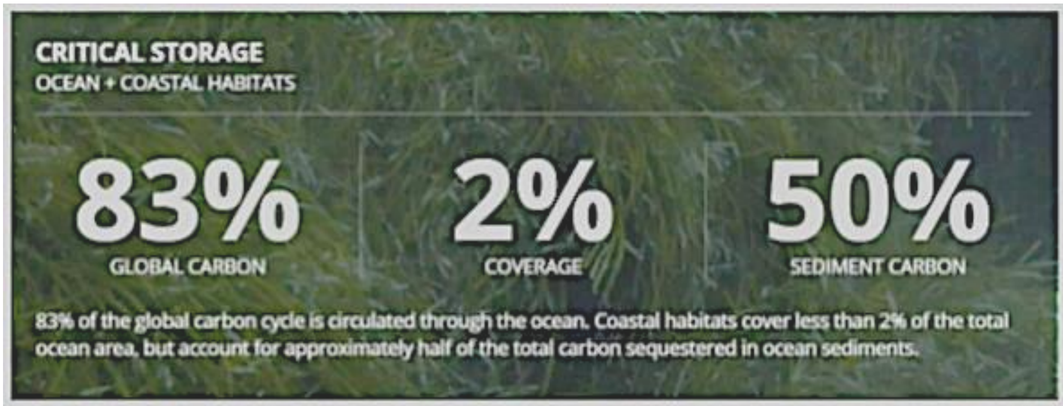


Figure 22. Global carbon storage in saltmarsh habitats (Coastal Futures, 2021)
Source: http://thebluecarboninitiative.org/bluecarbon

Recently there has been a growing recognition of the role and potential of carbon storage and sequestration in marine habitats in Wales. Blue carbon is a key tool in climate change mitigation. A recent study commissioned by NRW, assessed the potential of this untapped ecosystem service in marine environments, by mapping and quantifying Welsh marine carbon storage, sequestration and carbon budget (Armstrong *et al.*, 2020). The review highlighted the important role of marine habitats in tackling the Climate Emergency by offsetting carbon emissions via *significant* carbon storage and sequestration.

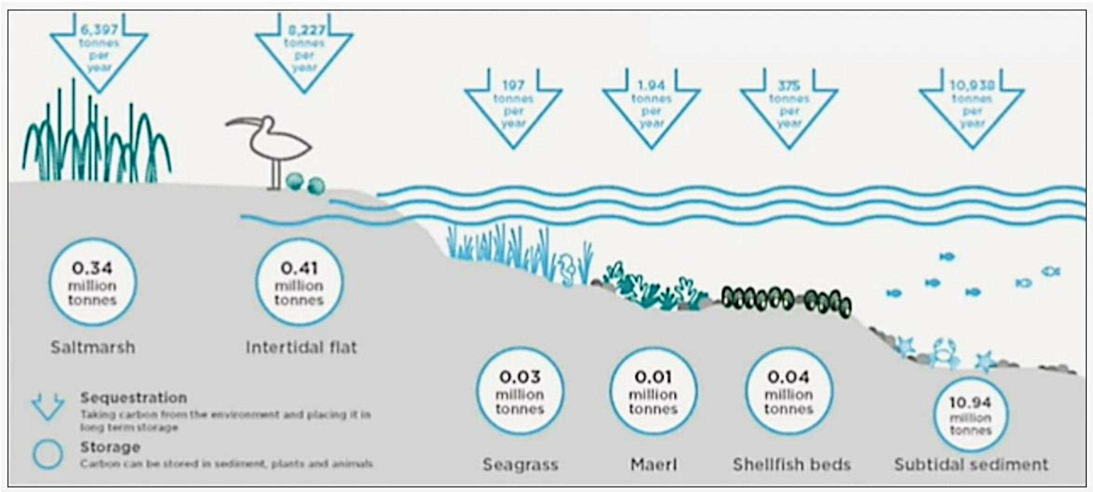


Figure 23. Carbon in Welsh Seas (Armstrong *et al.,* 2020).

Evidence gaps for marine carbon data in Wales, prevented accurate assessment of carbon fluxes and sequestration rates, impacts of marine activities on sequestration and effects of habitat condition and types on sequestration rates (Armstrong *et al.,* 2020). However, estimates concluded there are more than three million hectares of blue carbon marine habitats such as coastal salt marshes and seagrass beds in Wales, with an estimated current storage of at least 113 million tonnes of carbon in the upper 10cm of sediment - equivalent to 10 years' worth of Wales' emissions (BBC Wales, 2020) and 170% of carbon held in Welsh forests.

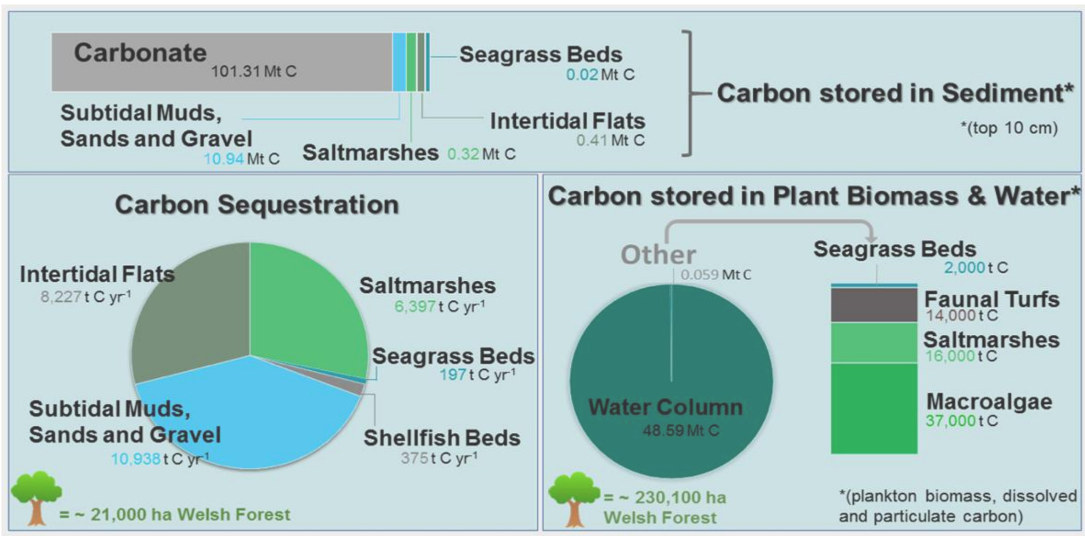


Figure 24. Blue carbon infographic (Armstrong *et al.,* 2020).

The table below illustrates the potential of blue carbon habitats in Wales (Armstrong *et al*., 2020). Of the habitats studied, *salt marshes* (*coastal wetlands)* that are constantly flooded and drained by the tides, were found to be most effective habitats for carbon storage and sequestration.

Table 5. The potential of blue carbon habitats in Wales (Armstrong *et al.*, 2020):

Habitat	Carbon storage (soil and biomass) (kg m^{-2})	Sequestration rates (kg m^{-2} y^{-1})
Maerl	12.51	-
Saltmarsh	4.41	0.084
Horse mussel bed	4.0	0.04
Seagrass	1.61	0.027
Intertidal flats	0.55-1.84	0.011- 0.037
Brittlestar beds	-	0.082

Armstrong *et al.* (2020) estimated that Welsh marine habitats sequester at least 26,100 tonnes of carbon (or 0.03 Mt C) equivalent to 95,900 t CO2e (CO2 equivalent units) every year, with saltmarshes and intertidal flats accounting for a large percentage of this value. This represents around 7 % of the amount sequestered by Welsh forests every year (approx. 21,000 ha of forest). Saltmarshes sequester the most out of all the habitats per hectare of habitat, though slightly less than a hectare of Welsh forest (about two-thirds) – mainly due to sedimentation processes. Hence areas with high suspended sediment loads would be likely to return higher sequestration rates.

These estimates for current carbon and sequestration in Wales, emphasise the importance of the protection and restoration of our high value blue carbon habitats to maximise their carbon sink potential and to build marine resilience. A large-scale restoration and regeneration programme, led by Swansea University, Sky and WWF, has been launched in Pembrokeshire to restore two hectares of seagrass meadows, with wide reaching catchment benefits (Section 5.3.2, Case Study 1).

Opportunities for building marine resilience via Blue Carbon investment
Greenhouse gas emissions (GHGs) and removals resulting from changes in salt marsh management can be included in national accounting under the Land Use, Land Change and Forestry sector (LULUCF). This opportunity for offsetting, provides attractive opportunities for policy makers to actively drive saltmarsh regeneration to build coastal resilience - realising their potential for climate change mitigation (Johnson *et al.,* 2016). This is currently the only sector of the national GHG Inventory (GHGI) that is a net sink, with scope to offset emissions to other sectors. The IPCC Wetland Supplement (IPCC 2013) to the IPCC guidelines provides expanded guidelines for the accounting of GHG emissions and removals associated with different wetland types, including tidal marsh drainage and rewetting.

Mapping carbon stocks in Wales could be used to provide an assessment of GHG removals from these habitats and integrated into the GHG inventory. This will create an opportunity to support Welsh Government's commitment to nature conservation at this time of both a nature emergency and climate emergency (Coastal Futures Conference, 2021).

Moving forward

Laffoley, Marine Vice Chair of The World Commission on Protected Areas, IUCN and Keynote speaker at Coastal futures Conference (2021): 'The ocean climate nexus and nature based solutions', suggested the following strategies to regenerate, restore and recognise the full potential of blue carbon ecosystems within MPA networks:

- Recognise the extent of blue carbon ecosystems present in MPAs.
- Reduce pressures causing disturbance or deterioration.
- Map extent and quality of carbon values in marine ecosystems less well documented within MPAs and implement management measures.
- Designate new MPAs based primarily on the carbon values for blue carbon ecosystems that lie outside existing MPAs, rather than only on traditional biodiversity values.
- Take measures to complement the MPAs using tools e.g. marine spatial planning and fisheries management measures to protect and best manage blue carbon opportunities.

Such a blue carbon strategy for Wales, would involve securing accurate carbon values of documented blue carbon ecosystems within our MPA network in Wales. The Marine Management Organisation (MMO) have current projects aimed at developing UK-wide GIS habitat maps for aiding identification of suitable areas for coastal and marine habitat creation or restoration in English waters. A similar project is currently underway in Wales. Such UK-wide resources will be important to underpin strategic NbS spatial planning in Wales.

Key message

Nature-based solutions (NbS) involve working with nature and harnessing the functioning of healthy ecosystems to provide benefits to both the environment and society. NbS offer low-risk and cost-effective strategies to address the current climate and biodiversity crises and build marine ecosystem resilience. To be effective however, they must be developed with clear and coordinated principles.

The significant potential for blue carbon habitats to transform and restore the ocean, build resilience, maximise nature benefits and rebuild the intrinsic value of the ocean should be unleashed. Coastal blue carbon investments are considered a cost-effective, '*no regrets'* mitigation strategy at the national MPA network level. Additional research is however, needed to improve knowledge and understanding of the complex carbon dynamics of coastal vegetation and associated systems.

5.3.2 Building marine ecosystem resilience through NbS in Wales: Case study examples

Figure 25. Case study 1: Seagrass Ocean Rescue to reinstate and regenerate blue carbon habitats, to build marine ecosystem resilience and deliver wide benefits.

Case study: Seagrass Ocean Rescue: a collaboration between Project Seagrass, Swansea University, Sky, and WWF.

Seagrass meadows were once common around the UK coast, but more than 90% have been lost as a result of pollution and anchor damage. Seagrass captures carbon from the atmosphere up to 35 times faster than tropical rainforests and supports up to 40 times more marine life than seabeds without grass – making these Blue Carbon meadows an important Nature-based mitigation strategy to combat climate change and build marine ecosystem resilience.

AIMS: Following 4 years of R&D work by Swansea University and Project Seagrass, the UK's biggest ever marine restoration project was launched in Dale, Pembrokeshire with the aim of restoring two hectares of seagrass.

DELIVERY: Over one million seeds are to be planted on the shallow seafloor in small hessian bags harnessed to 20 km of rope. The hessian bags increase seed survival rates - protecting against strong tidal currents, predators and sediment burial. Seeds will sprout through the bags and restore the seagrass meadow habitat. Techniques being implemented build on those successfully employed in Chesapeake Bay, US.

BENEFITS:

- The freshly planted seagrass is expected to trap up to half a tonne of CO2 per hectare from the atmosphere each year.
- Wide reaching catchment benefits including significant increases in biodiversity – the seagrass meadows act as a nursery for a wide variety of marine life, from endangered seahorses to sea snails. By restoring 20,000 square metres, the seagrass will be able to support 160,000 fish and 200 million invertebrates.
- The seagrass meadow acts as a filter, removing harmful pollutants including heavy metals from the seawater.

The following case-study examples demonstrate how NRW are currently building ecosystem resilience via an integrated nature-based solutions approach across catchments (‘Land to Sea’), to deliver wider coastal and marine ecosystem service benefits.

Figure 26. Case study 2: Sustainable tidal and fluvial flooding solutions: Fairbourne 'Brickpits' wetland habitat creation. (Maloney *et al*., 2019):

Case study: Fairbourne ‘Brickpits’ Wetland Habitat Creation

At risk from both tidal flooding and fluvial flooding from the Afon Henddol, Fairbourne- a village in West Wales has seen major benefits delivered via a NRW scheme to implement sustainable flood risk solutions whilst enhancing and conserving local biodiversity. The Scheme was future-proof designed by allowing for predicted climate change pressures over the next 50 years and has been awarded a “Best Practice” CIEEM award for nature conservation. Partners: NRW, supported by Black & Veatch Ltd and Galliford Try.

Location:

Major Scheme Initiatives:

- Completed in 2015, the scheme involved strengthening 1.8 miles of the tidal defences at Fairbourne and Arthog, and rebuilding the river Henddol and Morfa outfalls to provide better control of flood water
- A new channel was created for the river Henddol to divert storm flows and floodwater away from the village during high river flows

Benefits:

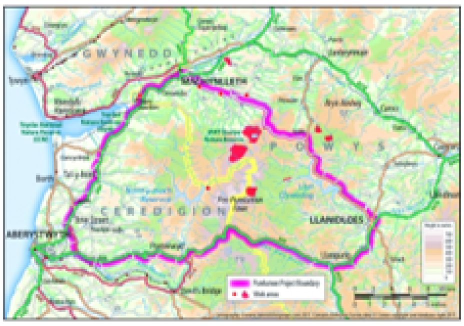
- NRW’s £6.8million scheme protects over 400 properties in Fairbourne from potential tidal flooding from the Mawddach estuary. The scheme also defends Fairbourne from river flooding
- Greater floodplain water storage in the channel that contributes to flood protection
- The reinstatement of natural habitat at Brickpits has led to greatly improved and enhanced biodiversity, enhanced coastal and terrestrial ecosystem resilience and improved community resources
- Wider ecosystem service benefits: water regulation, carbon storage, environmental resilience, recreation and amenity services
- 5ha of Biodiversity Action Plan habitat was created plus other Amenity enhancements: 2ha of Lowland Meadow habitat, 3.8ha of floodplain grazing meadow and 4 lagoons
- The grassland has been left to recolonise naturally to support regulatory function and enhance local native species

Coastal ecosystem resilience and communities are directly affected by upstream catchment processes. Hence, the importance of taking a broader-scale integrated approach to managing ecosystem resilience across 'Land to Sea' catchment scales. Implementing effective and sustainable nature-based solutions to upstream environments results in direct tangible improvements and benefits to coastal ecosystem resilience and communities, reducing flooding and pollution from agricultural run-off with associated water quality improvements.

Figure 27. Case study 3: Sustainable flood risk management solutions delivering wide-reaching benefits to coastal ecosystems and communities (Maloney *et al*., 2019):

Case study: Pumlumon Project, Montgomeryshire

Across 40,000 hectares of the Cambrian Mountains, an upland economy is being pioneered, built around long-term sustainability. Established in 2007, the Pumlumon Project is a radical rethink of how the landscapes and natural processes of upland Britain could offer sustainable flood risk management solutions. Partners: NRW, Welsh Government and Montgomeryshire Wildlife Trust



Catchment map illustrating Pumlumon project boundary and work areas.

AIMS: A large-scale ecological restoration project to revive the ecology and economy of the Welsh uplands. The primary aims are to increase flood water storage, reduce runoff potential and sediment loss to water courses, whilst also providing wide-reaching environmental catchment benefits – including to coastal ecosystems and communities.

DELIVERY: Increasing flood water storage is a central objective of the project and achieved by working with natural processes measures including peat regeneration, moorland grip-blocking and creation of flood storage areas. The water table was raised by a minimum of 5cm across the area.

Flood water storage

BENEFITS: The project has resulted in:

- Significant reductions in flood peaks in surrounding lowland catchment – including coastal communities.
- The peatbog restoration serves as an important carbon storage.
- Wide reaching catchment benefits: habitat creation and connection, increases in biodiversity with wildlife returning to the area and development of green tourism.

6. Marine ecosystem resilience enhancement opportunities

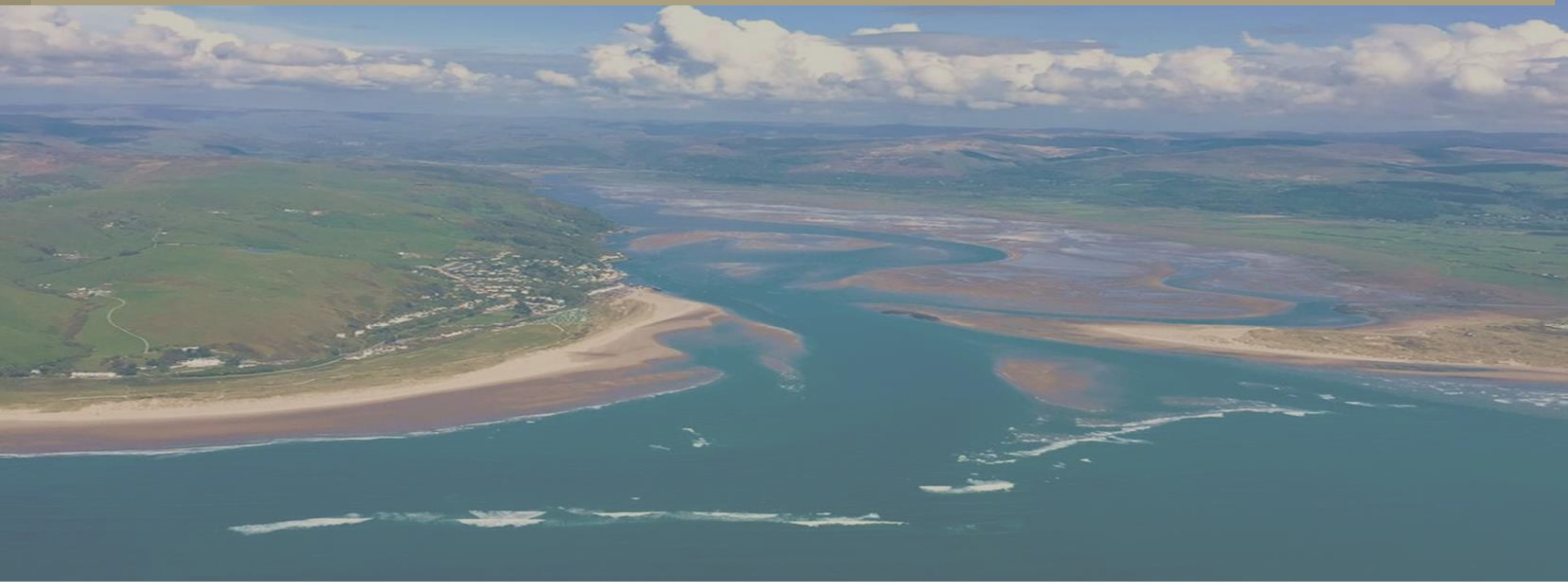


Image: Dyfi estuary, by Carl Hudson (Welsh Air Ambulance)

Holistic solutions that support healthy oceans for both nature and communities dependent on their services, are urgently needed for ocean sustainably and to restore/maintain marine biodiversity and the benefits it provides. Area-based tools such as MPAs can help achieve these goals, but parallel actions are also needed to achieve ocean sustainably. In an ever-changing, increasingly exploited ocean, our MPAs must work with one another in networks and with other tools e.g. Area Statements - across habitats, ecosystems and boundaries as part of an integrated ocean management strategy. MPAs are not a panacea, rather a powerful and often under-utilised marine management tool in a larger toolbox, to help achieve ocean protection. MPAs are less able to help with other SDG 14 targets, such as reducing pollution since MPA regulations end at their boundaries, but harmful pressures and impacts do not.

Marine ecosystem services are increasingly under threat and their future sustainability endangered by human exploitation that impacts the marine ecosystem resilience. As complex adaptive systems, marine ecosystems are composed of interacting individuals producing collective effects - integrating scales from individual behaviours to the dynamics of whole systems. Small changes are magnified through nonlinear interactions facilitating regime shifts and collapses. It is therefore important to align a resilience-based MPA management strategy to the appropriate system-level scale to protect essential ecosystem services for future generations (Levin & Lubchenco, 2008).

Action is now required to improve the resilience of our MPA networks, to ensure important ecosystem services are maintained. (SoNaRR2, 2020; Ocean Recovery, Coastal Futures Conference, 2021). Our ocean habitats need and deserve protection, with integrated actions across larger scales to build and enhance resilience.

This Marine Ecosystem Evidence Report has discussed the current understanding of marine ecosystem resilience, outlined how ecosystem resilience is currently assessed in Wales and has identified through a comprehensive literature review, key areas of opportunity and strategic actions to support marine resilience enhancement in Wales. These opportunities are summarised in bullet points below and presented in Figure 28.

The key opportunity areas and parallel strategic actions (summarised in Table 6, Figure 28) for enhancing marine resilience that have been discussed within this Report include amongst others: a wider-lens, 'Land to Sea' catchment approach to managing resilience, *game-changer* post-Brexit policy reforms and SMART targets to assess/improve resilience status.

Table 6. Key opportunity areas and strategic actions to enhance marine ecosystem resilience in Wales and support ocean sustainability

Key opportunity areas and strategic parallel actions to enhance marine ecosystem resilience in Wales and support ocean sustainability:

1. Integrated and interconnected spatial planning to 'make space for nature' and support healthier oceans via a 'joined up' planning approach. Ocean resilience-based management strategies are required across *all scales* (keystone species to watershed catchment level) to ensure integrated approaches to ocean sustainability. Our oceans and coastal zones are end destinations for catchment pollution. Resilience-based management should be viewed and actioned through an integrated 'catchment-wide' approach ('Land to Sea'), to shape and improve habitat resilience. Building resilience across the wider drainage catchment via an integrated approach is the most important approach for safeguarding marine ecosystems for the future.

2. 'Game-changer' Policy reform as a major post-Brexit opportunity to:

- Reform regulatory land management frameworks (e.g. future Agricultural Bill and National Minimum Standards) to drastically reduce anthropogenic pressures across drainage catchments ('Land to Sea'). Supported by robust monitoring and compliance policies to limit water pollution and drive improvements in catchment water quality. *Game-changer* policies that control/limit nutrient enrichment from agricultural fertilisers, land runoff and waste discharge are essential (nitrates and ammonia via Nitrate Vulnerable Zones and phosphates) to improve marine resilience.
- Reform Land Drainage Act (managed by NRW) to dramatically improve sustainable management of coastal low-lying Internal Drainage Districts (IDDs). Due for amendment, this presents a significant opportunity to improve management, drainage and coastal protection to deliver benefits for ecosystem resilience and carbon sequestration.

3. Unleash the carbon storage/sequestration potential of MPA networks to deliver integrated and effective nature-based solutions (NbS) both *within* and *outside* MPA boundaries, via strategic spatial planning and large-scale integrated approaches.

Recognise the potential for blue carbon habitats to transform and regenerate the ocean to maximise nature benefits and rebuild the intrinsic value of the ocean. Implement innovative and creative science based NbS solutions:

- *Within* MPA boundaries: with a significant drive towards improved opportunity mapping for blue carbon regeneration and implementation of innovative nature-based solutions to limit coastal erosion and coastal squeeze. Specific actions recommended include: improved robust mapping/monitoring of Welsh blue carbon habitats coupled with accessing available UK-wide environmental evidence databases, increased targeted scientific research to fill critical evidence gaps and increasing our understanding of the functional dynamics of blue carbon habitats in Wales, and improving knowledge exchange/collaboration between scientific research in Wales and policymakers.
- *Outside* MPA boundaries: NbS solutions in wider land-based catchment areas to deliver wider benefits for marine habitat resilience, for example: NbS for land-based flood storage, pollution mitigation solutions, fresh-water quality mitigation, nutrient enrichment mitigation. NbS case study examples 2 and 3 (Maloney *et al*., 2019) in Section 5.3.2.

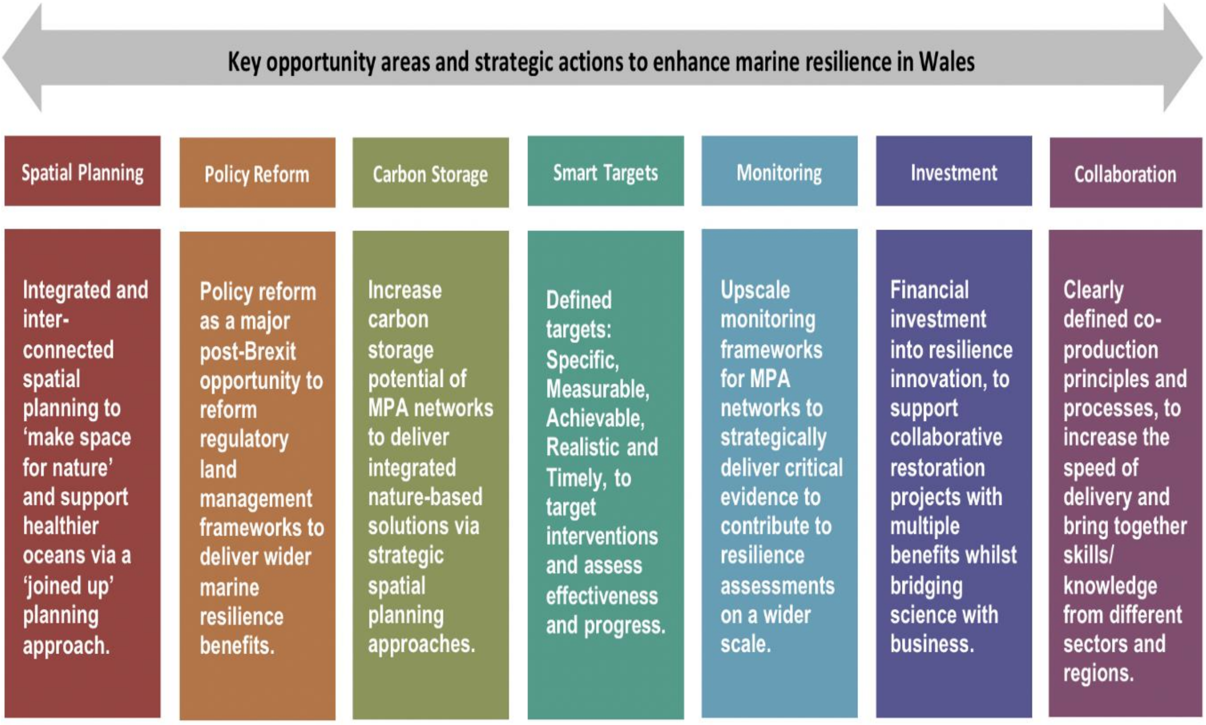
4. SMART targets (Specific, Measurable, Achievable, Realistic and Timely) to target interventions, assess effectiveness and progress.

5. Upscaling of monitoring frameworks for MPA networks to strategically deliver critical evidence and fill the gaps. Opportunities exist for marine monitoring in Wales to contribute evidence to support resilience assessments/reporting on a much wider seascape/ landscape scale, supporting a transformational resilience-based management approach.

6. Financial investment into ocean resilience innovation, to support collaborative restoration/regeneration projects with multiple benefits whilst bridging science with business to build ocean resilience in Wales.

7. Clearly defined co-production principles and processes to increase the speed of delivery, bringing together a wider set of skills and knowledge from different sectors, institutions and geographical areas. This action supports the SMNR principle for collaboration and engagement : '*to promote and engage in collaboration and cooperation'*.

Figure 28. Key opportunity areas and strategic actions to enhance marine ecosystem resilience in Wales.



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Appendices

Data Archive Appendix

The data archive contains:

The final report in Microsoft Word and Adobe PDF formats.