Cyfoeth Naturiol Cymru
Natural Resources Wales

The State of Natural Resources Report (SoNaRR): Assessment of the Sustainable Management of Natural Resources. Technical Report. Chapter 4. Resilient Ecosystems

Natural Resources Wales

Final Report

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About Natural Resources Wales

We look after Wales' environment so that it can look after nature, people and the economy.

Our air, land, water, wildlife, plants and soil – our natural resources - provide us with our basic needs, including food, energy, health and enjoyment.

When cared for in the right way, they can help us to reduce flooding, improve air quality and provide materials for construction. They also provide a home for some rare and beautiful wildlife and iconic landscapes we can enjoy and which boost the economy.

But they are coming under increasing pressure – from climate change, from a growing population and the need for energy production. We aim to find better solutions to these challenges and create a more successful, healthy and resilient Wales.

Evidence at Natural Resources Wales

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

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

The State of Natural Resources Report (SoNaRR) Report Contents

This document is one of eight chapters of the State of Natural Resources Report.

All of the SoNaRR documents can be downloaded from the NRW website: www.naturalresources.wales/sonarr.

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4. Resilient Ecosystems

Under the Environment (Wales) Act[1], NRW and other public bodies are required to seek to maintain and enhance biodiversity and promote the resilience of ecosystems. In the pursuit of sustainable management of natural resources, NRW is also required to consider resilience across all its functions. This chapter is the first attempt to set out a framework to assess the resilience of ecosystems in Wales so that we can understand the extent to which sustainable management of natural resources is being achieved.

4.1. Background to ecosystem resilience

Resilience is a term widely used across the public and private sectors. It relates to a broad range of issues, such as climate change, health, agriculture, community development, financial management, and drought and flood risk management. In our assessment of the sustainable management of natural resources we concentrate on ecosystem resilience: 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[2].

Quantifying resilience is difficult. Ecosystems are complex and dynamic. We cannot hope to recognise and understand all of the ways they respond to disturbance. 'Disturbances' themselves vary greatly in scale and duration, from one-off 'shock' events to long term, continuous pressures, which may also be part of natural or management processes. Of most concern, is our very poor understanding of thresholds - limits beyond which significant and perhaps catastrophic consequences follow. Evidence showing the extent to which thresholds are being approached or exceeded in Wales is very limited.

Despite these limitations, the evidence does indicate the range of activities and *direction* of improvements that are likely to improve the resilience of ecosystems. This is often reflected in targets or limits which, whilst not necessarily informed by causal mechanisms, provide reference points to help us to begin to assess resilience. The Environment (Wales) Act takes a pragmatic approach and brings in the idea of *building resilience*. This recognises five attributes (sometimes termed 'aspects') as building blocks of resilience which can be summarised as:

- Diversity
- Extent
- Condition
- Connectivity
- Adaptability

If interventions are targeted to these attributes, resilience is likely to be developed or enhanced, and the chances of crossing undesirable thresholds should be reduced.

The attributes provide a simple framework for considering the state of ecosystem resilience in Wales and can be applied across broad processes, scales, habitats and land uses. 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. This recognition of interconnections makes an approach based on resilience different to the traditional, more reactive responses in the management of natural resources**.**

4.2. Attributes for considering resilience

Diversity. Diversity matters at different levels and scales, from genes to species and from habitats to landscapes. It supports the complexity of ecosystem functions and the cascades of interactions that deliver services and benefits[3]. If diversity is lost, systems may collapse. For example, a forest's resilience to disease may increase with the number of tree species it contains as not all species are likely to succumb to disease simultaneously; transmission of disease may also be more likely within monocultures.

The function of individual components of a system are also susceptible to disturbance, so diversity is important for enhancing the capacity of the system as a whole to adapt to future change. We must also be aware that some individual and rare species may be disproportionately important for the delivery of key functions and therefore have a value beyond what we currently understand [4, 5]. It is important to note that diversity must also be 'appropriate'; some ecosystems, e.g. peat bogs, may have relatively low diversity, but, nonetheless, the particular range of species and habitats they contain are critical for their functioning. The bottom line is that our natural diversity – our native species and habitats – is vital for resilience.

Extent. The resilience of a system is linked to how large it is. The greater the extent of a habitat or species, the more able it will be to contain the effects of disturbance. For example, a larger area of habitat can support larger populations of species, which will be less likely to go extinct than a smaller one (and potentially also have a wider genetic diversity to provide more adaptive capacity) and be less affected by detrimental edge effects. There is also an influence of size on ecological processes, for example, a raised bog large enough to support its own hydrological system is likely to be more resilient to change than smaller examples. Consequently, the services provided by an ecosystem, such as water purification, flood attenuation or pollination will be become more stable and reliable as its size increases.

Many species have a minimum size of habitat required to support a population, below which they may become extinct. This process takes a long time (decades or even centuries) and so we may not yet have experienced the full impacts of past habitat loss and its effects on resilience[6].

Condition. Condition is a broad term that interacts with the other attributes in many ways. We are using it here to make a link to how a system is managed, what inputs are applied, what is taken from it, and how it is influenced by the management of the surrounding land. An ecosystem in poor condition will be 'stressed' and have reduced capacity to resist, recover or adapt to new disturbances, or to deliver ecosystem goods effectively.

Condition can be thought of in terms of broad ecosystem components relating to biodiversity, air, water and land. Resilience assessments therefore consider the condition of protected sites, soil, air and water quality, and the impacts of major land/sea uses and industries.

Connectivity. Connectivity is to do with movement within and between ecosystems. It usually applies to the movement of organisms: from foraging or migration of individuals, through dispersal of seeds and genes, to the major shifts of species' populations to adjust to a changing climate. It can also refer to movement within natural processes, for example, cycling of water and nutrients between different components of a landscape[7, 8].

Connectivity allows ecosystems to function and recover from disturbance but it is reduced through habitat loss and fragmentation, creation of barriers, and erosion of the 'permeability' that allows movement across the landscape. In the marine environment, there are situations where development interrupts connectivity in a similar way.

In certain situations connectivity may have negative aspects, for example, if it risks facilitating the spread of diseases, fire, or INNS. For this reason, plans to enhance connectivity need to be made in an informed and appropriate way.

Adaptability. Adaptability differs from the other attributes because it is part of the *definition* of resilience rather than an attribute that *supports* it. However, its inclusion in the Environment (Wales) Act is important because it emphasises one of the most important features of resilience: dynamism and the ability to adapt to change.

This is especially relevant to climate change where change is inevitable and we cannot expect to maintain the *status quo*. Instead we need to think in terms of changing species distributions, composition of ecological communities, and ecosystem function and process. This is where the elements of diversity, extent, condition and connectivity start to mesh and provide the basis for adaptation to happen. For example, maintaining diversity hotspots and connectivity between them can facilitate species' range shift[9].

Adaptability cannot yet be quantified in an equivalent way to the other attributes and so we have not used it in the assessment of resilience in this SoNaRR.

4.3. A framework for assessing resilience at different scales

Resilience can be considered at a wide range of scales and from the perspective of many different issues. Figure 4.1 suggests a framework for rationalising this complexity, based around three levels of detail. The top level considers how factors operating across ecosystems contribute to resilience at the national scale; this is equivalent to the level of national indicators, for example, those that will be used to report against national well-being goals. The next, more detailed level considers the overall resilience of broad habitats or land uses with respect to the resilience attributes. Finally, the most detailed level concerns individual places or issues; this is beyond the level of detail we could expect to consider within SoNaRR, but may be

important when developing Area Statements. The following sections present an assessment of the ecosystem resilience of Wales based on the top two levels in this scheme, and structured around the four quantifiable attributes: diversity, extent, condition and connectivity.

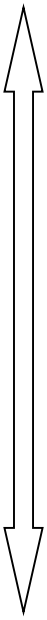
Scale	Scope	Relevant and related reporting mechanisms
National  Local	Broad factors operating across ecosystems	SoNaRR Well-being Indicators: • Biodiversity • Healthy ecosystems • Air • Soil • Water
	Broad habitat and land-use summaries	SoNaRR Other relevant schemes include: • Habitats Directive Article 17 • Water Framework Directive • GMEP • NCC methodologies[10] • Prioritised Action Framework for N2K Sites[11] • SSSI assessment and reporting • Woodlands for Wales Indicators[12]
	Specific sites and issues	Local and specific interest assessments, for example: • Methodologies published by the Resilience Alliance[13] • Resilience framework for resilience and tree health[14]

Figure 4.1 A simple framework to consider the assessment of resilience at different scales.

4.4. National scale – broad factors operating across ecosystems

This section uses evidence from Chapter 3 (and its supporting technical annex) to consider the state and potential for resilience at a national level based around the four quantifiable resilience attributes (i.e. excluding ‘adaptability’). Evidence is considered against four broad classes of natural resources (animals, plants and other organisms, air, soil, water) as well as in more detail through assessment of broad habitat types.

Diversity

Animals, plants and other organisms are fundamental units of biodiversity and a good starting point for considering resilience. For the ecosystems of Wales to be resilient, we would expect the full range of native species that remain to be maintained, with populations either stable or increasing. Exceptions are where species have unnaturally inflated populations through, for example, eutrophication; and where there are fluctuations in response to natural cycles.

The evidence presented in 3.1 of this report and its Technical Annex sets out a mixed picture, with populations of some species improving (e.g. birds, bats and freshwater species, but many others in decline over recent decades). Serious declines are reported for butterflies, moths and invertebrate species in general, many of which are considered Critically Endangered or Vulnerable (invertebrate Red List). For plants (including vascular, bryophytes and lichens) many are reported in decline, endangered or even extinct. Similar declines may be occurring within species groups we know little about – e.g. fungi and soil bacteria – but which are so essential for ecosystem functioning.

UK indicators for species abundance and distribution of priority species[15] corroborate these results, showing species declines continuing since the 1970s. The feasibility of a combined indicator of species abundance and distribution is being explored at a UK level. This has the potential in the future to be used as the WFG Act Indicator 44 'Status of biological diversity in Wales' and contribute to future SoNaR reports.

Habitats reflect ecosystem diversity. They are fundamental for providing the range of niches required for species and are often the functional units that deliver services (e.g. flood alleviation, pollination). Sections 3.6 – 3.13 and their Technical Annexes provide evidence of habitat loss, for example, for upland peatlands, semi-natural grassland, ancient woodland, sea cliffs and intertidal habitats. These losses are inevitably linked to the species declines described above and reinforce the picture of diversity decline across the natural environment.

Habitat survey can be used to examine broad patterns of natural diversity across Wales and will reflect overall ecosystem diversity. Figure 4.2 shows habitat diversity across Wales calculated on a $1km^2$ basis. There is clearly strong regional variation with notably higher diversity in more upland and coastal areas, and lower diversity along some major river valleys. Although these data are from a single survey and cannot show trends, patterns are consistent with evidence from Chapter 3 of regional variation of historical habitat loss.

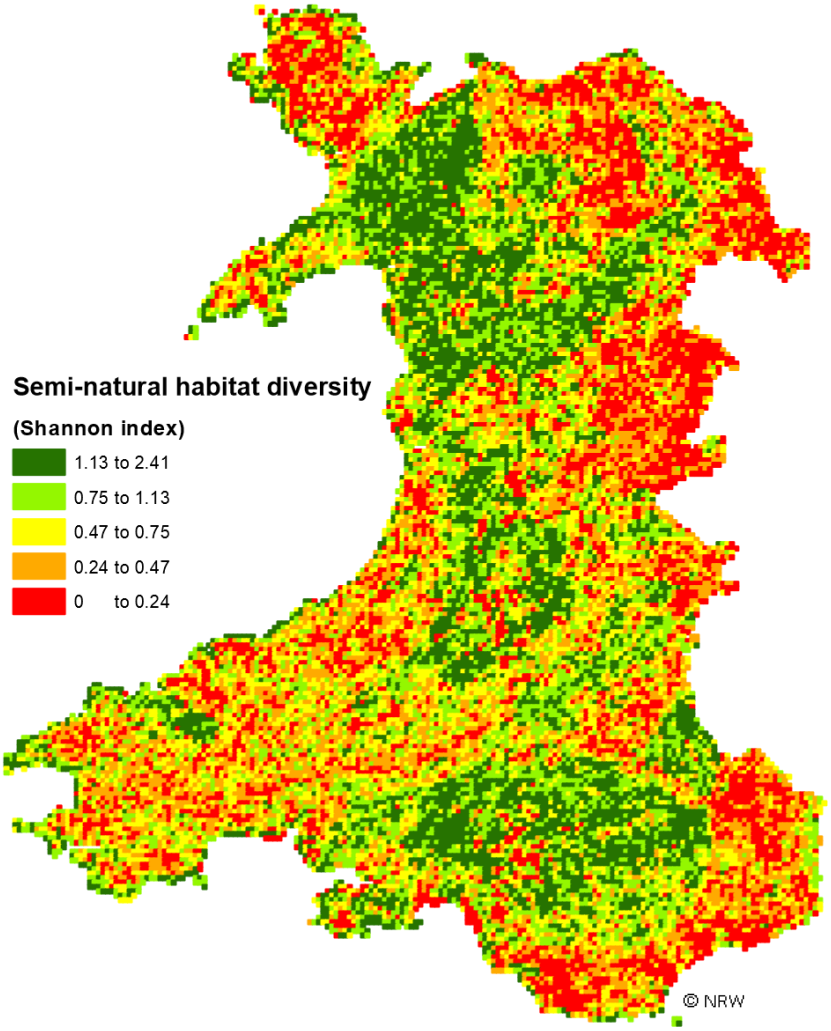


Figure 4.2 Habitat diversity of the land surface of Wales on a 1km^2 basis. Figure redrawn from Latham *et al*. (2008)[7]. Data are derived from the Habitat of Wales Survey[16], to which the Shannon Index (a standard measure of ecological diversity) has been applied: higher values mean higher diversity. **[H]**

Other measures of diversity

There are other aspects of diversity that will be relevant to understanding resilience, but are currently out of scope because data are not readily available or methods for assessment are not yet established. These evidence gaps need to be filled for future SoNaRRs and include:

- Genetic diversity
- Representation of biodiversity within protected sites, based on analyses of features
- Biodiversity within novel or modified habitats and its contribution
- Structural and spatial patterning of biodiversity
- Age structure within species' populations
- Soils and geodiversity
- Topography at regional and national scales
- Landscape evaluation statistics of changing overall diversity

Extent

The extent (i.e. size) of a particular ecosystem will affect how resilient it is. Looking at the total area of its component habitats is the simplest way to consider extent – specifically those habitats that have had least modification and are especially important for ecosystem function. This sort of information is available from habitat surveys.

At the national scale a simple measure could be based on the total area of semi-natural habitats in Wales. The National Indicator for WFG Act Indicator 43 'Area of healthy ecosystems in Wales' proposes this approach. The extent of semi-natural habitats at a national scale is seen as important because it reflects a number of environmental characteristics:

- The extent of habitat strongly influences biodiversity (e.g. it is linked to species population sizes and niche diversity).
- Habitat types reflect geodiversity, reinforcing the fundamental links within ecosystems.
- At the national scale, the extent of habitat will reflect the overall level of habitat connectivity.
- The relative proportion of more natural habitats will reflect ecosystem condition at a national scale.

The extent of habitats are described in Chapter 3. Major losses are well documented for individual broad habitats, and declines continue (see sections 3.6-3.13 and their Technical Annexes). Some habitats are considered to be at least stable or slightly increasing (e.g. semi-natural woodland, 3.9). These losses may have a fundamental impact on Wales' biophysical resilience, and the full impacts may take a long time to be fully realised because of the lag between habitat loss and species extinctions (extinction debt[6]).

Habitat surveys[16] can be used to identify regional variations in the extent of semi-natural habitats, as illustrated by Figure 4.3. The spatial pattern closely reflects diversity (Figure 4.2) and emphasises the differences between areas along the coast and in the uplands, where there is a high concentration of semi-natural habitat, and the more intensively managed lowlands and major river valleys, where there is relatively little semi-natural habitat.

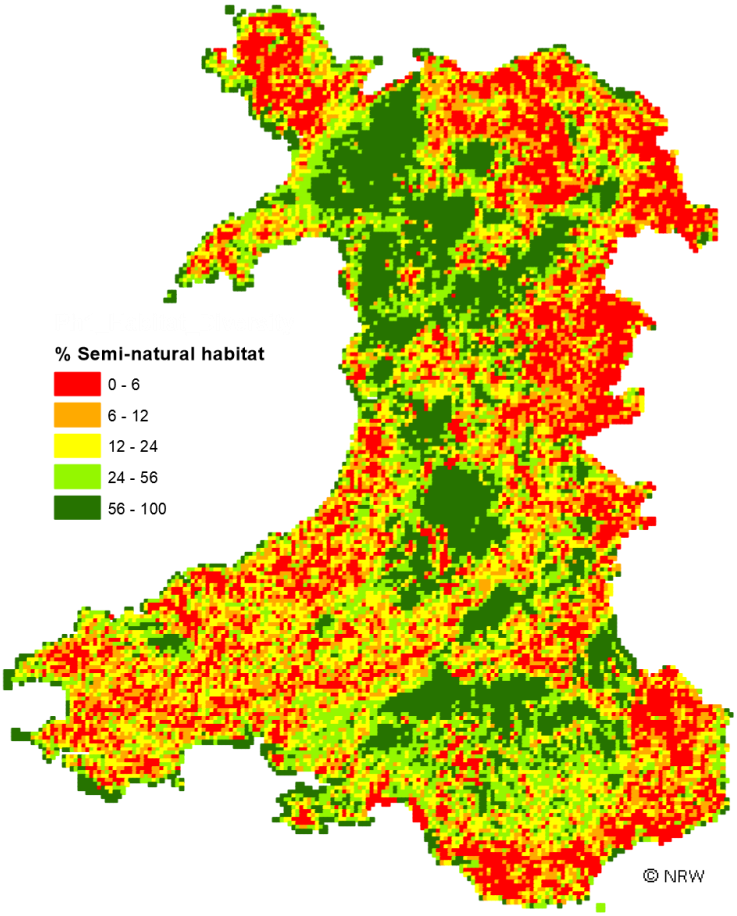


Figure 4.3 The relative abundance of semi-natural habitat on the land surface of Wales on a 1km^2 basis. Figure redrawn from Latham *et al*. (2008)[7]. Data are derived from the Habitat of Wales Survey[16] **[H]**

Condition

Condition covers a very wide range of factors. To summarise at a national level, we focus on the four components of ecosystems: biodiversity, land, air and water.

- **Animals, plants and other organisms** and **Welsh Ecosystems** sections provide evidence for biodiversity condition, especially with respect to the protected sites. For SPAs and SACs 55% and 75% of species and habitat features respectively were unfavourable (Sections 3 B; Welsh Ecosystems overview); only one in six freshwater habitat types are at Favourable Conservation Status (Section 3.10). SSSI data are not comprehensively available, but individual sections in Chapter 3 show that the majority of features for habitats and species are in unfavourable condition. Protected sites are generally managed to enhance their biodiversity features and therefore may be expected to be in better condition than the wider, unprotected resource[17, 18].
- **Soil.** Soils are crucial to terrestrial ecosystems and underpin vital ecosystem services. As such they provide a good starting point for considering resilience of 'the land' at this scale of assessment. Section 3.4 explains the importance of soils, their diversity in Wales (reflecting underlying geodiversity), their vulnerability and the many factors impacting on them. Evidence on the condition of soils is relatively limited, but available evidence suggests that the quality, overall, has decreased over time; peat soils in particular are shown to

be highly impacted. GMEP provides trend information for some aspects of soils for the past 30 years, indicating general stability but with improvements in condition with respect to pH and phosphorus levels over this period. The proportion of soil carbon has been proposed as a simple, general indicator of soil health and is included as WFG Act Indicator 13 'Concentration of carbon and organic matter in soil'.

- **Air.** Section 3.2 summarises evidence on the condition of air in Wales. There have been notable improvements in air quality in recent decades, although in some areas it still poses a major threat to human health and the natural environment. It is significant that 90% of nitrogen sensitive Welsh habitats still exceed Critical Loads for nitrogen which is likely to have impacts on ecosystem condition and implications for resilience. There is a link to WFA Indicator 4 'Levels of nitrogen dioxide (NO_2) pollution in the air' but this indicator relates primarily to human rather than wildlife and natural habitats.
- **Water.** Sections 3.3 and 3.10 summarise evidence on water resources and hydrological processes, and freshwater habitats in Wales. A picture emerges of a highly modified hydrological cycle and significant areas where there is no further reliable freshwater resource available for abstraction. Water quality and freshwater habitats remain degraded, despite some general improvements in water quality over the last 25 years. There are emerging risks from invasive species, increased run-off speeds, new chemicals and demand for water abstractions that are concerning. There is a link to the WFG Act Indicator 45 'Percentage of surface water bodies and groundwater bodies achieving good or high overall status '.

Connectivity

There is no accepted national measure of connectivity available yet, although JNCC has commissioned an indicator[19] and there is ongoing research by Forest Research and CEH on connectivity indicators. Various strands of evidence can be used to consider connectivity.

At the large scale, connectivity is closely correlated with habitat extent. As Chapter 3 has shown, there has been major habitat loss and fragmentation, and, as a consequence, connectivity will also have declined. Various metrics can be used to quantify fragmentation, for example, patch size and shape[16] but this only gives a partial picture. We also need to consider linking features in the landscape and the state of land between habitat patches (known as permeability). These factors can be modelled to map habitat networks, which indicate how habitat patches are likely to be functionally connected within the landscape for their typical species[20, 21]. Network maps can be over-lain for a number of habitats to give an indication of the overall level of connectivity for a broad range of biodiversity. Figure 4.4 shows an example of this sort of analysis at the Wales level.

At the national scale, connectivity mapped in this way is highest in the upland and in upland-fringe areas, and lowest in the most intensively managed lowland areas. Hedges are important for connectivity, especially in lowland landscapes where general connectivity is often low. Section 3.8 reports that although hedgerow loss has stabilised in recent years, condition remains poor with 78% of hedge area in an unfavourable condition likely to affect its connectivity function. Features such as road

verges, field-margins, stream-sides and individual trees will also contribute to connectivity, but we do not yet have standard ways of assessing their relative importance; this is an area that requires further work.

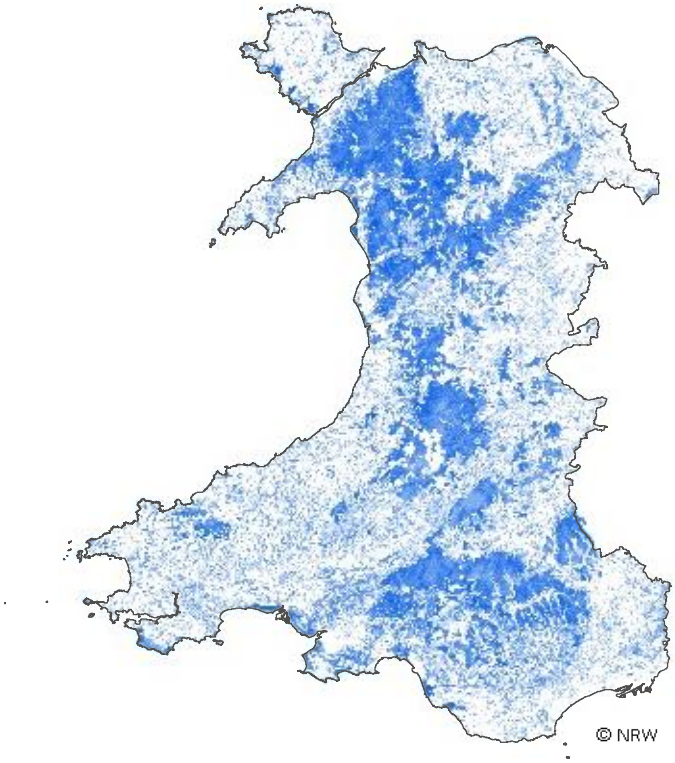


Figure 4.4 Semi-natural habitat connectivity for a range of terrestrial habitats combined, based on maps of least-cost habitat networks. The depth of blue reflects the overall strength of connectivity between habitats. Underlying data are from Habitat Survey of Wales[16], further background and methodology are available in Latham *et al.* (2013)[20]. **[H]**

Assessment of ecosystem resilience at the national scale

This analysis has considered the attributes of resilience at an all-Wales scale and indicates that there are significant problems which potentially impact on natural resources and ecosystems' capacity to provide services and benefits.

This report has shown losses of habitats and species' populations over at least the last century, indicating chronic declines in the diversity of Wales' natural resources and ecosystems. Given the fundamental importance of diversity to resilience, this is a concern and also a direct indication that ecosystems are not resilient because species are not recovering.

The overall extent of habitats has also declined significantly over the last century which implies significant impacts on resilience. Although there is evidence that rates of loss have slowed, recent research indicates that species extinctions may not take place for decades or centuries following habitat loss[22], [23]. Therefore, we have to be aware that resilience may continue to decline as a result of past events, and it is important that activities such as habitat restoration and creation are planned in an informed way to mitigate these effects.

Condition in this assessment is a broad-ranging attribute that combines many diverse factors, and, not surprisingly, the evidence reviewed here gives a mixed picture. In terms of biodiversity, features on protected sites are predominantly in unfavourable condition, which implies even poorer condition over the wider ecosystems.

Although the quality of air, soil and water has generally improved in recent decades, a number of significant problems remain. These include nutrient enrichment, diffuse pollution, soil compaction and sealing, metal-mine pollution, and Nitrogen Critical Loads; the long term impacts of chemicals in freshwaters is an emerging risk.

Connectivity has become much reduced through historical habitat loss and fragmentation as well as loss and degradation of landscape features such as hedges and ‘stepping stones’ (small pockets of habitat that allow species movement).

Some regional patterns in the resilience attributes are clear from the maps (Figure 4.2, Figure 4.3, Figure 4.4) which help us to understand the spatial risks to resilience as well as identifying potential opportunities for building resilience. At the national scale there is a close relationship between diversity, extent and connectivity, with high values of each in upland areas and the coastal fringe, but relatively low values in the lowlands, and especially along major river valleys. This pattern perhaps reflects historical land use, with greatest change to ecosystems where land is most productive and accessible. Condition cuts across this pattern: there are many factors impacting condition which do not always coincide geographically.

4.5. Resilience across broad habitats and land uses

This section takes a more detailed look at broad habitats and some land uses, assessing their general state and prospects for resilience with reference to the four quantifiable attributes: diversity, extent, condition and connectivity (i.e. excluding adaptability). The information is presented in a simple table of habitats against attributes, with notes summarising key evidence for each box within it. Each box has been colour coded (dark green = good, medium green =moderate, light green = poor) to draw out broad issues which are likely to influence resilience significantly. The summary notes and colour codes have been developed with the contributors to Chapter 3, interpreting evidence presented in the Chapter 3 and its Technical Annexes in the context of the resilience attributes, and using expert judgement where necessary. This process has been assigned MEDIUM confidence overall [M]; the confidence of individual statements within it have not been assigned but will reflect the source data in Chapter 3 and its Annexes. More background to the process is given in Box 4.1.

Box 4.1 Background to ecosystems and resilience table

This table compares ecosystems and land-use categories against the quantifiable resilience attributes: diversity, extent, condition and connectivity (i.e. excluding adaptability). NRW specialists used evidence from Chapter 3, its Technical Annexes and supporting material, to identify and summarise the main factors affecting resilience for each ecosystem/attribute combination. As the exercise involved expert judgement, other interpretations are inevitably possible. For ecosystems, the NEA broad habitat classification is used, but sub-divisions are included to reflect the practical level at which ecosystems are managed and drivers operate. In some places these cut across broad habitat categories. This is therefore a pragmatic rather than definitive list of ecosystems, and additional categories or sub-categories could be considered. 'Urban' has not been included because it doesn't form a coherent ecosystem in the way that other categories do, and so main messages and their colour coding could not be identified with a consistent meaning or confidence. However, the approach could be applied to 'urban' if broken down into its sub-habitats and microhabitats. Alternatively, the urban ecosystem category could be broadened to consider all types of green infrastructure to help consider the functioning of urban systems as a whole (see chapter 6). This may be useful to pursue in the future and could be a priority for the next SoNaRR.

The main intention is to identify the main factors affecting resilience *within* an ecosystem; it is much harder to make judgements of relative importance *between* ecosystems. For example, it may be impossible to say that factors affecting two ecosystems are of equivalent urgency because of fundamental differences in scale, distribution etc.

A simple colour shading scheme (dark green = good, medium green = moderate, light green = poor) has been used to imply the general state and prospects for resilience; this is an amalgam of state, trends and implications. Colours were assigned by NRW habitat specialists using expert judgement and are intended to help identify the attributes most likely to be impacting on resilience rather than being a definitive and quantitative assessment. The colours assigned have to be interpreted with care, as it is impossible to represent all the complexities of ecosystems and resilience in this way. For example, an ecosystem may be shaded dark green – good – for a particular aspect of resilience, but there may well be aspects of that attribute, or particular locations, where prospects are moderate or poor.

This process has been assigned MEDIUM confidence overall **[M]**; the confidence of individual statements within it have not been assigned but will vary, reflecting the source data in Chapter 3 and its Annexes.

In most cases the approach to shading should be intuitive, but the way diversity has been treated may need some further explanation. The diversity of semi-natural habitats is often naturally high compared to modified and artificial habitats. Whilst the notes reflect this, the shading emphasises how well that diversity has been maintained following historical interventions and therefore how likely it is to continue to contribute resilience.

Table 4.1 Ecosystems and Resilience Table. * These land uses are of major importance for the provisioning services they provide. Note that the comments in this table relate to their underlying ecosystem resilience rather than their resilience for social or economic values, although these aspects are likely to be linked as described in subsequent chapters

Ecosystem		Attribute of Resilience			
NEA Broad Habitat (section reference)	**Practical habitat unit**	**Diversity**	**Extent**	**Condition**	**Connectivity**
Mountain, Moorland and Heathland (3.6)	Uplands (includes wetland, grassland, heathland and mountain habitats managed as continuous units)	Naturally high, including a wide range of habitats and topographic variation that have generally been maintained.	Well defined by altitude and topography. Losses unlikely, except high montane to climate, and through intensification at margins.	Issues including over or under grazing, N deposition, drainage.	Naturally good because of physical parameters – but affected by condition.
	Ffridd[a]	Distinctive high diversity and mixtures of habitats but vulnerable to land-use and climate changes.	Impacts from intensification and inappropriate tree planting.	Varied, reflecting high diversity of component habitats.	High connectivity – involves many habitats and provides link between upland lowland
	Lowland heathland	Natural range of diversity has been moderately well maintained.	Much historical loss, significant reduction, losses continuing.	Issues with N deposition, grazing levels.	Rather clustered resource –reasonable in patch concentrations, poor elsewhere.

[a] Fridd - the upland fringe that encompasses land occurring between the intensively managed lowlands and the open moor

Ecosystem		Attribute of Resilience			
NEA Broad Habitat (section reference)	**Practical habitat unit**	**Diversity**	**Extent**	**Condition**	**Connectivity**
Semi-natural grasslands (3.7)	Lowland semi-natural grassland (upland versions considered above)	Naturally very high diversity of species and habitat types, but this has been considerably reduced.	Poor - major losses (> 90%) in 20th century.	Vulnerable to ploughing, pollution, fertilizers, pesticides, tree planting and scrubbing up.	Poor. Major fragmentation and decreased 'permeability' to species movement of land between habitat patches.
Enclosed Farmland (3.8)	Improved grassland	Often very low – these are heavily modified or artificial habitats with dominance of a few species.	Very high – half Wales' land surface.	Moderate, reflecting main uses. Major inputs and knock-on effects to water etc.	Inevitably good given vast extent.
	Arable	Generally low in intensively managed systems. High biodiversity in traditional systems has largely been lost and remnants are very vulnerable.	Much historical loss, remaining high diversity areas under threat from intensification.	Generally low – high input/output systems dominate.	Poor. Spatial and temporal connectivity has been largely lost.
	Hedgerows	Originally high with a distinctive range of types, but considerably reduced.	Impacted by intensive management.	Generally poor. Issues with management, high inputs and tree diseases.	Naturally very high, although often affected by poor condition.
	Orchards	High in traditional systems, but diversity poorly maintained.	Substantial loss historically, with newly created orchards of less biodiversity value than traditional sites.	Limited management of traditional sites.	Traditional sites very small, although often occurring in concentrations.

Ecosystem		Attribute of Resilience			
NEA Broad Habitat (section reference)	**Practical habitat unit**	**Diversity**	**Extent**	**Condition**	**Connectivity**
Woodlands (3.9)	Semi-natural broadleaf woodland	Overall, some of our most diverse habitats but challenges remain around diversity of species, structure and genetics.	Major historical losses but overall area now increasing.	Need for appropriate management, plus impacts from tree diseases, INNS, N deposition, grazing, climatic change and changing distribution of tree species.	Extensive connectivity across all woodland types, but semi-natural is much fragmented resource within that.
	Planted woodland (Note: native / non-native mixed)	Low – despite extensive improvements, still a high proportion of stands are even-aged with dominance of a few, usually non-native species.	Large extent, as proportion of total woodland.	Fair - tree pests & diseases a major factor. Climatic change and changing distribution of tree species.	Good by virtue of large extent across Wales, and within forest blocks due to networks of rides, roads, stream-sides and associated habitats.
Freshwater wetlands and floodplains (3.10)	Rivers and streams	Naturally diverse and high proportion of variation maintained.	Climate change impacts, e.g. flow; issues with relationship to wider floodplain; urban culverting.	Some improvement in recent years but locally variable and still issues, e.g. diffuse pollution, INNS.	Moderate, problems mainly with physical barriers affecting fish movement and linkage to surrounding land-use.
	Lakes and standing water	Naturally diverse and good maintenance of variation.	Defined by topography but future climate change impacts; increase in extent by virtue of reservoirs.	Problems with pollution, eutrophication, acidification.	Generally not a major issue, but some local problems (e.g. ponds if included in category).
	Floodplains	Naturally extremely diverse in terms of biodiversity, structure and function, but these are greatly reduced.	Losses through river control and development.	Problems with eutrophication, pollution, INNS.	Severe habitat fragmentation, physical disconnection of river processes.

Ecosystem		Attribute of Resilience			
NEA Broad Habitat (section reference)	Practical habitat unit	Diversity	Extent	Condition	Connectivity
	Lowland fens and bogs	Naturally diverse but variation of types only moderately maintained.	Major losses, e.g. 50% of area of lowland raised bog.	Problems with management - grazing, pollution, fertilizers.	Low connectivity but a function of highly clustered distribution.
Coastal margins (3.12)	Saltmarsh	Range of variation moderately well maintained, although loss of upper marsh and natural transitions to coastal defences.	Losses through coastal squeeze and historical land claim.	Grazing issues, pollution, coastal defences, eutrophication, and development.	Habitat losses, but clustered resource and aquatic element maintained.
	Sand dunes	High natural diversity of types which has been generally maintained.	Extent generally stable, although some climate related losses, and historic losses to forestry and development.	Issues with fixation, scrub invasion, grazing, pollution, invasive species, afforestation.	Problems with loss of connectivity between sites, although generally clustered resource.
Coastal margins (3.12)	Sea cliffs	High diversity but vulnerable to loss through land-use and climate change.	Losses where accessible (above vertical cliff zone) for hard cliffs and modification by coastal defences of vertical faces for soft cliffs.	Many issues –grazing, abandonment, eutrophication, sea defences, pollution, INNS.	Declining -progressively squeezed and interrupted, particularly outside protected sites.
	Shingle	Moderate diversity – largely maintained but vulnerable to loss.	Extent generally stable although losses through sediment starvation from coastal defences.	Issues include; climate change and sea level rise, anthropogenic damage, INNS, pollution, coastal defences.	Loss of connectivity as a result of coastal defences, also a clustered resource.

Ecosystem		Attribute of Resilience			
NEA Broad Habitat (section reference)	Practical habitat unit	Diversity	Extent	Condition	Connectivity
Marine (3.13)	Marine intertidal	Naturally very high, but the extent to which this has been maintained varies and there have been losses of some very diverse biogenic habitats.	Losses mainly due to coastal developments.	Many and varied issues including damage from activities such as unassessed or unregulated, fishing, pollution, coastal squeeze, development, INNS.	Localised disruption through alterations to hydrological processes.
	Marine subtidal	Naturally high, but the extent to which this has been maintained varies and there have been losses of some very diverse biogenic habitats.	Small losses mainly due to coastal development, energy development and cabling.	Varied issues with impacts from unassessed fishing[b], pollution, aggregate extraction[24c], coastal and energy development, INNS.	Generally uninterrupted with some localised alterations to hydrological processes in nearshore areas.

[b] Welsh Government have commissioned a project which will assess interactions between fishing activities and the features of European Marine Sites .The outputs from the Assessing Welsh Fisheries Activities Project will contribute valuable information on the sustainability of marine fisheries activities and their locations in Welsh waters

[c] Recent evidence by HR Wallingford (HR Wallingford. 2016. Review of aggregate dredging off the Welsh coast: Review of evidence) has found no impact on the adjacent coast from dredging activities in aggregate licence areas.

Assessment of resilience of broad habitats and land uses

All of the habitats considered in this analysis have problems with one or more attribute of resilience. This means that their capacity to provide ecosystem services and benefits may be at risk. No habitats, on the basis of this assessment, can be said to have all the features required for resilience. Habitats such as lakes, semi-natural broadleaf woodlands and the sub-tidal seem to perform relatively well, perhaps reflecting the relatively long time-scales operating in these habitats and long term appreciation of their value. Habitats dependent on specific, more traditional management regimes, e.g. lowland semi-natural grasslands, are generally more challenged. 'Floodplains' deserve a special mention as they show significant problems across all four attributes of resilience. This is noteworthy given their significance and potential for a wide range of ecosystem services, notably flood water retention, and that in natural systems they are notable for their high diversity.

Condition is the attribute that most frequently has been coded as 'poor'. This may have implications for opportunities to improve resilience which are discussed below. However, we do need to be careful about how this is interpreted. The attributes are not independent, and 'condition' is a more complex attribute than the others and so potentially more likely to register a 'problem'.

So what could be done to address resilience?
The following section considers each of the attributes in turn, summarising opportunities for building resilience. Individual attribute opportunities will often work in tandem with the others: emphasising their inter-dependence. This integrated approach should help to achieve the overarching attribute of 'adaptability'.

Addressing Diversity

The diversity of most semi-natural habitats is naturally high but has been eroded over time, and the degree to which it has been maintained varies considerably. Increasing diversity is not as simple as 'adding species': introducing non-native species is usually inappropriate as they are not part of native ecosystems and can cause many problems (see discussion on Invasive Non-Native Species in Chapter 2); re-introducing species that have gone extinct can be politically contentious as well as difficult to do. The priority is to ensure that mechanisms are in place to minimise further loss, and that conditions allow for species' populations to expand and naturally re-colonise their former range or adapt to future change (requiring improvements in extent, condition and connectivity). Preventing further loss is not necessarily straightforward. There needs to be recognition that species losses may continue for a long time after habitats have been fragmented or modified, and there may be future, and unpredictable, impacts from climate change. A combined approach is needed, so that existing biodiversity is maintained in the context of wider plans to re-establish adequate areas of habitat with connectivity between them in a planned and informed way.

Species are only one aspect of diversity and there will be opportunities for increasing structural diversity across many habitats through, for example, different management and grazing regimes. This is likely to reflect socioeconomic diversity and hence link to building resilience in a much broader sense.

Large areas of Wales are heavily modified habitats such as planted woodland and improved grassland. These often have a low diversity and are frequently dominated by a few species which have been selected for their high productivity. There may be great potential for improving the species and the genetic and structural diversity of these systems, thereby improving both their own resilience and that of the wider ecosystems around them. There are challenges around this of course, with work required on, for example, appropriate species and understanding plays-offs between productivity and benefits to resilience. Much progress is already taking place in this regard with forest resource planning.

Addressing Extent

Most terrestrial semi-natural habitats have suffered major decreases in extent over the past century, notably with lowland semi-natural grasslands suffering disproportionately high losses. This may have a serious impact on resilience, especially as we do not understand tipping points in Wales (or to what extent they exist). These are thresholds beyond which collapse of functions occur. In contrast, the extent of modified habitats, such as planted woodland and improved grasslands, have greatly increased and are likely to have sufficient extent to provide a good basis for resilience. Addressing extent requires effective mechanisms that allow maintenance of existing habitat areas and promote the restoration of damaged or modified habitat and the creation of new habitat. These actions have challenges associated with them: most obviously, competition for other land-uses and limited resources. There are also implications from changing management practices on neighbouring land.

Addressing Condition

Condition is the attribute most frequently assigned as ‘poor’ across habitats. This is a major concern, especially as many of these habitats (e.g. upland peatlands, floodplains and marine) provide crucial ecosystem services. ‘Condition’, of course, combines many factors and a wide range of actions will be relevant. At one level, how land or sea are directly managed is important, for example, how they are grazed, or fished, or what nutrients or pesticides are applied. Mechanisms are generally in place to control these sorts of activities, but there is a need to ensure that these mechanisms are appropriate and effective. There are a set of wider factors that impact condition which are harder to control, including such things as atmospheric pollution, plant diseases and INNS. The solutions to these may be at higher, perhaps international levels, illustrating the need for a wide-ranging policy framework to improve condition and hence ecosystem resilience.

Addressing Connectivity

The connectivity of semi-natural habitats often relies on their extent, degree of clustering within the landscape, and relationships to other habitats so will vary widely. However, in all cases it is likely to have decreased with historical habitat loss, exacerbated by loss and reduced condition of intervening habitats and connective features. Opportunities to improve connectivity can be targeted to develop functional habitat networks that operate across the landscape and build upon existing areas of high connectivity and quality. Opportunities arise from: enlarging habitat areas; developing buffers, corridors (which may include transport corridors, footpaths and bridleways, rivers and streams) and ‘stepping stones’; removal of barriers to fish migration in rivers and streams; and improved overall management of the landscape.

4.6. Overall conclusions on ecosystem resilience in Wales

All attributes considered to support ecosystem resilience in Wales have problems associated with them at both the national and habitat scale. Therefore, it is unlikely that ecosystems currently have sufficient resilience and this will impact on their capacity to provide services and benefits into the future.

This analysis has provided a starting point to understand where resilience is most at risk. The national maps (Figure 4.2, Figure 4.3 and Figure 4.4) show broad regional variations that reflect historical land use and habitat loss, with diversity, extent and connectivity tending to be relatively high in upland and coastal areas, and low in lowland areas and especially low along major river valleys. Condition cannot be mapped in an equivalent way, but seems likely to cut across this pattern. For example, the regional analysis shows that condition is a significant concern in the uplands. It is important to understand the root causes of problems affecting condition in areas which otherwise have good potential for resilience.

Analysis on a habitat by habitat basis adds detail to this picture. All habitats have problems with resilience, with condition being the most frequently poor attribute. The regional patterns described above are corroborated, with lowland habitats showing the greatest losses and being replaced with man-made or modified habitats with often low diversity.

By bringing this information together, it should be possible to begin to develop regional priorities for actions across the attributes and for individual habitats. For example, there may be a case for concentrating habitat restoration and creation in lowland and floodplain situations where historically greatest losses have occurred, whilst concentrating improvement of condition in upland, coastal and marine where large habitat extent remains but which is nonetheless vulnerable. Likewise, there could be an emphasis on maintaining and raising awareness of the value of habitats such as lowland semi-natural grasslands, which have been severely reduced in extent. However, prescriptions need to be flexible at a local scale to take into account variables, such as relative abundance of different habitats, the national and local values of different aspects of biodiversity, and the need and opportunities for particular ecosystem services and their relative benefits to support well-being. The Area Statements should provide a good basis for developing these ideas, supported by further, more detailed, analyses of ecosystem resilience and the opportunities for its improvement.

References for Chapter 4

("Accessed" refers to the date the link was last accessed)

[1] Welsh Government. 2016. *Environment (Wales) Act 2016. Section 6.* Available from: http://www.legislation.gov.uk/anaw/2016/3/contents/enacted [Accessed 1st August 2016]
[2] Latham J, Thomas Rh, Spode S & Lindenbaum K. 2013. *Ecosystem resilience: a discussion paper on the use of the concept for natural Resources Wales.* Ecosystem Understanding and Future Management Team, Living Wales Programme 2012-13.
[3] MacDougall AS, McCann KS, Gellner G & Turkington R. 2013. Diversity loss with persistent human disturbance increases vulnerability to ecosystem collapse. Nature, 494, 86-89.
[4] Atwood TB, Hammill E, Greig HS, Kratina P, Shurin JB, Srivastava DS & Richardson JS. 2013. Predator-induced reduction of freshwater carbon dioxide emissions. *Nature Geoscience*, 2013/02/017/online.
[5] Mouillot D, Bellwood DR, Baraloto C, Chave J, Galzin R, Harmelin-Vivien M, Kulbicki M, Lavergne S, Lavorel S, Mouquet N, Paine CET, Renaud J, & Thuiller W. 2013. Rare species support vulnerable functions in high-diversity ecosystems. *PLOS Biology*, 11 (5), 1-11.
[6] Kuussaari M, Bommarco R, Heikkinen RK, Helm A, Krauss J, Lindborg R, Öckinger E, Pärtel M, Pino J, Rodà F, Stefanscu C, Teder T, Zobel M, & Steffan-Dewenter I. 2009. Extinction debt: a challenge for biodiversity conservation. *Trends in Ecology and Evolution*, 24 (10), 564-571.
[7] Latham J, Blackstock TH & Howe EA. 2008. *Ecological connectivity in Wales: planning action to help terrestrial biodiversity respond to habitat fragmentation and climate change*. CCW Staff Science Report No. 08/7/1. Countryside Council for Wales.
[8] Crooks KR & Sanjayan M. 2006. Connecting conservation: maintaining connections for nature. In: Crooks, K.R. and Sanjayan (Eds) Connectivity Conservation, pp 1-20. Cambridge University Press, Cambridge.
[9] Thomas CD, Gillingham PK, Bradbury RB, Roy DB, Anderson BJ, Baxter JM, Bourn NAD, Crick HQP, Findon RA, Fox R, Hodgson JA, Holt AR, Morecroft MD, O'Hanlon NJ, Oliver TH, Pearce-Higgins JW, Procter DA, Thomas JA, Walker KJ, Walmsley CA, Wilson RJ & Hill JK. 2012 protected areas facilitate species' range expansion. *Proceedings of the National Academy of Sciences of the United States of America*, 109 (35), 14,063-14,068.
[10] Mace GM, Hails RS, Cryle P, Harlow J & Clarke SJ. 2015. Towards a risk register for natural capital. Journal of Applied Ecology, doi: 10.1111/1365-2664.12431.
[11] NRW. 2015. *A Prioritised Action Framework (PAF) for Natura 2000. Wales*. Doc Hab 12-04/04. Natural Resources Wales.
[12] Welsh Government. 2015. Woodlands for Wales indicators [online]. Statistics and Research section. Available at: http://gov.wales/statistics-and-research/woodlands-wales-indicators/?lang=en [Accessed 29th July 2016].
[13] Resilience Alliance. 20-16. Resilience Alliance website [online]. Available at: http://www.resalliance.org/. [Accessed 29th July 2016].
[14] Fuller L,Quine CP. 2016. Resilience and tree health: a basis for implementation in sustainable forest management. *Forestry*, 89: 7-19.
[15] JNCC. 2014. C4 Status of UK priority species: C4a Relative abundance. State indicator. UK Biodiversity Indicators. Joint Nature Conservation Committee. Available at: http://jncc.defra.gov.uk/page-4238. [Accessed 29th July 2016
[16] Blackstock TH, Howe EA, Stevens JP, Burrows CR & Jones PS. 2010. *Habitats of Wales: a comprehensive field survey 1979-1997*. University of Wales Press, Cardiff.
[17] European Commission. 2015. *Science for Environment Policy: The Value of Natura 2000*. DOI 10.2779/162593.
[18] Hewins E, Toogood S, Alonso I, Glaves DJ, Cooke A & Alexander R. 2007. *The condition of lowland heathland: results from a sample survey of non-SSSI stands in England*. Natural England Research Report, NERR002.
[19] Watts K & Handley P. 2009. Developing a functional connectivity indicator to detect change in fragmented landscapes. *Ecological Indicators*, 10 (2010), 552–557.
[20] Latham J, Sherry J. & Rothwell J. 2013. *Ecological connectivity and biodiversity prioritisation in the terrestrial environment of Wales*. CCW Staff Science Report No. 13/3/3. Countryside Council for Wales, Bangor.

[21] Watts K, Eycott AE, Handley P, Ray D, Humphrey JW & Quine CP. 2010. Targeting and evaluating biodiversity conservation within fragmented landscapes: an approach based on generic focal species and least-cost networks. *Landscape Ecology*, 25: 1305-1318.
[22] Dulinger S, Essl F, Rabitsch W, Erb K-H, Gingrich S, Haberl H, Hüber K, Jarošik V, Krausmann F, Kühn I, Pergl J, Pyšek P, Hulme PE. 2013. Europe's other debt crisis caused by the long legacy of future extinctions. *PNAS*, 110 (18), 7342-7347.
[23] Kolk J, Naaf T. 2015. Herb layer extinction debt in highly fragmented temperate forests – completely paid off after 160 years? *Biological Conservation* 182, 164-172.
[24] HR Wallingford (2016) Review of aggregate dredging off the Welsh coast: Review of evidence.