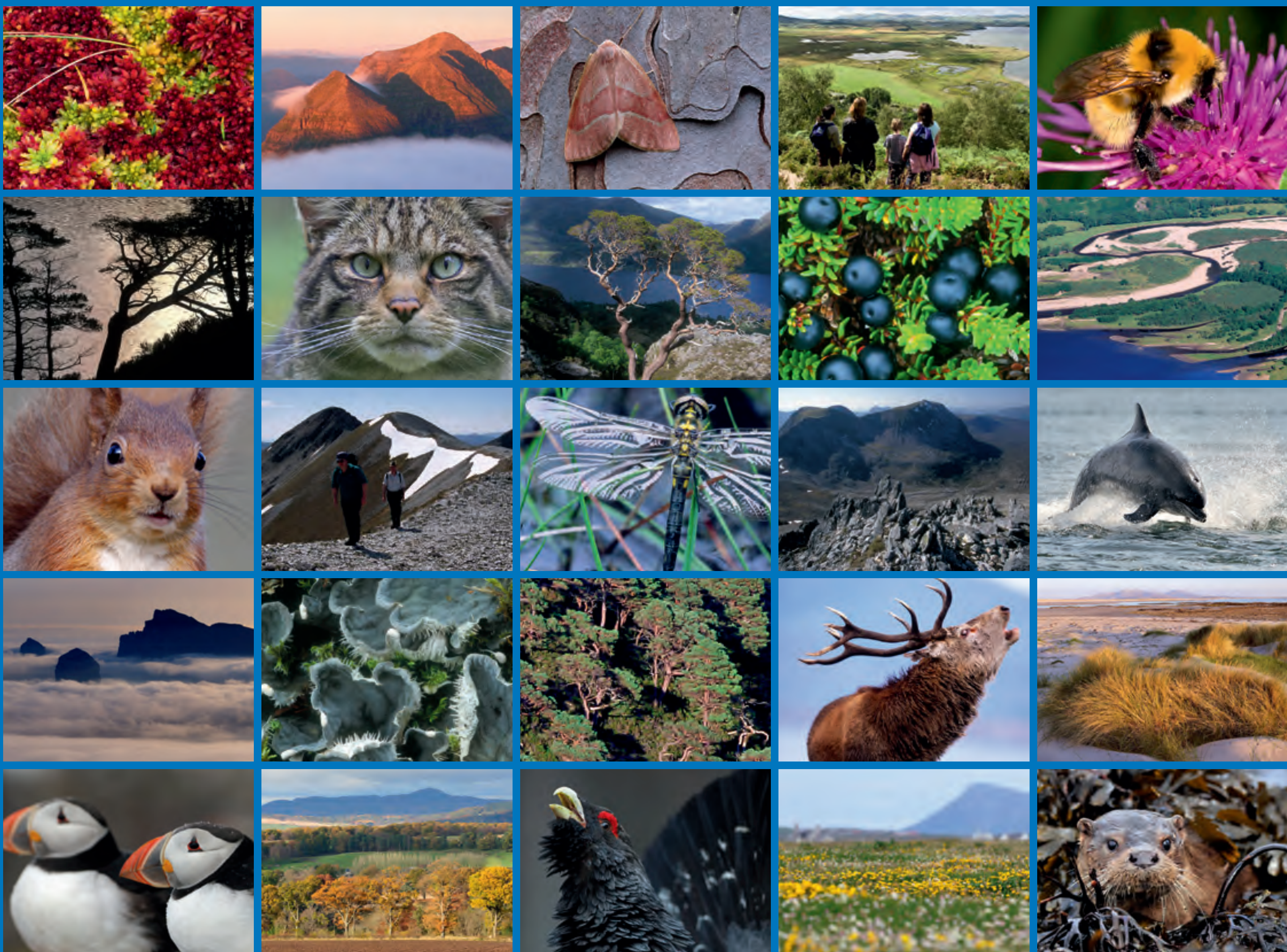
Scottish Natural Heritage
Commissioned Report No. 552

Ecological coherence definitions in policy and practice



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COMMISSIONED REPORT

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Ecological coherence definitions in policy and practice

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COMMISSIONED REPORT

Summary

Ecological coherence definitions in policy and practice

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Background

The main aims of this piece of research were to review existing definitions of ecological coherence, identify and evaluate relevant best practice and make recommendations for potential application in Scotland. This review should not be seen as a detailed or comprehensive assessment of this topic but rather as a representative overview of existing definitions and implementation in other European countries.

Main findings

- An internet-based keyword search, using five different search engines, was used to identify documents and websites containing the exact search term "ecological coherence". The results were subject to a three-stage, iterative filtering process so that only the full text of the most suitable documents and web pages were captured. A total of 1,132 documents were scrutinised for relevant information. Five additional search terms were also used to capture a wider ecological context. These were subject to the same filtering process and a total 500 documents were scrutinised. In both instances electronic copies of key documents were captured to support further research.

- In addition to the use of various search engines, relevant case studies were also identified through the use of the following electronic databases and information portals: Natura 2000 Good Practice Exchange; Ecosystem Approach Sourcebook; Collaboration for Environmental Evidence; Conservation Evidence; LIFE Programme; European Topic Centre on Biodiversity; BfN Coherence Activities; and INTERREG IVC Project Database. A total of 33 case studies from 20 different countries were selected using structured selection criteria and their relevance to Scotland was then scored against an evaluation framework agreed with the project Steering Group. The three most relevant projects, from Denmark and Austria, were outlined and relevant project website links and project documentation were captured.

- The literature review revealed that ecological coherence is a legally-defined term that lacks any clear conceptual or empirical basis in ecological science. Its definition, assessment and implementation are directly linked to the statutory duties associated with the designation and management of Natura 2000 sites, i.e. Special Protection Areas and Special Areas of Conservation. The legal definition, as defined under the Habitats Directive (92/43/EEC), was consequently considered in combination with published guidance and a working definition was developed for use in Scotland.

- The proposed definition is as follows: *In the context of the Natura Directives, an ecologically coherent network consists of sites designated for the protection of relevant habitats and/or species; it should support habitats and populations of species in favourable conservation status across the whole of their natural range (including the wider environment and marine areas beyond Natura 2000 sites); and contribute significantly to the biological diversity of the biogeographic region. At the scale of the whole network, coherence is achieved when: the full range of variation in valued features is represented; replication of specific features occurs at different sites over a wide geographic area; dispersal, migration and genetic exchange of individuals is possible between relevant sites; all critical areas for rare, highly threatened and endemic species are included; and the network is resilient to disturbance or damage caused by natural and anthropogenic factors.*

- This definition was used to frame a series of recommendations relevant to the Scottish conservation and land use policy context. A total of 8 recommendations were made which included establishing a baseline; evaluating the contribution of existing initiatives; formation of an indicator advisory group; development of new national initiatives; refinement of A-E targeting; identification of cross-sectoral policy levers; development of sector-specific guidance and the development of local projects that focus on specific sites. The last recommendation is based on 'lessons learned' from the case studies where the most effective were the ones that involved local stakeholders and which focussed on the requirements of specific Natura 2000 sites.

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1. INTRODUCTION

The main aims of this project have been to review the existing definitions of ecological coherence, identify (and evaluate) relevant best practice and make recommendations for its potential application in Scotland. It is important that this review is not seen as a detailed or comprehensive assessment of this topic but rather as a representative overview of existing definitions and implementation in other European countries.

The focus of this review has been necessarily limited in several ways. The first is that the review has only considered environmental management practice that has been explicitly linked to the delivery of ecological coherence. Although other initiatives might help to deliver coherence, unless this has been a stated aim, it was not possible to capture examples in the available time.

The second limitation is that the review has been restricted to English language publications and websites. Although official European Commission publications relating to Natura 2000 sites in the 27 EU countries are all available in English, there will clearly be a significant, potentially useful literature on conservation practice at a sub-regional level that is not published in English.

The third limitation is that the review does not provide any detailed analysis of the extensive literature on ecological networks. The reasons for this are twofold: detailed reviews already exist (e.g. Bennett & Wit, 2001, Jongman et al., 2003) and existing/planned networks do not necessarily include Natura 2000 sites as core areas (e.g. Lee, 2010).

The fourth limitation is that the review does not provide any analysis of the Scottish policy context and only a limited review of the wider European policy context. The main reasons for this are that the Scottish policy context is already known to the target audience and that European policies, which are not supported by specific legal instruments or funding streams, are unlikely to have any significant influence.

2. METHODS

An internet-based keyword search, using five different search engines, was used to identify documents and websites containing the exact search term "ecological coherence". Permutations were not used nor were terms that might be considered equivalent (e.g. on ecological integrity) on the advice of the project steering group. Different search engines were used to avoid search engine algorithm bias and access the full spectrum of available information from peer-reviewed publications to project websites, see table 1 for further details.

Table 1: Search engines and associated result statistics

Search Engine	Search Period	Number of Hits	Evaluated Hits
Google	unlimited	24,200	500 (2%)
Google Scholar	unlimited	476	200 (42%)
Bing	unlimited	3,100	200 (6%)
Yahoo	unlimited	3,150	200 (6%)
Edinburgh University Library	unlimited	32	32 (100%)

The results were subjected to a three-stage, iterative filtering process so that only the full text of the most suitable documents and web pages was captured. The first stage consisted of an examination of the publication title and/or web page fragment displayed in the search engine results. Suitability at this stage was simply determined by broad relevance to environmental management. If the information source met this criterion, a second stage filter was applied where specific relevance to conservation policy and practice was evaluated either through closer examination of an abstract, executive summary or web page. Relevant documents were then downloaded and a third filter was applied which involved searching documents for keywords. The following search term was used: "ecological coherence" OR "coherent" OR "coherence". Documents were retained if substantive content was present that related to the definition, evaluation or implementation of ecological coherence measures. This third stage evaluation was coupled with the extraction of relevant text, figures and tables to OneNote in order to support further evaluation and to act as a search record. The use of this application also enabled the integration of web-based information that was not supported by specific documentation.

A series of additional keyword searches were also undertaken to capture recent, peer-reviewed published literature on related topics. This information was not intended for review but simply to support future research on related topics. The search was restricted to the last five years and two search engines, Google Scholar and Edinburgh University library. The results can be seen in table 2.

Table 2: Additional search terms and result statistics (Searcher results shown in square brackets)

Search Term	Search Period	Number of Hits	Evaluated Hits
ecological connectivity	2006-2011	1,450 [114]	100 (7%)
habitat connectivity	2006-2011	4,130 [580]	100 (2%)
ecological network	2006-2011	3,750 [650]	100 (3%)
habitat network	2006-2011	738 [68]	100 (14%)
green infrastructure	2006-2011	3,950 [990]	100 (3%)

The results were subjected to the same three-stage filtering process but without extraction of key text, figures or tables. All electronic documents were, however, captured so that they could be evaluated at a later stage.

In addition to the use of various search engines, relevant studies were also identified through the use of the following electronic databases and information portals:

- Natura 2000 Good Practice Exchange
- Ecosystem Approach Sourcebook
- Collaboration for Environmental Evidence
- Conservation Evidence
- LIFE Programme
- European Topic Centre on Biodiversity
- BfN Coherence Activities
- INTERREG IVC Project Database

3. ECOLOGICAL COHERENCE DEFINITIONS

Before considering how ecological coherence has been evaluated and implemented in practice, it was necessary to review existing definitions to determine their potential relevance to Scotland. This review explicitly focussed on legislation, policy and science in order to capture definitions from these different communities of practice. The review has not considered the Scottish policy or legislative frameworks as this is already known to the intended audience. Instead, it has focussed on international frameworks for which Scotland either has a clear implementation duty, e.g. the Convention on Biological Diversity (CBD) or a mandatory legal requirement, e.g. Article 3 of the Habitats Directive.

3.1 Legal Definitions

Ecological coherence was originally defined in the Habitats Directive (92/43/EEC) under Articles 3(3) and 10. However, coherence appears elsewhere in the Directive where it has different meanings. As the following text shows, it can be found in the preamble, Articles 3(1), 4(4) and 6(4) as well as in Annex III. Although coherence is often just associated with Articles 3(3) and 10, there is clearly scope for a more balanced interpretation of this term given the range of meaning that is found within the Directive. In the absence of any explicit implementation guidance, some authors have even been led to conclude that there is still “much confusion about this term” (Leibenath, et al., 2004). The original text is worth considering at this point as it is crucial to understanding what constitutes ecological coherence from a legal perspective:

<u>Preamble</u>

*Whereas, in order to ensure the restoration or maintenance of natural habitats and species of Community interest at a favourable conservation status, it is necessary to designate special areas of conservation in order to create a **coherent European ecological network** according to a specified timetable;*

*Whereas all the areas designated, including those classified now or in the future as special protection areas pursuant to Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds (5), will have to be incorporated into the **coherent European ecological network**;*

Article 3(1): *A **coherent European ecological network** of special areas of conservation shall be set up under the title Natura 2000. This network, composed of sites hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II, shall enable the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range.*

Article 3(3): *Where they consider it necessary, Member States shall endeavour to improve the **ecological coherence** of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora, as referred to in Article 10.*

Article 4(4): *Once a site of Community importance has been adopted in accordance with the procedure laid down in paragraph 2, the Member State concerned shall designate that site as a special area of conservation as soon as possible and within six years at most, establishing priorities in the light of the importance of the sites for the maintenance or restoration, at a favourable conservation status, of a natural habitat type in Annex I or a species in Annex II and for the **coherence** of Natura 2000, and in the light of the threats of degradation or destruction to which those sites are exposed.*

Article 6(4): *If, in spite of a negative assessment of the implications for the site and in the absence of alternative solutions, a plan or project must nevertheless be carried out for imperative reasons of overriding public interest, including those of a social or economic nature, the Member State shall take all compensatory measures necessary to ensure that the* ***overall coherence*** *of Natura 2000 is protected. It shall inform the Commission of the compensatory measures adopted.*

Article 10: *Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the* ***ecological coherence*** *of the Natura 2000 network, to encourage the management of features of the landscape which are of major importance for wild fauna and flora. Such features are those which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species.*

Annex III - Criteria for Selecting Sites Eligible for Identification as Sites of Community Importance and designation of Special Areas of Conservation.

Stage 2(2): *The assessment of the Community importance of other sites on Member States' lists, i.e. their contribution to maintaining or re-establishing, at a favourable conservation status, a natural habitat in Annex I or a species in Annex II and/or to the* ***coherence*** *of Natura 2000 will take account of the following criteria:*

a. *relative value of the site at national level;*
b. *geographical situation of the site in relation to migration routes of species in Annex II and whether it belongs to a continuous ecosystem situated on both sides of one or more internal Community frontiers;*
c. *total area of the site;*
d. *number of natural habitat types in Annex I and species in Annex II present on the site;*
e. *global ecological value of the site for the biogeographical regions concerned and/or for the whole of the territory referred to in Article 2, as regards both the characteristic or unique aspect of its features and the way they are combined.*

Several points are worth stressing. The first is that although the wording of Article 10 emphasises the importance of "*linear and continuous features*", the desired outcome is actually "*migration, dispersal and genetic exchange*". Provided this occurs, the specific mechanism is irrelevant even though fixed ecological corridors are often promoted as the only solution to this problem (e.g. Anon., 1995). It also follows that the creation of an ecological network, even when it incorporates Natura 2000 sites, will not necessarily deliver ecological coherence unless dispersal, migration and genetic exchange is shown to be occurring between Annex II species. It is important to bear in mind that Articles 3(3) and 10 are entirely discretionary and that consequently, such processes are seldom monitored by Member States. However, implementation of these Articles could be considered mandatory if Favourable Conservation Status (FCS) is affected by pressures that could be reduced by increasing connectivity, e.g. climate change (Trouwborst, 2011).

The second point is that Articles 3(1) and 4(4) establish a clear relationship between the FCS of Annex I habitats and Annex II species and ecological coherence. Since Articles 1(e) and 1(i) require FCS to be considered across the whole biogeographical range of a 'feature', coherence is something that necessarily extends beyond the Natura 2000 site boundaries. Coherence in this sense differs from the way in which it is defined in Articles 3(3) and 10. Whilst increased connectivity may be important in delivering FCS in some circumstances (e.g. small, isolated sites or migratory stepping stones), other Natura 2000 sites may require a very different set of remedies. Increasing connectivity and creating ecological networks will not change an unfavourable condition assessment, for example, when sites are facing issues such as abandonment, overgrazing, eutrophication, invasive non-native species or disease outbreaks.

The third point is that Stage 2(2) of Annex III establish a number of other elements that also contribute to ecological coherence through the Natura 2000 site selection criteria. Not only are management, connectivity and the removal of external pressures important but also the value, size, representiveness and uniqueness of individual sites. From a legal perspective, as soon as candidate SACs and SPAs have been submitted by a Member State (and accepted by the Commission) these criteria are deemed to have been met and an ecologically coherent network is created. This represents a third meaning of the concept within the Directive. Clearly if other types of protected area are included as part of a wider national ecological network, then Annex III criteria would need to be applied in any assessment of overall coherence. Some authors (e.g. Kettunen, et al., 2007) view coherence and connectivity as separate entities but this is a false dichotomy if a holistic interpretation of the legislation is applied.

From a legal perspective, ecological coherence can be defined in the following manner: Sites should contain species and habitats of national conservation importance; be sufficiently large to maintain the special interest features; be managed appropriately; and have external threats and pressures reduced. At the scale of the whole network, coherence is present if: the full range of variation in specific habitats and species is represented; dispersal, gene flow and migration between sites is supported; and threatened species and habitats, listed in Annex 1 and 2, are protected. Scope is clearly present to extend this assessment to non-statutory sites so that an understanding of how these sites might improve the coherence (and FCS) of existing Natura 2000 networks can be gained. A meeting of international experts in Vilm in 2005 arrived at a similar conclusion and defined coherence as the: "*Sufficient representation (patch quality, total patch area, patch configuration, landscape permeability) of habitats / species to ensure favourable conservation status of habitats and species across their whole natural range*" (Anon, 2005).

Coherence is also mentioned in the preamble to the Birds Directive (79/409/EEC), specifically in relation to migratory species. Even though this is the only explicit reference to ecological coherence, Article 3(2) also has a direct bearing on the practical implementation and evaluation of measures to maintain and/or improve it. Again, the specific text is worth considering:

<u>*Preamble:*</u>

Whereas the preservation, maintenance or restoration of a sufficient diversity and area of habitats is essential to the conservation of all species of birds; whereas certain species of birds should be the subject of special conservation measures concerning their habitats in order to ensure their survival and reproduction in their area of distribution; whereas such measures must also take account of migratory species and be coordinated with a view to setting up a coherent whole;

Article 3(2): *The preservation, maintenance and re-establishment of biotopes and habitats shall include primarily the following measures:*

a) creation of protected areas;
b) upkeep and management in accordance with the ecological needs of habitats inside and outside the protected zones;
c) re-establishment of destroyed biotopes;
d) creation of biotopes.

Not only is the notification of a coherent network of sites required but also any additional measures that help to support scheduled bird species, wherever they may occur. This adds further weight to the need to consider ecological coherence beyond Natura 2000 sites. Legal opinion states that "*even the process of designating sites is not a one-time operation, but is a continuous process, as was confirmed by the Court of Justice* (Case C-209/04, Commission v Austria (Lauterachter Ried)*. If new bird species occur, because their habitats shift due to climate change, then Member States will have to designate new and additional areas*." (Cliquet *et al.,* 2009).

3.2 Policy Definitions

The main international, policy-based definition of ecological coherence comes from the OSPAR Convention. The Convention is the mechanism by which the governments of fifteen European countries cooperate with the European Commission in order to protect the marine environment of the northeast Atlantic. It was formed in 1992 and covers both territorial and international waters as well as the Exclusive Economic Zones of the participating Member States. At a meeting in Bremen, in 2003, additional measures that enabled the designation of Marine Protected Areas (MPAs) were adopted by the Contracting Parties. A target was set for the establishment of an ecologically coherent network of well-managed sites by 2012 (Recommendation 2.1 - von Nordheim, 2010):

The following definition of ecological coherence, based on the recommendations of OSPAR Biodiversity Committee and the work of Laffoley *et al.* (2006), was adopted in 2006 by the OSPAR Commission:

An ***ecologically coherent network*** *of MPAs:*

i. *Interacts with and supports the wider environment;*
ii. *Maintains the processes, functions and structures of the intended protected features across their natural range;*
iii. *Functions synergistically as a whole, such that the individual protected sites benefit from each other in order to achieve the other two objectives.*

Additionally, an ***ecologically coherent network*** *of MPA may:*

iv. *Be designed to be resilient to changing conditions.*

This rather vague definition was further developed by an INTERREG IIIB-funded project which specifically focussed on "*developing tools for assessment and establishment of an ecologically coherent network of marine protected areas (MPAs) in the Baltic Sea, Kattegat and Skagerrak – a sea area shared by 10 countries.*" (Andersson *et al.*, 2008). Both the BALANCE programme and OSPAR Commission produced a series of reports dealing with the definition and assessment of coherence in the marine environment. Although the detail is clearly not relevant within the current context, the broad principles are transferable and warrant further consideration.

The OSPAR Commission published 30 ecological coherence assessment guidelines that supported four broad criteria in 2007 (OSPAR, 2007). The same broad criteria were also identified by Piekäinen & Korpinen (2007). They are: adequacy, representation, replication and connectivity of the network. There are clear commonalities with the way in which ecological coherence has been defined for Natura 2000 sites. In the marine environment, adequacy was linked with the size, shape, location and quality of individual sites. Location was evaluated because of potential negative impacts arising from the local environment (e.g. anthropogenic disturbance) and to ensure an appropriate balance of inshore and offshore sites. Representation was linked to the capture of the full range of environmental variation in species, habitats, landscapes and ecological processes. Replication was stressed so that features (i.e. species and habitats) on sites were adequately duplicated across a wide geographic area in order to spread the risk of catastrophic loss and environmental change. Connectivity was stressed, as was the need to avoid an exclusive focus on any one element or species to the detriment of others. This point has been made repeatedly in relation to MPAs (OSPAR, 2006 & 2007; Korpinen & Piekäinen, 2006). The need to take account of different life history stages has also been stressed which is largely absent from terrestrial, non-vertebrate connectivity modelling.

The design of MPAs and the evaluation of coherence would seem to be an almost impossible task given the data limitations that are present within the marine environment. In spite of this fact, Jones & Carpenter (2009) noted that experts felt that sufficient information was available to develop 'rules of thumb', such as the percentage representiveness of different habitats, and that these could then be used as parameters in network design programmes, such as MARXAN (Ball & Possingham, 2000). Such tools can easily be applied to existing networks to identify gaps in coverage and to target actions that strengthen coherence. 'Rules of thumb' were used to develop three 'fast and frugal heuristics' (designed for data limited situations) in order to fulfil initial statutory reporting requirements:

- Is the network spatially well distributed, without more than a few major gaps?
- Does the network cover at least 3% of most (7 of the 10) biogeographic provinces?
- Are most (70%) of the threatened and/or declining habitats and species represented in the MPA network?

In this staged approach, unless sites passed these initial tests then no further assessment was seen as necessary (von Nordheim, 2010). The approach has, however, been criticised as a tautology by Jones & Carpenter (2009) because *"fulfilment of the policy aim of ecological coherence is evaluated through constructed heuristics that are politically realistic, in that they could potentially provide for a rather sparse network to be judged to be coherent, but are ecologically unrealistic, in that they are of little relevance to the actual extent and degree of connectivity within a given network, particularly for species with a limited larval dispersal potential."*

Several observations can be made at this point. The first is that given the comparatively greater availability of data for terrestrial and freshwater environments, it should be possible to undertake a systematic ecological coherence assessment of terrestrial and freshwater sites in Scotland, using spatially explicit indicators that define current levels of adequacy, representation, replication and connectivity. This could be extended to the wider socio-ecologic systems to include ecosystem service provision and multi-functional land use, provided the basic legal and ecological requirements of non-human species remain at the core of the process. The second observation is that a systematic approach was adopted (e.g. Korpinen & Piekäinen, 2006) to capture published autecological information and 'rules of thumb' through expert engagement which supported an initial assessment of coherence. Although a more robust, empirically supported approach would have been preferable, existing knowledge was used to best effect and the conclusion will be subject to regular review as new empirical information becomes available. Again, this could be adapted for application to freshwater and terrestrial networks in Scotland using tacit knowledge capture methods, such as Bayesian Belief Networks.

3.3 Scientific Definitions

Scientific definitions are almost completely absent from the literature owing to the legal origin of this concept (Ardron, 2008). Ultimately it may be desirable to support it with more evidence-based definitions associated with empirical research on ecological integrity (e.g.

Pimental *et al.,* 2000), ecological resilience (e.g. Peterson, 2000), metacommunities (e.g. Koelle & Vandermeer, 2005) and/or ecosystem health (e.g. Lu & Li, 2003) in order to provide a more robust conceptual framework. For the purposes of this review, only the literal definition of this concept was considered rather than any potentially synonymous terms. In plant community ecology, coherence has been used to indicate how typical a releve is within a phytosociological classification (e.g. Kazmierczak *et al*., 1995). In landscape ecology, coherence has been defined as *"the degree in which features of different kinds are associated with each other in space or time"* (Mander *et al*., 2010). A slightly more detailed (and potentially more useful) definition can be found in the work of van Mansvelt (1997) who suggested that the ecological coherence of the rural landscape could be assessed in three ways: vertical, horizontal and cyclical. Vertical coherence was defined as the suitability of a site or more general abiotic environment for a particular species. Horizontal coherence was defined as the functional relationships between different habitat mosaics at a landscape scale. Cyclical coherence was defined as the potential for the expression of the full range of ecosystem dynamics across a landscape. He succinctly states that: "*Against the background of the elaboration of biodiversity, it is clear that habitat is a concept indicating the coherence between species, and landscape is a concept indicating the coherence between habitats.*" He goes on to integrate economy, sociology and psychology into a more generalised model of coherence but this conceptual development does not appear to have much potential for practical application.

3.4 Working Definition

Taken together, with appropriate modification, the legal and policy-led definitions have significant relevance to Scotland. Clearly there is a mandatory requirement to consider Natura 2000 legislation but it should also be remembered that the associated sites cover a significant land area that helps to protect many rare and threatened species. At the end of March 2010 a total of 391 Natura 2000 sites were notified in Scotland, covering approximately 10% of its land area, comprising 245 Special Areas of Conservation and 148 Special Protection Areas (Scottish Government, 2010). This not only sets the boundaries for the definition of ecological coherence in Scotland but also means that specific sites, species and habitats must be considered if ecological coherence is being assessed and practical actions are going to be taken to improve it. The legislation requires that an ecologically coherent network of sites is sufficiently large, representative, connected, well managed and internationally important. From a more policy-orientated perspective, originating from marine conservation thinking, it is possible to suggest additional elements such as a sufficient degree of replication between sites, the maintenance of fundamental ecological processes and the reduction or avoidance of adjacent anthropogenic pressures. Although ecological science can contribute little to its definition, it clearly has a substantial role to play in the assessment of ecological coherence and the targeting of specific interventions. The following working definition is suggested as a way of encompassing the varying definitions and legal requirements associated with this term:

In the context of the Natura Directives, an ecologically coherent network consists of sites designated for the protection of relevant habitats and/or species. It should support habitats and populations of species in favourable conservation status across the whole of their natural range (including the wider countryside and marine areas beyond Natura 2000 sites); and contribute significantly to the biological diversity of the biogeographic region. At the scale of the whole network, coherence is achieved when: the full range of variation in valued features is represented; replication of specific features occurs at different sites over a wide geographic area; dispersal, migration and genetic exchange of individuals is possible between relevant sites; all critical areas for rare, highly threatened and endemic species are included; and the network is resilient to disturbance or damage caused by natural and anthropogenic factors.

4. ECOLOGICAL COHERENCE IN PRACTICE

One of the most obvious ways in which ecological coherence has been implemented, in practice, has been through ecological networks. Globally, ecological networks are becoming more prominent with more than 200 different initiatives documented (Bennett & Mulongoy, 2006). They also enjoy active promotion as a conservation measure by international organisations such as the CoE, IUCN and UNEP. A wide variety of approaches and definitions have been used in what is essentially a design-led process. However, it is important not to confuse this design process with the quantification of connectivity. The first is intended to meet specific conservation goals whilst the second is a quantitative evaluation of how species move through a landscape. In spite of an obvious synergy, spatially explicit connectivity metrics are not routinely used to underpin the design of ecological networks in many countries. Consequently, the presence of an ecological network does not necessarily mean that ecological coherence has been achieved. For this to occur, core areas need to be evaluated in a systematic manner according to the previously discussed criteria and connectivity quantified for relevant (Annex II) species. In practice, ecological networks have relied upon three basic design approaches (Jongman *et al.,* 2004):

1. Ecostabilisation: zoning of different land uses to specific areas which are then physically linked to create a network;
2. Riverine: enhancement of river corridors to provide a physically linked network; and
3. Ecological: range of different approaches, such as habitat suitability modelling, to define functionally linked habitat patches.

One thing that ecological networks do have in common with connectivity, however, is that they have almost as many definitions and interpretations. The following three authors summarise the range of opinion. They define ecological networks as:

- *"Systems of nature reserves and their interconnections that make a fragmented natural system coherent, so as to support more biological diversity (...)"* (Jongman *et al.,* 2004);
- *"(...) a set of ecosystems of one type, linked into a spatially coherent system through flows of organisms, and interacting with the landscape matrix in which it is embedded."* (Opdam *et al*., 2006); and
- *"(...) a representation of the answers to two questions: (1) who eats whom?, and (2) at what rate?"* (Ulanowicz, 2004).

Evidence suggests that implementation is most advanced in the highly fragmented landscapes of Western Europe. Bennett & Mulongoy (2006) note that:

"(...) the majority of ecological networks which are in an advanced stage of implementation are in developed countries where, in most cases, ecosystems have become highly fragmented. In these circumstances, the network approach is being applied to an important extent in order to restore ecological coherence. The Guadiamar Green Corridor in Spain and WildCountry in Australia are good examples of this approach. However, as some of the examples show, the ecological network is also being applied in order to retain the coherence of large ecosystems or ecoregions which are still relatively intact but are coming under increasing pressure — often through a combination of development and underdevelopment — such as the Far East Ecoregion and the Vilcabamba—Amboró Conservation Corridor. In these cases the goal of the network is to guide the region's development strategy so that conflicts with ecosystem processes and valuable concentrations of biodiversity are as far as possible avoided."

However, the authors admit that it is too early to assess the biodiversity conservation value of ecological networks across the full range of circumstances in which they are used, in spite of their popularity. They make a common assumption that networks = connectivity = ecological coherence. They also assume that the primary function of Western European networks is to restore coherence rather than to protect existing patterns of coherence that may occur beyond protected areas and non-statutory sites. This may be flawed if more quantitative, ecologically-based assessments are considered. For example, a systematic assessment of priority BAP habitat and statutory site connectivity in England indicated that around 8% of the total land area of England still had a significant level of residual connectivity (Catchpole, 2006). If these areas are not subject to effective conservation measures then the isolation of the embedded sites will increase, through inevitable land use intensification, and this element of ecological coherence will decline over time.

Before moving on to a wider consideration of what ecological coherence might mean in practice, two initiatives warrant particular attention: the Pan-European Ecological Network (PEEN) and the *Making Space for Nature* review (Lawton *et al.,* 2010).

PEEN is part of the first five year action plan of the Pan-European Biological and Landscape Diversity Strategy (PEBLDS). It was first proposed by the Council of Europe (CoE) at an EU Ministerial meeting in Lucerne (Switzerland) in April 1993. It was subsequently endorsed at the third Ministerial meeting in October 1995 in Sofia (Bulgaria). The main aims of PEBLDS over the next 20 years are to:

- Reduce threats to Europe's biological and landscape diversity.
- Increase the resilience of Europe's biological and landscape diversity.
- Strengthen ecological coherence of Europe as a whole.
- Ensure full public involvement in conservation of biological and landscape diversity.

This has led to the production of three large-scale maps, which together, constitute the PEEN. In relation to ecological coherence Jongman *et al.* (2011) noted that:

"They differ in terms of ecological coherence and the need for ecological corridors; for example, in Central and Western Europe corridors are essential to provide connectivity, while in Northern, Eastern and South eastern Europe larger, coherent natural areas still exist. The future steps in developing PEEN should include the implementation of national ecological networks and, in particular, the pursuit of international coherence through the development of trans-European ecological corridors."

At first sight this might seem to be something that could be used by Member States, especially in continental Europe, to develop national ecological networks where they do not already exist. However, data limitation and limited Member State participation in the mapping process has led to a series of maps that challenge this assumption. For example, the PEEN map for Western Europe (PEEN-WE) received significant criticism by Member States when it was first presented at a meeting of the CoE PEEN Expert Committee (Strasbourg, 18-19 October 2007). Whilst the location of corridors was derived from existing national ecological networks in some countries, in others this appears to have been achieved by drawing arrows between large blocks of habitat, with little or no ecological justification. In the UK it is hard to imagine the ecological role of the corridors that have been drawn between the New Forest and Salisbury Plain or the Scottish mainland and Orkney. Whilst it may be possible to use these maps to provide a strategic assessment of fragmentation and core area density at a Pan-European level, any assessment of overall ecological coherence (or even connectivity) seems to be beyond the capacity of the data and analytical methods at the current time.

Making Space for Nature (Lawton *et al.,* 2010) was commissioned by Defra to evaluate the adequacy of protected areas in the face of continuing declines in biodiversity in England. One of the key questions asked by the review panel was whether *"England's wildlife sites* *constitute a coherent and resilient ecological network?."* The assessment considered a range of statutory and non-statutory designations which ranged from individual sites to whole landscapes. It also included several IUCN protected area categories. Geographical information was merged in the analysis to give three tiers:

"Tier 1 sites are those whose primary purpose is nature conservation and which have a high level of protection (e.g. SSSIs);

Tier 2 sites are designated for their high biodiversity value but do not receive full protection (e.g. Local Wildlife Sites);

Tier 3 are landscape designations with wildlife conservation as part of their statutory purpose (National Parks and AONBs)."

The assessment then evaluated five different attributes within each Tier:

i. representiveness
ii. patch size
iii. protection and management
iv. connectivity
v. human accessibility

Although some commonalities with Natura 2000 obligations and MPA selection criteria were present, there was significant divergence with the inclusion of human accessibility and the extent to which sites were protected and managed within the different tiers. Whilst the former has little to do with ecological coherence, the degree of protection and the suitability of current management regimes could usefully be considered in Scotland. The review made extensive use of geospatial information ranging from least-cost connectivity assessments of priority BAP habitats (and protected areas), to simple spatial queries that characterised the patch size distributions of nature reserves within the different tiers. Although similar geospatial information exists for Scotland, information on the location of priority BAP habitats outside the protected areas and non-statutory sites is extremely limited. Until the necessary habitat inventories have been developed, either from field survey or remote sensing, any coherence assessment for Scotland would be constrained to areas of recognised nature conservation value. This applies not only to priority BAP habitats in Scotland but also to urban wildlife habitats that might be found in private/public green space, transport infrastructure curtilages, sustainable urban drainage systems etc. In spite of this limitation, there would still be value in undertaking a similar geospatial assessment to determine the coherence of existing Natura 2000 sites.

The review concluded that the SSSI site series, which (by definition) also includes Natura 2000 sites, was not coherent in England. As Member States are legally obliged to maintain a coherent network this could presumably lead to infraction proceedings unless a further tranche of Natura 2000 sites is notified. This may also be a risk in Scotland if a systematic analysis of coherence reveals significant gaps. Only representiveness was consistently satisfactory across the different tiers in the analysis but "*serious short-comings*" were present in relation to all other criteria. Five key approaches were identified which are outlined in the following text (Lawton *et al.,* 2010):

"The essence of what needs to be done to enhance the resilience and coherence of England's ecological network can be summarised in four words: more, bigger, better and joined. There are five key approaches which encompass these, and also take account of the land around the ecological network. We need to:

1. *Improve the quality of current sites by better habitat management.*

2. *Increase the size of current wildlife sites.*
3. *Enhance connections between, or join up, sites, either through physical corridors, or through 'stepping stones'.*
4. *Create new sites.*
5. *Reduce the pressures on wildlife by improving the wider environment, including through buffering wildlife sites."*

This represents a more practical and sequential application of ecological network thinking which helps to ensure that significant funding is not diverted to enhance connections and create new sites before fundamental site management issues have been addressed in the core network areas. This clearly echoes the recommendations made by Defra in guidelines on the adaptation of biodiversity to climate change (Hopkins *et al.,* 2007). However, such an approach could limit funding for larger-scale action if all core areas are retained. If site management issues cannot be resolved at specific locations, either through enforcement action or suitable financial incentives, then it could be argued that they should not be included as part of the network. Funding could then be diverted to support sites that are more viable after a suitably rigorous, systematic triage process has been applied.

A more recent approach that might help to deliver ecological coherence is Green Infrastructure. Although it has gained significant political purchase at the local and international levels, it lacks any proven implementation track record or a clear conceptual basis. Its adoption as a new conservation paradigm may need to be a longer-term aspiration given some of the issues that have already emerged in its definition and application. For example, just as connectivity measurements are not always used to inform the design of ecological networks so the design of green infrastructure is not always informed by any ecological information. For example, Natural England (2010) has provided the following definition:

"Green infrastructure is a strategically planned and delivered network of high quality green spaces and other environmental features. It should be designed and managed as a multifunctional resource capable of delivering a wide range of environmental and quality of life benefits for local communities. Green infrastructure includes parks, open spaces, playing fields, woodlands, allotments and private gardens. We believe green infrastructure should be delivered via the spatial planning system, as an integral part of new development everywhere. We are working with partners in the Growth Areas, Growth Points and proposed Eco-towns to prepare and implement green infrastructure strategies and demonstrate good practice on the ground."

Ecological networks are nowhere to be seen in this deeply urban, anthropocentric definition. At a local level in England, green infrastructure elements have often been mapped without any regard for existing ecological networks or protected areas even though readily accessible spatial data have been available (e.g. Devon County Council - Anon, 2011). At a European level the situation differs significantly and the definition is much more closely aligned to ecological networks and biodiversity conservation. A recent information note from European Commission (2011) illustrates this point:

"Building a green infrastructure will help to reconnect existing nature areas, for instance through wildlife corridors or stepping stones and eco-bridges, as well as improve the general ecological quality of the wider environment so that it is more friendly and permeable to wildlife. […] A European green infrastructure can be developed using a variety of techniques. They can include for instance: 1.) Improving connectivity between existing nature areas in order to counter fragmentation and increase their ecological coherence e.g. by safeguarding hedgerows, wildlife strips along field margins, small watercourses; 2.) Enhancing landscape permeability to aid species dispersal, migration and movement e.g. through the introduction of wildlife friendly land uses or agri/forest environment schemes that

support extensive farming practices; 4.) Identifying multifunctional zones. In these areas, compatible land uses that support healthy biodiverse ecosystems are favoured over other more destructive practices."

Although this repeats the mantra of 'linear and continuous features' and the 'patch-corridor-matrix paradigm', it does at least propose a more balanced and integrated approach that explicitly includes biodiversity. In another document, the Commission make the role of Natura 2000 sites clear and, by implication, the deeper meaning of ecological coherence (Anon, 2009):

"Considering that biodiversity is also the driving force behind healthy, resilient ecosystems which, in turn, provide valuable ecosystem services, it was felt that the overall objective of an EU green infrastructure should be two-fold:

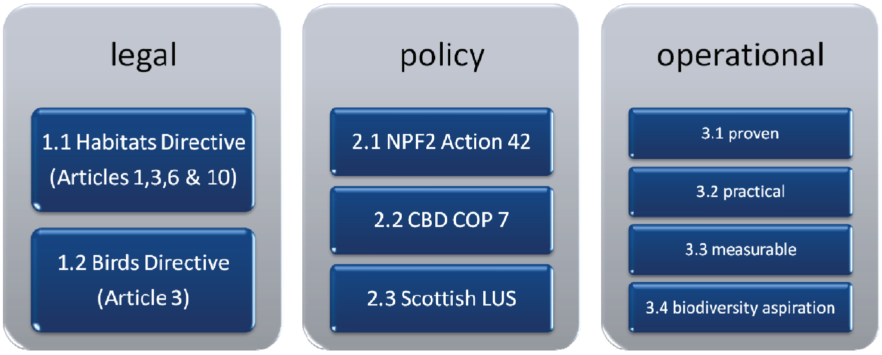
- *to safeguard and maintain Europe's biodiversity, inter alia by ensuring the ecological coherence of the Natura 2000 Network; and*
- *to strengthen and regenerate functional ecosystems at a broader landscape level."*

As with ecological networks, the challenge will be to translate green infrastructure into robust action that is appropriate to specific landscapes rather than just imposing a set of high-level prescriptions that has no relevance or ownership below the Pan-European level. Appropriately-framed, locally adapted implementation will be necessary if green infrastructure is to persist in the longer term as a spatial planning concept. Spatial planners, who often have a minimal knowledge of ecology and nature conservation, will need to be actively supported in this process.

5. IMPLEMENTATION EVALUATION

The purpose of this evaluation was to identify examples of projects that have explicitly attempted to deliver ecological coherence through practical implementation. As with the literature review, a wide range of projects could potentially deliver coherence but unless this is a stated aim, these examples are impossible to identify without the use of highly subjective value judgements. In a strict sense, all implementation is related to the designation and management of Natura 2000 sites. The absence of any independent definition or, indeed, any supporting conceptual scientific framework, makes the identification of any wider examples problematic. Another issue for the review has been how to evaluate examples after they have passed through the selection process detailed in Section 2.0. Although this was based on ecological coherence, a wider implementation evaluation framework was used to determine potential relevance of case studies in Scotland, as detailed in Figure 1.

Figure 1: Implementation Evaluation Framework (Legal = direct implementation of specific Articles of the Habitats and Birds Directives (1.1 & 1.2). Policy = direct implementation of ecological networks (2.1), the ecosystem approach (2.2) and multifunctional land use plans (2.3). Operational = quantified benefits to biodiversity (3.1), potential for practical application (3.2), outcomes can be assessed (3.3) and intended biodiversity benefits (3.4).



The framework was developed in consultation with the project steering group in order to provide a way of rapidly assessing examples through the legal, policy and operational perspectives that are relevant to Scotland. The legal and practical criteria are self-explanatory but the policy context requires further consideration. The three elements were selected so that examples of ecological coherence projects which implemented ecological networks, adopted ecosystem management approaches and stressed multi-functional land use could be evaluated. These elements were felt to provide a partial reflection of current priorities in Scotland in relation to the delivery of increased public benefit from improved ecosystem service provision, green infrastructure development and more integrated, sustainable land use planning.

As with the literature review, the evaluation was not designed to be comprehensive. It was used as a screening process for initiatives which could then be examined in greater detail at a later stage. Only information sources that were published in English were considered. This has an obvious limitation in that a significant amount of practical information will be published in other languages. While this issue could not be addressed with available resources, international project databases and information portals were used to try to capture the widest possible range of information, as detailed in Section 2.0. Search terms for “ecological coherence/coherent”, “coherence” and “coherent” were applied to website search facilities as well as individual documents and web pages. This led to the capture of examples from over 20 different countries, including the UK, four of which were English-speaking.

The evaluation used five subjective assessment categories to reflect the uncertainty in the highly variable information content that was captured. These were related to potential relevance which was summarised using a modified Red-Amber-Green system, shown in table 3. Red indicates no relevance and green indicates that the example may be relevant and warrants further investigation. Intermediate categories of amber-red (probably no relevance), amber (possible relevance) and amber-green (probably some relevance) were also used. All the examples that were evaluated were captured and supplied as separate documents to the project Steering Group, irrespective of whether they were individual web pages or stand-alone documents. Wherever possible the contact details of project officers and organisations were also captured to enable further investigation.

Table 3: Implementation Evaluation (Information ID (source) is marked with a (*) for specific publications and a (^) for a web extract. Potential relevance of different examples is as follows: red = none [0], amber-red = probably none [2], amber = possibly [3], amber-green = probably some [4] & green = relevant [5])

Project	ID	1.1	1.2	2.1	2.2	2.3	3.1	3.2	3.3	3.4
22 Balanced Seas Project (GB)	^									
33 BIOREGIO Carpathians	^									
33 Flintshire UDP (GB)	^*									
23 ICOSTACY LIFE Project (CY)	^*									
20 JUNICOAST - Crete & South Aegean (GR)	^									
15 Canal de Castilla LIFE Project (ES)	^									
33 Ecological Corridors in Murcia (ES)	^									
27 Natura 2000 in Bulgaria (BG)	^									
35 Swiss-Polish Cooperation Programme (CH/PL)	^									
26 German-Bulgarian Cooperation Project (DE/BG)	^									
26 Prokić (2008) - PEEN in Serbia (RR)	*									
15 SCALES Project	^									
21 Ruuhka-Suomi Project (FI)	^									
34 Danube floodplain LIFE Project (AT)	^									
29 Danube fish habitat LIFE Project (AT)	^									
38 Restoring the Lech LIFE Project (AT)	^									
40 Wadden estuary LIFE Project (DK)	^									
29 Anstey & May (2003) - Forest management (NZ)	*									
28 CBD (2010) - Mesoamerican Corridor	*									
25 CBD (2010) - Cascade Corridor (US)	*									
30 CBD (2010) - Vilcamba-Amboro Corridor	*									
29 CBD (2010) - Terai Arc Landscape (NP)	*									
35 CBD (2010) - The Gondwana Link (AU)	*									
30 CBD (2010) - Yellowstone to Yukon (US)	*									
15 Chabrerie et al. (2001) - The Seine (FR)	*									
17 Daugava River Basin Project (LV)	*									
36 Forfang (2001) - Forest management (DK)	*									
20 Good (1998) - Corridors & conservation (IE)	*									
23 Kasprzak (2011) - Port development impacts (PL)	*									
34 Lawton et al. (2010) - Making Space (GB)	*									
33 WTs (2006) - Living Landscapes Project (GB)	*									
28 Lucius et al. (2011) - Comana Wetlands (RO)	*									
22 Anon (2010) - Green-blue structure (DK)	*									

The total additive score across all categories, without any weighting, is shown before the reference for each initiative. This was done to provide a relative ranking of the different initiatives to aid comparison rather than as an objective, quantitative analysis. The way in which each category has been scored can be found in the table legend.

Overall, an estuarine-based LIFE project in Denmark scored most highly (LIFE99 NAT/DK/006456). The main aim of the project was to improve the conservation status of Annex 1 habitats and Annex 2 species in an area that had been subject to extensive agricultural intensification. This involved raising water levels, reducing the use of pesticides and artificial fertilisers and the extensification of agricultural production. The project covered an area of 2,700 ha and involved around 436 different landowners. By the end of the project, in 2002, natural hydrological function had been restored over 92% of the area and 250 landowners had entered into 20-year conservation management agreements. This enabled a successful economic transition from the production of grass pellet feedstock to a more extensive agricultural system. A major factor in this transition was the collapse of the existing market as well as sustained engagement with local landowners. Although this example was only directly associated with two Natura 2000 sites, it was part of a larger-scale initiative to improve the coherence of the Western Palaearctic Flyway across Denmark through the restoration of key stepping stones for migratory birds. The emphasis on restoring fundamental ecological processes, the active participation of local communities and the delivery of benefits at multiple scales also fulfils the ecosystem approach criteria in addition to improving the overall coherence of the Danish Natura 2000 network.

The second most highly scoring example was another LIFE project, located in Austria (LIFE00 NAT/A/007053). The main aim of this project was to restore riparian habitats along the River Lech in the Austrian Tyrol. As with the previous example, restoration activities were directly linked to improving the conservation status of Annex 1 habitats and Annex 2 species. This involved the removal of flood protection dams, widening of the river and creation of scrub habitat to support key target species. Gravel extraction activities were modified so that silt could be trapped and impacts on the natural river flow minimised through extraction site relocation. Several tributaries were also targeted for restoration work which not only created new habitats but also provided a sustainable water source for cattle and improved fishing opportunities for local communities. A key factor in the success of this initiative was the close involvement of local regulatory bodies and the participation of local stakeholders. Because the Forestry and Avalanche Control Authority and the Water Management Authority were project partners, they were able to act as ‘honest brokers’ between the local communities and the conservationists, who were not generally trusted. At the end of the project, in 2007, the natural function of a 6 km stretch of river was restored. This not only benefitted wildlife but also the local people through increased recreation opportunities, improved ecotourism infrastructure and more sustainable agriculture. In addition to improving the coherence of a Natura 2000 site, around 40 riparian ponds were either restored or created, a bird observation tower was erected and an unspecified area of semi-natural vegetation was restored.

For the third example, we consider a multifunctional forestry project (Forfang, 2001). A forest management model was developed through experiences from a project that was managed by the Danish Forest and Nature Agency called “Project Sustainable Forest”. The aim of the project was to develop and test operational guidelines for sustainable forestry management through a local forum of land owners, local authorities and NGOs representing nature, outdoor recreation and hunting sectors. This forum was supported by an expert group comprising ecologists, economists and sociologists. The resulting guidelines were tested on four Danish forest districts, two of which were privately owned and two of which were publicly owned. Key habitat inventories were developed for each district which supplemented traditional silvicultural information. This enabled more informed forest management plans to be developed. The integration of economic, ecological and social considerations in this evidence-based approach has since led the Danish Government to provide subsidies to produce key habitat inventories in other districts in support of local decision-making. The guidelines have also formed the basis of the Danish FSC standard. Although the extent to which this has helped to improve the coherence of Natura 2000 sites is unclear, it has raised the overall environmental standard of Danish forestry operations and helped to protect key habitats wherever they occur. In this sense it could be viewed as potentially contributing to the FCS of Annex 2 species. This shows how participation at higher organisational levels can be used to support decision-making at a local level and set sustainable management standards.

Hyperlinks and references have been provided for all the other examples that were captured.

6. CONCLUSIONS AND RECOMMENDATIONS

The legal definition of coherence clearly states that it is a property that is related to both individual sites and **networks** of sites. Bearing this in mind, the following **operational definition** might usefully be adopted:

In the context of the Natura Directives, an ecologically coherent network consists of sites designated for the protection of relevant habitats and/or species; it should support habitats and populations of species in favourable conservation status across the whole of their natural range (including the wider environment and marine areas beyond Natura 2000 sites); and contribute significantly to the biological diversity of the biogeographic region. At the scale of the whole network, coherence is achieved when: the full range of variation in valued features is represented; replication of specific features occurs at different sites over a wide geographic area; dispersal, migration and genetic exchange of individuals is possible between relevant sites; all critical areas for rare, highly threatened and endemic species are included; and the network is resilient to disturbance or damage caused by natural and anthropogenic factors.

If we accept this definition then coherence must be assessed (and managed) at the level of the individual site as well as at larger geographic scales if legal obligations are to be met. This means that ecological coherence, in Natura 2000 terms, should mean that sites should: contain species and habitats of national conservation importance; are sufficiently large to maintain the special interest features; are managed appropriately; and have external threats and pressures reduced. At the scale of the wider Natura 2000 network, coherence is present if: the full range of variation in specific habitats and species is represented; dispersal, gene flow and migration between sites is supported; and threatened species and habitats, listed in Annex 1 and 2, are protected. This could be seen as a *de minimus* requirement for the delivery of ecological coherence in Scotland. It raises the question of the extent to which non-Natura 2000 sites might support coherence. However, unless the preceding criteria are applied, as part of a systematic evaluation, no assertions can be made about whether or not they help to form an ecologically coherent network. Another related issue is the extent to which initiatives that seek to restore, create or manage habitats in the wider environment are targeted to improve the coherence of existing Natura 2000 sites. For example, how have Natura 2000 sites and the dispersal requirements of associated Annex II species been incorporated into Forest Habitat Networks and green infrastructure assessments in Scotland? This leads to the first two recommendations:

Recommendation 1: *Determine the extent to which sites that have been designated for the protection of key habitats and/or species are ecologically coherent. This should be done through spatially explicit analyses that quantify: the patch size distribution of different habitats (within and between sites); the size class distribution of core areas of each habitat type; the number and geographical separation of sites containing the same species and habitats; the degree of matrix hostility and/or reasons for adverse condition around each site; the temporal occupancy of relevant sites in Scotland by key species; the correspondence of rare species hotspots (across different taxa) with designated areas; and connectivity between sites with similar species and/or habitats.*
Timescale: *Short-term.*
Audience: *SNH and Scottish Government.*
Category: *Scientific.*

Recommendation 2: *Gather geographic information and evaluate the extent to which existing conservation initiatives help to deliver ecological coherence. This will require the capture of fully attributed vector-based, polygon data showing the location of current conservation initiatives. The information attribution must include the species and habitats that are the primary focus of the intervention and be structured in a manner that permits*

geostatistical analysis. The capture of other potentially useful sources of spatially explicit quantitative information, such as financial expenditure, should also be included wherever possible. However, this must either be captured in a consistent manner for the whole of Scotland or for a representative number of geographical areas. The evaluation of this information should use similar techniques to the ones outlined in Recommendation 1.
Timescale: *Short-term.*
Audience: *SNH and Scottish Government.*
Category: *Operational.*

As most protected area networks have been selected on a cumulative, ad hoc basis (Gaston *et al.,* 2006), it could be argued that periodic, systematic assessments are necessary to identify and remedy any emerging gaps in coherence that might be caused by factors such as environmental change, changing socio-political priorities or natural population trends. Indeed, as Margules & Pressey (2000) point out, drastic modification of scientific prescriptions that underpin reserve selection have often occurred through the influence of social, economic and political imperatives. The location of reserves in remote areas, on unproductive land is cited as one such consequence. Even though regular reviews of scheduled species (JNCC, 2008) and site condition (Williams, 2006) are undertaken, this is not the case for ecological coherence. Whilst some elements have been quantified, e.g. connectivity (Catchpole, 2006) and size (Lawton *et al.,* 2010), there remains a need for a repeatable, integrated assessment that draws upon established spatial ecological methods and the full criteria that have been developed for the selection of Natura 2000 sites/MPAs. This would not only mean evaluating the management, adequacy, representation and replication of sites in Scotland but also the migration, dispersal and gene flow of key species across the wider network of sites, i.e. functional connectivity. Measuring success or targeting action to improve ecological coherence in the absence of such a baseline assessment would be problematic.

Given the lack of a supporting, scientifically-based conceptual framework for evaluating ecological coherence, there would also seem to be a need to develop more objective underlying performance criteria that are independent from policy aims. As previously mentioned, the degree to which key ecological concepts, such as ecological integrity (e.g. Pimental *et al.,* 2000), ecological resilience (e.g. Peterson, 2000), metacommunities (e.g. Koelle & Vandermeer, 2005) and/or ecosystem health (e.g. Lu & Li, 2003), are able to provide this framework warrants further consideration. This would avoid the tautology trap pointed out by Jones & Carpenter (2009) where assessments that meet political requirements can provide positive results but remain ecologically unrealistic and fail to deliver viable populations. Another alternative could be to use an appropriately stratified analysis of time series data from national species monitoring programmes (e.g. Botham *et al.,* 2009) and/or national biodiversity indicators (e.g. Defra, 2011) to provide an independent performance assessment of ecological coherence in the absence a more rigorous, empirically supported conceptual framework. This leads to the third recommendation of this report:

Recommendation 3: *Convene a working group to develop an ecological coherence indicator and define a more scientifically robust conceptual framework. The indicator should be based on the working definition, utilise existing geographical information and be repeatable so that meaningful progress towards greater ecological coherence can be reported on a regular basis. It should also be spatially explicit so that it can be used to target specific conservation interventions. Developing a credible scientific conceptual framework is a priority and should ideally occur before the development of an indicator. As a starting point, this review should consider empirical and model-based conclusions arising from scientific research into ecological integrity, ecological resilience, metapopulation ecology, metacommunities and ecosystem health.* ***Timescale:*** *Long-term.*
Audience: *SNH, Scottish Government and Research Institutions.*

Category: *Scientific.*

One of the key recommendations of the Lawton Review (Lawton *et al.,* 2010) was to apply a staged sequence of practical measures that improve ecological coherence at key locations, ensuring that immediate pressures and site management issues are resolved before moving to the implementation of wider, "landscape-scale" actions. This thinking was very similar to some guiding principles on biodiversity climate change adaptation that were published several years earlier (Hopkins *et al.,* 2007). Even though the Lawton Review had greater impact and political support, some consideration of these principles may be worthwhile in supporting the delivery of ecological coherence at an operational level in Scotland. In adapted form, the principles are:

1. Conserve biodiversity wherever it may occur as insurance against future biodiversity loss in a changing world;
2. Conserve protected areas and other high quality sites as their characteristics will continue to favour high biodiversity;
3. Conserve the full range and ecological variability of habitats and species to maximise adaptation potential;
4. Reduce all sources of harm that are driving biodiversity loss wherever possible;
5. Conserve and enhance local variation in vegetation structure and the physical environment;
6. Make space for the natural development of rivers and coasts;
7. Establish ecological networks at different scales through habitat protection, restoration and creation;
8. Adopt an evidence-based approach to the application of specific actions, e.g. climate change adaptation.
9. Respond to changing conservation priorities to ensure resources are directed effectively; and
10. Integrate adaptation and mitigation measures into conservation management, planning and practice.

This leads to a further four recommendations:

Recommendation 4: *Identify priorities and specific projects for enhancing ecological coherence in Scotland. Using the outcomes from Recommendations 1 and 2, undertake a Gap Analysis of designated sites and existing conservation initiatives to identify where new actions and projects need to be developed to enhance ecological coherence. Active consideration of the role that non-statutory sites, urban areas and green infrastructure might play in this process should occur in order to maximise the delivery of multiple benefits wherever possible.*
Timescale: *Medium-term.*
Audience: *Landowners, NGOs, SNH, SEARS and RPID.*
Category: *Operational.*

Recommendation 5: *Refine the targeting of agricultural subsidies and designate new protected areas to improve ecological coherence in Scotland. As the Scotland Rural Development Programme (SRDP) will spend £1.5 billion on a range of environmental and socio-economic activities over the next six years, information arising from the preceding recommendations should be used to ensure that it supports ecological coherence. This will require evaluation at two levels: the first should consider how this funding can be used to directly deliver coherence, e.g. CAP payments, whilst the second should consider how other socio-economic activities can be used to indirectly deliver coherence and avoid negative impacts, e.g. regeneration schemes. The designation of new SPAs and SACs should be considered where no other measures are available to improve the coherence of Natura 2000 sites at specific locations. This need should be identified through the outputs from the*

preceding recommendations and balanced against other priorities in the site designation programme. Consideration of transboundary issues resulting from climate change impacts, e.g. migratory species, expanding ranges etc., will also be necessary.
Timescale: *Medium-term.*
Audience: *SEARS, RPID and SNH.*
Category: *Operational.*

Recommendation 6: *Identify relevant policy levers for supporting the delivery of ecological coherence in Scotland. A cross-sectoral policy analysis should be undertaken to identify the full range of policies that could be used to enhance coherence, either through direct or indirect means. This should have the widest possible terms of reference and focus on levers that can be implemented at different organisational levels, i.e. national and local. It should also seek to identify policies that have a negative impact on ecological coherence as well as any 'perverse' incentives so that may require alteration.*
Timescale: *Short-term.*
Audience: *Politicians and Scottish Government.*
Category: *Political.*

Recommendation 7: *Develop sector-specific guidance on how to implement a staged approach to improve coherence at a practical level. This guidance should be based on the outputs of Recommendation 6 and also include a review of practical land management and land use planning measures that can be directly applied by individuals who are working in different sectors. The guidance should be written in an accessible language, and use checklists, summaries and practical examples that are relevant to specific sectors, e.g. forestry. They should also clearly indicate other sources of information that can help support decision-making, e.g. habitat network maps.*
Timescale: *Medium-term.*
Audience: *Spatial Planners, Land Managers and Conservation Advisors in Local Authorities and National Parks.*
Category: *Operational.*

The main utility of the Lawton Review in Scotland, in the context of this review, is threefold: 1.) It has stressed the importance of management and protection as additional coherence assessment elements; 2.) Provided a demonstration of what can be achieved through the simple geospatial analysis of existing data; and 3.) Demonstrated that existing nature conservation sites in England were inadequate on all counts apart from representation. Although this last point may not apply in Scotland, until a similar assessment has been undertaken it can neither be refuted nor confirmed.

The main conclusion from the project implementation evaluation was that the examples that are most relevant appear to be centred on the delivery of conservation objectives related to individual Natura 2000 sites that have been placed in a wider ecosystem context, i.e. an estuary, a series of catchments, a migratory bird route and an entire forest biome. Critically, these initiatives have not tried to 'join the dots' through linking a disparate collection of Natura 2000 sites through habitat restoration or ecological networks. Instead, they have focussed on influencing the functional links that are present with local communities, the surrounding land use matrix and fundamental biophysical processes (i.e. hydrology and migration). Participation has been a key feature of the three most relevant initiatives. This has been achieved either through direct engagement or through third parties when hostility or mistrust of conservation organisations was present. Another key feature of the selected examples, as well as many of the other examples, was the provision of highly focussed funding to improve the integrity of specific Natura 2000 sites. Although this bias originated from the search terms that were used, this clarity of purpose supported the development of effective actions at larger geographic scales. The most successful projects appear to have been able to work beyond site boundaries to reduce pressures and threats through local community engagement and modification of the physical environment. This is not the same as designing a “landscape-scale” initiative in the hope that it will deliver multiple benefits, where Natura 2000 sites are just one of many delivery objectives. The integration of actions between different initiatives, in support of the Western Palaearctic Flyway, also raises the question of how Scotland will ensure that the overall coherence of the Natura 2000 network, at a GB level, will be improved or adapted in the face of climate change. Increasing levels of devolution or independence may mean that any such co-ordination will become increasingly difficult and may require specific trans-boundary initiatives. Significant divergence in nature conservation legislation and policy development has already occurred. Some of the examples may offer new insights into how cross-border co-operation to improve ecological coherence may be undertaken in the UK in future. This leads to the final recommendationof this report:

Recommendation 8: *Develop community and catchment-based initiatives that deliver site-specific improvements in coherence. A range of projects should be developed to strengthen the ecological coherence of specific sites, based on the outputs from the preceding recommendations. Even though the geographical scale of remedial action might seem restricted, wide-area initiatives that encompass whole catchments and communities should be developed to deliver more sustainable, multiple benefits at larger scales. Interreg IVC and EU LIFE programmes should be considered as potential sources of funding.*
Timescale: *Long-term.*
Audience: *Local Communities, SEPA and SNH.*
Category: *Operational.*

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ANNEX 1: SUMMARY OF MSC DISSERTATION

In the summer of 2012 an MSc student at Edinburgh University, Mie Winstrup, produced a dissertation that partially implemented recommendation one of this report. The topic was set and supervised by the author, in collaboration with SNH and with supervision support from Marc Metzger, in order to determine the feasibility of assessing ecological coherence in Scotland using existing information. There were two main elements to the work: the spatial definition of Annex I habitats and the calculation of a series of ecological coherence metrics. Three habitats were selected to explore the different elements and develop a prototype approach for application to other habitat types. These were: Caledonian pinewood (H91C0), *Tilio-acerion* forests of slopes, screes and ravines (H9180) and Northern Atlantic wet heath with *Erica tetralix* (H4010). The spatial distribution of these habitats was defined using knowledge-based rules that were identified from the British National Vegetation Community (NVC) descriptions as well as a number of other information sources, as outlined in Table 1.

Table 1: Knowledge rules used to identify the habitats based on vegetation community description extracted from Rodwell (2003; 1991), Jackson (2000) and Salmela et al. (2010).

Annex 1 Habitat	Land Cover Type	NVC Type	Elevation (m)	Slope (°)	Soil Type	Precipitation (mm/yr)
Caledonian pinewood	Coniferous woodland coincident with ancient woodland inventory	W18	16-465 (640 max)	0-35	Freely drained brown earths or brown podzolic soils or peaty podzols or gleypodzols or strongly leached, lime-free, podzolic soils	3000 (in western Scotland) & 700 (in eastern Scotland)
Tilio-acerion forests of slopes, screes and ravines	Broadleaved woodland	W8	8-240	0-85	Calcareous mull soils over sedimentary limestones, shales and clays and base-rich conditions with a varying extent of gleying or brown soils or mull soils	< 1000
		W9	6-335	0-70	Permanently moist brown soils derived from calcareous bedrock or acid brown earths or rankers or fragmented rendzinas	>1,200 but typically >1,600
Northern Atlantic wet heath with *Erica tetralix*	Heather and heather grassland	M15	35-550	0-42	Moist acid peats or peaty mineral soils or podzolised soils or shallower peats over gleyed mineral profiles	>1,200 but typically >1,600
		M16	<500	-	Acid and oligotropic mineral soils or shallow peats or gleys or gleyed podzol soils	<1,600

The data used in this approach were Land Cover Map 2007 (CEH 2011), Ancient Woodland Inventory (Forestry Commission 1980), Land Form Profile (Ordnance Survey 2009), long-term monthly gridded rainfall (UK Met Office 2005) and the Scottish National Digital Soil Map (Macaulay Institute 1984). A multi-criteria analysis was used to identify grid cells where the suitability criteria were met. The selection of individual variables varied between habitats and was determined by stepwise, multiple regression techniques. The accuracy of the regression model was validated through the use of protected area NVC field surveys, obtained from SNH. The cells were then extracted to create habitat distribution maps for each of the Annex I habitats. The analysis was undertaken at a resolution of 250m.

Ecological coherence was determined by using the extracted grid cells to quantify the representiveness, replication, patch size and connectivity of the different Annex I habitat types. Representivity and replication were assessed by determining the area and number of cells that intersected Natura2000 sites. The size class distribution was quantified for each habitat to determine the balance between smaller and larger patches. Connectivity was modelled using a least-cost distance approach. Results of these analyses were reported for the whole of Scotland as well as the Scotland Rural Development Programme's Regional Project Assessment Committee regions.

Approximately 202,648 ha of Caledonian pinewood, 252,216 ha with ravine woodland and 1,551,805 ha of wet heath were identified. However, NVC field survey validation indicated a low classification accuracy of between 34% and 61%, as summarised in Table 2.

Table 2: Rule-based cell selection and NVC validation results.

Annex 1 Habitat	Total Number of Cells	Number of cells with suitable land cover	% of NVC cells coincident	Number of cells in the final extraction	% of NVC cells coincident
Caledonian pinewood	88340	54930	62.2%	54190	61.3%
Tilio-acerion forests of slopes, screes and ravines	22799	13730	60.2%	13279	58.2%
Northern Atlantic wet heath with *Erica tetralix*	643920	220456	34.2%	219477	34.1%

Unfortunately insufficient time was available to refine the selection criteria or explore new variables in order to improve the identification of Annex I habitat patches or the accuracy of the associated coherence assessment. Exploration of similar methods, such as the one recommended by Muncher et al. (2009), merits further consideration and this has subsequently been set as an Edinburgh University dissertation topic for 2013.

Bearing the low classification accuracy in mind, the following results should only be treated as indicative and in need of further refinement. The coherence analysis indicated low representiveness with more than double the area of habitat occurring outside Natura2000 sites. The habitat patches were significantly skewed to smaller size classes and their shapes were not compact, indicating a reduced core area. Connectivity between the sites varied significantly depending on the cost surface and land cover type that were used. This observation has been widely noted in other studies. A lack of definitive cost values associated with a specific focal species meant that no conclusions concerning connectivity could be drawn from this study.

In conclusion, further research is required to determine whether or not the selected Natura2000 habitats are ecologically coherent and whether a similar approach might be extended to a wider range of habitats.

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