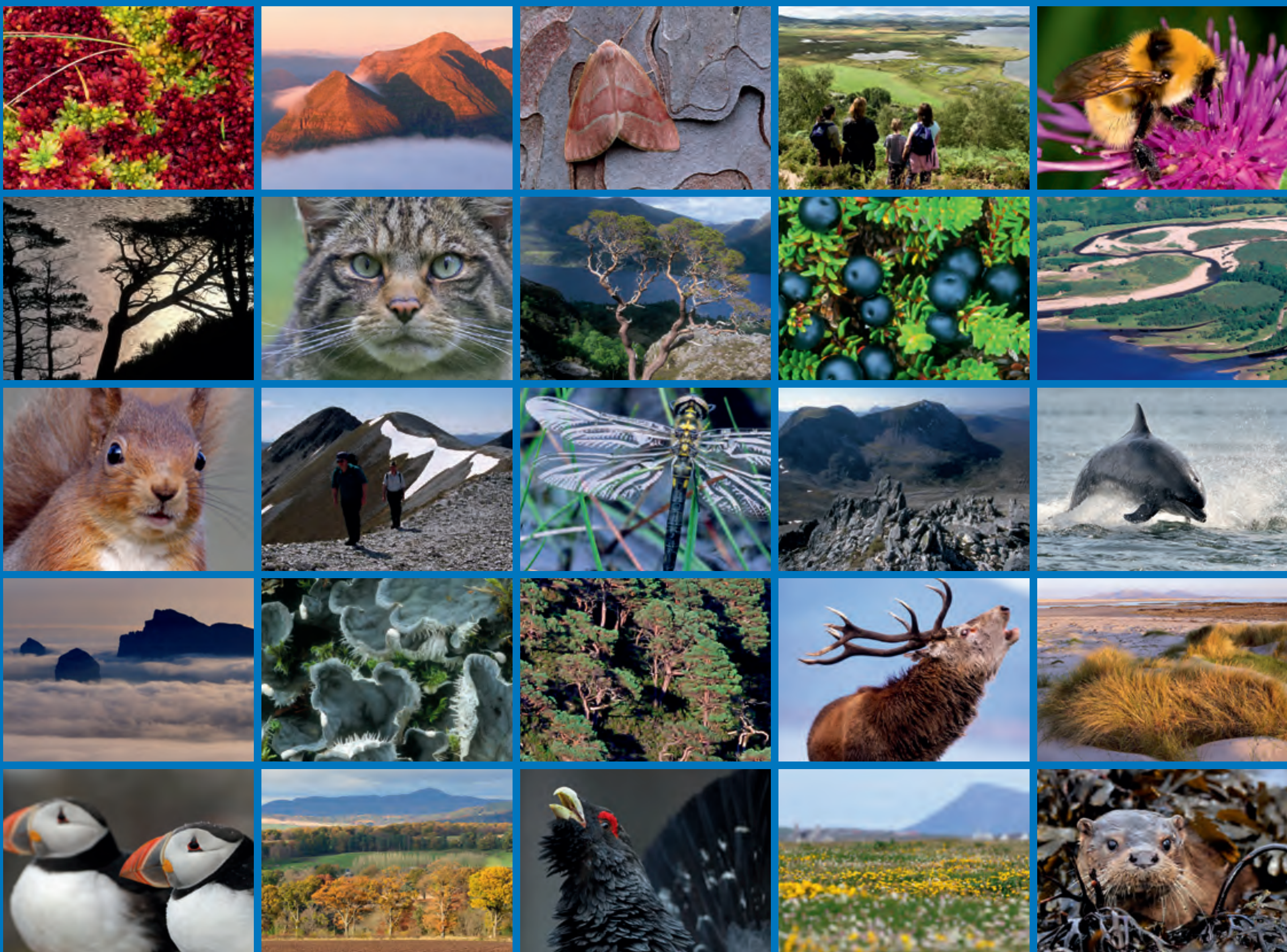
Scottish Natural Heritage
Commissioned Report No. 750

Piloting a Natural Capital Asset Index



Scottish Natural Heritage
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COMMISSIONED REPORT

Commissioned Report No. 750

Piloting a Natural Capital Asset Index

For further information on this report please contact:

Paul Watkinson
Scottish Natural Heritage
Great Glen House
INVERNESS
IV3 8NW
Telephone: 01463 725276
E-mail: paul.watkinson@snh.gov.uk

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COMMISSIONED REPORT

Summary

Piloting a Natural Capital Asset Index

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This report informed the development of the Natural Capital Asset Index and has been previously available from other sources.

Background

There is widespread interest in developing indicators of the quality of the stock of natural capital capable of delivering sustained ecosystem services. This study explored the nature and quality of data which might be used to build a (Scottish) national index based on the area and quality of major habitat types in Scotland, and the possible structure of such an index.

Main findings

Although the Statement of Requirements envisaged that valuation of ecosystem services could be used as a basis for weighting the subsidiary indices related to each major habitat type, it is concluded that these valuations were too restricted in scope and insufficiently robust to justify any differential weighting.

The identification and valuation of ecosystem services was however found to serve as the logical basis for structuring, selecting, and in some cases weighting subsidiary indicators within each major habitat.

Candidate indicators for key ecosystem services for three major habitats (sea, woodland, peatland-moorland) were assessed, and the way these might be aggregated to generate subsidiary indices, and the overall NCAI are discussed.

A preliminary overview of indicators which might be used for other major habitats has also been undertaken but more work is required to finalise the index.

Conclusions

The development and piloting of a natural capital asset index is a major task and beyond the scope of this study. This study should however serve as a useful scoping and testing exercise.

Monetary estimates for ecosystem service values are probably inappropriate as a basis for differential weighting of major habitat types. However, they can be usefully used to structure the index and support the selection of indicators for each major habitat type.

If the index is to be based solely on existing published data which is readily available on an annual basis, it will be a rather poor reflection of ecosystem services, and may not merit the name "natural capital index", though it might serve as a useful index of environmental quality. However, several indicators are being developed which may allow for a more credible index to be developed in the next few years. In particular, indicators of "ecosystem health" currently being explored by SNH and others, are likely to be of direct relevance, as are indicators of habitat structure.

The final choice of indicators and possible weightings has both objective and subjective dimensions, and will be best decided through a more inclusive process with technical experts and key stakeholders. A process is recommended which includes a lead facilitator/project manager, supported by expert panels and workshops. This might lead to the development of a preliminary or pilot index which could then be improved as new and more appropriate indicators become available.

However, alternatives to an NCAI, based on a basket of more broadly based environmental quality indicators, related to agreed environmental objectives and outcomes, and unrelated to the area of specific habitats may offer a simpler and more robust way forward.

For further information on this project contact:
Paul Watkinson, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725276 or paul.watkinson@snh.gov.uk
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research@snh.gov.uk

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1. EXECUTIVE SUMMARY

1.1 This study

The aim of this study is to “evaluate and develop an index of Scotland’s natural capital assets (NCA) to be piloted as an additional indicator (and to allow comparison with annual GDP changes) …..and to establish Scotland’s current position with regard to recent trends in NCA”. Natural capital is the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future. The TOR also suggested a basic structure for the index which amounts to:

Weighted average (broad habitat area x broad habitat quality)

It was suggested that the weight afforded a broad habitat should reflect the monetary value of ecosystem services delivered.

1.2 Area and broad habitat categories

There are several sources of data for the area of broad habitats, and the availability of accurate area data in part informs the selection/definition of broad habitats. The following (Table 1) were selected as the most important habitat types and the source of data on area.

Table 1. Areas of broad habitat in Scotland

Broad habitat category	**Area 2007 square km**	**source of data on area**	**frequency of updating of area**
Marine (Scottish territorial waters including estuaries)	547,800	Marine Scotland	Occasional estimates – but should show little if any change
Freshwater (lakes and rivers)	1,103	Countryside Survey – CEH Land Cover Map	Periodic estimates – ca. 6 years
Agricultural land (arable, horticulture and improved grazing)	14,410	Agricultural census data	Annual
Coniferous woodland	9,560	Forestry Commission	Annual
Broadleaved woodland	2,510	Forestry Commission	Annual
Fen, marsh, swamp	2,390	Countryside Survey – CEH Land Cover Map	Periodic estimates – ca. 6 years
Semi-natural grasslands and bracken	16,020	Countryside Survey – CEH Land Cover Map	Periodic estimates – ca. 6 years
Dwarf shrub heath (heather moor) and bog (peatland)	8,940	Countryside Survey – CEH Land Cover Map	Periodic estimates – ca. 6 years
Montane	380	Countryside Survey – CEH Land Cover Map	Periodic estimates – ca. 6 years

The lack of annual data for most habitats is likely to diminish the value of the overall index as a parallel to GDP. The 6 yearly estimates for most broad habitats available from the land Cover map associated with the Countryside Survey exceed normal political planning horizons.

Bog (peatland) and dwarf shrub heath (heather moor) have been provisionally amalgamated as a single category because in reality most of Scotland is covered by a mosaic habitat of the two, and some of the quality indicators also reflect the quality of this mosaic rather than the individual habitats. However, the historic trends in terms of area are divergent, suggesting they should be separate, and there are also functional arguments for separation, including carbon storage. The advantages and disadvantages of amalgamation deserve further exploration as the index is developed.

The huge diversity in areas between habitats, and in particular the dominance of marine suggests that all areas should be normalised to (say) 1 in 2000, effectively representing the trend in area as a percentage change.

1.3 Habitat weighting

The SOR suggest biomes/habitats should be weighted according to ecosystem service values as determined by Costanza *et al* 1997, Williams *et al* 2002, and other more recent studies. If this is to be done, it must be robust. It implies a *differential trade-off* between biomes – effectively driving an increase in more “valuable” biomes at the expense of less – with the greatest practical implications for biomes which can change (area, quality) most easily.

In practice these values are inadequate to generate a credible set of habitat weightings:

- Coverage of the different ecosystem services is poor for Scotland and “benefit transfer” is not feasible in most cases.
- Total values assigned to a habitat would be heavily biased toward direct services, and exclude supporting services, many regulating services, and key values such as option values.
- Deriving values in the form of £/ha is problematic for some services.
- Service values are unlikely to be independent of area, and would have to be updated on a regular basis, which is unlikely to be feasible.
- There are issues of credibility with some valuation techniques.

If it is decided that some form of habitat weighting is required this might be delivered through expert/stakeholder workshops, taking full account of government policy (for example in relation to woodland expansion), to ensure agreement and buy-in. However, agreement would be difficult, and subjugation to national policy would undermine the index as an international measure.

Overall we conclude there should be equal weightings across broad habitat types.

1.4 Categories – quality indicators

The inadequacy of valuation studies to reflect the value of the flow (and in particular the potential flow) of ecosystem goods or services associated with broad habitat types presents a significant challenge – since this is precisely what the NCAI is all about.

A way round this is to ensure that the quality indicators adequately represent the full range of ecosystem services with which they are associated. Ecosystem services are commonly allocated to one of three major categories:

- Regulating services
- Provisioning services
- Cultural services

These are considered to be underpinned by “*supporting services*” whose current measurable value is reflected in the three direct value categories, but whose potential value is arguably infinite. This is one of the reasons why ecosystem service valuation is so difficult.

Natural heritage and biodiversity are intimately related to supporting services as well as to cultural services. For this reason some analysts include a category of "*habitat services*". The inclusion of biodiversity in either cultural or supporting services, or as a separate habitat services category affects the weighting afforded biodiversity, irrespective of any weighting applied to the categories, and is therefore an important issue.

We are unconvinced of the argument for a separate habitat services category, and have therefore used the 4 basic and widely agreed categories (supporting, regulating, provisioning and cultural). Natural heritage/biodiversity indicators have been allocated mainly to cultural services. However, some biodiversity indicators are poor indicators of cultural service value, but serve nonetheless as useful indicators of supporting services – especially where other good indicators are lacking. In this report we have therefore taken a flexible approach to ensure reasonable indicator coverage across all four categories. This is a difficult and partly subjective issue, and deserves further discussion.

Indicators for climate regulation are clearly important, but present particular difficulties. The actual rate of carbon sequestration is not strikingly different between broad habitats. Peatland scores little better than other habitats, and indeed may be worse than some if release of methane is taken into account. However if peat is converted or used the stored carbon may be released – a major disservice – which should be accounted. There is thus a problem of asymmetry and uncertainty: increased area may provide a small marginal benefit (increased sequestration); decreased area may be associated with a small or large cost depending on the extent to which the carbon store is released. A simple indicator of quality which is meaningful when multiplied by quantity is therefore difficult to define. This requires further consideration.

1.5 Index structure

The NCAI is constructed as a hierarchy as in Figure 1. "Baskets" of quality indicators are averaged to develop a set of four *service subsidiary indices* for each major habitat. These again are averaged and multiplied by the area index for the broad habitat to generate the *broad habitat subsidiary indices*. These are then averaged to give an overall index. Weightings may be introduced at quality indicator level, service index level and broad habitat indicator level if required.

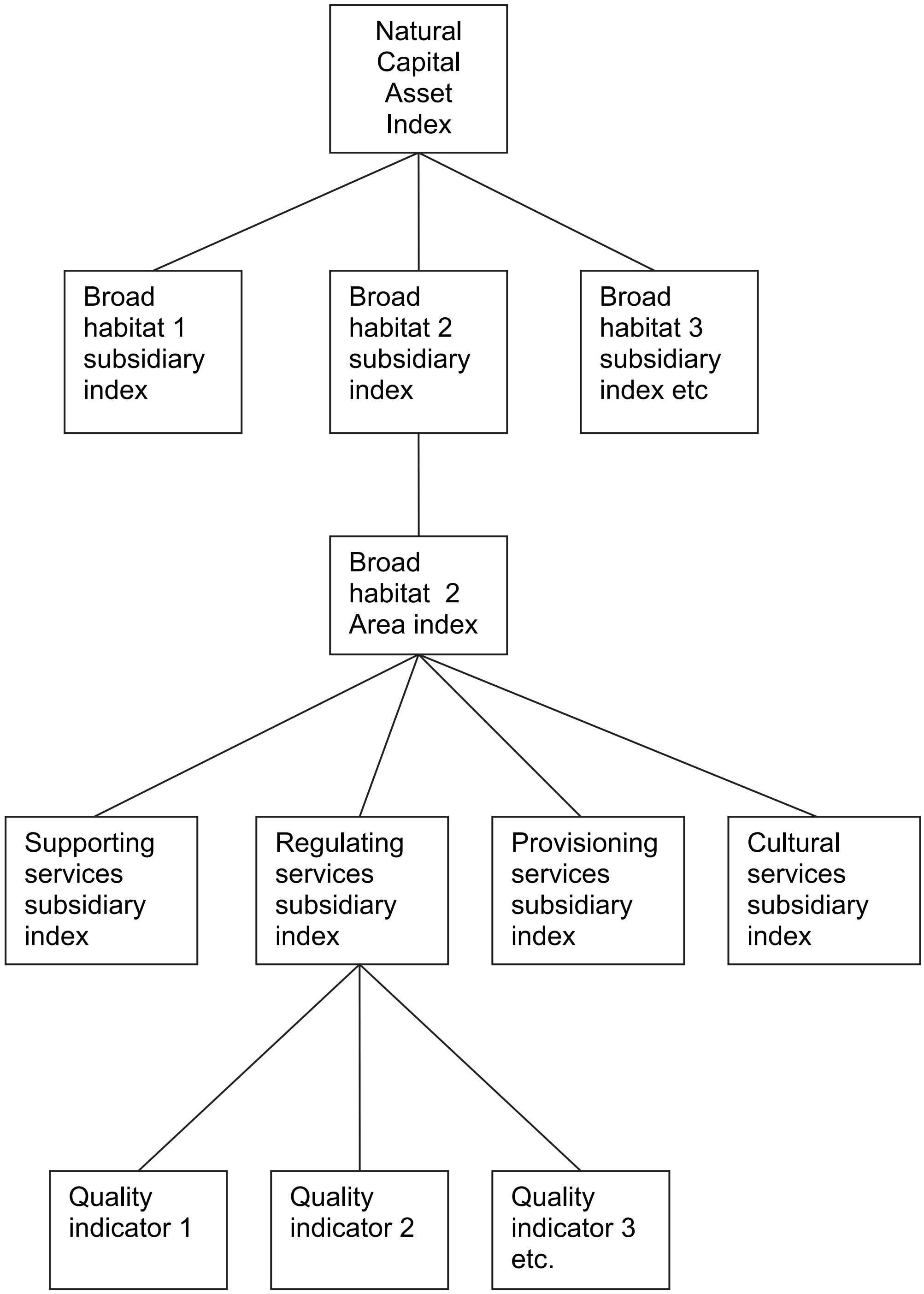

Figure 1. Proposed structure for a NCAI

1.6 Indicator selection

The following criteria have been used to assess the suitability of candidate "quality" indicators:

- data availability and quality
- data collection frequency
- reporting and compilation delay
- measurable and relevant across habitat
- related to stock generating important ecosystem service/s
- meaningful interpretation
- credibility and importance for policy makers and public
- conformity with European/international initiatives

Meaningful interpretation is taken to mean that trends can be discerned and interpreted within a meaningful time frame (ideally less than 4 years), can be assigned to human activity, and will be meaningful when aggregated. In the case of marine, an additional criterion was "allocation to Scottish waters".

1.7 Dummy indicators

In some cases it was not possible to identify a suitable indicator for all categories of ecosystem service, despite the probability that these services were valuable. This leads to the potential for overall index to be "weighted" in favour of those broad habitats and ecosystem services for which indicators are available.

A solution to this is to introduce a dummy indicator with a fixed value of 1. Within the final index this would represent a loss of service directly proportional to area. This may not be too unrealistic insofar as many supporting services are likely to be proportional to area (up to a critical point), and there is little evidence that quality/unit area is declining. Indeed, if there was serious concern about a loss of quality it is likely that an indicator would already be available.

The impact of dummy variables on the performance and interpretation of the index requires further exploration.

1.8 Data scaling and normalisation

Individual *quality* indicators come in a multitude of units and must be scaled or normalised before they can be compared or aggregated. This can be done in several ways:

a) Scaled between 0 and 1 where 1 = yr 2000 value and 0=0.
b) Scaled between 0 and 1 where 1 = yr 2000 value and 0 = lowest or highest value recorded.
c) Scaled between 0 and 1 where 1 = yr 2000 value and scale 0-1 = historic range.
d) Scaled between 0 and 1 where 0 = no annual change and 1 is the maximum recorded annual change

a) will reduce the relative movement of the indicator, and the degree to which this occurs will vary between indicators depending on the nature of the original measurement. This is unsatisfactory. c) is the preferred approach, but is nonetheless difficult to apply because it depends on the period over which data has been collected, and the degree of variation in the indicator. d) is also a possibility but is less easy to relate to the current area or quality of the environment.

Area comes in standard units, but if the index is not to be completely swamped by the big habitats such as seas and peat/moorland, it will also need to be normalised to 1 for all habitats for the year 2000. Since units are standard, a) could be used, but this means the index will be relatively insensitive to changes in area, and the NCAI will be dominated by changes in quality. Using b) or c) is also problematic because historic data is limited and the historic range very narrow in most cases – meaning that the NCAI will be very sensitive to changes in area. Overall a) is probably preferable (and intuitively attractive) and is used in the pilot NCAI - but again deserves further consideration and testing.

1.9 Annualisation

Many important indicators are not collected or published on an annual basis. If these indicators are excluded, coverage of major ecosystem services becomes inadequate, and it is arguable that the index will be largely value-less.

We propose to include indicators for which data is only available (for example) on a 6 year reporting cycle where no adequate annually collected indicator is available. This will require extrapolation on the basis of historic trends, with periodic re-adjustment and historic interpolation. This is unsatisfactory, but the alternative is an index with very limited coverage of ecosystem services. Although this might be useful as a broadly based environmental quality indicator, it would lack credibility as a natural capital index.

1.10 Indicator weighting

It is arguable that some quality indicators are superior to others in terms of representation of an ecosystem service category, and weighting might be assigned through a workshop or panel process. Although we discuss possible rationale for differential weights in the assessment, equal weights are assumed for the pilot index.

1.11 Ecosystem service group weighting

Any weighting assigned to a basket of indicators reflecting a category of ecosystem service gives relative weight to both the category and to the subsidiary indicators, and would need a strong rationale. Again, we discuss this in the assessment for each major habitat type, but assume equal weights for the pilot index.

1.12 Interpretation (habitat subsidiary index)

For each broad habitat it is possible to generate a trend graph for the overall combined broad habitat index, a trend graph for the four ecosystem service categories, and a trend graph of all component indicators.

1.13 Interpretation - NCAI

An overall decline in the value of the index may be attributed to either decline in area, or decline in quality or both. If we include all major semi-natural and farmland habitats in the index, and if habitats are equally weighted, then an area related decline in one subsidiary habitat index will usually be compensated by an area related increase in another – except where these losses are to urban development. In other words area will contribute rather little to the NCAI trend. This is reinforced by the fact that most habitats show very little measurable change from year to year.

This raises the question as to whether it is worth including area, especially since when interpreting the index we would normally wish to understand whether a downward trend was related to area or to quality; and if to area, then we would wish to know which habitat.

However, a purely quality based index would rather undermine the whole point of the index = which is about natural capital stock.

1.14 Conclusions

1. It is possible to construct a hierarchical natural capital index which broadly reflects the qualities of major habitats in terms of delivery of ecosystem services.
2. A thorough understanding of the nature and derivation of indicators and their strengths and weaknesses is required if a robust index is to be built up. The scale of the task, coupled with limited resources has meant that we have only been able to complete the task for three broad habitats, and this still requires some form of workshop validation.
3. The quality and coverage of valuation studies is inadequate to justify a differential weighting of major habitats based on ecosystem service value.
4. There are significant differences between the broad habitats in terms of indicator availability, and effective representation of important ecosystem services (table 2). This partly undermines the credibility of the index.
5. If the availability of annual data is considered to be a critical criterion for indicator selection, then coverage of important ecosystem services for most major habitats is inadequate to develop a credible index. In many cases appropriate indicators are only available on a (ca) 6 year cycle.
6. Interpretation may be difficult. Many of the indicators relate to ecological processes or characteristics which vary substantially through time - sometimes as a result of human activities, sometimes related to climatic changes, and sometimes the result of poorly understood ecological cycles. Bringing these together may result in confusing and sometimes misleading trends.
7. Although multiplication of (area x quality indicator) is a logical representation of natural capital stock, sensible interpretation would require disaggregation of these two dimensions, raising the question as to whether such an index has any real strengths compared to a basket of environmental quality indicators, along with area trends, as is currently undertaken by the Countryside Survey.
8. Partly for these reasons we have constructed the index as a hierarchy which can be explored at different levels – including ecosystem service subsidiary index for each broad habitat, broad habitat combined (area/quality) index and NCAI combined index.

Table 2. Indicator quality assessment by broad habitat and ecosystem service category

broad habitat	**supporting services**	**regulating services**	**provisioning services**	**cultural services**	**overall coverage**
seas	fair	good	good	poor	fair
woodland	fair	fair	good	good	fair
dwarf shrub heath - peatland	good	fair	poor	fair	fair

Note: In practice this assessment may be considered rather positive. If lack of annual data is considered to be critical criterion, overall rating would be generally poor.

1.15 The way forward

We have undertaken significant background work on possible indicators for other broad habitats, and the value of associated ecosystem services. The marginal cost of completing an indicator assessment for each of these will be relatively modest, as will be actual data import and construction of a pilot index.

Completion of this work would then serve as the background and basis for engagement with other interested parties in a broader participatory process to assess the value of such an index, and if appropriate to change/further develop/refine the structure and protocols, and make a final selection of agreed indicators for generating the index on a regular basis. This would probably require expert working groups to finalise the subsidiary index for each major habitat, coordinated by a well-informed facilitator/reporter.

Other interested parties include specific project initiatives such as the European Beyond GDP initiative, the CEH led Natural Capital Initiative, the National Ecosystem Assessment, The European Economics of Ecosystems and Biodiversity (TEEB) project, the DEFRA ecosystem services research programme and various projects under the European Environment Agency. The on-going work on ecosystem health indicators and more structurally based environmental quality/greenspace indicators within SNH is also relevant.

However, alternatives to an NCAI, based on a basket of more broadly based environmental quality indicators, related to agreed environmental objectives and outcomes, and unrelated to the area of specific habitats may offer a simpler and more robust way forward.

2. INTRODUCTION

2.1 The meaning of natural capital

In normal parlance, capital is thought of as the basic funds and assets used by people, governments and businesses to sustain and equip their income-earning activity. Natural capital is the extension of the economic notion of capital to environmental goods and services. Natural capital is therefore the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future. Since the flow of services from ecosystems requires that they function as whole systems, the structure and diversity of the system are important components of natural capital. Biodiversity is therefore an important underpinning of natural capital. Indeed, the European Commission's communication on the 2020 biodiversity targets suggests that "Biodiversity – the variety of ecosystems, species and genes – is the world's natural capital." According to the Millennium Ecosystem Assessment (MA 2005a), natural capital is "an economic metaphor for the limited stocks of physical and biological resources found on earth".

2.2 Aims and objectives

SNH currently reports on various biodiversity and other natural heritage trends. However, there is now a desire to also account for Scotland's natural assets from an economic perspective, thus an index of natural capital needs to be developed.

According to the Statement of Requirements this project aims to "evaluate and develop an index of Scotland's natural capital assets (NCA) to be piloted as an additional indicator (and to allow comparison with annual GDP changes) …..and to establish Scotland's current position with regard to recent trends in NCA". The focus is on the asset or stock of living natural capital (major habitats such as forest, grassland) rather than consumption, and excludes extracted materials such as aggregates and fossil fuels. Measurement is in terms of quantity and quality.

Quantity is measured in terms of area, although for most natural assets this will vary very little from year to year. Quality is measured using a variety of proxy indicators of habitat health and/or its ability to generate a stream of ecosystem services.

Indicators are then weighted in accordance with their relative importance in terms of the delivery of ecosystem services, and in terms of their quality/utility more generally to generate a compound index reflecting overall trends in the quality and quantity (i.e. overall value) of natural capital.

2.3 Methodology

The methodology was set down in the SOR as follows.

This project will entail a desk-based review of data sources and discussion with SNH staff. In addressing these objectives the evaluation should as a minimum consider the following research tasks:

Identification and evaluation of annual data / indicators for the monitoring of sustainable performance with regard to Scotland's natural capital. Both terrestrial and marine capital will be covered. For land the area of agricultural land (classes), woodland, peatland, and upland might be included, along with possible indicators of soil quality, as well as farmland, woodland, and upland breeding bird abundance as a proxy for the vegetative quality of this land. For water a measure of river pollution (and/or ecological status) is likely to be required along with bathing water pollution, seabird breeding abundance, percentage of fish stocks within safe biological limits, and annual seal data as proxies for marine habitat quality.
Base data for any indicators should be extracted from available records published and recorded in the Excel database.

Weightings within the index. Similar to weightings of items purchased for price index (inflation) calculations, the data / indicators identified above must be weighted to produce an overall compound index. The preferred weighting of land uses will be based on the average value of ecological services delivered per year (using a previous SEPA study), adjusted by area. Likewise weighting of water would be based on the average value of ecological services delivered per year (using a previous SEPA study) for fresh water and sea, divided by area. However, the weighting system to be used has not been finalised at this stage and alternative approaches should be explored, including their impact on the stability of the index. However, there should be a clear rationale (probably based on economic or accounting theory) for this weighting. The final selection of data / indicators and weightings will be determined in consultation with the nominated project officer and other SNH staff.

The actual calculation exercise should be undertaken in Excel, most likely with the year 2000 as the base year for the index (i.e. 2000 = 100). The calculation exercise is expected to be fairly 'mechanical', but with clear identification of where data entry is required and where weightings are used and their values.

The initial proposal is to include the following habitats:

- Estuaries
- North Sea
- Forests
- Grassland
- Peatlands
- Lochs and rivers
- Cropland

2.4 Outputs

This report will include:

- The identification of appropriate existing annual data / indicators (going back at least several years) that could be used to feed into the NCA index. Criteria would include availability (i.e. publication dates), data quality, etc.

- An evaluation exercise, to determine how the data / indicators identified above perform within the compound index (e.g. variability), and thereby develop a final list of the most suitable data / indicators,
- Alongside (ii), an analysis of weightings that could be used for the components of the index.
- A calculation of the index back to approx year 2000, to allow publication of the previous trend as well as the change in the latest year.
- A short manual (note) on the use of the data / indicators (sourcing etc) and an MS Excel database with calculations for producing the index."

2.5 Time and resources required

An index of natural capital, capable of being considered "alongside GDP" clearly has the ambition to be extremely important. It seeks to encompass a very wide range of natural, economic and cultural values. Developing a credible index is therefore a complex and difficult process, and will require input and "buy in" from a very wide range of interests. This study - based on 26 days work including assistance - could do little more than make a modest start – beginning to explore how such an index might be built up. We did not feel it was possible to "pilot" such an index within the very modest resources of the study, but hopefully this preliminary analysis will serve as a starting point and help to define more clearly what is desirable and what is feasible.

3. THE POLICY ENVIRONMENT AND PARALLEL INITIATIVES

The development of indicators and indicator frameworks related to environmental quality and natural assets has become a crowded field over the last decade, and it is important that this initiative draws on experience from elsewhere, and contributes to or integrates with other current initiatives.

3.1 Green accounting

Green accounting – as a compliment to more conventional national accounting has been around for several decades and is closely related to the idea of a natural capital index. It has arisen in response to the widespread recognition that while "'GDP growth percentages' are substantially misleading as yardsticks of growth, development, wealth, or well-being" they are used widely and consistently by policy-makers, planners, businesses, and the media (Gundimeda *et al* 2006).

A major impetus to Green Accounting in the '80s was the widespread recognition that deforestation was making a substantial contribution to GDP in developing countries, yet involved a major drawdown in natural resources or capital.

A notable current example is the "Green Accounting for Indian States and Union Territories project" (GAIST) (Gundimeda *et al* 2006). GAIST proposes to build a framework of adjusted national accounts that represents genuine net additions to national wealth. This addresses a whole range of social and economic values not normally captured in conventional national accounts, including carbon and forest resources, agricultural land, biodiversity values, educational capital, health and pollution control, ecological services (such as soil formation and water regulation).

Despite widespread awareness of the limitations of GDP, and numerous green accounting initiatives throughout the world over the last 3 decades, it is notable that Green Accounting has not yet been established in the mainstream of national economic or environmental accounting. This relates in large part to the technical and conceptual difficulties and complexities, and the costs of data collection and analysis.

3.2 SNH Natural Heritage trends

Scottish Natural Heritage publishes data on natural heritage trends which are readily available through the SNH website.[1] These include:

- Biodiversity indicators (state, engagement)
- Countryside Survey (a periodic comprehensive assessment of the status of the Scottish Countryside as part of a UK wide exercise)

These data sets allow for periodic reporting on the state of Scotland's Natural Heritage, but do not relate closely to the quality of the environment in terms of its capacity to generate a wide range of valuable ecosystem services.

3.3 Beyond GDP

In November 2007 the European Commission, together with European Parliament, OECD, the Club of Rome and WWF organised a conference "Beyond GDP" which confirmed widespread support for the development of new indicators to complement GDP in support of more informed policy decisions. Several national initiatives followed, some of which are described below.

Building on these initiatives, and influenced also by the European Economic Recovery Plan[2] which recognised that the economic crisis should also be taken as an opportunity to "set our economy more firmly on the path to a low carbon and resource efficient economy" the European Commission published a "communication" in August 2009 entitled "GDP and beyond: measuring progress in a changing world".[3] This points out the widespread use and acceptance of GDP as a key measure of national performance, but also its increasingly recognised limitations – and in particular its inadequacy to measure environmental sustainability or social inclusion. The Communication identifies actions that can be taken in the short and medium term. "The Commission intends to cooperate with stakeholders and partners to develop indicators that are internationally recognised and implemented".

3.4 Natural Capital Index Framework

One practical outcome of the beyond GDP initiative has been the development of an index framework by ten Brink (2007). Brink cites the following requirements for a useful index:

- Accurate description of the process of biodiversity loss
- Relevant and appealing for policy development
- Quantitative
- Sensitive
- Affordable
- Measurable
- Universally applicable
- Represent entire ecosystem
- Linkable with socio-economic scenarios

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[1] http://www.snh.gov.uk/trends/
[2] COM (2008) 800 Final
[3] Commission of the European Communities. Communication from the Commission to the Council and European parliament: GDP and beyond: measuring progress in a changing world. Brussels 20.8.2009. COM(2009) 433 Final.

The NCI is calculated quite simply as ecosystem quantity (percentage area of country or region) x quality (average abundance of a core set of characteristic plant and animal species), i.e.

50% loss of biome area x 50% loss of species = NCI for that biome of 25%.

The index favours species abundance as a more sensitive and measurable indicator of biodiversity loss than species richness.

Brink suggests that a baseline should be at an arbitrary but practical point in time. The CBD liaison group suggests “a postulated baseline, set in pre-industrial times” or “a low impact” baseline.

Although this claims to be a natural capital index, the indicators used relate to biodiversity, not to ecosystem services, the assumption being that biodiversity quality is the most appropriate indicator of ecosystem service delivery. This is questionable for a variety of reasons discussed further below.

3.5 The Economics of Ecosystems and Biodiversity (TEEB)

The EC sponsored TEEB project arose out of a discussion at the meeting of G8+5 environment ministers which took place in Potsdam in May 2007 where it was decided to launch a joint initiative to draw attention to the global economic benefits of biodiversity and the costs of biodiversity loss and ecosystem degradation. The ambitions for phase II of TEEB are to:

- firm up and publish a “science and economics framework” which can help frame valuation exercises for most of Earth’s ecosystems, including in its scope all material values across the most significant biomes;
- further evaluate and publish “recommended valuation methodology”, including biomes (e.g. oceans) and some values (e.g. option values and bequest values) which have not been investigated in depth in Phase I

This study addresses in particular the contribution of biodiversity to ecosystem services. Clearly this work is of great relevance to the current study and should be taken into account in any further work/refinement of the methodology

3.6 DEFRA ecosystem services research

DEFRA has sponsored a series of studies on the nature and value of ecosystem services, including guidance on approaches to valuing ecosystem services. These are of direct relevance to this study and are reviewed in more detail in annex 1.

3.7 National Ecosystem Assessment NEA

The UK National Ecosystem Assessment (UK NEA) is “the first analysis of the UK’s natural environment in terms of the benefits it provides to society and continuing economic prosperity. Part of the Living With Environmental Change (LWEC) initiative, the UK NEA, which commenced in mid-2009, will be reporting in early 2011. It is an inclusive process involving many government, academic, NGO and private sector institutions”.

NEA will take place at UK and regional level, and look back 50 years and forward to 2060.

3.8 The Natural Capital Initiative (NCI)

The Natural Capital Initiative[4] coordinated by CEH, the Ecological Society and the Society for Biology is primarily concerned with promoting a better understanding of our life support services.

3.9 Ecosystem health indicators

Over the last decade there has been growing interest in deriving measures or indicators of ecosystem health. Examples of the type of indicator that may be used include:

- Landscape integrity, from near natural to highly modified
- Extent of habitat fragmentation
- Proportion of non-native invasive species
- Habitat complexity
- Presence or absence of functional groups

There are various examples of ecosystem health assessment, including for example an assessment of the ecosystem health of Lake Michigan and the "report card" system used in Queensland Australia to assess the health of aquatic ecosystems. SNH is currently exploring/developing indicators of ecosystem health.

In practice it is difficult to define ecosystem health without reference to the quality, value and sustainability of the ecosystem services with which it is associated. Though not yet readily available, these indicators are likely to be of direct relevance to the development of a natural capital index.

3.10 Local environmental quality indicators

There are several current initiatives seeking to develop one or more indices of environmental quality with direct relevance to local planning procedures and the Scottish Performance Framework. These are likely to relate strongly to some key ecosystem services, and in particular to drainage/flood mitigation, biodiversity/connectivity, carbon sequestration, recreation and health. These may serve to inform an extension of the NCAI to include a "peri-urban major habitat type".

4. INDICES – LEARNING FROM EXAMPLES

Before considering the structure of a NCI for Scotland it is worth briefly reviewing the structure and protocols for developing indices more generally, drawing on some well known and widely used examples.

As a general principle, an index should be as simple as possible and understandable, in principle at least, to policy makers, politicians and the wider public. Two examples are worth exploring in more detail:

- The retail price index, and
- The Scottish index of multiple deprivation

[4] http://www.naturalcapitalinitiative.org.uk/

4.1 The retail price index

This index is comprised of more than 650 separate price indicators – the "shopping basket" – whose movements are taken to represent the price changes for all goods and services covered by the index, including those for which prices are not specifically monitored. There are, for example, several price indicators for bread - such as a large white sliced loaf and large wholemeal loaf - that are combined together to estimate the overall change in bread prices.

The shopping basket is updated every year to ensure it is up-to-date and is representative of people's spending patterns: "the places and shops we go to, the goods and services that we buy and the amounts we spend on them."

Since we spend more on some things than others (e.g. petrol v. socks) the components of the index are 'weighted' to ensure that it reflects the importance of the various items in the average shopping basket, and the amounts we spend in different regions of the country and in different types of shops. The weights for the index are derived from a number of sources but mainly from ONS's Expenditure and Food Survey covering several thousand households from across the country. Subsidiary indices are developed for some more vulnerable groups such as pensioners.

Changes in prices of sample goods are measured by comparing them to their levels in the previous January. These are then weighted together using the weights for the current year to produce an overall average price change. The final stage in the calculation is to link the average price changes with the figures for earlier years. Only by 'chain-linking' the calculations in this way can the index take account of changes in the make-up of the shopping basket from year to year; and provide like with like comparisons between different years. This procedure ensures that the index is not distorted when items are either removed or introduced.

4.2 The Scottish Index of Multiple Deprivation (SIMD)

Drawing on Scottish Neighbourhood Statistics data that have a clear relationship with deprivation, the Scottish Government has developed an index of deprivation. This is based on 7 domains and 37 indicators. Each domain comprises several correlated indicators. Indicators are aggregated in various ways for each domain, and then each domain is weighted to generate an overall weighted index or score. The score is reported as a rank, with 1 for the most deprived data zone and 6505 for the least. The weighting for each domain or sub domain is based on "the robustness of the data, the time lag between data collection and the production of the SIMD and the relative importance of the domain in measuring multiple deprivation". Table 3 below shows the six domains and their respective weighting.

Table 3. Weights applied to each of the domains in the SIMD 2006

Domain	**% of overall weight 2006**
Current Income	28
Employment	28
Health	14
Education	14
Geographic Access	9
Housing	2
SIMD Crime	5

Scottish Neighbourhood Statistics have recently (2006) looked at including indicators of the physical environment in SIMD - specifically air pollution; proximity to derelict land; and proximity to Scottish pollutant release inventory sites - but there was no correlation between these at data zone level and therefore each indicator would have to be a separate domain which was considered inappropriate.

4.3 International Geosphere-Biosphere Programme (IGBP) Climate-Change Index

The IGBP Climate-Change Index brings together key indicators of global change: atmospheric carbon dioxide, temperature, sea level and sea ice. It will be released annually. Each climate change indicator is normalised between -100 and +100. Zero is no annual change. One hundred is the maximum-recorded annual change since 1980. The normalised parameters are then averaged. This gives the index for the year. The value for each year is added to that of the previous year to show the cumulative effect of annual change.

4.4 General principles for designing indices and criteria for selection of indicators

4.4.1 Scope or coverage

Indices and performance measures can have perverse effects. In order to simplify, or because of a lack of readily available data, sets of indicators may be inadequate in terms of covering all society's values. This can have serious and perverse consequences, driving a simplified agenda which undermines some key values.

In the habitat-indicator assessment presented in the following sections we have tried to address this through rigorous analysis of the various dimensions of value associated with each major habitat, identifying not only suitable indicators, but also serious gaps. The analysis is then used to inform an overall appraisal of the quality and utility of each subsidiary (major habitat) index.

4.4.2 Objectives and target audience

Much has been written about what makes a good indicator (or index). TEEB 2008 and others suggest that the most important criterion is that the indicator be relevant to purpose and be designed for a specific purpose and audience.

The purpose of this proposed indicator is presented in the SOR as follows:

"This project aims to evaluate and develop an index of Scotland's natural capital assets (NCA) to be piloted as an additional indicator (and to allow comparison with annual GDP changes). Therefore the general aim of this project will be to establish Scotland's current position with regard to recent trends in NCA" and "This study is being commissioned to create a new index indicator to measure sustainability"

The **practical purpose** of the indicator may therefore be taken as:

To monitor the extent and quality of Scotland's major natural habitats in terms of their ability to generate valuable ecosystem services.

If the index is to be used alongside GDP the target audience is just about everyone – and this must be kept in mind when selecting/weighting indicators.

5. HABITAT CATEGORIES AND AREA

The choice of categories should be based on a range of criteria:

- Clearly identifiable boundaries
- Availability of regularly updated data on area
- Availability of regularly updated indicators of quality
- Availability of quality indicators which apply/are relevant across the range of subsidiary or component habitat types

The TOR suggest in the first instance that the main categories of natural capital (or major habitats) should include:

- North Sea
- Estuaries
- Lochs and rivers
- Forests
- Grassland
- Peatlands
- Cropland

5.1 Categories related to ecosystem services initiatives

The TOR classes are broadly consistent with those proposed by TEEB (de Groot *et al* 2008)

- Marine/open ocean
- Coastal systems
- Wetlands
- Lakes and rivers
- Forests (wooded tundra, boreal, cool coniferous, temperate mixed, temperate deciduous, warm mixed, tropical)
- Woodland and scrubland
- Grass and rangeland
- Desert
- Tundra
- Ice/rock/polar
- Cultivated areas
- Urban areas

And the NEA which uses the following categories:

- Marine and coastal margins
- Rivers/Lakes/Wetlands/Floodplains
- Semi-natural grassland
- Enclosed farmland (arable and improved grassland)
- Woodland
- Mountain/Moorland/Heaths
- Urban (includes avenues and green spaces)

The separation of forest and woodland in the TEEB classification would be difficult to apply in practice. Tundra may be regarded as broadly equivalent to peatland. The main difference is the absence of wetland in the initial (TOR) suggested list.

5.2 Categories based on existing data sources for area

Sources of data on area are an important consideration for the selection of categories. There are no statutory requirements for land cover surveys of the UK (except for the requirement for the June Agricultural Census which farmers complete annually.) This has meant that there is no standard UK land cover classification. At the present time there are four main sources:

- Countryside Survey and Land Cover Map of Great Britain
- Land Cover of Scotland (1988)
- National Countryside Monitoring Scheme

5.2.1 Countryside Survey and UK Land Cover Map (CS-LCM)

Survey method

- Sample based, field survey mapping, statistically robust at national level; coupled with satellite based imagery.
- Integrated with OS Mastermap and Agricultural land parcel data sets

Dates of data collection

Years: 1976, 1984, 1990, 2000, 2007

Box 1. Landcover Map 2007

- is a spatial database (GIS) of land cover and broad habitats at a 'field-by-field' scale for the whole of the UK
- will be produced by a combination of data from satellites, digital cartography, ground reference data and other datasets
- will provide information at a range of scales (from local sites to the whole UK) and will contribute to European land cover mapping (source http://www.countrysidesurvey.org.uk/land-cover-map-2007)

Land cover categories

Table 4. Areas of broad habitats in Scotland in 2007 (LCM-CS)

Broad habitats	Area in sq km
bog	20,440
acid grassland	9,830
coniferous woodland	9,560
improved grassland	9,070
dwarf shrub heath	8,940
arable and horticulture	5,340
neutral grassland	4,610
Broad leaved, mixed and yew woodland	2,510
fen, marsh, swamp	2,390
built up areas and gardens	1,530
bracken	1,320
linear features	950
standing open waters	890
inland rock	840
other land	740
montane	380
un-surveyed urban land	380
calcareous grassland	260
rivers and streams	213
Total	**80,193**

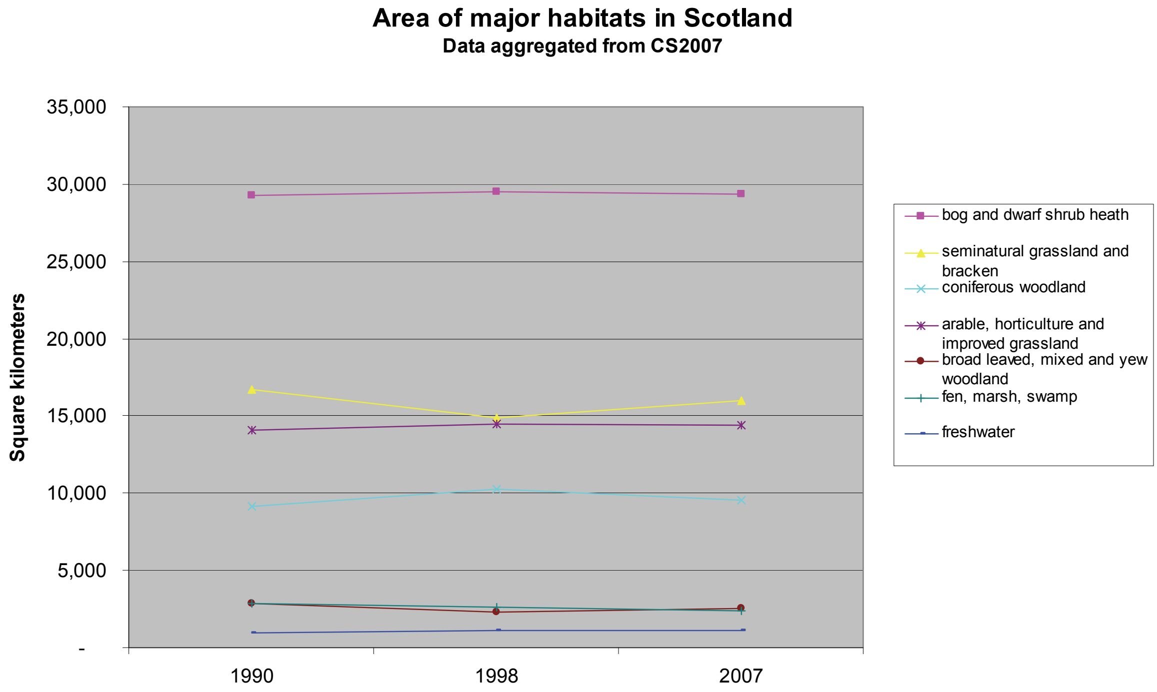

Figure 2. Trend data for major habitats (aggregated broad habitats)

Strengths

- Satellite based area assessments for major habitats corresponding to UKBAP habitat classification. Corresponding data on quality indicators such as species richness.
- Part of the major national survey of the state of the British Countryside and therefore likely to be repeated in future
- Area data is cross related to the most comprehensive survey of the state of the British Countryside

Weaknesses

- Data collection periodic - typically 6 year cycle
- Future data not guaranteed

5.2.2 Land Cover of Scotland (LCS88) MLURI

Survey method: Aerial photography – specifically designed as a monitoring baseline

Dates of data collection: 1988

Land cover categories: There are 6 principal features; total of 126 land cover features expanded to 1323 when mosaics included (e.g. heather moorland and peatland). Digitised and can be combined with other digital maps. Land cover can be aggregated as required for purpose. A list of major and subsidiary landcover features is presented below.

Principal features:

- Farms and developed rural land
- Bare ground
- Miscellaneous features
- Woodland
- Agricultural land
- Semi-natural ground vegetation

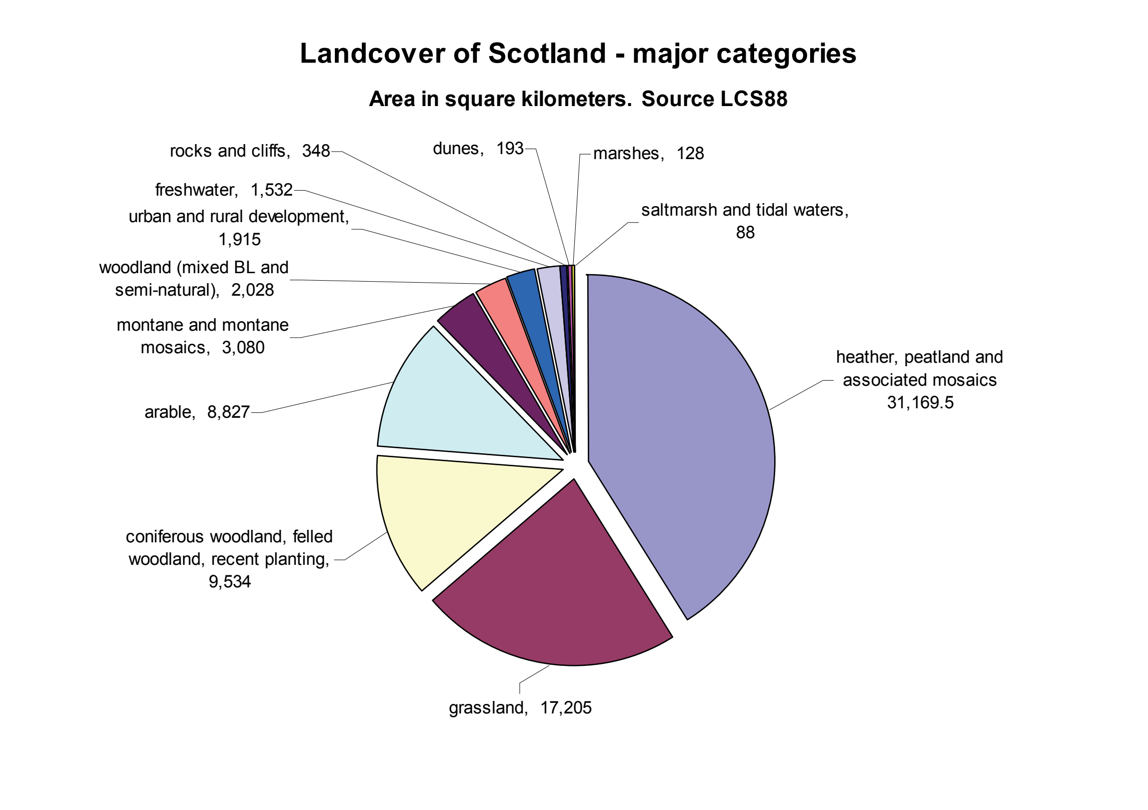

Figure 3. Figure 3: LC88 landcover

Table 5. Area of Scottish land categories. Single features and important mosaics (M). LCS88.

Habitat	Area in sq km
heather moorland-peatland M	12,370.9
improved grassland	10,281.1
arable	8,826.9
heather moorland	6,881.5
peatland	6,600.2
coniferous plantation	6,142.1
poor rough grassland-heather moorland M	3,230.0
recent planting	3,092.0
good rough grassland	2,472.2
poor rough grassland	2,011.0
montane	1,604.5
freshwater	1,532.0
good rough grassland-heather moorland M	1,452.9
urban	1,444.8
broadleaved woodland	1,024.3
peatland-montane	935.5
mixed woodland	854.5
good rough grassland-poor rough grassland M	848.0
improved grassland-good rough grassland M	814.8
good rough grassland-bracken M	660.9
poor rough grassland-peatland M	634.0

heather moorland-montane M	539.9
rural development	470.3
rocks and cliffs	348.1
felled woodland	299.6
dunes	193.1
marshes	127.9
bracken	117.3
semi-natural coniferous	75.0
scrub	74.4
saltmarshes	60.4
tidal waters	27.3
total	**76,047.4**
other mosaics M	2,524.9
data na	256.0
Total	**78,828.3**

Insights

At 12,371 sq km heather moorland-peatland mosaic is the largest single category, suggesting that there is little point in separating these two habitats. The importance of peatland/heather moorland mosaics with grassland also suggests some difficulty in separating these, and it is arguable that a single category for upland semi-natural vegetation should be used.

Strengths

- Designed as a baseline specific to Scotland. Comprehensive and comparable data for all features and important habitats
- Includes important mosaics – significantly heather moorland and peatland which covers roughly 16% of Scotland, and heather moorland and poor rough grassland. These subsidiary categories can be grouped according to need.

Weaknesses

- Now 22 years out of date
- Very expensive – interpretation aerial photography - regular repeat unlikely
- Unnecessarily detailed for purposes of index
- Access to full database expensive

5.2.3 National Countryside Monitoring Scheme (NCMS)

- Historic aerial photography within sampling framework
- Periodic since 1947, early 70's; late '80s.

This has probably been superseded by the CS/landcover of UK database

5.2.4 Forestry Commission survey data

Data on the area of conifers and broadleaves is published annually by the forestry commission and in national statistics. Periodic survey data is also available which gives more detail (such as area of ancient and semi-natural woodland).

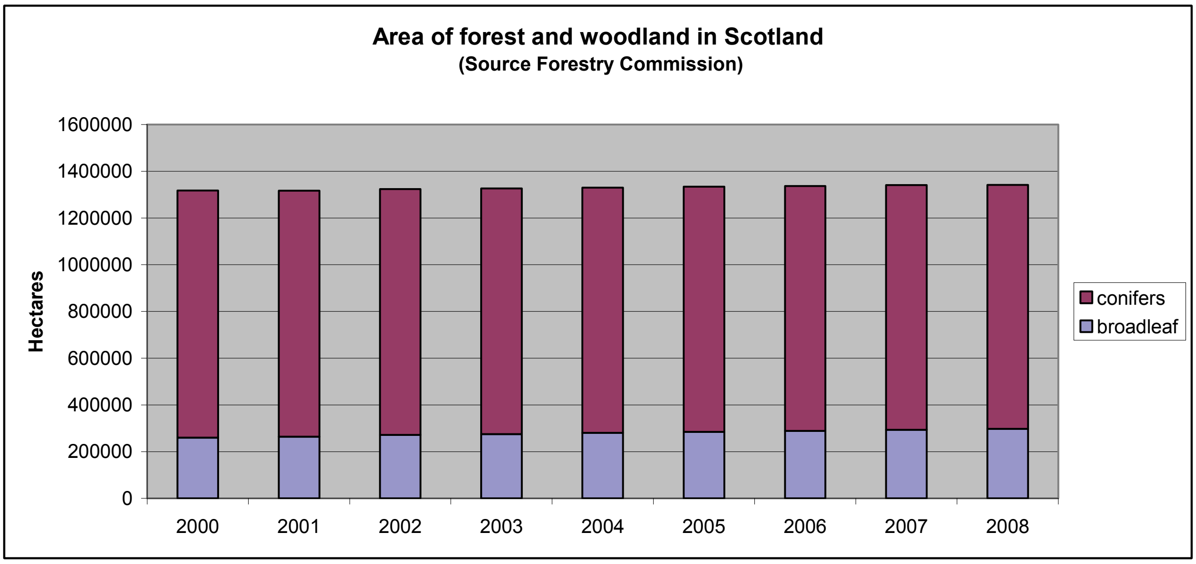

Figure 4. Forestry Commission data on woodland area

5.2.5 Agricultural census data

The Scottish Government reports the total area of land allocated to agriculture on an annual collection (June) and reporting (September/October) with a smaller sample survey in December. The figures for total area of major land-use types is presented in table 6 for 2006 and the trend since 2000 shown in figure 5

Table 6. Total area of major land-use types

2006 data	**Area in sq km**
Total crops, fallow, and set-aside	6,003
Total grass	12,457
Rough grazing	33,922
Woodland	2,466
Other land	822
Total	**55,669**

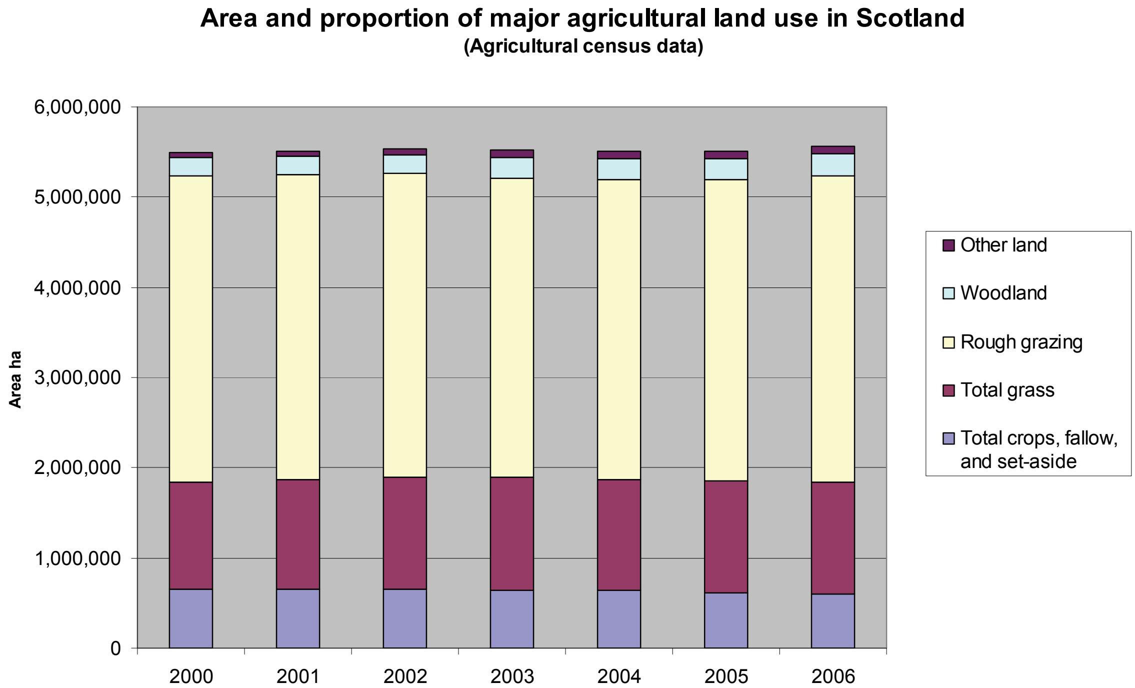

Figure 5. Areas from agricultural census data

5.3 Broad habitat categories: options

Selection of broad habitat categories is constrained to a large degree by available data. However, there remain important options.

5.3.1 Woodland and forest

There are four major options for woodland.

1. A single category for all forms of woodland. This would be compatible with all data sets. However, the ecosystem services generated by the different forms of woodland are distinct.
2. Two categories: coniferous woodland; broad-leaved and mixed woodland. This is compatible with CS-LCM and annual FC data
3. Two categories: native woodland (coniferous and broadleaved); coniferous plantation. Compatible with LCC88, but no regularly updated area data.
4. 4 categories – semi-natural coniferous; mixed woodland; coniferous plantation and scrub. This is compatible with LCS88.

The first of these is used initially but the second may be adopted later in the light of indicator assessment.

5.3.2 Peatland, heather and bog

These categories are problematic. Bog may include heather moorland; heather moorland may include peatland; peatland may include bog. This explains why the numbers for these categories derived from LCS-88 do not readily match those of CS-LCM (Table 7).

In fact the most extensive habitat in Scotland is a mosaic of heather moorland and peatland (bog) (LC-88 database), suggesting that a combined category of heather moor and bog may be most appropriate in the first instance. However, given the exceptional nature of peatland/bog as a carbon store, the desirability or otherwise of aggregating these categories will be explored further following indicator evaluation.

5.3.3 Grassland

Although the LCS-88 data shows that poor rough grassland-heather mosaic is an important habitat, it is also clear that grasslands represent a very large area in their own right and deserve their own category. Although improved grassland could be included in this we feel it is better to allocate this to agricultural land since this is part of the "farm management land-use system" and corresponds to indicators such as "farmland birds".

5.4 Working list of habitat categories

For the purposes of indicator evaluation the following is proposed as a provisional "working list" with the option to change this in light of the findings of the research on indicators.

- UK (Scottish) territorial waters (including estuaries and firths)
- Lochs and rivers
- Wetland (Fen, marsh and swamp)
- Forest/Woodland
- Semi-natural grassland and bracken
- Peatland (bog)-heather moor (dwarf shrub heath)
- Cropland (arable, horticulture) and improved grassland

This is consistent with the most suitable primary area based data source (LCM-UK; Forestry statistics; agricultural census data).

Additional but far less extensive categories that might also be included:
- Montane habitats
- Littoral and supra-littoral rock and sediment
- Built-up areas and gardens
- Inland bare ground

Areas for these categories from various sources are presented in table 7.

Table 7. Area of major habitat types in Scotland (square kilometres)

	CS-LCM 2007	**LCS-88**	**Agricultural census data (2006)**	**Forestry Commission 2007**	**Marine Scotland**
UK (Scottish) territorial waters (including estuaries and firths)					547,800
Lochs and rivers	1,103	1,532 (freshwater)			
Wetland (Fen, marsh and swamp)	2,390	127.9 (marshes)			
Coniferous woodland	9,560	9,533.7[5]		10,480	
Broad leaved/mixed woodland	2,510	2028.2[6]		2,930	
Semi-natural grassland and	16,020	16,390.5[7]	33,922		

[5] (coniferous woodland + felled areas)
[6] (mixed broad leaved, semi-natural coniferous, scrub)

bracken			(rough grazing)		
Bog (peatland)	20,440	6,600.2[8]			
Heather moorland (dwarf shrub heath)	8,940	12,370.9[9]			
Cropland (arable, horticulture) and improved grassland	14,410	19,922.8[10]	18,459 (crops and grass)		
Native pinewoood		included with 5 above			
Montane habitats	380	3,079.9[11]			
Littoral and supra-littoral rock and sediment		348.1 (rocks and cliffs)			
Built-up areas and gardens	1,910	1915.1 [12]			
Inland bare ground and rock	840	348.1 rocks and cliffs			
Saltmarsh and tidal waters		87.7			
Linear features	950				
other	740				
total	80,193	78,828	55,669	13,410 (forest)	547,800

It is probable that the best source of data on area for these categories would be the Landcover of Great Britain data set. This is because:

- The data is satellite derived, and therefore likely to be consistent with data sets from other countries
- Data is likely to be cheaper than that sourced from comprehensive (census) aerial photography
- There is a likelihood that the database will be updated roughly every 10 years.
- It may be possible to interpolate intermediate data points using other data sources.

This source has therefore been used except where annual data is available from government statistics (agriculture, forestry).

6. WEIGHTING OF HABITATS

The SOR suggest that broad habitats should be weighted according to e*cosystem service values* as determined by Costanza *et al* 1997, Williams *et al* 2002, other more recent studies. If this is to be done, it must be robust:

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[7] (poor rough grassland, good rough grassland, poor-good rough grassland m; bracken; good rough grassland bracken m)
[8] "pure" peatland only)
[9] (includes mosaics with peatland and grassland)
[10] (arable and improved grassland –including improved grassland-good rough grassland mosaic)
[11] (including montane mosaics with heather and peatland)
[12] (urban and rural development)

- It implies a *differential trade-off* between broad habitats – effectively driving an increase in more "valuable" habitats at the expense of less – with the greatest practical implications for habitats which can change (area, quality) most easily.
- There are powerful groups with interests in particular broad habitats. An inferior valuation of "their" habitat would lead to a scramble to question/adjust the relative valuation.

6.1 Ecosystem services

Before reviewing valuation studies it is worth briefly reviewing the meaning and nature of ecosystem services.

There are functional (ecological) and economic (input, service) definitions of ecosystem services:

"The direct and indirect contributions of ecosystems to human wellbeing" (TEEB 2008).

"The components of nature, directly enjoyed, consumed or used to yield human well-being" (Boyd & Banzhaf 2006).

There are many different classifications of ecosystem services, and there continues to be much debate as to what categories should be used, and what should be included in the various categories. However, drawing on the Millenium Ecosystem Assessment, our own work for CCW (Hambrey and Senior 2008), and the more recent work by TEEB (De Groot *et al* 2009), they may be broadly classed as:

- regulating services,
- provisioning services,
- cultural services

The Millenium Ecosystem Assessment included also supporting services (such as nutrient cycling) and more recently de Groot *et al* (2009) have included "habitat services".

Box 2. Classification of ecosystem services (de Groot *et al*).

Provisioning services
- Provision of food
- Water provision (2), including regulation of water flows (10) and water purification (11).
- Raw material, fibre, energy resources
- Genetic resources
- Medicinal and other biochemical resources
- Ornamental resources

Regulating services
- Air quality regulation and other urban environmental quality regulation
- Climate regulation
- Moderation of extreme events (flash floods, landslides, avalanche, storm surge, tsunami, pollution+temperature, fire, shelter belt/wind damage, binding of sediments)
- Erosion prevention
- Maintenance of soil quality (carbon input (incl. organism faeces…), nitrogen fixing; symbionts, mycorrizal fungi facilitate P uptake by plants in more natural systems.(only 5-10% recovered in crops.
- Pollination services
- Biological control

Habitat Services (supporting services?)
- Maintenance of life cycles of migratory species
- Maintenance of genetic diversity (overlap with provisioning genetic resources above)

Cultural services
- Cultural services: aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, information for cognitive development

From a valuation perspective the inclusion of supporting services is problematic, since their value is realised through the more direct services they underpin, and inclusion of values related to these supporting services would risk "double counting". However, from the perspective of securing natural capital, it may be appropriate to take account of this category in the NCAI since it is arguable that though their current value is realised through more direct services, their potential value (or option value) as an underpinning of possible future services is almost infinite.

These issues are of particular importance to SNH since biodiversity is related to supporting services and habitat services, though the actual relationships are poorly established.

6.2 Valuation of ecosystem services

The valuation of ecosystem services is controversial. Most economists accept that the methodology is weak, especially when global or ecosystem level valuations are attempted (see for example O'Gorman *et al* 2008). On the other hand it is argued that decisions are made on the basis of monetary valuation, and the lack of valuation studies to date has meant that ecosystems services are systematically undervalued in decision making processes.

We have undertaken a thorough review of recent studies on ecosystem valuation (Annex 1) with a view to generating monetary values for each of the broad habitats discussed in section 5, which might serve as the basis for differential weightings. The conclusions of this review are that the conditions for a credible weighting based on ecosystem service values have not been met:

- Few studies relate specifically to the Scottish broad habitats listed in section 5, and the conditions required for reliable "benefit transfer" (i.e. use/adaptation of figures derived from studies elsewhere) are not in place;
- Even if benefit transfer were to be undertaken coverage of all the key dimensions of value of each of the broad habitat categories would be limited, and biased in favour of those direct services most easily monetarised;
- It is arguable that from a natural capital perspective, the values associated with supporting services (and in particular "option" value) are the most important – yet we lack credible valuations for these, and they cannot be added to more direct values.
- The relationship between area and value is complex and the validity of a £/ha figure questionable;
- Value/ha will change with time, but it is not feasible to update valuation figures on a regular basis;
- Cultural and biodiversity values are typically derived using stated preference/contingent valuation methods, with well-established limitations;
- The implications of inaccurate/partial valuations – in terms of perverse policy effects – could be serious.

This view is reinforced by other recent reviews (see for example box 3).

Box 3. Views on the valuation of ecosystem services

"A total valuation (of England's terrestrial ecosystem services) is not useful in considering the implications of policy related changes".
"It remains challenging to sum valuations for different benefits in different places at different scales"
"the values presented are likely to significantly under-estimate the full value received by society"
"For policy decisions and an understanding of sustainability issues, an analysis of marginal changes which facilitates consideration of trade-offs and change over time is needed"
O'Gorman et al 2008. DEFRA Ecosystems Research programme

However, some valuations are useful, and it would be possible to use these as input to a panel based weighting process. Such a weighting would remain controversial however, and it is unclear that it would usefully inform policy response to any change in index value.

If it is decided that some form of habitat weighting is the best way forward, these might be generated through expert/stakeholder workshops, taking full account of government policy (for example in relation to woodland expansion), to ensure agreement and buy-in. However, agreement would be difficult, and subjugation to national policy would undermine the index as an international measure.

For the pilot index therefore we assume equal weights between broad habitat types.

7. INDEX STRUCTURE AND INDICATOR SELECTION CRITERIA

Indicator selection depends in large part on the structure of the index. However, because indicator selection must also be based on pragmatic considerations, and in particular data availability, the index structure will depend to some extent on the nature of available data. Indicator selection and the refinement of index structure must therefore be a parallel/iterative process, leading to a feasible, rather than ideal index. Nonetheless, it is necessary to start with some basic idea of structure in order to define preliminary categories of indicator.

7.1 Dimensions of quality

An index of natural capital assets should reflect the quality of these assets in terms of the ecosystem services they deliver or underpin. Quality indicators for each major habitat type should therefore include at least one indicator for each major service category (where such services are considered significant), and more than one where the values for subsidiary service categories are considered to be significant. These service categories have been discussed in section 6 and are:

- Supporting (and habitat) services
- Regulating Services
- Provisioning Services
- Cultural services

These are considered to be underpinned by "*supporting services*" whose current measurable value is reflected in the three direct value categories, but whose potential value is arguably infinite. This is one of the reasons why ecosystem service valuation is so difficult.

Natural heritage and biodiversity are intimately related to supporting services, although the relationship between biodiversity, supporting services and direct ecosystem services is not simple (see for example Elmqvist *et al* 2009; Balmford *et al* 2008). Natural heritage and biodiversity is also directly and indirectly related to cultural services. For these and other reasons some analysts include a category of "*habitat services*" (de Groot *et al* 2009). The inclusion of biodiversity in either cultural or supporting services, or as a separate habitat services category affects the weighting afforded biodiversity, irrespective of any weighting applied to the categories, and is therefore an important issue.

We are unconvinced of the argument for a separate habitat services category, and have therefore used the four basic and widely agreed categories (supporting, regulating, provisioning and cultural). Natural heritage/biodiversity indicators have been allocated mainly to cultural services. However, some biodiversity indicators are poor indicators of cultural service value, but serve nonetheless as useful indicators of supporting services – especially where other good indicators are lacking.

More generally, it may be difficult to find an indicator for a particular ecosystem service category; equally, it may be difficult to match an indicator with a service category – suggesting either the categories are inadequate, the indicators are inadequate, or that the indicators reflect quality across several categories. In this report we have therefore taken a flexible approach to ensure reasonable indicator coverage across all four categories.

7.2 Proposed structure

The NCAI is constructed as a hierarchy as in Figure 6. “Baskets” of quality indicators are averaged to develop a set of four *service subsidiary indices* for each major habitat. These again are averaged and multiplied by the area index for the broad habitat to generate the *broad habitat subsidiary indices*. These are then averaged to give an overall NCAI.

Weightings may be introduced at quality indicator level, service index level and broad habitat indicator level if required. Weighting of indicators may be based on data quality, representation of the ecosystem service, and interpretation; weighting of service groups may be made based on evaluation of the relative importance of those services for that particular habitat; weightings of broad habitats are not recommended, despite the original suggestion that weightings should be based on valuation studies.

7.3 Indicator selection criteria

Criteria for the selection of indicators are generally well known, and have been adapted for the purposes of this study:

1. Data availability (at reasonable cost) and quality
2. Frequency of collection and reporting (including consideration of delay)
3. Measurable and relevant across the major habitat category, and specific to it.
4. Related to a definable natural capital stock generating a valued ecosystem service
5. Interpretation:
    - Sensitive to a manageable human activity;
    - Relatively insensitive to uncontrolled events;
    - Trends discernible and meaningful over a practical response time frame
    - Meaningful when aggregated with other indicators
6. Credibility and meaning for policy makers and public (and how well does it relate (directly or indirectly) to the key higher level policy objectives of sustainability, quality of life and opportunity, and the National Performance Framework more generally).
7. Conformity with other European and international initiatives

It is arguable that interpretation is of particular importance, and should be afforded particular weight in the assessment.

7.4 Dummy indicators

It may not be possible to identify a suitable indicator for all categories of ecosystem service, despite the probability that these services are valuable. This leads to the potential for the NCAI to be perversely “weighted” in favour of those broad habitats and ecosystem services for which indicators are available.

A solution to this is to introduce a dummy indicator with a fixed value of 1. Within the final index this would represent a loss of service directly proportional to area. This may not be too unrealistic insofar as many supporting services are likely to be proportional to area, and there is little evidence that quality/unit area is declining. Indeed, if there was serious concern about a loss of quality it is likely that an indicator would already be available.

The impact of dummy variables on the performance and interpretation of the index requires further exploration.

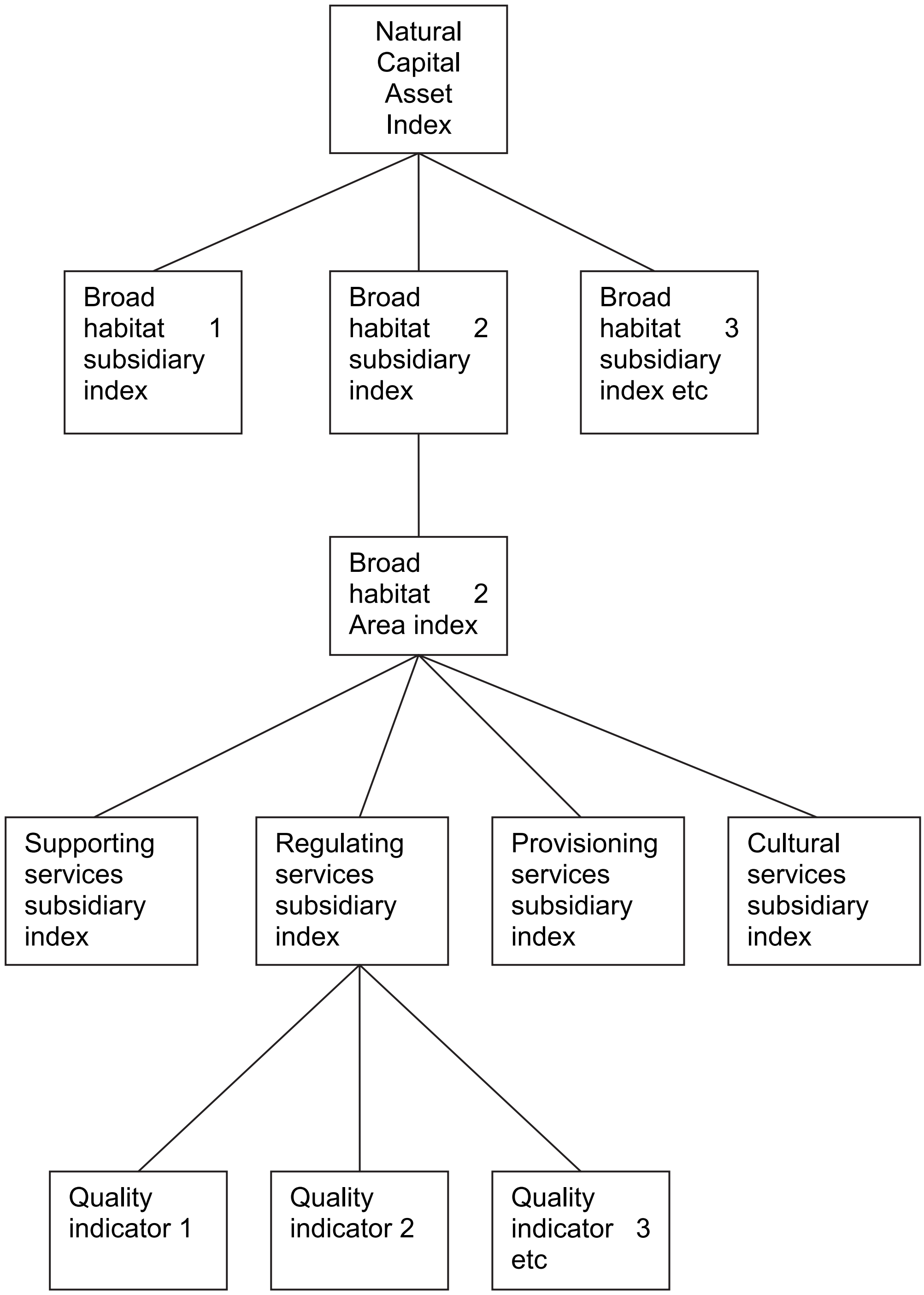

Figure 6. Proposed structure for a NCAI

7.5 Data scaling and normalisation

Individual ***quality indicators*** come in a multitude of units and must be scaled or normalised before they can be compared or aggregated. This can be done in several ways:

a) Scaled between 0 and 1 where 1 = yr 2000 value and 0=0.
b) Scaled between 0 and 1 where 1 = yr 2000 value and 0 = lowest or highest value recorded.
c) Scaled between 0 and 1 where 1 = yr 2000 value and scale 0-1 = historic range.
d) Scaled between 0 and 1 where 0 = no annual change and 1 is the maximum recorded annual change

a) will reduce the relative movement of the indicator, and the degree to which this occurs will vary between indicators depending on the nature of the original measurement. This is unsatisfactory. c) is the preferred approach, but is nonetheless difficult to apply because it depends on the period over which data has been collected, and the degree of variation in the indicator. d) is also a possibility but is less easy to relate to the current area or quality of the environment.

Area comes in standard units, but if the index is not to be completely swamped by the big habitats such as seas and peat/moorland, it will also need to be normalised to 1 for all habitats for the year 2000. Since units are standard, a) could be used, but this means the index will be relatively insensitive to changes in area, and the NCAI will be dominated by changes in quality. Using b) or c) is also problematic because historic data is limited and the historic range very narrow in most cases – meaning that the NCAI will be very sensitive to changes in area. Overall a) is probably preferable (and intuitively attractive) and is used in the pilot NCAI. Again this deserves further consideration and testing.

7.6 Annualisation

Many important indicators are not collected or published on an annual basis. If these indicators are excluded, coverage of major ecosystem services becomes inadequate, and it is arguable that the index will be largely value-less.

We propose to include indicators for which data is only available (for example) on a 6 year reporting cycle where no adequate annually collected indicator is available. This will require extrapolation on the basis of historic trends, with periodic re-adjustment and historic interpolation. This is unsatisfactory, but the alternative is an index with very limited coverage of ecosystem services. Although this might be useful as a broadly based environmental quality indicator, it would lack credibility as a natural capital index.

7.7 Indicator weighting

It is arguable that some quality indicators are superior to others in terms of representation of an ecosystem service category, and weighting might be assigned through a workshop or panel process. Although we discuss possible rationale for differential weights in the assessment, equal weights are assumed for the pilot index.

7.8 Ecosystem service group weighting

Any weighting assigned to a basket of indicators reflecting a category of ecosystem service gives relative weight to both the category and to the subsidiary indicators, and would need a strong rationale. Again, we discuss this in the assessment for each major habitat type, but assume equal weights for the pilot index.

7.9 Interpretation (habitat subsidiary index)

For each broad habitat it is possible to generate a trend graph for the overall combined broad habitat index, a trend graph for the four ecosystem service categories, and a trend graph of all component indicators.

7.10 Derivation of preliminary habitat index

In the following sections (6-13) we

- Identify the more important ecosystem services associated with the major habitat;
- Identify candidate indicators which reflect the quality of the habitat in terms of the sustained delivery of these services;
- Assess the quality of the indicators against the selection criteria;
- Make a preliminary selection of promising indicators;
- Consider whether there is a rationale for weighting the indicators;
- Formulate a subsidiary "habitat" index;
- Review the strengths and weaknesses of the index, in particular in terms of coverage of key ecosystem services.

A more detailed review of the values of ecosystem services, and the methodologies used to derive these values for different habitat types, is presented in Annex 1.

8. SCOTTISH TERRITORIAL WATERS

8.1 Area

According to SEGIS 2002, as quoted in Williams *et al* 2003, the area of Scottish Shelf Seas is 88 597 square kilometres.

In the Scottish Marine Bill (2009) the "Scottish marine area" means the area of sea within the seaward limits of the territorial sea of the United Kingdom adjacent to Scotland and includes the bed and subsoil of the sea within that area……. In this Act, unless the context otherwise requires, "sea" includes—
(a) any area submerged at mean high water spring tide,
(b) the waters of every estuary, river or channel, so far as the tide flows at mean high water spring tide.

In the Scottish Government's response to the CFP consultation, the area of Scotland's Fisheries Zone is given as 470,063 km^2. However, Marine Scotland commissioned a project in which it was calculated that Scotland is responsible for approximately 547,800 square kilometres of water within its 200 nautical mile limit. We take this figure to be equivalent to the legally defined "Scottish Marine Area" and serves the purposes of this exercise because of its direct relationship with management jurisdiction. In practice this area extends beyond the traditional shelf area to encompass significant areas of deep water and sea mounts to the West of Scotland. This definition includes estuaries, and is one reason for aggregating seas with estuaries as a single "major habitat".

It may be assumed that the area is relatively constant, although in the long term there will be changes related to both erosion and inundation.

8.2 Economy

The economic benefits derived directly from Scotland's seas are substantial. Marine related industry Gross Value Added (GVA) has been estimated as follows from Scottish Input-Output tables (Baxter *et al* 2008):

Table 8. GVA and employment generated by marine industries in Scotland (excluding activities related to oil and gas extraction)

Marine related industry	direct and indirect GVA (£m)	direct and indirect employment (FTE)
sea fishing	149.5	2,684
fish farming	121.7	2,468
processing and preserving of fish and fish products	481.4	14,104
building and repairing of ships and boats	312.9	7,216
construction of water projects	4.2	94
sea and coastal water transport	160.6	2,896
Total	1,230.3	29,462

8.3 Value of marine ecosystem services

The ecosystem services provided by the marine environment have been described by Beaumont *et al* (2006). Some none-use values have recently been estimated by McVittie and Moran (2008).

The analysis by Beaumont *et al* (2006) illustrates clearly the difficulty of valuing the full range of ecosystem services. Of the 13 "goods and services" they identify, valuation was not possible for 5, values derived were considered to be underestimates for 5, and overestimates for 2. A further estimate was considered unreliable. Even the market valuations – probably the most robust – were considered to be significant under or over-estimates.

MacVittie and Moran (2008) used contingent valuation and choice experiments to estimate the stated preference value of developing marine conservation zones in the UK. They concluded that the figure for the non-use values (primarily biodiversity) for the UK lies in the range £487m-£1170.7m/yr. It is arguable however that these figures are unreliable; median values from four different samples ranged by a factor of more than 6.

8.4 Candidate quality indicators

In the following sections we describe the characteristics of indicators relating to each of the above. This section has drawn heavily on Baxter *et al* (2008) "Scotland's Seas – Understanding their State". Annex 2 of this report offers a thorough summary/overview of data sources and quality relating to the monitoring of the marine environment.

Supporting and habitat services

8.4.1 New primary production

Primary production is widely regarded as a key measure of ecosystem function, and as such underpins a range of other services including fisheries production. It may relate to both positive impacts from a human perspective (e.g. increased fisheries production) or negative impacts (e.g. increased frequency of harmful algal blooms (HABS). It raises a policy dilemma in so far is increased primary production might reasonably regarded as generally a positive indicator of natural capital, it is, in some locations, closely related to increased nitrogen run-off related to human activity – which is generally regarded as negative.

Although data has been collected and analysed on a periodic basis (with detailed analysis between 1960 and 2003), an adequate current time series of data is not available.[13] It is therefore not considered further here.

8.4.2 Plankton (Scottish Biodiversity indicator)

CPR. The UK has exceptional long term records (since the 1930s) of plankton composition from the “Continuous Plankton Recorder (CPR)”, and four survey routes pass through Scottish waters. Plankton ecology is fundamental to primary production and is likely to affect the whole food chain. Plankton composition responds to changes in the flow of water from the West of Scotland through into the North Sea and also reflects changes in temperature. There are indications that seabird breeding success in Shetland is lower in years when there are more warm-water plankton.

CPR records of *Calanus finmarchius*, a cold water species, show no obvious trends over the last few decades, despite more general reports of a decline and northward shift in this species.

Stonehaven marine ecosystem. A coastal ecosystem monitoring site was established off Stonehaven in 1997 to monitor the state of the marine ecosystem in the north-east of Scotland. There have been significant variations in chlorophyll a concentrations, phytoplankton composition, and zooplankton composition and abundance. Zooplankton composition and abundance is also strongly linked to water temperature, with an exponential relationship between monthly mean temperatures abundance and biomass. Relationships with other factors, and in particular human related pressures, are as yet unclear. Of particular importance in the longer term will be establishing relations between plankton composition, abundance and nutrients or acidification.

Although the CPR trend data, and the more recent Stonehaven data is excellent in terms of quality and availability over a substantial period of time, it is unclear that plankton composition or abundance is useful as a practical indicator of natural capital or ecosystem services (such as fisheries production). In particular it is subject to very wide and erratic changes that may be related to temperature and/or oceanic circulation.

Harmful algal blooms. Under EC 854 2004 the UK is required to monitor for toxic phytoplankton in shellfish harvesting areas (*Pseudo-nitzschia; Dinophysis; Alexandrium*) and presence of toxins in shellfish flesh.

Although it is commonly thought that toxic blooms are related to anthropogenic influences (such as nutrient enrichment), recent independent reviews find no relationship between human activity and toxic blooms. Indeed, the worst affected areas of Scotland tend to be the far northwest and northern Isles.

The incidence of toxic phytoplankton could be used as an indicator, but interpretation is likely to be difficult.

Regulating services

Beaumont *et al* (2006) list several regulating services for marine waters: bioremediation of waste; gas and climate regulation, resilience and resistance, and disturbance prevention and alleviation.

[13] See Annex 4, Scotland’s Seas Understanding their State

8.4.3 *Water quality (waste assimilation)*

Coastal and estuarine water quality classification. Data is only available for this indicator between 1996 and 2006. A new system of assessing coastal water quality has now been introduced under the WFD. This indicator is therefore not considered further.

WFD classification of transitional and coastal waters. This classification system which is to be applied to 507 transitional and coastal water bodies (out to the 6m limit plus substantial sea areas in the Minches and around the islands) is based upon an assessment of the status of: phytoplankton; other plant; invertebrates; fish; structural features; physico-chemical features; specific pollutants; tidal regime. Ecological and chemical status is measured against an ideal or "reference" condition, and overall status assigned as bad, poor, moderate, good or high. Monitoring began in 2007 and the first assessment is now due.

At present this indicator only applies out to 3nm but a similar assessment to be introduced under the Marine Strategy Directive should extend this across Scottish Territorial waters. The proportion of water bodies which achieve good or high status could serve as a useful indicator which already integrates across many dimensions of natural capital.

Clean safe seas environmental monitoring programme (CSEMP). This programme fulfils the UK's commitment to European directives including its mandatory monitoring requirements under the Oslo and Paris Convention (OSPAR) Joint Assessment Monitoring Programme (JAMP). Sampling stations are strategically located with a concentration in the Forth, Clyde and Moray Firths, Loch Linnhe and the far NW. Data has been collected, mainly relating to nutrient and pollutant concentrations, since 2001.

Classification of shellfish production areas. Under the Shellfish Waters Directive (79/923/EEC) SEPA monitors the quality of waters in which shellfish live, and also the quality of the shellfish themselves in terms of food safety (bacterial/viral contamination).

Waters are classified as suitable (sub-categories A, B, C) and unsuitable according to the number of *E.coli* bacteria/100g of shellfish flesh sampled in the area. An area may have different classifications at different times of year. Data is collected quarterly and reported annually.

A relatively simple indicator, based on the proportion of waters in category A, or in categories A and B (throughout the year), could be used. This provides a useful indicator of the extent to which the "waste assimilation" service is functioning.

There are two limitations associated with this indicator. The bacteria may survive or possibly multiply within the shellfish, and may not accurately reflect numbers in the wider environment. The numbers in the wider environment are heavily influenced by heavy rain and increased runoff from agricultural land.

8.4.4 *Radioactive substances (waste assimilation)*

Data is collected and reported annually on levels and concentrations of radioactive isotopes and doses to public. An indicator could be based on marine contamination incidents – for example % of sediment and seafood samples outside accepted limits

8.4.5 *Carbon sequestration (climate regulation)*

Carbon sequestration is a significant process in both coastal and offshore waters. However, it is unlikely to see any significant change which might be attributable to human activity, and there are no readily available trend data.

No indicators are readily available relating to resilience, disturbance prevention etc.

Provisioning services

8.4.6 Status of commercial fish stocks

Our fish stocks are one of the most obvious categories of natural capital, delivering a stream of valuable services in terms of fisheries production. Fortunately fish and shellfish populations in Scotland are amongst the most intensively managed and monitored in the world. FRS makes a major contribution to the international ICES stock assessment process.

Stocks – many of which cross national boundaries - are assigned to smaller or larger areas dependent upon their migratory characteristics. Thus mackerel is assessed as a single Northeast Atlantic stock, while herring, haddock, cod and whiting are assessed separately for the West of Scotland and for the North Sea. Saithe and monkfish are assessed for an area from the West of Scotland, across the shelf areas to the North of Scotland and into the North Sea.

Key parameters which are estimated on an annual basis include:

- Fishing mortality rate (F);
- Spawning stock biomass (SSB);
- Recruitment

For the first two of these, ICES has determined two reference points – a precautionary reference point (pa) beyond which management action should be taken; and a limit reference point (lim). For SSB, the latter is the point beyond which there is a serious risk that the reproductive capacity of the stock may be impaired; for F it is the level of fishing mortality likely to drive SSB below SSBlim.

Prior to 2004 the expression “outside safe biological limits” was commonly used and taken up widely by various interest groups. Unfortunately there was some confusion and ambiguity over its meaning, and ICES has since adopted a more exact terminology framework.

Table 9. Stock assessment terminology

Term	**Definition**
Pre 2004	
Outside safe biological limits:	Spawning stock biomass (SSB) below precautionary reference point
Harvested outside safe biological limits:	SSB above precautionary reference point, but fishing mortality higher than precautionary reference point
Post-2004	
Full reproductive capacity	SSB above precautionary level
At risk of reduced reproductive capacity	SSB between precautionary and limit reference points
Suffering reduced reproductive capacity/stock dynamics unknown	below SSB limit reference point
Harvested sustainably	Fishing mortality less than precautionary reference level

At risk of being harvested unsustainably	Fishing mortality between precautionary and limit reference points
Harvested unsustainably	Fishing mortality above the limit reference point

The stocks for which assessments are made which are relevant to the Scottish territorial waters include:

- Northeast Atlantic mackerel stocks
- North Sea herring stocks
- West of Scotland herring stocks
- North sea haddock stocks
- West of Scotland haddock stocks
- Rockall haddock stocks
- North sea cod stocks
- West of Scotland cod stocks
- North sea whiting stocks
- West of Scotland whiting stocks
- Saithe stocks (northern shelf)
- Monkfish stocks (northern shelf)

Standard data on fishing mortality and spawning stock biomass is not available for:
Deepwater fisheries west of Scotland; Scottish *Nephrops* stocks

On this basis the best "state of the capital stock" indicator would be *the proportion of Scottish fisheries at full reproductive capacity.*

Nephrops is a key fishery for Scotland generating the bulk of added value. Time series data are available on abundance on the main fishing grounds of the North Sea and to the West of Scotland. *An index based on abundance relative to 2000 could be used for this species.*

8.4.7 Marine trophic index and length based indices

There has been much interest over the last two decades in an index which reflects the trophic structure of the marine ecosystem in terms of the relative abundance of different components in the food chain. The rationale for this is that modern fishing is tending to "fish down the food chain" resulting in an unbalanced ecosystem with many smaller fish and other organisms lower down the food chain. A marine trophic index (MTI) has been proposed to reflect this trend. A major review of opportunities for developing such an index, or alternative indices which reflect "ecosystem integrity" has recently been undertaken by Cotter *et al* (2009). The authors conclude that the MTI is not recommended for use by UK due to its cost, difficulties of interpretation, and the availability of more suitable indicators of on marine ecosystem integrity.

The authors see more merit in *length based indices (LBI),* which have already been developed as ecological quality objectives by ICES/OSPAR. These have the important advantages of being relatively well understood, and of being widely applicable without new expense because lengths are already routinely measured for most species of fish caught commercially or on surveys. It is likely that one or other of these will become available/widely used over the next few years. They also reviewed recently developed *"threat" and occupancy indices* which address the issue of loss of less common species and therefore might also serve to reflect the needs for a biodiversity index.

Cultural and supporting services

Biodiversity has both cultural value and is also related to the quality of supporting services. The following indicators might be assigned to either category depending on the balance in the index.

8.4.8 Marine mammals

Cetaceans. Trends in abundance remain unknown for most cetacean species in Scottish waters. 2 surveys were carried out in 1994 and 2005 on harbour porpoise and minke whale, and data is periodically available relating to the Moray firth dolphin population. These data are not adequate to serve as an indicator of marine natural capital.

Seals. More information is available in respect of harbour and especially grey seal populations for which annual data is available. Grey seal populations have increased dramatically from around 15,000 in 1984 to around 40,000 at the present time. The increase seems to have levelled off in the last few years. Harbour seal populations have declined rapidly in Orkney and the east Coast, especially the Firth of Tay. A decline is not evident in the West Coast.

The main causes of the local reduction in common seal populations in the Northern Isles and the Firth of Tay are unclear, but "predation by killer whales in the Northern Isles and competition for food supplies with grey seals could be significant factors" (SCOS 2008). It is arguable that both sets of data may be appropriate, especially if a major factor in relative numbers is competition. In any case, total seal numbers might be a better indicator of overall natural capital. Unfortunately data on harbour seal populations is relatively infrequent (N Isles and east Coast; 4-6 years).

Persistent organic pollutants in Scottish harbour seals. As top predators, seals may serve as useful indicators of persistent pollutants in the marine environment. However, data/analysis is infrequent (1989, 2003)

8.4.9 Seabirds (Scottish Biodiversity Indicator)

Most seabirds are relatively high up the food chain and may serve as indicators of the wider state of the marine ecosystem. The seabird monitoring programme, coordinated by JNCC, collects data on the breeding numbers of 19 species and productivity of 18 seabird species (of 24 that breed in Scotland) from a representative sample of colonies around Scotland. Data has been collected on an annual basis since 1986, although only 13 species were originally monitored.

Changes in seabird abundance and productivity may reflect changes in weather, availability of food, predation, or more usually a combination of factors. For example, poor weather and lack of food may result in adults spending more time foraging while chicks get cold, hungry – and eaten. Seabird numbers show a slow response to pressures because most delay breeding until they are 3-9 years old.

Overall there has been a decline in recent years, mainly due to big decline in common species such as arctic tern, arctic skua, black legged kittiwake – all of which show a strong dependence on sand eels off Orkney, Shetland and east coast of Scotland. The reduction in sand eel abundance in the North Sea is thought to be the result of changes lower down the food chain caused by warming of the sea. Commercial sandeel fishing may in the past have had a detrimental impact on kittiwake survival and productivity, but little sand eel fishing is now conducted off Scotland. Snake pipefish is now increasing, and is now prey for many seabirds but may be less suitable as a food. In certain populations predation by non-native invasive mammals (e.g. brown rat, American mink) has caused reductions in productivity and abundance at some colonies and complete abandonment of others (e.g. Craik 1997).

Despite the overall decline in abundance, seven species (including Northern gannet) have shown an increase in numbers.

Data is updated annually and available 1 year after collection. Care is required in using the trend data given the increase in species sampled in recent years. The indicator is normally presented as % of 1986 level.

A report commissioned by SNH recommended use of the indicators as in Box 4. The cautions regarding interpretation are of particular relevance to this assessment. More detailed general review of the use of seabird indicators can be found in Einoder (2009).

Box 4. Recommendations for the use of seabird abundance and productivity data.

1. Aggregated trend (index of abundance) for 13 species of seabird – the average trend of the constituent species …..should be used as an indicator of seabird populations in their own right but it should be noted that the constituent species showed considerable variation in how their respective populations varied in size over time. *It should not be used to infer anything about the marine environment, given the diversity of species contained in the group and the complexity of factors responsible for population change.*

2. Aggregated trend for sandeel–specialist species of seabird – the average trend of five species that rely on sandeels as their main prey during the breeding season - was found to be the most ecologically appropriate of several multi-species groupings that were investigated. This indicator should be used primarily as a way of communicating the conservation issues surrounding sandeel availability (given that direct measurement of sandeel availability is currently not technically possible). *However, given some of the constituent species' trends were driven by other marine and terrestrial influences, we suggest that this indicator be based instead on the trend of a single sandeel specialist - the black-legged kittiwake – in order to convey a less ambiguous message.* (Parsons *et al* 2006).

8.4.10 Nature conservation

Data on site condition of all marine Natura 20000 sites, based on the status of qualifying features, is collected in support of a 6 yearly reporting cycle to the EC. 6 yearly assessments are also made of the conservation status of all habitats and species listed in the annexes of the EC Habitats Directive, though this is based on limited information. All of this data and other similar data is uploaded onto the marine Recorder database and disseminated through the National Biodiversity network gateway, and through the MESH (Mapping European Seabed habitats) project.

These data are difficult to interpret insofar as marine habitats are naturally dynamic and subject to change There will therefore always be a significant number of sites apparently in poor condition as a result of purely natural phenomena – and in particular changes in temperature, water column structure, or marine currents and circulation.

Scotland is home to many UK priority species and habitats and others on the Scottish list. These include, for example maerl, rocky reefs (sponges, soft corals and seafans), file shell beds, burrowing anemones and tall sea-pens, tubeworm reefs, coldwater coral reefs. There is no comprehensive monitoring data available on the status of these habitats.

8.4.11 Number of non-native species

It is estimated that there are 24 non-native marine and brackish water species in Scotland (79 in the UK). However, there is no established monitoring/port survey programme in place.

8.4.12 Recreation

Classification of bathing waters. There are 61 recognised EU bathing waters around Scotland's Coast (2006). Data is collected on faecal coliform concentration annually and reported the following year.

An indicator based on the average annual faecal coliform concentration for all samples from the 60 continuously designated EU bathing waters could be used. There has been a strong downward trend, but interrupted by poor results in 2007 related to heavy rain and increased runoff.

This provides an indicator of both the extent to which the "waste assimilation" service is functioning, and also the quality of the "recreational" service. Approaches to shellfish sampling and shellfish waters monitoring may change under the new EU Directive.

8.5 Overall assessment

Table 10 offers an overview of the strengths and weaknesses of the various candidate indicators in terms of the assessment criteria.

Performance of the indicator in relation to each of these criteria is ranked as:

Poor
Fair
Good
Excellent

Availability of annual data and interpretation are considered to be priority criteria and are given more weight in the overall assessment.

Table 10. Assessment of indicators of the quality of the Scottish Marine Area.

Criteria in italics considered to be critical indicators

assessment criteria	data availability and quality	*data collection frequency, reporting and compilation delay*	measurable and relevant across habitat	allocation to Scottish waters	related to stock generating important ecosystem service/s	*interpretation*	meaningful when aggregated	credibility and importance for policy makers and public	conformity with European/international initiatives	overall rating
Supporting services										
CPR	high quality	*annual*	good	excellent	fair	*fair*	fair	poor	fair	poor-fair
Stonehaven marine ecosystem	high quality	*annual*	fair	fair	fair	*fair*	fair	poor	poor	poor
HAB	high quality	*annual*	good	excellent	good	*fair*	fair	good	excellent	fair
Regulating services										
WFD classification of coastal and transitional waters	high quality readily available data; SEPA	*Fair. rolling assessment with annual publication (?)*	good (excellent once MSFD provisions in place)	excellent	good	*excellent*	good	good	excellent	fair
Classification of shellfish production areas	high quality readily available data; SEPA	*Excellent. quarterly; annually*	limited to shellfish waters	excellent	excellent	*fair*	good	excellent	excellent	good
CSEMP	high quality	*Fair. Some annual, some periodic*	good	excellent	good	*excellent*	good	excellent	good	fair
Provisioning services										
proportion of Scottish fisheries at full reproductive capacity	good FRS/ICES	*Good annual; 2year*	good	fair partial	excellent	*good*	good	excellent	excellent	good
Marine trophic index	under development	*Fair*	good	fair	fair	*fair*	fair	poor		na
Length based index	under development	*Good.*	good	good	good	*good*	good	fair		na
Cultural/supporting services/biodiversity										
Classification of bathing waters	high quality readily available data; SEPA	*Excellent. regular, summer; annual reporting*	limited to bathing beaches	excellent	excellent	*good*	good	excellent	excellent	very good

Threat index	under development		fair	good	fair	*excellent*	good	good		na
Plankton composition	excellent historic time series	*Fair. Annual collection and some reporting*	good	excellent	fair	*fair*	poor	fair	fair	fair
Grey and harbour seal populations	good	*Annual for grey; 4 years for harbour*	excellent	good	good	*fair*	poor	fair	fair	fair
Seabird abundance/productivity	excellent	*Annual*	good	good	good	*fair*	fair	excellent	good	good
Marine Site condition	excellent	*Rolling assessment(?); 6 yearly reporting cycle*	fair	excellent	good	*good*	good	good	good	fair
priority species and habitats status	fair	*Rolling assessment(?); 6 yearly reporting cycle*	good	excellent	good	*good*	good	good	good	fair

8.6 Indicator selection

8.6.1 Supporting services

Good indicators are not available. The best available is harmful algal blooms as recorded in relation to shellfish waters.

8.6.2 Regulating services

Indicators are better for regulating services. WFD good environmental status has the advantage of covering a range of subsidiary quality indicators, and the disadvantage of not being annually reported. Shellfish waters classification has the advantage of being closely related to an important ecosystem service and being annually monitored and reported – but being less encompassing. It is arguable that both of these should be included.

8.6.3 Provisioning services

The proportion of Scottish fish stocks at full reproductive capacity serves as an excellent indicator of natural capital in relation to fisheries. In future a length based index might be included.

8.6.4 Cultural services (including nature conservation)

Classification of bathing waters is a good indicator of recreational services. Otherwise, there are no outstanding indicators in this category, and interpretation – a critical criterion - is a particular problem in 4/7 of the indicators considered. Seabird abundance has the advantage of annual data, but interpretation is problematic, especially over shorter time horizons. Data availability on an annual basis is more problematic with site condition and priority species and habitats, but one of these should be chosen since interpretation is better.

8.7 Marine subsidiary indicator: derivation and preliminary trend data

Table 11. Selected indicators:

Service category	Indicators
Supporting	• Harmful algal blooms
Regulating	• GES • Shellfish waters
Provisioning	• Proportion of fish stocks at full reproductive capacity
Cultural	• Bathing waters • Site condition

Weighting: There is no obvious rationale for a differential weighting between ecosystem service groups, or between indicators within groups.

- equal within group; equal across groups

8.8 Overall assessment: representation of key dimensions of natural capital

This subsidiary index may be rated as fair. Its main weakness is the lack of annual data relating to Good Environmental Status and site condition.

9. FOREST AND WOODLAND

The vision, as set down in the Scottish Forestry Strategy, is that "Scotland will be renowned as a land of fine trees, woods and forests which strengthen the economy, which enrich the natural environment, and which people enjoy and value".

A compendium of statistics about woodland, forestry and primary wood processing is published annually by National Statistics. This compiles data from a range of sources including inventory surveys, recreational use surveys, business surveys, annual management returns from Forestry Commission estate, data from grant schemes etc. It also draws on data from other organisations. Other sources include SNHi and a range of reports to central government and international agencies, including a periodic forest resources assessment for FAO.

9.1 Area

The current forest estate comprises roughly 1,342,000 ha of broadleaf and coniferous woodland.

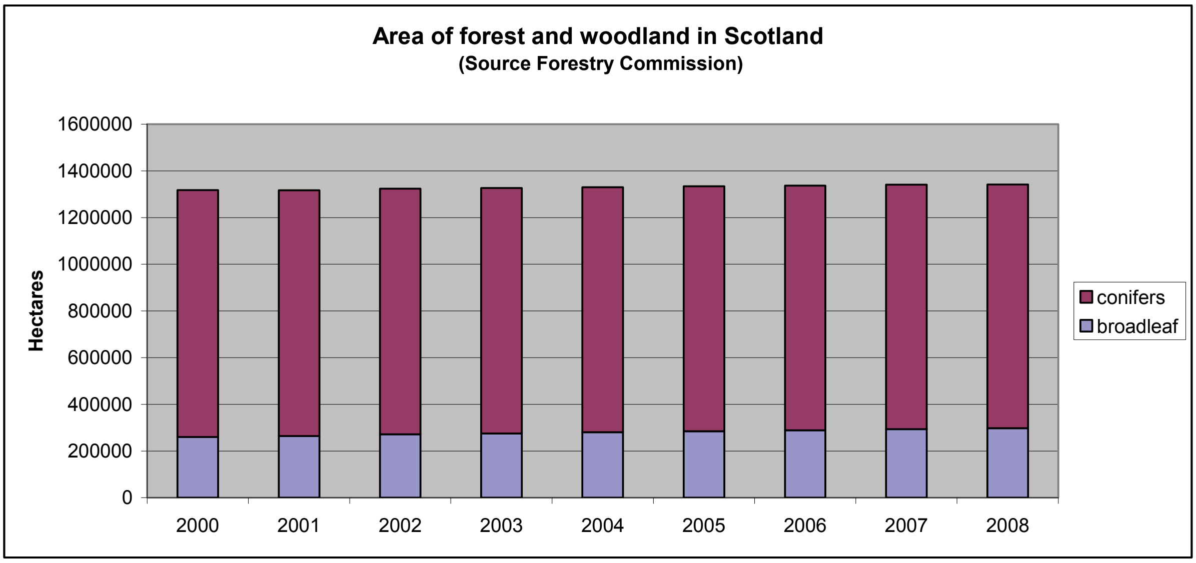

Figure 7. Area of forest and woodland in Scotland (Source Forestry Commission)

Scotland has a target of 25% of wooded land cover by 2050, which would require 10,000ha to be added each year. Over the last decade expansion has been at an average rate of around 7,500ha.

9.2 Economy

It has been estimated that the Scottish forest/woodland sector generates around £460m total GVA (2007/8 prices) equating to and 13,200FTEs (direct, indirect, induced) plus around 18,000 FTE associated with first round spending.

GVA of direct visitor spending attributable to woodland spending (woodland primary reason for the visit) has been estimated at £209m.

9.3 Value of ecosystem services

Overall, an annual value of £104 million has been placed on the non-market benefits from all forests in Scotland, with recreation and carbon sequestration contributing £66m per year

(Willis *et al* 2003), although, there is some uncertainty about the estimate of recreational value (CJC consulting 2004).

CJC Consulting (2004) concluded that gains from reduction in air pollution, and water related and archaeological impacts were relatively small.

The most important ecosystem services delivered by forest and woodland, and which might be readily measured, include:

Supporting services
- Soil formation

Regulating services
- Water quality
- Water quantity (might also be classed as provisioning)
- Air quality
- Carbon sequestration

Provisioning services
- Timber
- Shelter

Cultural and habitat services
- Nature conservation/biodiversity
- Landscape
- Recreation

Figure 8 shows the area of UK forest/woodland assigned to different major "service" categories (data source FAO 2010). This illustrates the steady shift from production to multi-use.

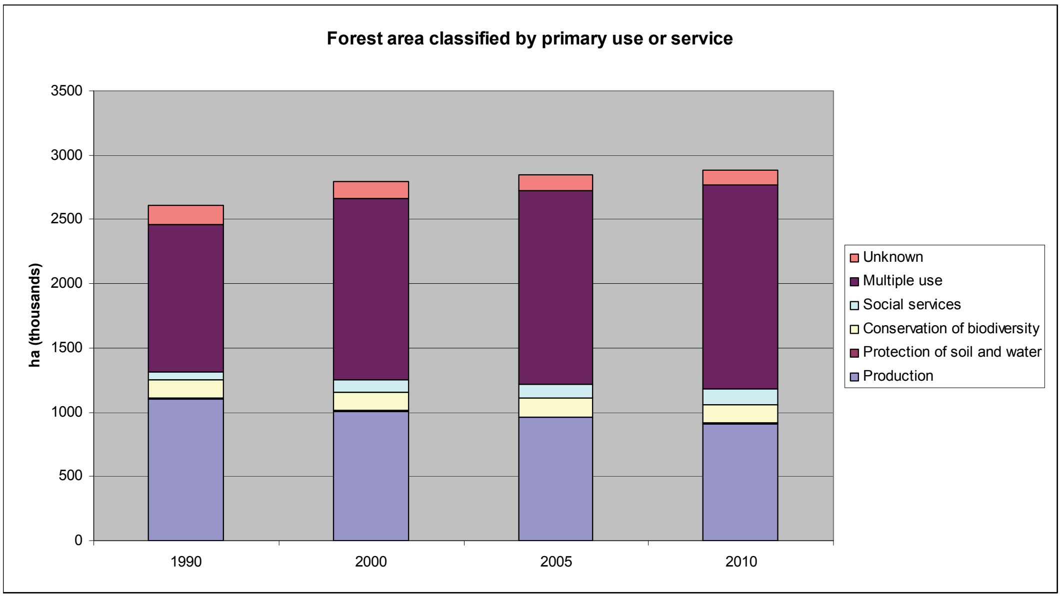

Figure 8. Area of UK forest classified by use or function

The multi-use nature of woodlands makes allocation of value to specific services difficult.

9.4 Candidate quality indicators

Supporting services

9.4.1 Soil formation

A possible indicator of soil creation/soil quality is the estimate of soil carbon generated in support of the periodic Global Forest Resources Assessment (FAO 2010). This generates data on a five year cycle, and includes a five year forecast. At present this published data is aggregated to UK level, but data for Scotland could be generated. Although estimates are 5 yearly, the existence of a fairly reliable five year future projection (based on known trends) would allow for interpolation and generation of reasonable annual estimates.

Regulating services

9.4.2 Carbon stock

Carbon sequestration is a significant service provided by Scottish Woodlands. The equivalent of 10 million tonnes of CO_2 is accumulated annually as carbon in growing trees, deadwood and organic matter, and by incorporation into forest soils. Annual removals of CO2 from the atmosphere by Scotland's existing forests equate to around 15% of Scotland's annual greenhouse gas emissions.

The net annual change in carbon (CO_2 equivalent) in UK woodlands has been estimated as in figure 9.

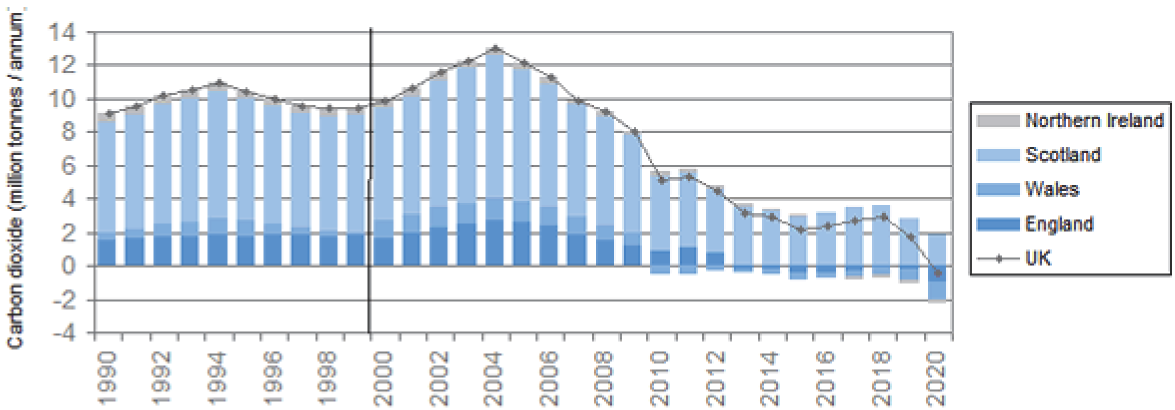

Figure 9. Net annual change in carbon (CO_2 equivalent) in UK woodlands

These figures are derived from a one-off/periodic assessment (CEH 2009).[14]

The UK makes a five yearly assessment of the forest carbon stock, including a prediction for 5 years in advance (FAO 2010). This is based on periodic calculations based on forest models. Annual data could be realistically generated based on interpolation. Given that this is area related, it will be necessary to divide the estimated carbon stock by woodland/forest area to generate a measure of quality (carbon stock/unit area) to avoid double counting.

Trees accumulate carbon as they grow, but beyond a certain age, sequestration rates are reduced and something closer to an equilibrium is established (Broadmeadow and Mathews 2003). An alternative and relatively simple indicator would therefore be to use data on the

[14] http://www.forestry.gov.uk/website/forstats2009.nsf/0/C53E30E3F153D1EF8025735D003383B9

proportion of forest/woodland above a certain age (say 60 years), which can be derived from the forest estate models.

9.4.3 Water quality and quantity

There are no existing indicators available relating to the quality of woodland or forestry in terms of regulating water flow or quality. The area (or length) of riparian woodland might serve as a partial indicator. Biodiversity indicators (see below) might also be considered as underpinning these and other regulating services. However, it is notable that in a valuation study by Willis *et al* (2003) water services were considered to contribute a very small proportion of total value.

9.4.4 Air quality

Although woodland and forest do play a role in enhancing air quality (by "settling" particles, by removing CO_2/enhancing oxygen), this is only significant in urban areas and no suitable indicators are available.

Provisioning Services

9.4.5 Softwood availability forecast (40 year total)

By far the most important material product from our forests is timber (though low prices mean the current value of this is low). The value of the forest resource in terms of its capacity to generate a steady stream of income from timber or fuel wood production would ideally be measured as the net present value associated with this future income stream. Such a figure is not readily available. A possible indicator might be the softwood availability forecasts which are typically prepared every 5 years or so, and project softwood availability over 20/40 years, allowing for an annual figure to be derived (Halsall *et al* 2005).

9.4.6 Shelter

There is no suitable indicator available to measure the shelter value of Scottish forests, though this is likely to be substantial for both domesticated stock and wild animals.

Cultural and habitat services

9.4.7 Amenity value of Scottish woodlands

In the last ten years the ability of woodlands to deliver social benefits has been increasingly recognised. In 2007, 569 schools were involved in woodland-based learning activities and an estimated 63% of Scottish children, and around half of adults, made around 50 million visits to Scottish woodlands. An estimated 138 community woodland groups are active in Scotland with a total membership of around 13,500.

Recreational quality might be measured in terms of *recreational use,* which is measured through the Scottish Recreation Survey. Figure 10 illustrates visits to Scottish Woodlands as measured through various surveys. Since 2004 sampling has been relatively consistent through the Scottish Recreation Survey. Most visits are for less than 2 hours and take place within 5 miles of home. The main activity is walking – mainly regular walking with a dog (50%), though cycling has increased in recent years. Visitor numbers could be used as an indicator of recreational quality, but survey data is clearly inconsistent between years, and interpretation is problematic given that the number of visits is likely to be as much influenced by social and economic trends as by resource quality.

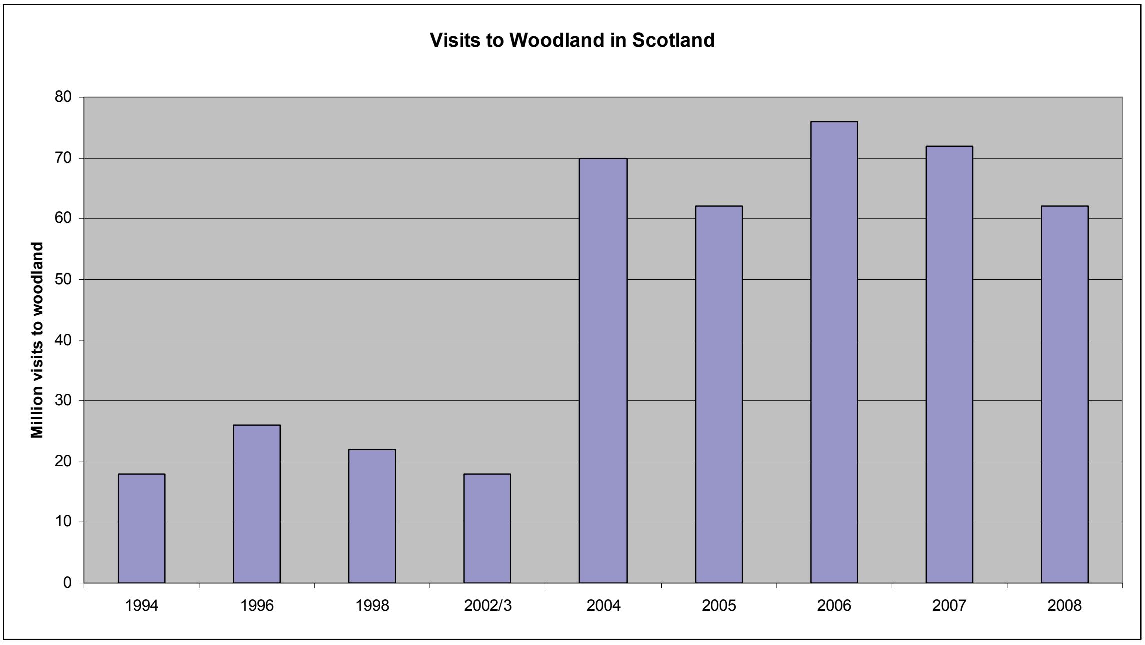

Figure 10. Visits to woodland in Scotland.

Accessibility is probably a better measure of amenity value. Increasing the amount of accessible woodlands in urban areas has been a focus of the Woods In and Around Towns Initiative. In 2006, 25% of Scotland's people had accessible woodland greater than 2ha within 500m of home, and 68% had accessible woodland greater than 20ha within 4km of home. It is unclear whether or not these figures will be updated on an annual basis.

The "Woods for People" project has created a UK wide provisional inventory of accessible woodland which rose from 57% in 2004 to 58% in 2008 in Scotland. Although this might be used as an indicator, it is unclear whether the database will be maintained in the longer term and whether it is sensitive enough to reveal significant changes in quality.

Proportion of ancient and semi-natural woodland is a potential measure of both amenity and biodiversity value. The Forestry Commission provides some data on the area of ancient semi-natural woodland (ASNW), plantation on ancient woodland sites (PAWS), and other semi-natural woodland (OSNW), but figures are derived from survey in the 1990s. Furthermore, as the area of forest increases, the proportion of ASNW will decline unless the increase in semi-natural woodland (through e.g. natural regeneration) can also be accounted.

Native woodland. Taking into account all species including broadleaves, there is an estimated 398,000ha of native woodland in Scotland, comprising approximately 10% of Scottish woodland. Around 4,000ha of additional native woodland are created annually. Assuming that annual data on new planting/natural regeneration can be readily accessed from grant award information, the proportion of new and restocked planting which is native could serve as a useful indicator of both amenity and biodiversity. A possible problem relates to the trade-off with softwood availability.

Proportion of broadleaves. A less satisfactory indicator, though one for which routine annual data is available is the proportion of broadleaves. Broadleaved varieties have increased steadily from 264,000ha in 2001 to 300,000ha in 2009.

Landscape. Although this is an important cultural value, also closely related to other recreational values, there are no readily available indicators of the landscape quality of the forest resource.

9.4.8 Habitat/ Biodiversity value

There are many possible indicators related to biodiversity value.

Woodland diversity. This indicator is based on woodland structure (shrub layer cover; mean number of tree and shrub species per 0.25ha; mean volume of deadwood; percentage of total woodland in old growth stage), and is closely associated with a wide range of biodiversity values. The baseline was derived under the NIWT survey of the 1990s, but it is anticipated that trend data will be supplied by the NIWT rolling programme, allowing regular updates of the indicators values from 2010 onwards.

Index of woodland butterflies. Annual data is available on the abundance of terrestrial butterflies in Scotland, with data collected on both specialists and generalists. Data is not published specifically on Scottish Woodland Butterflies, though it should be readily available. Butterfly abundance varies tremendously on cyclic (roughly 7 year) basis and is also heavily influenced by weather. As such interpretation over the short-medium term is difficult, and may bear little relation to natural capital.

Plant species richness. Data on plant species richness in both broadleaved and conifer plantation in Scotland is collected periodically (ca 7 years) by the National Countryside Monitoring Survey. Although trends should be more consistent than those for butterflies, trends since 1998 are nonetheless inconsistent and difficult to interpret.

Condition status of protected areas where woodland is a designated feature could be used as an indicator. This is a direct reflection of quality, but some work would be required to compile the data, which is collected through a rolling process over 6 years.

9.4.9 Index of woodland breeding birds

Birds are widely regarded as useful indicators since they are readily observed, long term historic data is available, they are relatively high in the food chain, and have diverse habitat requirements. They are likely to reflect changes throughout the ecosystem.

SNH’s biodiversity indicator, abundance of terrestrial breeding birds, includes a trend indicator for woodland birds based upon 23 woodland species. The indicator shows a strong upward trend in recent years. The indicator is published annually with the latest data available for 2008 (as of march 2010).

9.4.10 Proportion of woodland under positive management

Forest certification assesses forest management practices against an agreed standard, and awards a label to those forest products that meet the standard. Both forest management practices and the Chain of Custody must be assessed in order for products to achieve certification. 746,000 hectares of woodland in Scotland (447,000 FC/FS; 300,000 other) were certified under the Forest Stewardship Council (FSC) in March 2009, representing 56% of the total Scottish woodland area. Annual data is readily available.

Protected areas. There is no regularly updated published assessment of the *area* of woodland under different statutory and non-statutory designations. The last assessment was by Pryor and Peterken in 2001. Data could undoubtedly be extracted from a variety of sources (SNH designation data, SNH site management data, woodland grant scheme data etc), but significant work would be required. However, this is not a specific measure of quality – rather a measure of policy.

9.5 Indicator assessment

Table 12. Assessment of indicators of the quality of Scottish Forest and Woodland.

Criteria in italics considered to be critical indicators

assessment criteria	**data availability and quality**	***data collection frequency, reporting and compilation delay***	**measurable and relevant across habitat**	**related to stock generating important ecosystem service/s**	***interpretation***	**meaningful when aggregated**	**credibility and importance for policy makers and public**	**conformity with European/international initiatives**	**overall rating**
Supporting services									
soil carbon/area	readily available; good quality; FCS/FAO	5 year estimates including projection. Interpolation (annual) possible	excellent	excellent	good	excellent	good	good	fair
Regulating services									
carbon stock/area	readily available; good quality; FCS/FAO	5 year estimates including projection. Interpolation (annual) possible	excellent	excellent	fair	excellent	excellent	excellent	fair
% woodland > 50 years	availability fair; quality high	annual possible, based partly on forest models	excellent	good	good	good – but trade-off	fair	poor	fair
provisioning services									
softwood 40 yr availability forecast (per ha?)	readily available; quality good	periodic (typically 5 year) forecast but potential annual projections	good	excellent	excellent	good – but trade-off	excellent	fair	good
Cultural/habitat services									
visits to woodland in scotland	readily available; quality good	annual at present	good	excellent	fair	good	excellent	fair	good
% accessible woodland	readily available; quality good	project based; future uncertain; poor/fair	fair	excellent	excellent	excellent	excellent	fair	fair
proportion of ASNW	readily available; quality good	based on survey from '90s	fair	good	good	good –but trade-off	good	good	poor
proportion of native woodland	partial estimates available	90s survey estimate adjusted with annual data	good	good	good	good, but trade-off	good	?	fair
proportion of broadleaved woodland	readily available	annual reporting, 1 yr delay	good	good	fair	good-but trade-off	good	?	good
woodland diversity	readily available	one-off 90s baseline; may become available more regular basis	excellent	excellent	good	excellent	good	good	good if becomes available

index of woodland butterflies	readily available	annual data	good (check Scottish coverage)	good	fair: long term only	fair	excellent	good	fair
index of woodland breeding birds	readily available	annual data	good (check Scottish coverage)	good	fair: multiple dependencies some unrelated to forest quality	fair	excellent	good	good?
plant species richness	readily available; quality?	6 yr NCMS	excellent	good	fair: erratic trend	good	excellent	excellent	fair
condition status of protected area	readily accessed	6 yearly rolling reporting	fair	good	good	good	excellent	excellent	fair
proportion of protected area	could be accessed	could be annual	fair	fair	fair	fair	good	good	fair
proportion of FCS certified woodland	published	annual	excellent	good	excellent	excellent	good	good	good
proportion of woodland under positive management	proportion of protected area + proportion of FCS								fair

9.6 Preliminary indicator selection

9.6.1 Supporting services

Soil carbon is a useful index of soil formation and data is readily available.

9.6.2 Regulating services

Carbon stock/unit area is a useful indicator likely to conform with ecosystem/environmental reporting, and for which annual estimates could be derived relatively easily.

9.6.3 Provisioning services

Periodic projections of softwood availability should allow for an annual assessment of future (40 yr) yield, serving as a good indicator of provisioning services. A similar estimate for broadleaves is not available – related to the multi-function nature of such woodland.

9.6.4 Cultural/habitat/supporting services

Although visits to woodland are rather weak in terms of interpretation, it is probably the best available reflection of recreational quality. Measures of access would serve our needs better, but the data is as yet unreliable. Proportion of broadleaved woodland is a reliable and readily available indicator with biodiversity and amenity dimensions. The bird, butterfly and species richness indices are superficially attractive, but interpretation is a significant problem, especially for butterflies, and there may be a problem of compounding with area. Proportion of certified forest encompasses a range of values and is also readily available. Other indicators such as woodland diversity are attractive but data as yet unreliable.

9.7 Woodland subsidiary indicator: derivation and preliminary trend data

Table 13: Selected indicators.

Service category	Indicators
Supporting	• Soil carbon/unit area
Regulating	• Carbon stock/unit area
Provisioning	• Softwood 40 year yield projection
Cultural	• Visits to woodland
	• Proportion of broadleaved woodland
	• Woodland birds
	• Proportion of certified forest

Weighting:
It is arguable that carbon sequestration is a priority issue and carbon stock should be afforded a higher weighting than the other service indicators. Other differential weightings are likely to be controversial.

- equal within group; double weighting for regulating services (carbon stock)

9.8 Overall assessment: representation of key dimensions of natural capital

This subsidiary index may be rated as fair. Its main weaknesses are:

- The difficulty of interpretation of biodiversity indicators
- The lack of good indicators of landscape and recreational quality.

An important point for interpretation of the woodland sub-indicator may be the competing trends from broadleaved woodland proportion and softwood yield projections. These may cancel out, and on that basis perhaps should perhaps be excluded.

10. PEATLANDS-HEATHER AND ASSOCIATED MOSAICS

It is difficult to separate out peatland from heather moorland. SNH specifically note this difficulty in their description of the land cover Scotland process[15] - 16% of the land area of Scotland is comprised of a peatland-heather moorland mosaic. The LCS-88 database shows that peatland, heather and associated mosaics comprise 40% of the land area of Scotland.

It is also difficult to separate heather and peatland from rough grassland, and from montane habitats. Grassland-heather/peatland mosaics comprise a further 5,000 square kilometres (7%). In the Countryside Survey (2007) for general reporting purposes, dwarf shrub heath and bog are lumped together with bracken, fen-marsh-swamp, inland rock and montane as "mountain, moor and heath" which could serve as suitable overall category. The possible strengths and weaknesses of a single "uplands" category of this kind are considered further in the discussion.

10.1 Area

The CS-LCM data base provides the following area trend data:

Table 14. Area trends for major upland habitats

Broad habitats	1990	1998	2007
bog	19,220	20,390	20,440
dwarf shrub heath	10,070	9,120	8,940
total bog-heath	29,290	29,510	29,380

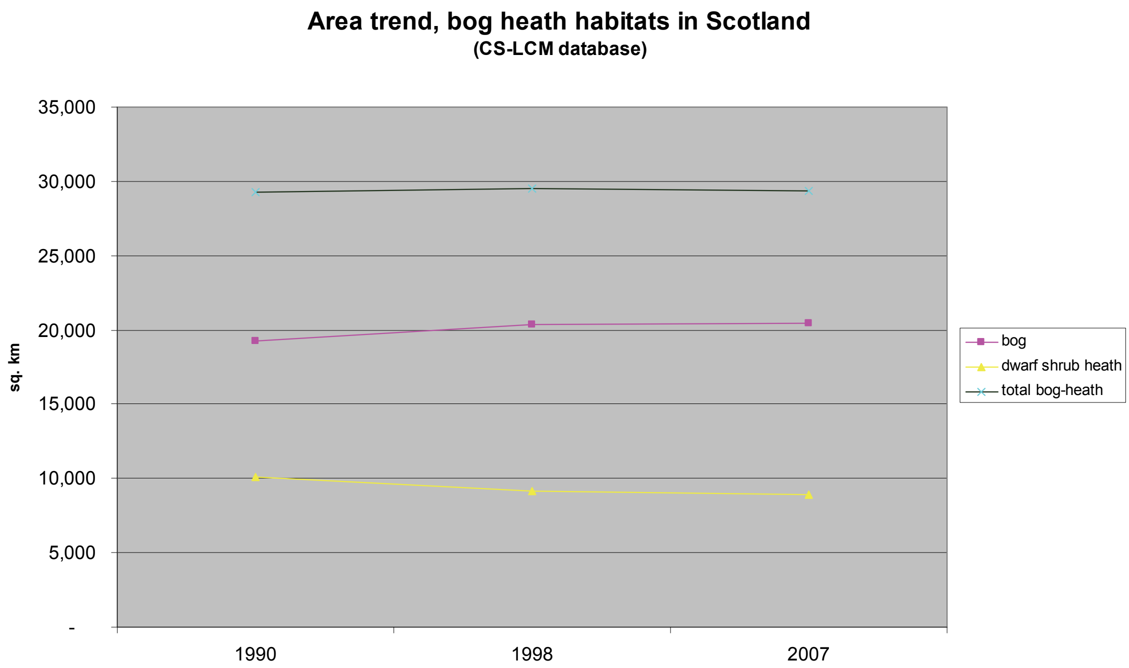

Figure 11. Area trend for bog and dwarf shrub heath in Scotland.

"Bog" probably comprises around 50% blanket bog or basin peat – a major carbon store.

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[15] http://www.snh.org.uk/publications/on-line/education/advances4/7-land-cover-map-scotland.asp

The decline in dwarf shrub heath is associated with associated with transformation into a range of other habitats including in particular bracken and acid grassland. The divergence in the two trends suggests that these may be better as separate categories.

10.2 Economy

Traditionally these habitats have had value primarily as grazing for deer and sheep, and for recreation. In the past peat was highly valued as a source of fuel and also as a horticultural product; it is now increasingly valued as a major sequester and store of carbon, and significant peat extraction is discouraged. This particular value may reduce other "use" values, since any significant change in land use may release significant amounts of carbon dioxide.

10.3 Ecosystem services and value

The main services provided by dwarf shrub heath and peatland (bog) are as follows:

Supporting services
- Soil formation

Regulating services
- Water purification
- Water regulation
- Waste assimilation
- Climate regulation

Provisioning services
- Sheep grazing
- Deer grazing

Cultural and habitat services
- Recreation, landscape
- Biodiversity, nature conservation

10.4 Candidate quality indicators

Supporting services

There are no readily available indicators of basic function such as nutrient cycling.

10.4.1 Soil creation – soil carbon

The Countryside Survey collects periodic information on soil carbon concentration and mean carbon content (0-15cms) of broad habitat soils in Scotland, and this might be used as an indicator of soil creation and quality.

Regulating services

Water purification and regulation. There are no readily available suitable indicators.

Waste assimilation. Heather and peatbog absorb nutrients from the atmosphere and from water. There are no readily available suitable indicators.

Climate regulation. Both heather moor and peat bog are effective at sequestering carbon, and peat bog is particular effective in terms of storage. However, peat bogs may also release methane and in some cases may contribute to global warming. The balance between CO_2 capture and methane release is likely to become less favourable under climate change (Bousquet *et al* 2000).

There are three possible approaches to considering the capital value in terms of delivery of climate regulation:

- Sequestration rate
- CO2-methane balance
- Total carbon stock.

Unfortunately, there are no readily available indicators collected on a routine basis for sequestration rate or CO_2/methane balance. There are some possibilities related to carbon stock.

10.4.2 Proportion or area of bog/peatland

The proportion of bog/heath within the combined habitat class could be used as an indicator of quality with regard to carbon storage. In so far as bog is bog, and short of removing or converting it, it is likely to continue to function as a carbon store, it is arguable that area alone is all that is required as an indicator of this important ecosystem service. This could be measured in terms of the proportion of the amalgamated class (heath-bog) which is bog; or if the two habitats were kept separate, simply in terms of area. If the latter, then carbon storage/sequestration would be incorporated as a dummy indicator with a value of 1.

10.4.3 Indicator based on carbon increment

The total amount of carbon stored in Scotland's soils is obviously related to both carbon content and depth, and has been estimated in a recent study (Smith *et al* 2009). This would be useful as an equivalent of the stock indicator chosen for woodland. However, there is currently no regular audit/data and this would be prohibitively expensive. However, since sequestration rate is likely to be relatively constant, it would be possible to represent the annual incremental increase in stock value as:

((sequestration rate/unit area)+(carbon store/unit area))/carbon store/unit area

If this were to be used, it is arguable that it should be used for all habitats, drawing on the analysis in the Ecosse study (Smith *et al* 2009).

10.4.4 Mean carbon content (t/ha) (0-15cm)

Countryside survey now makes an estimate mean carbon content (t/ha) in the top 15cm of soil. In 2007 this was 81.9t/ha for dwarf shrub heath and 75.9t/ha for bog. In the absence of depth data – and also the change in carbon density with depth – it is unclear that this serves as a useful measure of the quality of the stock, and interpretation is in any case difficult. It is certainly not a particularly good reflection of sequestration rate.

Provisioning services

The main provisioning services are deer (for sport and for venison) and sheep production. These services are provided by a mosaic of habitats including dwarf shrub heath, bog, montane, grassland, and for deer at least, woodland. This is perhaps an argument for a single "upland" category.

The quality of these habitats in terms of sustainable yield of these products is surprisingly difficult to determine. There are no management reference points as there are for marine fisheries. There is no well informed consensus on what the carrying capacity of dwarf shrub-bog mosaics is for deer, and the figures are rough and locally variable for sheep.

10.4.5 Deer, sheep numbers

Annual estimates of upland deer and sheep numbers are available from the Deer Commission and Agricultural census data. However, interpretation is problematic. Higher numbers suggest higher yield and "improved service". However, this may be at the cost of the long terms quality of the range – in other words it is a poor indicator of long term productivity or productive potential.

10.4.6 Deer, sheep numbers as a proportion of carrying capacity

This indicator would address the weaknesses associated with 10.4.5. Unfortunately there are no reliable indicators of carrying capacity. Carrying capacity is likely to change with climate but might also be related to the proportion of heather moorland (or grassland if this were to be included in the broad habitat.), the degree of muirburn etc. This is a controversial and complex issue (Nicholson 2008) and we are some way away from a useful measure of carrying capacity.

It might nonetheless be possible to generate a rough consensus on the carrying capacity (per unit area) of the Scottish uplands through an expert workshop or panel process. Quality would then be some function (probably inverse logarithmic) of proportion of carrying capacity used.

Cultural, supporting, habitat services

Biodiversity. Scotland hosts by far the greatest extent of heather moorland in Europe (Thomson *et al* 1995). 75% of the global total is found in the UK, mainly in Scotland. Moorland is an important breeding or feeding habitat for 57 bird species, of which 12 are of European importance. Moorlands in the UK support exceptionally high densities of, for example, red grouse *Lagopus lagopus scoticus*, a distinctive endemic race of the willow grouse, golden plover and hen harrier *Circus cyaneus.*

Scotland also holds 10% of the world's blanket bog, and the flow country is the largest expanse of blanket bog in Europe.

10.4.7 Mean species richness score

Species richness is measured in sample 200m^2 plots across the habitat as part of the Countryside Survey. These show a decline for dwarf shrub heath and for bog. The advantage of this indicator is that it is specific to the habitat and is based on plant species richness – likely to be reflected in biodiversity at higher trophic levels (insects, birds etc). The disadvantage is the 6 year data cycle.

10.4.8 Other Countryside Survey indicators

Countryside survey also uses a set of other biodiversity indicators including number of bird food species; number of butterfly food species; grass: forb ratio; competitor score; stress tolerator score; ruderal score; light score; fertility score; Ellenberg pH score and moisture score. These are all important and may support and help interpret changes in species richness.

10.4.9 Abundance of terrestrial breeding birds (Upland)

This index, now published annually, is based on 16 species of bird based on a baseline (=1) in 1994. It has shown no significant change over that period. This indicator is relatively robust and changes in breeding bird abundance are likely to reflect wider changes in the environment. The disadvantage would be that they are also likely to reflect changes in climate – with warmer winters in particular probably leading to increases in abundance.

10.4.10 Site condition

Data on site condition (upland sites) could be used as a general indicator of biodiversity quality. Data would have to be extracted, and are collected on a six year rolling cycle.

10.4.11 Status of priority habitats: Upland Heathland and Blanket Bog

Data on status of priority habitats could also be used as a general indicator of biodiversity quality. Again, data would have to be extracted, and are collected on a six year rolling cycle.

Recreation and landscape
There are no readily available indicators of the quality of the uplands in terms of providing for recreation (other than biodiversity as above).

10.4.12 Area of peatland under conservation management

This data could be extracted, but is now unlikely to change significantly, and in any case is not a good "quality" indicator.

10.5 Indicator assessment

Table 15. Assessment of indicators of the quality of dwarf shrub heath and peatland (bog)

Those in italics considered to be critical indicators

assessment criteria	**data availability and quality**	***data collection frequency, reporting and compilation delay***	**measurable and relevant across habitat**	**related to stock generating important ecosystem service/s**	***interpretation***	**meaningful when aggregated**	**credibility and importance for policy makers and public**	**conformity with European/international initiatives**	**overall rating/comment**
Supporting services									
Soil carbon	good	*fair. 6 year cycle*	good	good	*good*	good	good	good	fair
Regulating services									
C sequestration rate/ha	good	periodic measurement; poor	good	excellent	fair. More closely related to climate etc than to any human influence	fair	good	fair	fair
proportion of bog/peatland	excellent	fair 6 yr cycle	good	fair	fair	fair	fair	poor	fair
Indicator of carbon stock/ha	good	calculated annual increment based on sequestration rate and current depth	excellent	excellent	fair	good	excellent	excellent	Fair. Main problem is lack of methane account.
mean carbon content: t/ha (0-15cm)	excellent	fair 6 yr cycle	excellent	excellent	poor – unlikely to change; does not reflect stock or rate	good	good	good	fair
provisioning services									
deer and sheep numbers	excellent	excellent	excellent	excellent	poor – does not reflect the quality of the underlying provision which underpins productivity -	fair	fair	fair	fair. Possibly poor – interpretation/aggregation are key criteria.
livestock units/carrying capacity	poor- fair	good	excellent	excellent	excellent	excellent	excellent	fair	?. Would require expert panel to agree rough carrying capacity
Cultural/habitat/supporting services									
mean species richness score	excellent	fair – 6 year cycle	excellent	good	good	good	good	good	good

Index of terrestrial breeding birds (upland)	excellent	excellent	excellent	good	good	good	excellent	excellent	good-excellent
Site condition	fair	fair 6 year cycle	fair	fair	fair	fair	good	excellent	fair
proportion under conservation management	excellent	fair 6 year cycle?	good	fair	fair	fair	fair	good	fair
Status of UKBAP priority habitats	good	five year cycle?	good	good	good	good	good	excellent	good

10.6 Preliminary indicator selection

10.6.1 Supporting services

The only possible indicator here is soil carbon, collected on a 6 year cycle.

10.6.2 Regulating services

Despite the importance of this habitat in terms of carbon sequestration and storage, good indicators collected on an annual basis are not readily available. The two main options are:

a) to assume that the value of peatland as a carbon store is relatively fixed (i.e. fixed sequestration rate) and can therefore be represented as a dummy indicator with a fixed value of 1; or
b) calculate an indicator of stock based on current stocks plus an annual increment derived from standard sequestration rates;

These are fundamentally different ways of treating quality – as fixed – generating a continuous flow of services at a fixed rate; or as changing based on the accumulation carbon. However, neither of these take account of methane generation. To address this some form of annual net benefit calculation would be required.

10.6.3 Provisioning services

Again, indicators are poor for this, and will remain so unless a better understanding of carrying capacity is developed.

Again, it may be appropriate to use a dummy variable fixed at value 1 for this service, though it may be possible to use livestock units/carrying capacity in the future, possibly through an expert/user workshop process to agree on carrying capacity.

10.6.4 Cultural/habitat/supporting services

Two indicators stand out as superior: the index of upland breeding birds and status of UKBAP habitats. The first is annually available; the latter less regularly, but taken together they would be effective.

Table 16: Selected indicators

Service category	Indicators
Supporting	• Soil carbon
Regulating	• Carbon stock (estimated proportional increment)
Provisioning	• Dummy indicator (fixed value)
Cultural	• Upland breeding birds • Status of UKBAP habitats

10.7 Overall assessment: representation of key dimensions of natural capital

This subsidiary index is weak in terms of indicators representing supporting, regulating and provisioning services, but relatively strong in terms of biodiversity (which may also serve as indicators of supporting services).

11. DISCUSSION AND CONCLUSIONS

The difficulty of developing a NCAI should not be under-estimated. An NCAI should:

- Be important and credible to policy makers, key stakeholders and the wider public;
- Represent the most important ecosystem services;
- Generate meaningful trends which can stimulate a focused policy response.

Due to the unexpected complexity of the study, it has only been possible to address parts of the TOR, and we have been able to assess indicators for only 3 of the proposed 7 habitat categories, though we have collected much background information on the others. Nor have we been able to generate a "pilot" index.

This is partly because we spent a good deal of time reviewing ecosystem valuation studies with a view to informing a habitat weighting system, which in the end proved unsatisfactory. It also takes considerable time to identify possible indicators, understand their strengths and weaknesses, correlations, and – crucially - issues of interpretation. More than 50 indicators were evaluated for the three broad habitats covered. In many cases, though the indicator was superficially attractive, there were significant weaknesses with respect to interpretation that would undermine the meaning and impact of a compound index. The process of sourcing and importing data, normalising etc. is also time consuming. This should therefore be seen as a scoping study rather than as a piloting study.

Simpler approaches are possible, as in the Natural Capital Index developed by ten Brink (2007), but this is based on the assumption that natural capital can be measured in terms of a limited set of biodiversity indicators. Though this may appeal to biologists, it is unlikely to have significant credibility with wider interests; it would certainly not stand parallel to GDP; and adds little value to existing periodic reporting initiatives in the UK such as the Countryside Survey.

It may also be argued that only indicators available on an annual basis should be considered – which would greatly reduce the scope of the process – but coverage of important ecosystem services then becomes very limited. Where data is periodic the extent to which data might be meaningfully projected or interpolated needs careful consideration.

11.1 Broad habitat categories

The broad habitat categories which define the basic structure of the index are largely constrained by the availability of information on area. In practice this is available from the agricultural census for farmland, the Forestry Commission for woodland, and the Countryside Survey for other major habitats. UK (Scotland) territorial waters are taken as the most useful marine/coastal category for which a one-off estimate is available from the Scottish Government.

There is considerable flexibility in terms of separation or grouping of major terrestrial habitats as defined in the Countryside Survey-Land Cover Map. A key outstanding question is whether heather moorland (dwarf shrub heath) and peatland (bog) should be treated as separate habitats. Although most of Scotland is covered by a mosaic of the two, they are nonetheless ecologically and functionally distinct. A key advantage of grouping is conformity with "upland biomes" as identified in many discussions of ecosystem services at international level.

There are several less extensive habitats, such as montane, fen-marsh-swamp, saltmarsh, dune, as well as sub-categories of e.g. woodland which might also be included. In so far as some of these are far less extensive in area, their value may be considered to be much lower in terms of natural capital; however, their very rarity and distinctiveness also enhances their value in cultural and ecological terms. Inclusion of these habitats would however make the index very complex.

The inclusion or otherwise of agricultural land is also an issue. Had we pursued the idea of habitat weighting by ecosystem service valuation as suggested in the TOR, this would have presented significant difficulties, in so far as we would have been comparing well established valuations based on provisioning services from agricultural land, with more subtle and less easily quantified values associated with a range of ecosystem services on semi-natural land. Under the proposed revised structure however, under which different types of service are effectively weighted equally, the inclusion of agricultural and commercial forest broad habitats makes good sense, and indeed enhances the utility of the index.

11.2 Valuation and weighting

A thorough review of ecosystem valuation studies has been undertaken to in order to explore the possibility of weighting broad habitats in accordance with published monetary valuations. It is concluded that this is not a credible approach for the following reasons:

Supporting services. Estimated values for important supporting services are problematic. Thus Beaumont *et al* using a replacement cost method, estimate the nutrient cycling value of UK territorial waters at between £800 and £2320 billion, and these values would swamp other estimated ecosystem service values. But in reality nutrient cycling is relatively fixed and resilient, occurs in all habitats, and is essential to all life. As such it may be regarded as infinite in value, but relatively meaningless in policy terms. In any case, some economists would argue that its value is realised in more direct services (food production, waste assimilation etc.) and that to include it would be to amount to double counting. This becomes more complex however when the value of the more direct services are realised in one set of habitats, and the supporting services are offered in another.

Methodological problems. Estimated values of other non-market services are typically estimated through stated preference methods (e.g. contingent valuated, choice experiments etc.). These are highly context dependent, highly scenario dependent, and highly sample sensitive. There are also fundamental methodological problems which prevent a “hypothetical market” realistically reflecting a real market (see Macmillan and Duff 1998 for a brief discussion of the “scope” and “feel good” problems). In any case coverage of the various dimensions of value of ecosystem services is poor (these are expensive studies), and though “benefit transfer” (i.e. using values generating from studies elsewhere) is advocated by some, it is rarely valid.

Allocation of ecosystem service values to particular habitats is problematic, since such services are typically generated by a complex of habitats. For this reason O’Gorman *et al* concluded that it was inappropriate to assess ecosystem service values for particular habitats.

Coverage. Exploring all possible valuation studies still left major gaps in valuation. More detailed studies of particular habitats (e.g. Beaumont *et al* 2006) reveals major gaps in terms of values for important services.

Option value. Natural capital is very much about maintaining future opportunity – conserving the nation’s natural wealth. None of the existing valuations are capable of addressing “option value”. A practical example of this would relate to recreation. A valuation of the recreational value of Scotland’s broad habitats would be based on current usage and spending. Yet in 20 years in any particular location this might increase many times. Ensuring this potential value is maintained without compromising other more immediate values is the key to sustainable development.

Other authors have reached similar conclusions. In particular, a comprehensive review by O'Gormon *et al* 2008 concluded that summing different valuations was "challenging", and that total valuation "is not useful in considering the implications of policy related changes".

Dropping a weighting system based on ecosystem service however presents a dilemma, since an index of natural capital must represent in some way the value of ecosystem services generated. A structure for the index is therefore proposed which incorporates indicators for each of the four key dimensions of ecosystem service value for each of the major habitats. This effectively distinguishes the proposed NCAI from an environmental quality index, and from periodic assessments such as the countryside survey.

11.3 Indicator categories

Quality indicators for each broad habitat are grouped into four sets representing key ecosystem services. Provisioning and regulating services are relatively discrete, and allocating potential indicators is relatively straightforward. However, biodiversity indicators may be allocated to cultural services or supporting services (on the basis that biodiversity underpins supporting services, and is valued in its own right by humans). In practice inconsistencies in this allocation are not too serious – unless differential weightings are applied to ecosystem service categories – which we do not recommend for the reasons discussed above.

Some analysts have suggested the need for a "habitats" category of ecosystem services, and if this was used it would effectively increase the weighting afforded biodiversity within the overall index. However, the rationale for a "habitats" category is weaker than for other categories, and would need to be supported by invoking the "precautionary" principle.

11.4 Indicator coverage and frequency

Although environmental quality and biodiversity indicators are relatively plentiful, coverage of key ecosystem services is poor, and we have struggled to find credible indicators which generate meaningful trends over a sensible time horizon.

For the 3-4 broad habitats we have explored in detail, very few useful indicators could be found for supporting services, and only a limited number for regulating and provisioning services. Indicators for many cultural services also few and inadequate – for example there is very little annual data for e.g. recreational quality. Biodiversity indicators are relatively plentiful, though many of these are only generated on a five or six year cycle, and are often heavily influenced by the effects of weather/climate change and subject to natural cycles. This makes interpretation of an aggregated index difficult. Furthermore, their links with other ecosystem services are poorly understood.

There is considerable interest in indicators and broader indices of ecosystem health, and as these are developed they may serve as a stronger basis for the development of an NCAI.

11.5 The carbon question

Carbon sequestration and storage is a key ecosystem service which needs to be reflected in the NCAI. The quality of a habitat in terms of delivery of this service is reflected in net sequestration rate. In practice this is relatively fixed, i.e. sequestration rate and therefore quality changes little over time. However, an alternative perspective is to consider the accumulation of carbon as a steady increase in quality of that habitat. An appropriate indicator would therefore be the proportional increase in carbon stock, i.e. (annual increase in stock + previous stock)/previous stock. This has been proposed for peatland but arguably should be used for all habitats. The feasibility, strengths and weaknesses of this approach require further consideration. It is unclear that our understanding of the dynamics of carbon across the various habitats (including consideration of methane/CO_2) is adequate to justify this approach.

11.6 Strengths and weaknesses

The value or otherwise of a NCAI will depend on *interpretation*: would a decline in the index mean that our natural capital is being depleted.

An overall decline in the value of the index may be attributed to either decline in area, or decline in quality or both. If we include all major semi-natural and farmland habitats in the index, and if habitats are equally weighted, then an area related decline in one subsidiary habitat index will usually be compensated by an area related increase in another – except where these losses are to urban development. In other words area will contribute rather little to the NCAI trend. This is reinforced by the fact that most habitats show very little measurable change from year to year (but see discussion in 1.7).

This raises the question as to whether it is worth including area, especially since we would normally wish to understand whether a downward trend was related to area or to quality; and if to area, then we would wish to know which habitat. However, a purely quality based index would rather undermine the whole point of the index = which is about natural capital stock.

An important assumption implicit in the proposed structure is that the relationships are linear – in other words if we halve the area we halve the value (whereas in fact unit value tends to increase as area is reduced); or we halve the quality sub-index, we halve the overall value. The second of these is compounded by the weakness in some cases of the relationship between quality indices and ecosystem service value.

For some of the habitats there is a problem of correlation/trade-off between indicators. For example, an increase on the softwood yield projections (positive in terms of provisioning) would tend to work in the opposite direction from the proportion of broadleaves (positive for amenity), so that the two cancel out.

Many of the best indicators in terms of data availability and high level representation of ecological quality are problematic from the perspective of interpretation. Butterfly abundance for example varies substantially from year to year, related to natural cycles. Seabird populations, after a prolonged period of rise, are now in decline, but the reasons are complex and probably related as much to climate and shifting patterns of food availability as to any changes associated with human activity. Woodland birds are increasing, but this may be related to the increase in area of woodland rather than quality, and this indicator cannot be adjusted to a per unit area base.

However the index is finally constructed there will remain significant questions of interpretation. As currently constructed it is likely to be relatively stable, reflecting the evolving trade-offs between different values which constantly take place. Further development and testing of the sensitivity of the index would be required to explore these issues.

11.7 Taking the process forward

A good deal of background work has been done on ecosystem values and indicators for all broad habitats, and the marginal cost of a thorough indicator assessment for all of these will be relatively modest.

Completion of this work would then serve as the background and basis for engagement with other interested parties in a broader participatory process to assess the value of such an index, and if appropriate to change/further develop/refine the structure and protocols, and make a final selection of agreed indicators for piloting. This would probably require expert working groups to finalise the subsidiary index for each major habitat, coordinated by a well informed facilitator/reporter.

Other interested parties include specific project initiatives such as the European Beyond GDP initiative, the CEH led Natural Capital Initiative, the National Ecosystem Assessment, The European Economics of Ecosystems and Biodiversity (TEEB) project, and the DEFRA ecosystem services research programme. The on-going work on ecosystem health indicators and more structurally based environmental quality/greenspace indicators within SNH is also relevant.

Import, normalisation, projection/interpolation etc. of data to generate a pilot index will be a significant task, unless the number of indicators is restricted. Given the range of ecosystem service values that arguably should be represented, it would be difficult to justify such a restriction. For this reason we recommend that this stage is delayed until after the more participatory process described above has been completed.

Given the various uncertainties and costs involved in taking the process forward, it may be appropriate to stand back at this stage and consider alternatives. For example, a basket of more broadly based environmental quality indicators, related to agreed environmental objectives and outcomes, and unrelated to the area of specific habitats may offer a simpler and more robust way forward.

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ANNEX 1: VALUATION STUDIES AS A BASIS FOR WEIGHTING BROAD HABITATS

The terms of reference for this study suggest the use of weightings as follows:

"Weightings within the index. Similar to weightings of items purchased for price index (inflation) calculations, the data / indicators identified above must be weighted to produce an overall compound index. The preferred weighting of land uses will be based on the average value of ecological services delivered per year (using a previous SEPA study), adjusted by area. Likewise weighting of water would be based on the average value of ecological services delivered per year (using a previous SEPA study) for fresh water and sea, divided by area. However, the weighting system to be used has not been finalised at this stage and alternative approaches should be explored, including their impact on the stability of the index. However, there should be a clear rationale (probably based on economic or accounting theory) for this weighting. The final selection of data / indicators and weightings will be determined in consultation with the nominated project officer and other SNH staff".

A review of the literature was undertaken to identify appropriate valuations and explore the feasibility of this approach. This review drew in particular on recent major research programmes, and in particular the DEFRA Ecosystem Services Research Programme and the European Economics of Environment and Biodiversity (TEEB) project. It also draws on methodological critiques from various sources.

Given the potential significant effects of weighting in terms of driving policy, we suggest valuation studies should only be used as a basis for such weightings if the following conditions can be met:

- the valuations encompass all the most important ecosystem services;
- there are significant differences between broad habitats;
- the valuations are sufficiently robust that they would be accepted as providing the basis for differential weightings by a panel of informed stakeholders and technical specialists.

Definitions and categories

There are functional definitions and economic definitions of ecosystem services. The former generally proposed by ecologists, emphasises the underlying ecological processes; the latter, generally proposed by economists, emphasises the direct service or "input" to human activity and survival. In practice these definitions serve different purposes and are not contradictory. The distinction between the two is however critical from a management perspective, and when considering the scope and application of valuation studies.

Thus TEEB 2008 offer a relatively inclusive definition:

> "the *direct and indirect* contributions of ecosystems to human well-being".

A more restrictive "economic" definition is offered by Boyd and Banzhaf (2006):

> "the components of nature, *directly* enjoyed, consumed, or used to yield human well-being".

Under this latter definition ecosystem services have direct value for human beings and this value can in principle be measured; the underlying (indirect) functions only have value in so far as they underpin the services, and their value is encompassed in the value of those services. To value them separately would be to double count. This definition of services effectively excludes underlying functions such as primary production, decomposition processes, nutrient cycling, stability etc. – not because they are unimportant, but simply because they are fundamentally different from a practical management or economic valuation perspective. Direct services are dependent on them, but not all their function is used in the delivery of direct services. This "redundancy" is nonetheless valuable: it corresponds to future options or potential, or to stability, resilience and insurance value.

Categories of ecosystem service

Ecosystem services have been bundled and categorised in many different ways, partly reflecting these different perspectives (e.g. Wallace 2007, Hambrey & Senior 2008; Fisher *et al* 2009).

The Millenium Ecosystem Assessment (MEA) proposes 4 categories:

- Supporting services
- Regulating services
- Provisioning services
- Cultural services

De Groot *et al* (2002) created a classification system specifying the relationship between, and transitions from ecosystem processes and components to goods and services. Haines-Young and Potschin (2008) also propose categories based on this "delivery system".

Based on a major meta-analysis, TEEB (de Groot *et al* 2009) proposes a typology of 22 ecosystem services divided in 4 main categories: provisioning, regulating, habitat and cultural services. These are listed in Box A1.1 (and Box 2 of the main report).

Box A1.1 Classification of ecosystem services (de Groot *et al*)

Provisioning services
- Provision of food
- Water provision (2), including regulation of water flows (10) and water purification (11).
- Raw material, fibre, energy resources
- Genetic resources
- Medicinal and other biochemical resources
- Ornamental resources

Regulating services
- Air quality regulation and other urban environmental quality regulation
- Climate regulation
- Moderation of extreme events (flash floods, landslides, avalanche, storm surge, tsunami, pollution+temperature, fire, shelter belt/wind damage, binding of sediments)
- Erosion prevention
- Maintenance of soil quality (carbon input (incl. organism faeces…), nitrogen fixing; symbionts, mycorhizal fungi facilitate P uptake by plants in more natural systems.(only 5-10% recovered in crops.
- Pollination services
- Biological control

Habitat Services
- Maintenance of life cycles of migratory species
- Maintenance of genetic diversity (overlap with provisioning genetic resources above)

Cultural services
- Cultural services: aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, information for cognitive development

No doubt there will be further variations on these classification systems, but from a valuation perspective it is clear that there are two major categories:

- direct services which can in principle be measured and valued;
- indirect services (supporting services; some "habitat" services") which are much more difficult to value.

The difficulty with the latter relates to

a) the danger of "double counting" since a part of their value (arguably all) is realised through direct services;
b) the impossibility of assigning value to unrealised, potential or future "option" value relating to these supporting services.

For this reason many analysts argue that supporting services have infinite value, since without them life is not possible, and they encompass unknown and infinite potential future values. Others argue that their value cannot vary in the manner of a market price: there is a critical amount of natural capital with infinite value (Farley 2008); there is an additional amount required for "insurance value" (Baumgartner 2008); and there is that required to underpin the directly valued ecosystem services.

Whatever perspective is taken on this, it is clear that any values related to supporting services cannot credibly be added to values related to more direct ecosystem services. A "total valuation" of ecosystem services related to a particular habitat would either be infinite (by including supporting services) or incomplete (encompassing only currently used, direct and measurable values). In so far as the conservation of natural capital is all about handing down not only existing services, but also opportunities and potential to future generations, an incomplete valuation is inadequate and does not provide the basis for a differential weighting.

Coverage of key dimensions of value

Irrespective of the argument presented above, it is clear that any credible differential valuation of habitats should be based on reasonable coverage of the value of the various direct ecosystem services with which they are associated.

Although many valuation studies have been undertaken, relatively few have been undertaken related to specific habitat categories in the UK and in Scotland in particular. While studies from elsewhere might be used ("benefit transfer") the conditions for such transfer are demanding (Hoehn 2006; Plummer 2009; Eftec 2009). This is because – as has been widely discussed in the literature – ecosystem service valuations are "context specific, ecosystem specific, and related to the initial state of the ecosystem" (Ten Brink and Brauer 2008).

The most comprehensive recent review of the value of ecosystem services in the UK is that of O'Gorman *et al* 2008. They specifically used a service based, rather than habitat based valuation approach because of the lack of data and difficulty of assigning many ecosystem service values to particular habitats. Several conclusions from this study are of direct relevance to this analysis:

- the total economic valuation approach which they attempted represents a significant under-estimate of the true value of these benefits;
- it represents only a snap-shot in time;
- data is poor or lacking in relation to some key services such as water purification and waste treatment;
- establishing a baseline against which to measure the total value of many services is lacking or impossible to define.

These baseline problems also led to a more general conclusion that valuation studies to inform policy and understanding of sustainability should be based on marginal analysis rather than total economic value.

Many of the studies which attribute values to particular habitats or "biomes" (including the analysis by Williams *et al* 2003) are based on the comprehensive review presented by

Costanza *et al* (1997) which provides (global) average ecosystem service values per unit area. This was undertaken to demonstrate the enormous value of ecosystem services, but it was never intended to demonstrate differential values between biomes. The paper makes it clear that there are major gaps, and inconsistencies between categories. In any case, examination of source data for this study (previously available as an online supplement) reveals huge variation between studies *within* biomes, suggesting that differences *between* biomes would not be statistically significant. This variation is related to both contextual and methodological variations as discussed below, and this makes “transfer” of ecosystem service values from one study/location to another fraught with difficulty.

In Scotland/UK the following valuation studies of possible relevance have been undertaken:

Broad habitat	**Ecosystem service**	**Method**	**Source**
Forest	Recreation	Contingent valuation	Hanley 1989; Hanley *et al* 2002
Forest	Recreation, landscape, biodiversity, carbon	Various	Willis *et al* 2003
Forest	Recreation/biodiversity	Contingent valuation	Macmillan and Duff 1998
Forest	All services		Stenger *et al* 2009
Rivers and lochs	River Spey Catchment recreational fishery	Direct market value	Butler *et al* 2009
Marine	Biodiversity and associated services	Various	Beaumont *et al* 2006, 2007, 2008
Marine	Biodiversity	Stated preference	McVittie and Moran 2008; Hussain *et al* 2009
Marine	Recreational sea angling	Direct market value	Economic Impact of Recreational Sea Angling in Scotland, Scottish Government, Jul-09
Peatland/upland	Soil carbon	Artificial market	SNH IN 2009; Moors for the Future Research Note 12
Peatland	Cultural		DEFRA 2002
Upland	Provisioning (deer)	Direct market value	Pacec 2006 Deer management;
Upland	Water provisioning and regulation; recreation, climate regulation, food and fibre, renewable energy, biodiversity and wildlife.	Economic impact of management change	Natural England 2009 Commissioned Report NECR029
Peatland-mire	Storm runoff; erosion prevention; nutrient retention.	Qualitative analysis	Bragg 2002
Rock/montane	recreation	Demand modelling	Hanley *et al* 2001
Grassland, cropland	Provisioning	Direct market value	Food and Drink Scotland Key Facts; Agricultural census
Grassland	Gas regulation, soil formation		Pearce 2001

Cropland	Provisioning	Market value	Food and drink Scotland key facts 2009; Agricultural census

In addition to the above there is a wide range of information relating to the direct economic values associated with recreation (Scottish Recreation Survey) agricultural production, forestry production etc. which might be allocated to different broad habitats, for example on a pro-rata (area) basis.

The following broad conclusions may be drawn on coverage:

- *Supporting services: v*ery few valuations are available relating to supporting services, and there are serious conceptual/methodological problems associated with these, and with adding them to other values (as discussed above).
- *Regulating services*. Valuations relating to carbon sequestration and storage are readily available. Valuations relating to other regulating services are generally lacking, especially when considering discrete habitats or biomes.
- *Provisioning services*. Accurate estimates are available relating to fisheries and agriculture production. Information is available on deer production/management, and allocation to broad habitats might be feasible. Significant information is available on recreational values, especially for woodland and some specialist recreational activities in the marine/coastal environment. Allocation of recreational values to other broad habitats is problematic and a pro-rata approach (i.e. allocation according to the proportion of countryside covered by habitats) is questionable, could be controversial (economic interests are at stake) and would require stakeholder input to be credible.
- *Cultural and habitat services.* Valuations relating to these services are generally poor or lacking, and “benefit transfer” approaches are unlikely to address the deficiency.

Table A1.2 offers a graphic indication of the quality and availability of the valuations relating to different ecosystem services (as categorised in box A1.1) for broad habitats in Scotland. Although it is arguable that many of the subsidiary service categories are relatively unimportant, it is nonetheless clear that coverage is poor. Weighting based on these values would be seriously biased in favour of historic or current direct market values (including carbon sequestration) and selected indirect values which particular studies have sought to highlight. Since this index seeks to offer a more inclusive and longer term alternative to market driven economic performance indicators, this limitation is serious.

Table A1.2: Valuation studies or estimates relating to different ecosystem services

Provisioning services	
• Provision of food	
• Water provision, including regulation of water flows and water purification.	
• Raw material, fibre, energy resources	
• Genetic resources	
• Medicinal and other biochemical resources	
• Ornamental resources	
Regulating services	
• Air quality regulation	
• Climate regulation	
• Moderation of extreme events (flash floods, landslides etc)	
• Erosion prevention	
• Maintenance of soil quality.	
• Pollination services	
• Biological control	
Habitat Services (supporting services?)	
• Maintenance of life cycles of migratory species	
• Maintenance of genetic diversity	
Cultural services	
• Cultural services: aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, spiritual experience, information for cognitive development	

Red – not available or seriously inadequate
Orange – some valuations available or estimates could be made – but not robust or comparable between broad habitats
Yellow – some robust values are available, but coverage is partial or limited in some way
Green – valuations robust and could be assigned to broad habitats

The relationship between biodiversity and ecosystem services

The relationship between biodiversity and the various services listed above is a complex and difficult issue (e.g. Balmford *et al* 2007; Costanza *et al* 2007; Marrs *et al* 2007; Baumgartner 2008; Beaumont *et al* 2008; Hambrey and Senior 2008; Elmqvist *et al* 2009), and is the focus for much current work, including that being undertaken by TEEB. A key question is the extent to which it also serves as an important underlying process or condition for the delivery of specific regulating, provisioning and cultural services. Biodiversity is also related to the concept of "resilience" and ecosystem health. It is often argued that highly biodiverse systems are better able to cope with stress, disease and environmental change. Many ecologists are of the view that biodiversity represents the "cogs" in the ecosystem lying behind the delivery of all ecosystem services – and that we can't afford to lose any of the cogs (Hambrey and Senior 2008).

The literature shows that there are generally positive relationships between biodiversity (in terms of species richness) and a range of ecosystem functions and processes, some of which underpin the services listed above. However these relationships are poorly specified - in most cases we do not know the *shape* of the relationships - and the links may be weak, especially through to services.

For example, higher levels of biodiversity may be associated with higher levels of primary productivity, but only up to a point, and for natural (as opposed to experimental systems) this point is very hard to specify. In any case primary productivity in the broad sense is not a service to humans; productivity of particular valued organisms or groups of organisms is the issue (or service) of concern.

Other features of ecological structure – such as the number and type of organism at particular trophic levels, or within particular niches, may be more important (perhaps corresponding to the "cogs" metaphor). Ecologists have identified key functional species which have a major impact on ecosystem state (for example sea urchins and wolf-fish together have a radical impact on marine vegetation structure and associated biota). Many authors identify functional or ecological redundancy ("spare" species which can kick in if functionally important species are lost) as a form of insurance or backup, but this is hard to pin down, especially in terms of how much redundancy is required to sustain service delivery in the face of anticipated shocks or events. In order to apply the precautionary principle we demand some insurance (to maintain "resilience") – but it is a matter of perspective and judgement, informed by (as yet) inadequate knowledge, as to how much.

There are however much clearer and more specific relationships between particular habitats or species groups and a range of services. Carbon sequestration, carbon release, methane release, water quality, flood mitigation, erosion etc. are all closely related to land use and its associated habitats and biodiversity. Seagrass beds, and other coastal habitats, are known to be nursery areas for commercially important fish species, and as such are important in the continued functioning of fisheries for those species. Many of these relationships are only just beginning to be explored by scientists in the UK, but this is where the focus of further research should be.

In practice however, it is likely that in many cases species or habitat diversity could be reduced/changed substantially without serious long term impact on ecosystem services. The strongest rationale for maintaining biodiversity at present or enhanced levels *and configurations* is probably not to underpin other services in general, but rather in its own right as a cultural and genetic resource, or in more specific cases as a resource which underpins some clearly identified services such as flood mitigation at a local level.

For all of these reasons, the valuation of biodiversity and its contribution to ecosystem services is a crucial issue for any consideration of natural capital. To date most valuation of biodiversity has been based on stated preference or contingent valuation methods, which can capture only a part of the values discussed above, and which are problematic in their own right, as discussed below.

Methodological problems

The valuation of ecosystem services has been thoroughly reviewed by DEFRA 2007, O'Gorman *et al* 2008 and guidance on benefit transfer by eftec (Bateman *et al*) 2009. Perhaps unsurprisingly the valuation of direct services (e.g. provisioning services) is relatively straightforward; valuation of regulating services is often difficult, as is the valuation of cultural services; and valuation of biodiversity and supporting services is both conceptually problematic and methodologically difficult. Furthermore, the methods required to determine these different values are themselves very different, and summing these diverse values is “challenging” (O Gorman *et al* 2008).

Scale and allocation

Hein *et al* (2006) have discussed some of the scale issues associated with valuing ecosystem services. Many services (especially those related to water quality, nutrients etc) are provided by a mix of habitats, for example within a watershed. Furthermore, while services may be generated in one location (or over a very wide area) they may be consumed in another (or within a small area). The value of the service *per unit area of habitat* is therefore difficult to define and may be misleading.

It is equally difficult to define the beneficiary group – from local to global- which may be used to derive total value. For example “In the De Wieden wetland, reed cutting and fisheries are only important at the municipal scale, recreation is most relevant at the municipal and provincial scale, and nature conservation is important in particular at the national and international level” (Hein *et al* 2006).

Value and area

To generate the natural capital asset index, area is to be multiplied by value. However, these are not independent. Value is likely to be a function of area, and regular updates of the valuation would be required if area changes significantly. Given the cost and difficulty of these valuations this is not feasible.

Inclusion and positive bias

There may have been a positive bias in valuations. Although habitats provide many services, they also provide disservice – such as midges, ticks disease etc. These are rarely specified in willingness to pay (for biodiversity) studies.

Summing different types of value

Although it is possible to assign monetary values to the various ecosystem services, it is questionable as to whether these diverse values, derived using very different methodologies, can be summed or traded off against each other.

Marginal studies cannot be summed in order to estimate total economic value (see for example Farley 2009) – yet these are the only studies which appear to be valid. O’Gorman *et al* (2008) have highlighted the lack of credible “baseline” for genuine total economic valuations.

Specific problems with Contingent Valuation (CV) studies

Knowledge and context

What people are willing to pay for something depends on their understanding and appreciation (Hoehn *et al* 2003). In stated preference/contingent valuation methodologies researchers set the scene by explaining what is on offer. Respondents may be familiar with some dimensions and values (e.g. landscape, squirrels) and less so with others (supporting services, regulatory services). The bids will depend critically on how the values are explained and presented. There is probably a positive in-built bias to most studies since researchers are seeking to establish positive values.

Scope and scale

In most CV studies some dimension of the natural environment, a particular service, or a change to the natural environment is the focus for the valuation. Perhaps unsurprisingly it has been found (MacMillan and Duff 1998) that people will not offer twice as much for double the area or double the service. Therefore the scale at which the valuation is attempted will have a huge effect on any £/ha estimates arising from the study. This compounds the problems with £/ha estimates noted under 12.5.1.

Feel-good problem

A key problem with any methodology which seeks to create an artificial market and ask people what they are willing to pay, is that the "bid" may be for something perceived as good rather than for the explicit service on offer. In other words if you ask someone what they are willing to pay for something which they think is good or important they will tend to say they would pay (typically) something between £10 and £100 a year (depending on their relative wealth). That this may be the case is reinforced by the results of studies which offer a much bigger service (see scope problem above) yet generate a similar result.

Budget

In normal market based economic transactions, people allocate their budget across competing demands or opportunities, and they will consider alternatives to any purchase decision. A CV study which offers a wide range of environmental products/scenarios will generate lower values for each product than one in which only one product is on offer. Arguably there are an infinite number of environmental values, and the budget would need to be shared across them all – resulting in infinitely small values.

Changes in WTP through time

People willingness to pay changes through time (Winkler 2006). Thus it is probable that WTP for "green" products has declined since the recession. WTP for less directly used services will probably decline relatively more than that for direct servces. While market prices rapidly adjust and are readily available, CV studies are occasional and expensive. Using historic CV studies – irrespective of adjustments for inflation, is therefore problematic. This relates closely to the problems of benefit transfer.

Overall validity and utility for decision making and management

In part because of these methodological problems many analysts are of the view that SP/CV studies are inappropriate for informing policy. Thus Wilson and Howarth (2002) suggest that "because the allocation of ecosystem services directly affects many people and raises normative questions about social equity, it is argued that carefully designed discursive methods will help ensure the achievement of social equity goals".

Conclusions

We do not believe that the conditions for a credible weighting based on ecosystem service values have not been met:

- Few studies relate specifically to the Scottish broad habitats listed in section 5, and the conditions required for reliable "benefit transfer" (i.e. use/adaptation of figures derived from studies elsewhere) are not in place;
- Even if benefit transfer were to be undertaken coverage of all the key dimensions of value of each of the broad habitat categories would be very limited, and biased in favour of those direct services most easily monetarised;

- It is arguable that from a natural capital perspective, the values associated with supporting services (and in particular "option" value) are the most important – yet we lack credible valuations for these, and they cannot be added to more direct values.
- The relationship between area and value is complex and the validity of a £/ha figure questionable;
- Value/ha will change with time, but it is not feasible to update valuation figures on a regular basis;
- Cultural and biodiversity values are typically derived using stated preference/contingent valuation methods, with well established limitations;
- The implications of inaccurate/partial valuations – in terms of perverse policy effects – could be serious.

However, some valuations are useful, and it would be possible to use these as input to a panel based weighting process. Such a weighting would remain controversial however, and it is unclear that it would usefully inform policy response to any change in index value.

ANNEX 2: CONSULTEES

Interim meeting/workshop

A progress meeting/workshop witgh video link to Edinburgh was held 10.00-12.30, on Monday 14 December 2009 to discuss progress with the project and bring in a range of perspectives from other agencies and interested parties. The following attended and contributed to discussions:

Claudia Rowse (SNH)
Greg Mudge (SNH)
Ralph Blaney (SNH)
Sue Marrs (SNH)
Alan Cameron (SNH)
Archie Prentice (HIE)
Rebecca Badger (SEPA)
Mary Christie (SNH)
Sandra Dandie (SG)
Daniel Hinze (SG)
John Crawford (SE)
Tony King (SWT)
Phil Matthews (SDC)

Telephone discussions were held with:
David Donan (SNH)
Chris Sydes (SNH)
Jane Mackintosh (SNH)
David Allison (SG)

Email exchanges took place with:
Simon Foster (SNH)
Patrick ten Brink (TEEB)
Olga Anderson (eftec)
Dominic Moran (SAC)
Nicola Beaumont (PML)
Iain Strachan (SNH)
Yvonne Grieve (FC)

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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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