Written 2013. Minor updates 2nd January 2017

Monitoring and indicators of UK biodiversity change

A review for the Tomorrow's Biodiversity Project

BRINGING ENVIRONMENTAL UNDERSTANDING TO ALL

Dr Richard Burkmar
Biodiversity Project Officer
Field Studies Council
Head Office
Montford Bridge
Shrewsbury
SY4 1HW

richardb@field-studies-council.org
Tel: (01743) 852125

Tomorrow's Biodiversity Project funded by the Esmée Fairbairn Foundation

1 Contents

1 Contents ... 2
2 Introduction ... 3
3 Monitoring and indicators ... 4
3.1 Monitoring ... 4
3.2 Indicators ... 5
3.2.1 Meanings and definitions ... 5
3.2.2 Operational frameworks and typologies for indicators ... 7
3.2.3 Widely used ‘indicator species’ terminology ... 11
3.3 Selection of indicators ... 13
4 Headline biodiversity indicators ... 19
4.1 UK headline biodiversity indicators ... 19
4.2 National–level headline biodiversity indicators ... 22
4.3 European and global headline biodiversity indicators ... 30
5 The anatomy of a state indicator ... 33
6 Representation of species and habitats by headline indicators ... 35
6.1 Species ... 35
6.2 Habitats ... 37
7 Conclusions ... 38
8 References ... 41
9 Appendix A. Glossary of data providers ... 46

2 Introduction

The Convention on Biological Diversity (CBD) defines biodiversity as: " *the variability among living organisms from all sources including,* inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" (CBD 1992). Biodiversity encompasses a huge range of complexity and levels of organisation in nature, from genes to ecosystems. Biodiversity is subject to a wide range of anthropogenic pressures and is declining at an alarming rate (e.g. Butchart et al. 2010). Biodiversity loss is likely to have serious consequences for the functioning of the entire biosphere, on which we depend as a species, in ways in which we are barely starting to comprehend (Rockström et al. 2009).

As a signatory to the CBD which aims to tackle biodiversity loss, the UK government is committed to the *Aichi targets* set out in the Strategic Plan for Biodiversity 2011-2020 (CBD 2010). Among these targets are those to improve the 'status of biodiversity' and there is a corresponding commitment to monitor progress towards these targets at a national level (JNCC 2012). These commitments also filter down to local levels so that, for example, England's National Planning Policy Framework stipulates that local plans should "*promote the preservation, restoration and re-creation of priority habitats, ecological networks and the protection and recovery of priority species populations, linked to national and local targets, and identify suitable indicators for monitoring biodiversity*" (UK Government 2012).

Biodiversity exists within a complex system – the biosphere – and it is not possible to measure its state using a few simple metrics (Gregory et al. 2005). Consider another complex system – the economy. To assess the state of the economy, economists use countless metrics including, for example, Gross Domestic Product (GDP), stock market indices, price indices, inflation rates, unemployment rates, interest rates, industrial production, government budget balance, exchange rates, etc, etc. The list is endless and none of these metrics, on its own, provides a comprehensive picture of the 'state of the economy'. Rather each produces a different signal, throwing some light on one or more facets of the economy which, when considered together, can give an impression of its overall state. Given the difficulty of describing the state of the economy, how much more difficult then to describe the state of a vastly more complex system – the biosphere? As the plant ecologist Frank Edwin Egler put it: "*[...] nature is not only more complex than we think. It is also more complex than we* can *think*" (Turnhout et al. 2007). Noss (1990) noted that indicators are themselves a valuable way of surmounting this complexity (which he characterised as the "*vagueness associated with the biodiversity issue*").

Rapport & Hildén (2013) note that: "*the role of ecological indicators has evolved considerably from a primary focus on environmental quality (air and water) to a more holistic description of ecosystem characteristics* [including] *indictors of biotic community structure, primary productivity, biological diversity, size spectra, and other measures that track changes in the organization, vitality, and resilience of ecosystems.*" Vačkář et al. (2012) advocate a multi-index approach to monitoring biodiversity in order to deal with this complexity, stating: "*The approaches to biodiversity indices [...] are mutually complementary and each stresses a different aspect of the multidimensional concept which biodiversity undoubtedly is*". Feest (2013), states that "[...] *in the most recent work* [...] *biodiversity is viewed as a qualitative characteristic that can be assessed or measured by a number of* *indices reflecting the overall characteristic*". Thus the need for measuring biodiversity via a suite of complementary indicators is widely accepted (Jones et al. 2011).

The approach cannot be perfect, but it is clear that a suite of complementary indicators is a vital tool for expressing and communicating the state of biodiversity to a wide audience. For example, in an overview of the trends for 31 indicators of global biodiversity change, Butchart et al. (2010) showed that those describing the state of biodiversity (species population trends, extinction risk, habitat extent and condition, community composition) showed declines (and no reduction in *rate* of decline) whilst those relating to drivers (resource consumption, invasive alien species, nitrogen pollution, overexploitation, climate change) showed increases. There were some local positives (e.g. extent of protected areas, sustainable forest management, policy responses to invasive aliens and biodiversity-related aid), but the overall assessment of global biodiversity from these indicators is grim. That Butchart et al. were able to deliver their message so convincingly and with scientific authority is thanks to the implementation of monitoring and indicators.

This working paper presents an overview of how biodiversity is monitored in the UK, but it does so within certain limits: consideration of biodiversity is more or less limited to *species* and *habitats*. Noss (1990) recommended considering the monitoring of biodiversity within a framework of four major levels of organisation: regional landscape; community/ecosystem; populations/species; and genetic (and to this we can now add, at the top end, ecosystem services). Within that framework, this paper concentrates on community/ecosystem and population/species. These are the levels of biodiversity organisation where direct observations of species and habitats – requiring skills for which the FSC has a strong record in training and resource development – can make a real contribution. Notwithstanding this, the levels are not completely independent and so, for example, species diversity does, to some extent, reflect genetic diversity and habitat condition does, to some extent, reflect the ecosystem service provision.

In practice, biodiversity monitoring happens to satisfy the requirements of a number of different audiences. We can think of these audiences – or consumers of biodiversity monitoring outputs – on a continuum. At one end of this continuum are the biophiles, people that deeply value nature for its intrinsic value, and at the other end are the policy makers, those charged with undertaking high-level governance in accordance with environmental aspirations like the Achai targets. In the middle are people such as land managers who can directly affect biodiversity on the ground. (Any given individual, of course, can belong to any number of audiences along the whole continuum.) We should consider biodiversity indicators and monitoring schemes in relation to all of the audiences which consume their outputs.

3 Monitoring and indicators

3.1 Monitoring

Hellawell (1991) provided the following widely accepted definition of monitoring.

Monitoring: "*Intermittent (regular or irregular) surveillance carried out in order to ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm*" (Hellawell 1991).

Since this definition distinguishes monitoring from surveillance, it is also appropriate to consider Hellawell's definition of that.

Surveillance: "*An extended programme of surveys, undertaken in order to provide a time series, to ascertain the variability and/or range of states or values which might be encountered over time (again without any preconceptions of what these might be)*" (Hellawell 1991).

By these definitions a key distinction between monitoring and surveillance is that monitoring operates within an evaluative framework where levels of the monitored entities are ascribed value and/or meaning and may even trigger action if they reach certain pre-determined levels. In general consumers of the outputs of biodiversity surveillance tend towards the biophile end of the audience spectrum and consumers of the outputs of biodiversity monitoring tend towards the policy makers. In practice the two terms are often used interchangeably and within the context of biodiversity monitoring, so called 'monitoring schemes' are often, strictly speaking, surveillance programmes.

Biodiversity monitoring schemes in the UK are usually established from the ground up by people who are directly interested in the taxonomic subjects of the monitoring programmes because of their intrinsic value to them. For these audiences (the biophiles) surveillance is an end in itself – it allows them to get a handle on the fate of the taxa in which they are interested and can also provide a solid base of evidence on which other activities, e.g. lobbying or conservation management, can be built. Surveillance programmes are often pressed into use as monitoring programmes by the post-hoc addition of evaluative frameworks and there are few, if any, objections to this since there are no fundamental operational differences, in the field, between well-designed surveillance and monitoring; the differences lie only in how the outputs are used. Indeed, surveillance programmes are the basis of all monitoring programmes.

Kremen et al. (2007) state: "*In the conservation context, neither inventory nor monitoring programs can be exhaustive. Such programs must therefore rely on indicator species or indicator assemblages*". Jones et al. (2011) defined global biodiversity monitoring thus: "*a process that includes collection of primary biodiversity data, synthesis of data into an indicator, and public dissemination of trends in the indicator*". Clearly 'indicators', in several senses, are an integral facet of inventory, surveillance and monitoring.

3.2 Indicators

3.2.1 Meanings and definitions

In the fields of ecology and environmental planning & management, the term 'indicator' is used in many related but different senses. The word is often combined with others – e.g. ecological indicator, biological indicator, environmental indicator, indicator species – but this does little to define, or differentiate between, the different ways in which it is used. There is no widely accepted standard of lexical semantics for discussing indicators and Turnhout et al. (2007) note that the concepts of 'indicator' are both relative and nested: "*This means that a criterion such as diversity, which can be assessed through an ecological indicator such as species richness, is in its turn an ecological indicator for ecological quality.*"

The lack of consistency and clarity surrounding the use of the word, and the concepts to which it relates, results in a lot of confused and lazy thinking. The term 'indicator species', for example, is often assigned to certain taxa outside of any meaningful context with the apparent aim of conferring some vague ecological cachet on them. Heink and Kowarik (2010) put it thus: "*The word indicator has a scientific aura, but there is no overall accepted precise definition of this term that is free from a halo of associations. The connotation of indicator is positive and conveys expert knowledge. Its mere sound is fascinating. Its function of bridging science and policy and of representing expertise dominates while the content retreats.*"

Examples of the definitions employed around the concepts of ecological indicators are given in Box 1. The word indicator is often used, interchangeably, to refer both to the organisms being monitored and the numeric measure (sometimes called the 'index') derived to express a trend. The definitions have much in common, but the most obvious common feature is that the value of an indicator (either a numeric value or presence/absence), which is a relatively small part of an ecological system, allows us to infer information about the state of a relatively much larger part of that ecological system.

Box 1. Example indicator concepts demonstrating their similarity, overlap and differences. (Note that these definitions are not completely context independent, for example that of Gregory et al. refers specifically to birds.)

Indicator: a group of species whose population trends, when taken together, reflect the average behaviour of the constituent species, but also cast light on trends in attributes of other taxa and act as a surrogate for ecosystem health (Gregory et al. 2005).

Indicator: a measure to quantify and communicate complex phenomena in a simple manner (Bibby 1999).

Indicator species: species whose status is indicative of the status of a larger functional group of species, reflects the status of key habitats, or acts as an early warning to the action of an anticipated stressor (Dale & Beyeler 2001).

Biological indicator: a species or group of species that readily reflects the abiotic or biotic state of an environment, the impact of environmental change on a habitat, community or ecosystem, or is indicative of some aspect of diversity within an area (McGeoch 1998).

Hyatt (2001) distinguished indices, from indicators, saying: "*Indices can be aggregates, or suites, of individual indicators. Furthermore, indices are used as quantitative tools in simplifying, through discrete and rigorous methodologies, the attributes and weights of multiple indicators with the intention of providing broader indication of a resource, or the resource attribute(s), being assessed.*" However, few other authorities seem interested in pursuing this semantic distinction between index and indicator and indices that are comprised of multiple indicators are still often simply referred to as indicators or, more explicitly, as 'composite indices' (Buckland et al. 2005; Pereira & Cooper 2006). Jørgensen et al. (2013) observed an increasing demand, over the last ten years, for indices which summarise trends from a number of indicators. The pressure for this has come largely from the desire to use indicators at the strategic and policy levels.

Heink and Kowarik (2010) recommend that in providing contexts for the operation and evaluation of different indicators, it is useful to position an indicator in respect of two pairs of contrasting types:

1. descriptive indicators *versus* normative indicators; and
2. indicators as measures of ecological attributes *versus* indicators as ecological components.

Descriptive indicators are those used to reflect the state, or change in state, of environmental systems whereas normative indicators are those which are used to *evaluate* the same or otherwise set goals for the state of systems. The former can be characterised as tools for scientific monitoring while the latter can be characterised as tools for policy and management. Sometimes a single indicator can be used in both ways (referred to by Heink and Kowarik [2010]as a 'hybrid measure'). In terms of the contrast made earlier between surveillance and monitoring, descriptive indicators describe the outputs of surveillance whilst normative indicators describe the outputs of monitoring.

Indicators as 'measures of ecological attributes' are characterised by the production of a quantitative value, for example species richness, whereas 'ecological components' are not characterised by measurements, but rather by the actual objects or phenomena themselves, for example the *presence or absence* of certain species such as species indicative of ancient woodland.

In the editorial for the first edition of the journal Ecological Indicators, (Hyatt 2001) drew a distinction between indicators of:

- baseline condition; and
- long-term trends.

Essentially this amounts to a difference between spatial and temporal indicators (Kremen et al. 2007). Baseline or spatial indicators can be used for site quality or condition assessment such as a Site Quality Index (outputs of surveys). Trend indicators are used to describe change over time (outputs of a series of surveys – i.e. surveillance and monitoring). Pereira et al. (2013) suggests that, at the global scale, the two approaches compete for resources with some calling for redoubled efforts to describe all species on the planet (the spatial or baseline approach) and others advocating that resources should preferentially go into monitoring of change (the temporal trend approach).

3.2.2 Operational frameworks and typologies for indicators

A high level definition of an indicator was given by Heink and Kowarik (2010): "*An indicator in ecology and environmental planning is a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals. Environmentally relevant phenomena are pressures, states, and responses as defined by the OECD* (2003)." The definition is useful because it refers to a causal chain framework for evaluating or selecting indicators called the 'pressure-state-response' (PSR) framework.

Niemeijer & de Groot (2008) summarise the PSR framework together with a number of alternative, though very closely related, frameworks – the 'driving force-state-response' (DSR) and 'driving force-pressure-state-impact-response' (DPSIR) frameworks (Figure 1).

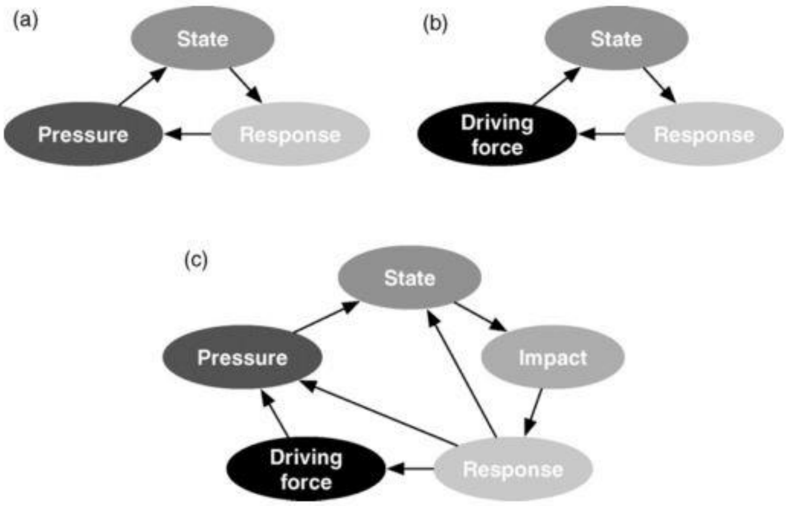

Figure 1. Schematic illustration of causal chains as represented by the (a) PSR, (b) DSR, and (c) DPSIR frameworks. After Niemeijer & de Groot (2008).

These causal chains all distinguish between (and link) the following elements:

1. Forces acting on the environment (driving forces and pressures);
2. Resulting changes to the environment (state and impact); and
3. Societal reaction to environmental changes (response).

Indicators of forces and pressures acting on the environment and societal response to environmental changes are outside the scope of this paper. Here we are interested specifically in indicators of the condition of biodiversity and these sit within the 'state' and/or 'impact' elements of these causal change frameworks, i.e. those that describe the 'state of nature' – the 'natural system' box of Figure 2.

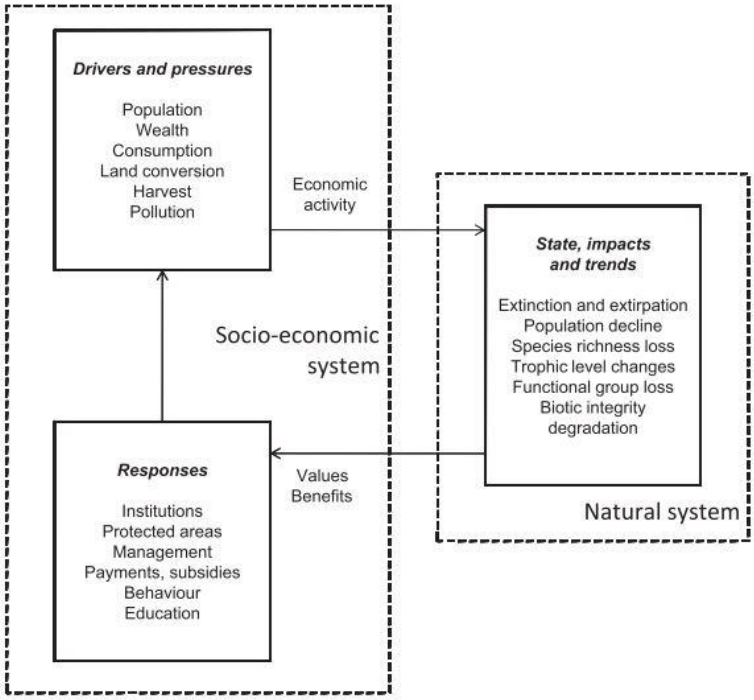

Figure 2. The DPSIR framework (Vačkář et al. 2012). The operating space of biodiversity indicators and monitoring is in the 'state-impact' area (labelled 'state, impacts and trends').

Gregory et al. (2005) developed a typology of indicators which is useful because it categorises indicator species within the context of monitoring by considering their strength along two axes, firstly their representativeness of a broader set of biodiversity components and attributes and secondly the strength of their link to a driver of biodiversity change (Figure 3).

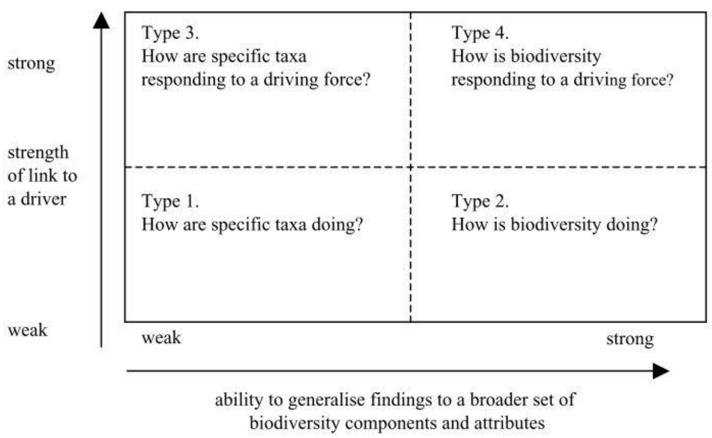

Figure 3. A classification of indicators for biodiversity based on our ability to generalize their findings to a broader set of biodiversity components and attributes, and potential links to natural or man-induced drivers. From Gregory et al. (2005).

This is a useful way of thinking about indicator species because it provides a neat framework for evaluating their utility in monitoring. The most useful indicators for monitoring are type 4 because they are both representative of a broader set of biodiversity components and have a clear link to an environmental driver (which could be affected by management or policy). Type 2 and 3 indicators are also useful for monitoring – though obviously less so than type 4. Type 1 indicators are not particularly useful for true monitoring although they may well be the subjects of valuable surveillance programmes, especially if the taxa they cover are considered to have high intrinsic value.

van Strien et al. (2009) used the typology of Gregory et al. (2005) to evaluate a number of biodiversity indicators in the Netherlands (Figure 4).

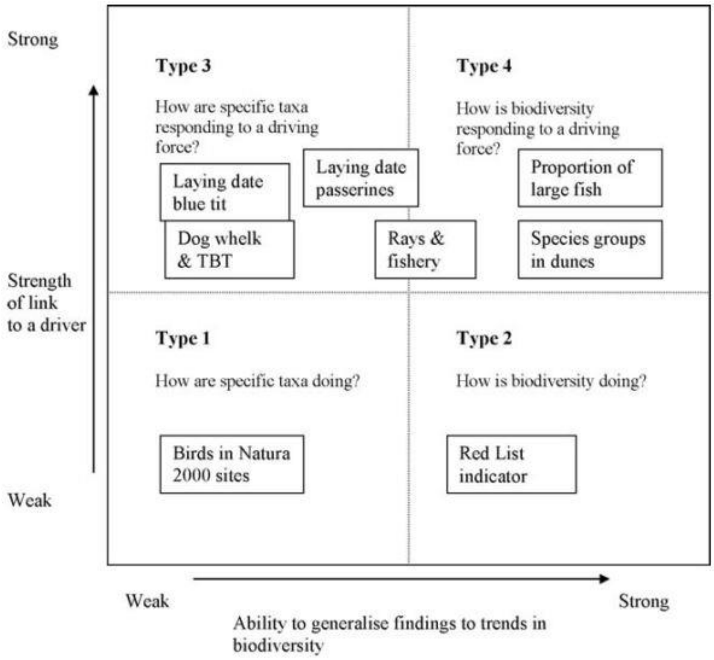

Figure 4. Assessment of biodiversity indicators within the evaluation framework of Gregory et al. (2005). From van Strien et al. (2009).

For a full explanation of how each of these key Netherlands biodiversity indicators was assessed within the framework, consult van Strien et al. (2009), but a few highlights are summarised here for illustrative purposes. 'Birds in Natura 2000 sites' were considered to be a type 1 indicator because although the indicator is designed to demonstrate the success, or otherwise, of the European Birds Directive, no clear causal link with drivers could be posited and there are question marks over how well the species that contribute to the indicator represent wider biodiversity in the Netherlands. The 'Red List indicator' is derived from a large number of red-listed species across many taxonomic groups and is therefore considered to be a fair representation of wider biodiversity, but there are no clear links with drivers and therefore this is best considered a type 2 indicator. The 'Laying date of blue tits' has a clearly demonstrated link with climate change but cannot, on its own, be considered representative of wider biodiversity and is therefore considered a type 3 indicator. Note however that a similar indicator – 'Laying date of passerines' – is further towards the type 4 end of the scale because it is a multi-species index and therefore more representative of wider biodiversity. The 'Proportion of large fish' is an index with a very strong link to a driver – the commercial fishery – and it is also considered to be representative of wider biodiversity because of the key importance of fish in that ecosystem: this is therefore a level 4 indicator.

There are a large numbers of typologies and categorisations for indicators in the literature but their utility is normally highly context dependent. A few of the more generally applicable ones are outlined below. By framing the concept of indicators differently, each can contribute to our overall understanding of them.

Rapport & Hildén (2013) discuss a typology of indicators with three categories: conceptual, legitimising and instrumental:

- **conceptual** indicators strengthen the cognitive basis for decisions and are primarily aimed at increasing knowledge of ecological components;
- **legitimising** indicators generate information used in arguments without actually influencing decisions and are aimed at environmental education (e.g. state of nature reporting); and
- **instrumental** indicators directly influence decisions and are designed to prevent further ecological damage.

In their estimation, most ecological indicators are either conceptual or legitimising with relatively few that are truly instrumental. This, they argue, is a serious shortcoming which needs to be addressed is ecological degradation is to be arrested or reversed.

McGeoch (1998) discusses three main classes of 'bioindicators': environmental, ecological and biodiversity:

- **environmental** indicators are species or groups of species which respond in easily observed and quantified ways to changes in environmental state;
- **ecological** indicators are species or groups of species which are sensitive to identified environmental stresses and whose *responses* to those stresses are characteristic of a larger group of taxa; and
- **biodiversity** indicators are groups of taxa whose diversity reflects some measure of diversity in a broader group, or different level of biodiversity organisation.

In McGeoch's typology, environmental indicators cover the classic use of taxa as proxy indicators for some environmental condition, e.g. using lichens to infer information about air pollution. The use of such proxies where direct measurement is feasible is pointless, but in some cases, e.g. because of the expense of equipment or cost of deployment, environmental indicators are useful. The key difference between ecological and environmental indicators is that ecological indicators reflect the *response* of biota to environmental state rather than being a direct reflection of the environmental state itself and this is the sense in which the general unqualified term 'indicator species' is often used. Biodiversity indicators are quite distinct from the other two because they produce a measure of diversity (therefore a single taxon cannot be used as an indicator in this sense).

3.2.3 Widely used 'indicator species' terminology

A number of terms used in the context of ecological indicators, or indicator species, are in common everyday use – as well as being frequently encountered in the scientific literature (Box 2).

Box 2. The meaning of some widely-used 'indicator species' terms.

Umbrella species: a species that is so demanding in its habitat and/or area requirements that satisfying those requirements will automatically benefit many other species (Simberloff 1998; Dale & Beyeler 2001). Umbrella species are normally the focus of conservation management with the idea that promoting management that favours them will also favour a suite of other species too. There is little empirical evidence to back the idea up, but it does seem like common sense. Umbrella species may or may not be charismatic species. See also flagship species.

Flagship species: a species that is used as the focus of a conservation campaign (Simberloff 1998). Like umbrella species, flagship species are usually also the focus for conservation management. Because of the 'campaigning' element, flagship species are almost always 'charismatic'. Flagship species are really tools for campaigning rather than monitoring, but some may be suitable for both.

Keystone species: a species that impacts on many others, sometimes to an extent which is disproportionately related to its numbers or biomass (Simberloff 1998). Keystone species differ from umbrella species because, unlike the latter, there are ecological dependencies between the keystone species and the species affected by it. With umbrella species, other species benefit incidentally as a result of conservation measures for the umbrella species. Underwood & Fisher (2006) proposed that ants should be used in monitoring programmes (particularly those tied to adaptive management regimes) because of their qualities as keystone taxa rather than any inherent 'indicator' qualities.

Ecological engineer species: species that significantly alter the structure of habitat to meet their own needs and, in so doing, benefit other species (Dale & Beyeler 2001). An example is the Beaver (*Castor fiber*). This is close to the keystone species concept, but the element of structural engineering is what separates them.

Focal species: a suite of species which each indicate different characteristics of landscape attributes, the full suite of which cover all desired landscape characteristics (Lambeck 1997). Note though that the term focal species is often used in many different ways, for example (Dale & Beyeler 2001) used it as a high-level term encompassing many of the other categories of indicators outlined here.

Link species: species which play a critical role in the transfer of energy or matter across trophic levels or are otherwise critical parts of the food web (Dale & Beyeler 2001).

Special interest species: a rather vague concept variously ascribed to species that are vulnerable, endangered or threatened, game species and charismatic species (Dale & Beyeler 2001).

Surrogate species: sometimes used as an equivalent to 'indicator species' or 'biological indicator'. However the terms 'surrogates' or 'surrogate taxa' are also used to describe aggregations of lower-order taxa like species into higher-level units, both taxonomic, e.g. genera and family, and non-taxonomic, e.g. morpho-species. When temporal and/or spatial patterns of surrogate taxa are thought to reflect those of the aggregated taxa, they can be a useful tool in monitoring programmes – reducing the level of identification precision required (Bevilacqua et al. 2013).

In terms of the typology of Gregory et al. (2005), umbrella species, focal species, keystone species, link species and ecological engineers would all score reasonably highly on the x-axis since they are considered to represent, in some way, a broader range of biodiversity. If their representativeness can be justified, these types of indicators might all be the subject of monitoring programmes. But note that each of these terms is loaded (with the concepts described above) and usually appeals to a specific part of the audience continuum described earlier. For example umbrella species appeal to land managers with the idea being that if the land is managed for the benefit of these species, then many other species will benefit too. It simplifies the practice of management because the land managers need only consider few species instead of very many.

Flagship species appeal to an audience concerned with campaigning and motivating rather than monitoring and, in terms of their utility for monitoring, they could fall anywhere in the typology of Gregory et al. (2005). Likewise special interest species and surrogate species refer to more general concepts and are therefore less useful terms.

Considering the large number of terms coined to describe different types of ecological indicators, there may, at first sight, seem to be remarkably few describing different types of environmental indicators (species that demonstrate a strong link to an environmental driver). But they do exist – e.g. climate change indicator (Chambers et al. 2005), pollution indicator etc – but their meanings are generally self-evident and less ambiguous.

3.3 Selection of indicators

There seems to be general agreement that there is a lack of consistency, rigour and transparency in the selection and application of indicators (McGeoch 1998; Niemeijer & de Groot 2008; van Strien et al. 2009; Rossi 2011).

McGeoch (1998) noted that most indicators are selected on the basis of some a-priori list of suitability criteria but suggested that this is rarely backed up with any objective testing of the indicator's suitability or performance. Table 1 suggests possible criteria drawn from many sources (see McGeoch [1998] for fully referenced sources) for use in the selection of species to be used as indicators.

Table 1. Suggested criteria for the selection of indicators from McGeoch (1998). Not all criteria are relevant for all indicators. The columns 'En', 'Ec' and 'B' indicate those criteria that are particularly relevant to environmental, ecological and biodiversity indicators respectively (as defined in McGeoch's typology). Those that can be assessed before trialling the indicator are marked in the 'a-priori' column. Those that are unmarked in the 'a-priori' column can usually only be assessed after the indicator is piloted. For a full list of original sources for the suggested criteria, consult McGeoch (1998).

Criterion	a-priori	En	Ec	B
Cost efficient and effective (time, funds, personnel)	*	*	*	*
Sampled and sorted easily	*	*	*	*
Adequate representation in samples	*	*	*	*
Be abundant	*	*	*	*
Ease and reliability of storage	*	*	*	*
Taxonomically well-known group, readily identified, taxonomic expertise readily available	*	*	*	*

Sampled individuals expendable	*	*	*	*
Spatial and temporal distribution predictable to ensure long-term continuity	*	*	*	*
Relatively independent of sample size				
Changes visible by remote sensing				
Baseline data on biology available	*	*	*	
Abundant autecological data	*			
Low genetic and functional variability	*	*		
Sufficiently sensitive to provide early warning		*		
Able to differentiate between natural cycles and trends and those produced by anthropogenic stress factor		*	*	
Representative of critical components, functions and processes		*	*	
Show a well-defined response, i.e. either (a) die or decrease, (b) change or mutate, (c) replace or be replaced by other species		*	*	
Be non-target species if to be used to monitor pesticides	*	*	*	
Readily accumulate pollutants		*		
Easily cultured in the laboratory	*	*		
Capable of providing continuous assessment over a wide range of stress		*		
Recognised importance to agriculture, environment etc.	*			
Economic importance as a resource or pest	*			
Representative of all trophic levels and major functional guilds				*
Matching with target group				*
Representative of related and unrelated taxa			*	*
Full range of body sizes and growth forms	*			
Tend to be distributed over range of habitats or environments	*			*
Information rich: representative distribution				*
Group should have species that are disjunct, and environmentally dispersed, in their distributions	*			*
Representatives from low-, medium- and high-diversity groups	*			*
Wide range of host-specificities	*			

Many of the criteria listed in Table 1 can be assessed prior to trialling an indicator but McGeogh asserts that several can only be assessed once the indicator has been piloted. McGeoch also argues that assessment of some criteria (e.g. representativeness for biodiversity indicators) are often not justified in a rigorous empirical manner. It is very often argued that many indicators held to be representative of wider biodiversity aren't empirically shown to be so (McGeoch 1998; Lindenmayer et al. 2000; A. J. van Strien et al. 2009). van Strien et al. (2009) noted that many indicators are not subject to rigorous enough testing or justification of their implied representativeness of wider biodiversity and they advocate that all such indicators should be considered as type 1 indicators (Gregory et al. 2005) until such justification is demonstrated.

Caughlan & Oakley (2001) present a framework for assessing the costs of monitoring and argue that the true cost of monitoring programs (and, by implication, indicator selection) are usually not adequately evaluated.

Niemeijer & de Groot (2008) reviewed the application of causal chain frameworks for the selection of indicators and recommended an enhanced DPSIR framework (eDPSIR) which, unlike the others, accounts more explicitly for the relationships between the indicators and the overall framework. They also extended the idea of a causal chain to a causal network, advocating a more hollistic approach to the process of selecting indicators – especially in reference to the overall causal network within which they sit.

The selection criteria and evaluation frameworks for indicators discussed above have been developed largely within a scientific paradigm, but Turnhout et al. (2007) characterise the operating space of normative ecological indicators as being the boundary between science and policy (we tend to call them 'headline indicators'). Normative ecological indicators can only be effective if they operate within both scientific *and* policy paradigms. Evaluation of actual and potential indicators must therefore take this into account. Turnhout et al. (2007) advocate the incorporation of stakeholder perspectives (in addition to scientific perspectives) in the selection and evaluation of ecological indicators.

Monks & Wright (2013) describe a high-level process taken in New Zealand to select a list of indicator taxa for monitoring trends in widespread taxa. This was conducted by employing a process of 'expert elicitation' (Barnard & Boyes 2013) to identify and evaluate taxa against the list of criteria identified in Table 2.

Table 2. Criteria used in the selection of widespread native taxa to act as indicators as part of New Zealand's national indicator framework. After Monks & Wright (2013).

Biological attribute	Explanation
Well-known biology	Understanding the factors influencing a population indicator is important for understanding its relationship with a particular threat process and its potential ability to indicate trends in other populations.
Relatively high abundance	High abundance is useful for achieving a statistically robust, cost-effective sample.
Easy to locate, identify and monitor in the field	Species that can be monitored relatively easily and reliably give confidence in data and are likely to be more cost-effective than alternatives.
Clearly measurable	It is important to be able to repeatedly collect relevant demographic data for the indicator species (e.g. abundance, size, growth, structure or frequency) in order to evaluate population trends.
Geographical attribute	**Explanation**
Resident within the ecosystem of interest prior to environmental change	Resident species are subject to sustained environmental pressure and will usually make the best indicators. However, migratory species may be useful in specific situations.
Sensitive to environmental change within the period of measurement	A species should be sensitive, though not hypersensitive, to environmental change and respond rapidly and predictably to it. This enables a population to act as an early warning of disturbance and inform decisions about mitigation of a threat.
Occurs on a scale relevant to the threat process	The scale on which a species occurs (mobility, home range size) should be considered relative to the threat process.

Widespread	The chosen indicator species should be widespread (as opposed to localised) within a broad habitat type in order to indicate processes operating throughout the area.

Criteria reflecting whether or not taxa already had a history of monitoring were deliberately left out to avoid repeating biases in focal species. 251 taxa and 50 ecological groups[1] were initially identified as candidates for selection. Some taxonomic groups were excluded from the lists of candidate taxa/groups because biological knowledge of them (one of the main selection criteria) was poor (e.g. bryophytes). To make the final selection, 18 experts (from across the taxonomic groups) numerically rated each candidate taxa/group based on each selection criteria. Those with the highest scores were the best candidates, but the authors note that when making the final selection of indicators, priority was given to achieving representation of taxonomic group, environment, pressures and functional role. The selection process resulted in 106 taxa or groups of ecologically equivalent taxa being identified as a minimum set of indicators (Table 3).

Table 3. Representativeness of 80 taxa and 26 groups of ecological equivalents selected as a minimum set of indicators of trends in widespread taxa in New Zealand. After Monks & Wright (2013).

Biodiversity facet	Representation
Environment	Marine (18 taxa or groups)
	Terrestrial (56 taxa or groups)
	Freshwater (35 taxa or groups)
Broad ecosystem types	Alpine (6 taxa or groups)
	Coastal terrestrial coastal marine (13 taxa or groups)
	Deepwater (5 taxa or groups)
	Estuaries (12 taxa or groups)
	Forest (26 taxa or groups)
	Freshwater (17 taxa or groups)
	Rivers/gravels (8 taxa or groups)
	Shrubland (10 taxa or groups)
	Tussock grasslands (4 taxa or groups)
Taxonomic group	Bats (2 taxa)
	Birds (26 taxa or groups)
	Freshwater fish (4 taxa)
	Freshwater invertebrates (1 taxon)
	Herpetofauna (12 taxa or groups)
	Marine fish (4 taxa)
	Marine invertebrates (9 taxa)
	Marine mammals (2 taxa),
	Vascular plants (38 taxa; of which 24 were terrestrial and 14 aquatic)
	Terrestrial invertebrates (8 taxa or groups)
Functional roles	Ecosystem engineers (13 taxa or groups),
	Mid-trophic species (37 taxa or groups),
	Pollinator and/or seed disperser (12 taxa or groups)
	Primary consumer (7 taxa or groups),
	Primary producer (30 taxa or groups)
	Top predator (7 taxa or groups)

[1] Ecological groups were geographically restricted taxa considered to be ecologically equivalent and which, considered as a group, give adequate geographic spread

A strategic approach to the selection of headline indicators like that described for New Zealand is comparatively rare. Normally a more pragmatic approach is taken whereby indicators already in use for scientific surveillance and monitoring are pressed into use as strategic headline indicators. Consider the UK headline biodiversity indicators (Table 5). This indicator suite was, effectively, cobbled together from existing indicators, e.g. those of the British Trust for Ornithology. A strategic approach was also taken by Switzerland and was commented on by Hockley et al. (2009) in their excellent review of UK biodiversity indicators and recommendations for a Wales biodiversity indicator set.

Recently the Group on Earth Observations Biodiversity Observation Network (GEO BON) has proposed the development of a suite of Essential Biodiversity Variables (EBVs) as the basis for a new framework to facilitate the development of biodiversity indicators towards assessing progress on the Aichi 2020 targets (Pereira et al. 2013). This is a new approach for biodiversity monitoring but the concept is based on that of Essential Climate Variables (ECVs), which has been very successful in the Global Climate Observing System (GCOS). The EBV framework is designed to facilitate the development of indicators that fit within the 'state' and 'impact' regions of the DPSIR framework and has been embraced by the Convention on Biological Diversity (Walters et al. 2013). Figure 5 shows the position of EBVs within the wider biodiversity monitoring framework.

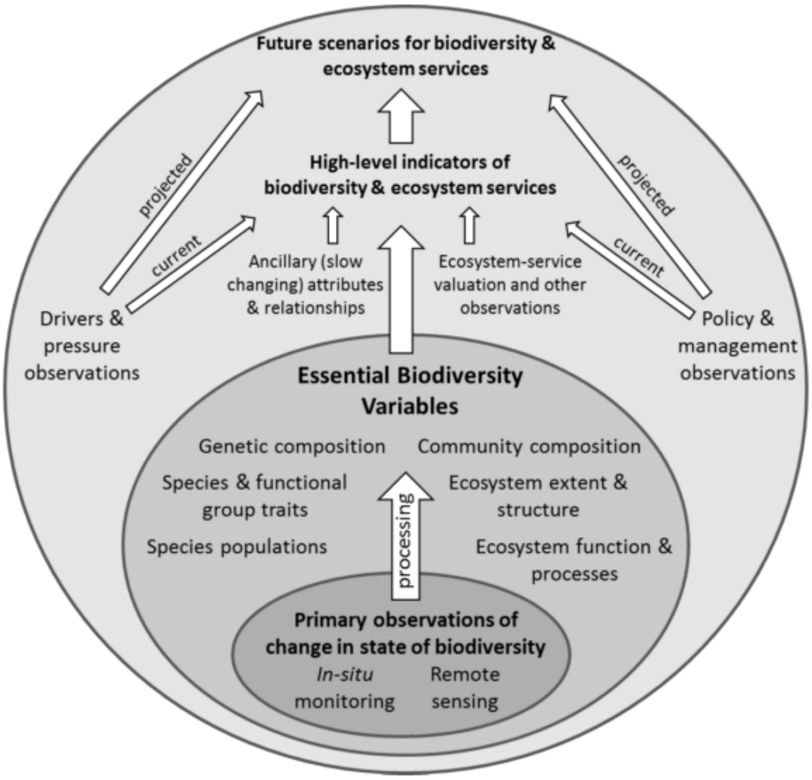

Figure 5. The Essential Biodiversity Variables framework. Primary observations from in situ monitoring and remote sensing systems are pre-processed and combined into EBVs, which bridge the space between primary measurements and indicators. From Walters et al. (2013).

A group of 22 EBVs, grouped into six major categories, has been proposed (Table 4) and is undergoing consultation and development during 2013 (Walters et al. 2013).

Table 4. The 22 proposed EBVs falling into six categories covering composition, structure and function of both species (genetic composition, species populations, species traits), and ecosystems (community composition, ecosystem structure, ecosystem function). After Walters et al. (2013).

EBV Class	Essential Biodiversity Variable
Genetic composition	Allelic diversity
	Co-ancestry
	Population genetic differentiation
	Breed and variety diversity
Species populations	Species distribution
	Population abundance
	Population structure by age/size class
Species traits	Phenology
	Body mass
	Natal dispersal distance
	Migratory behaviour
	Demographic traits
	Physiological traits
Community composition	Taxonomic diversity
	Species interactions
Ecosystem structure	Habitat structure
	Ecosystem extent and fragmentation
	Ecosystem composition by functional type
Ecosystem function	Net primary productivity
	Secondary productivity
	Nutrient retention
	Disturbance regime

Walters et al. (2013) state that: "*Essential Biodiversity Variables represent a minimal set of fundamental observations needed to support multi-purpose, long-term biodiversity information needs at various scales.*" They are positioned between raw biodiversity data collected from primary sources and the biodiversity indicators that those data inform. Defining a minimal set of EBVs has the potential to help us be more strategic about the collection of primary data and ensure that we get the most out of those data in terms of the number of biodiversity indicators they can contribute to. Figure 6 illustrates how a single EBV – in this case 'species abundance' – can contribute to many different 'operational' and 'headline' biodiversity indicators.

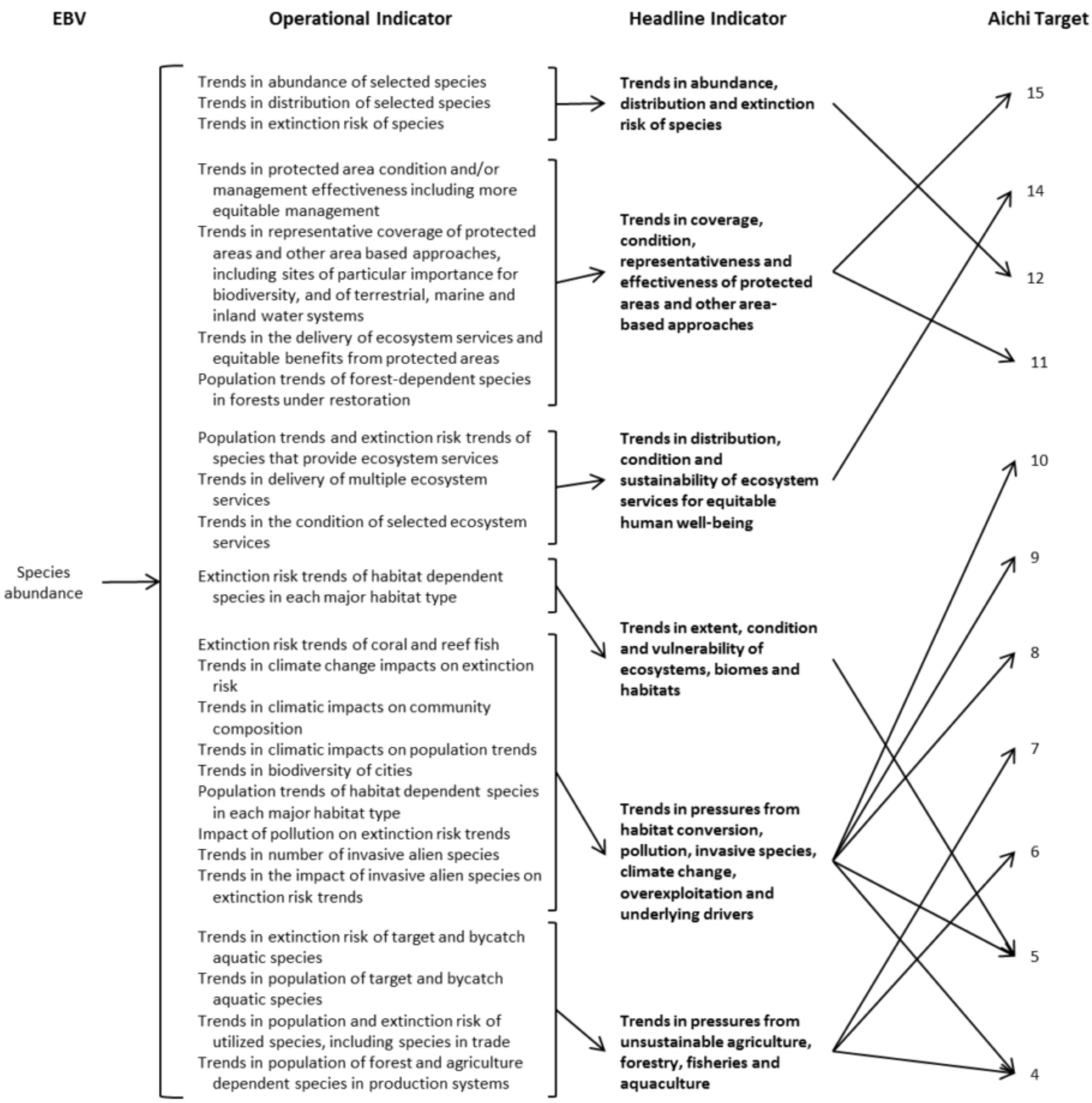

Figure 6. An illustration of how EBVs may be combined with other variables to derive multiple high-level indicators used to measure progress against multiple targets. In this example the EBV 'species abundance' feeds into 24 indicators used to derive the headline indicators for monitoring progress towards 11 of the Aichi biodiversity targets. After Walters et al. (2013).

4 Headline biodiversity indicators

4.1 UK headline biodiversity indicators

There are currently 24 UK Biodiversity 'headline' indicators adopted by Defra (JNCC 2013). Headline indicators are normative indicators that operate at the boundary of science and policy. Each of the UK headline indicators is linked to one of five 'strategic goals' (Table 5). The indicators cover all elements of the DPSIR framework with a particular emphasis on state and response, probably because these elements are the easiest to measure using existing metrics and monitoring programmes. Within the context of the Tomorrow's Biodiversity project, we are particularly interested in indicators measuring state and impact since these are where biological records and data on habitat extent and condition are directly applicable.

Table 5. UK headline biodiversity indicators and their component measures. The indicators are grouped by strategic goals. The 'type' of each indicator – with reference to the DPSIR framework – is also indicated. This column also indicates if an indicator is still under development. Any indicator which relies, to some extent, on biological records or records of habitat condition are indicated in the final column together with the sources (organisations) from which the data are sourced (sources expanded in Appendix A). After JNCC (2013).

Goal A - Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society		
Indicator (and component measures)	**Type**	**Species/habitats, notes & sources**
A1. Awareness, understanding and support for conservation	Response (under devel)	
A2. Taking action for nature: volunteer time spent in conservation	Response	
A3. Value of biodiversity integrated into decision making	Response (under devel)	
A4. Global biodiversity impacts of UK economic activity / sustainable consumption	Driver (under devel)	
A5. Integration of biodiversity considerations into business activity	Response (under devel)	
Goal B - Reduce the direct pressures on biodiversity and promote sustainable use		
Indicator (and component measures)	**Type**	**Species/habitats, notes & sources**
B1. Agricultural and forest area under environmental management schemes B1a. Area of land in agri-environment schemes B1a(i). Higher-level / targeted schemes B1a(ii). Entry-level type schemes B1b. Area of forestry land certified as sustainably managed	Response	
B2. Sustainable fisheries	Pressure	
B3. Climate change adaptation	Impact (under devel)	One measure may be extent of coastal habitats (e.g. saltmarsh)
B4. Pressure from climate change	Impact	Phenology of limited taxa relying on limited biological records. UKPN
B5. Pressure from pollution B5a. Air pollution B5a(i). Area affected by acidity B5a(ii). Area affected by nitrogen B5b. Marine pollution	Pressure	
B6. Pressure from invasive species B6a. Freshwater invasive species B6b. Marine invasive species B6c. Terrestrial invasive species	Pressure / State	Relies heavily on biological records of invasive species. CEH, MBA, BTO & NBN
B7. Water quality	State	Biological records used in standard freshwater ecological condition assessment. EA
Goal C - Improve the status of biodiversity by safeguarding ecosystems,		

species and genetic diversity		
Indicator (and component measures)	**Type**	**Species/habitats, notes & sources**
C1. Protected areas C1a. Total area of protected areas: on land C1b. Total area of protected areas: at sea C1c. Condition of A/SSSIs	State / Response	Involves habitat condition monitoring by national agencies (measure C1c).
C2. Habitat connectivity C2a. Broad-leaved, mixed and yew woodland C2b. Neutral grassland	State	
C3. Status of habitats of European importance	State	Involves habitat condition monitoring by national agencies
C4. Status of threatened species C4a. Status of priority species C4b. Status of species of European importance	State	Requires biological records for priority species (including some formal monitoring). BCT, BTO, BC, CEH, Defra, JNCC, PTES, Roth, RSPB, BWARS, HRS, ORS, BDS
C5. Birds of the wider countryside and at sea C5a. Farmland birds C5b. Woodland birds C5c. Wetland birds C5d. Seabirds C5e. Wintering waterbirds	State	Requires biological records for birds within the framework of formal monitoring. BTO, JNCC and RSPB
C6. Insects of the wider countryside (butterflies) C6a. Semi-natural habitat specialists C6b. Species of the wider countryside	State	Currently butterflies only. Requires biological records (including some formal monitoring). BC & CEH
C7. Plants of the wider countryside C7a. Change in plant species richness (arable and horticultural land) C7b. Change in plant species richness (woodland and grassland) C7c. Change in plant species richness (boundary habitats)	State	Assessed through vascular plant biological records within the strict monitoring framework of the periodic Countryside Survey. CEH
C8. Mammals of the wider countryside (bats) C8a. Bat populations C8b. Historical pipistrelle bat roost counts	State	Currently bats only. Requires biological records (including formal monitoring). BCT
C9. Genetic resources for food and agriculture C9a. Animal genetic resources C9a(i). Native sheep breeds C9a(ii). Native cattle breeds C9b. Plant genetic resources - Enrichment Index	State / Response	Measure C9b includes measurement of accessions to biological collections which involves biological recording to a limited extent. Various academic sources
Goal D - Enhance the benefits to all from biodiversity and ecosystems		
Indicator (and component measures)	**Type**	**Species/habitats, notes & sources**
D1. Biodiversity and ecosystem services (marine – fish size classes in the North Sea)	State	
D2. Biodiversity and ecosystem services (terrestrial)	State / Impact (under devel)	Measures being considered include indices of bumblebee and other pollinator species abundance and diversity which will require biological records – some of which may be within the framework of new formal monitoring

Goal E - Enhance implementation through planning, knowledge management and capacity building		
Indicator (and component measures)	**Type**	**Species/habitats, notes & sources**
E1. Biodiversity data for decision making	Response (under devel)	May include metrics depending on biological records
E2. Expenditure on UK and international biodiversity E2a. Expenditure on UK biodiversity E2b. UK Expenditure on international biodiversity	Response	

Of particular interest are indicators which are based on the abundance and distribution of animals and plants or the extent and condition of habitat. Most of the UK headline biodiversity indicators were adopted, or adapted, from extant surveillance or monitoring programmes. The UK headline biodiversity indicators were not selected on the basis of a strategic planning exercise such as that described by Monks & Wright (2013) for New Zealand or assessed against the typology of Gregory et al. (2005) (Figure 3). As a result there are significant taxonomic gaps in their coverage. (The issue of coverage will be revisited later in the document.)

4.2 National–level headline biodiversity indicators

In the UK, responsibility for biodiversity is devolved to the four countries, England, Wales, Scotland and Northern Ireland and each country is developing separate biodiversity strategies and suites of indicators to monitor them. The biodiversity indicators in these national sets are, to some degree, geographically restricted versions of those used at the UK level. The relationships between these emerging sets of indicators is still evolving.

In England there is a suite of indicators that measure progress against England's Biodiversity 2020 strategy (Defra 2013a). Rather confusingly, there is another set called the England Natural Environment Indicators (ENEI) which specifically track progress on the 2011 Natural Environment White Paper (Defra 2013b). While there is considerable overlap between these two suites of indicators, there are also important differences, even in the vocabulary used to contextualise and group them. For example the Biodiversity 2020 set has 'indicators' grouped by 'themes' and the ENEI has 'measures' grouped by 'indicators'; the Biodiversity 2020 terms 'theme' and 'indicator' are equivalent to the ENEI terms 'indicator' and 'measure' respectively. This is a confusing use of terminology which is indicative of a current lack of joined-up thinking and coordination between the various UK biodiversity indicator sets.

Table 6. England Biodiversity 2020 indicators. The indicators are grouped by 'strategy' (in the black rows), themes and indicators. The 'Cross-ref' column indicates a relationship with indicators in the UK Biodiversity Indicator set. Indicators which rely, to some extent, on biological records or records of habitat condition are indicated in the final column together with the sources (organisations) from which the data are sourced (sources expanded in Appendix A). After Defra (2013a).

A more integrated, large-scale approach to conservation on land and at sea		
Themes and indicators	**Cross-ref**	**Species/habitats, notes & sources**
1. Extent and condition of protected areas and local sites • Extent of protected areas on land	C1. Except local sites	SSSIs in favourable condition involves habitat condition monitoring by national agencies.

• Extent of protected areas at sea • Sites of Special Scientific Interest in favourable condition • Local sites under positive management		Local sites under positive management involves reporting from Local Authorities which may or not involve collection of biological records & habitat data.
2a. Extent and condition of priority habitats • Extent of priority habitats • Condition of priority habitats	C3	
2b. Status of habitats of European importance • Percentage of UK habitats of European importance in favourable or improving conservation status	C3	Involves habitat condition monitoring by national agencies.
3. Habitat connectivity in the wider countryside • Broadleaved mixed and yew woodland • Neutral grassland	C2	Mostly through data from Countryside Survey. CEH
4a. Status of priority species • Change in status of priority species	C4	Requires biological records for priority species (including some formal monitoring). BCT, BTO, BC, CEH, Defra, JNCC, PTES, Roth, RSPB, BWARS, HRS, ORS, BDS, WWT
4b. Status of species of European importance • Percentage of UK species of European importance in favourable or improving conservation status	C4	Requires biological records for priority species (including some formal monitoring). Compiled from data compiled by JNCC for Habitats directive reporting (which relies on other unnamed data providers).
5. Species in the wider countryside: farmland • Breeding farmland birds • Butterflies of the wider countryside on farmland • Bat populations • Historical pipistrelle bat populations • Plant diversity – enclosed farmland • Plant diversity – neutral grassland and boundary habitats	C5, C6, C7 & C8	Requires biological records, mostly within the framework of formal monitoring. The plant diversity measures are derived from the Countryside Survey. BTO, JNCC, RSPB, BC, BCT, CEH
6. Species in the wider countryside: woodland • Woodland birds • Butterflies of the wider countryside in woodland • Plant diversity – woodlands and hedgerows	C5 & C7	Requires biological records, mostly within the framework of formal monitoring. The plant diversity measures are derived from the Countryside Survey. BTO, JNCC, RSPB, BC, CEH
7. Species in the wider countryside: wetlands • Breeding water and wetland birds • Wintering waterbirds	C5	Requires biological records, mostly within the framework of formal monitoring. BTO, JNCC, WWT
8. Species in the wider marine environment • Breeding seabirds	C5	Requires biological records, mostly within the framework of formal monitoring. BTO, JNCC, RSPB
9. Biodiversity and ecosystem services: terrestrial habitats	D2	

• To be developed		
10. Biodiversity and ecosystem services: species • To be developed	D2	Likely options include Bumblebee abundance and Hoverfly and wild bee diversity. The indicator will require biological records. Probably BWARS
11. Biodiversity and ecosystem services: marine • Marine ecosystem integrity (size of fish in North Sea)	D1	
12a. Effective population size of sheep and cattle breeds • Native sheep breeds • Native cattle breeds	C9	
12b. Plant genetic resources • Cumulative Enrichment Index	C9	Includes measurement of accessions to biological collections which involves biological recording to a limited extent. Various academic sources
Putting people at the heart of biodiversity policy		
Themes and indicators	**Cross-ref**	**Species/habitats, notes & sources**
13. Public use and enjoyment of the natural environment • Proportion of population visiting the natural environment several times a week	A1? (A1 is under development)	
14. Taking action for the natural environment • Conservation volunteering • Proportion of households undertaking wildlife gardening	A2. Except wildlife gardening	
15. Funding for biodiversity in England • Public sector expenditure on biodiversity	E2	
16. Integrating biodiversity considerations into local decision making • To be developed	A3	
17. Global impacts of UK consumption • To be developed	A4	
Reducing environmental pressures		
Themes and indicators	**Cross-ref**	**Species/habitats, notes & sources**
18. Climate change impacts and adaptation • Timing of biological events – Spring Index	B3, B4	Phenology of limited taxa relying on limited biological records. UKPN
19. Trends in pressures on biodiversity: Pollution • Area affected by Sulphur (acidity) Area • Area affected by nitrogen deposition • Marine pollution: combined input of hazardous substances	B5	
20. Trends in pressures on biodiversity: invasive species • Terrestrial species • Freshwater species • Marine species	B6	Relies heavily on biological records of invasive species. CEH, MBA, BTO & NBN
21. Trends in pressures on biodiversity: Water quality • Proportion of rivers classified as 'high' or 'good' status for biological status in the WFD	B7	Biological records used in standard freshwater ecological condition assessment. EA
22. Agricultural and forest area under environmental	B1. Except for	

management schemes • Targeted agri-environment schemes • Entry-level agri-environment schemes • Uptake of priority ELS options • Percentage of woodland certified as sustainably managed	uptake of priority ELS options.	
23. Sustainable fisheries • Percentage of fish stocks harvested sustainably	B2	
Improving knowledge		
Themes and indicators	**Cross-ref**	**Species/habitats, notes & sources**
24. Biodiversity data and information for decision making • **To be developed**	E1	

There are very few real differences between the UK biodiversity indicator set and the England Biodiversity 2020 indicators. The only state/impact indicator in the England indicators that is not represented in the UK set is 'Local sites under positive management'. There are no state/impact indicators in the UK set which are not also reflected in the England indicators.

Table 7. England Natural Environment Indicators (ENEI). The indicators are split into several component measures. The 'Cross-ref' column indicates relationships with indicators in the England Biodiversity 2020 Indicator set (B2020) and indicators in the UK Biodiversity Indicator set (UK). Indicators which rely, to some extent, on biological records or records of habitat condition are indicated in the final column together with the sources (organisations) from which the data are sourced (sources expanded in Appendix A). After Defra (2013b).

All indicators		
Indicators and measures	**Cross-ref**	**Species/habitats, notes & sources**
1. Species in the Wider Countryside • Breeding farmland birds • Butterflies of the wider countryside on farmland • Widespread bats • Breeding wetland birds • Wintering water birds • Breeding woodland birds • Butterflies of the wider countryside in woodland • Breeding seabirds	B2020 4a. UK C5, C6 & C8.	Requires biological records, mostly within the framework of formal monitoring. BTO, JNCC, RSPB, BC, BCT
2. River Water Quality • Proportion of rivers with biological quality classed as good or high • Proportion of rivers that pass on chemical status	B2020 21. UK B7. Except chemical status.	Biological records used in standard freshwater ecological condition assessment. EA
3. Marine Ecosystem Integrity • Fish size class • Marine Litter	B2020 11. UK D1. Except marine litter.	
4. Priority species and habitats • Number of priority species that are stable or increasing • Number of priority habitats that are stable or increasing	B2020 2a & 4a. UK C3 & C4.	Requires biological records for priority species (including some formal monitoring). BCT, BTO, BC, CEH, Defra, JNCC, PTES, Roth, RSPB, BWARS, HRS, ORS, BDS,

		WWT
5. Land Use • Land Use (context) • Development on undeveloped land • Percentage of woodland in active management		
6. Natural Stocks • Sustainable fisheries • Water abstraction • Forest carbon stock • Soil carbon concentration	B2020 23 & 9 (? under devel). UK B2 D2 (? under devel). Except abstraction.	
7. Raw Material Consumption • Raw material consumption		
8. National Environmental Accounts • National environmental accounts		
9. Integrating biodiversity and natural environment considerations into business activity • Integrating biodiversity and natural environment considerations into business activity		
10. Public Engagement with the Natural Environment • Proportion of people visiting the natural environment several times or more a week • Number of visits made by children • Conservation volunteering	B2020 13 & 14. UK A1 (? under development) & A2	
11. Ease of access to local woodland, green space and countryside • Ease of access to all green space		
12. Environmental Quality and Health • Number of air pollution days classed as moderate or higher: urban • Number of air pollution days classed as moderate or higher: rural • Mortality caused by anthropogenic air pollution • Percentage of people affected by noise		
13. International and EU • Not assessed		

There are considerable differences between the England Natural Environment Indicators (ENEIs) and both the England Biodiversity 2020 Indicators and the UK Biodiversity Indicators. That is mainly because the scope of the ENEIs is wider than biodiversity. Limiting the comparison to those ENEIs that are specifically biodiversity related reveals that there are no biodiversity state/impact ENEIs that are not also represented in the other two sets.

Table 8. Welsh biodiversity indicators from the Wales State of the Environment indicator set. These are all of the indicators in the theme 'Distinctive Biodiversity, Landscapes & Seascapes'. Other themes from the Wales State of the Environment indicator set are not included in the table. The indicators are grouped by outcomes. The 'Cross-ref' column indicates a relationship with indicators in the UK Biodiversity Indicator set. Indicators which rely, to some extent, on biological records or records of habitat condition are indicated in the final column together with the sources (organisations) from which the data are sourced (sources expanded in Appendix A). After Statistics for Wales (2012).

Distinctive Biodiversity, Landscapes & Seascapes theme		
Outcomes and indicators	**Cross-ref**	**Species/habitats, notes & sources**
19: The loss of biodiversity has been halted and we can see a definite recovery in the number, range and genetic diversity of wildlife, including those species that need very specific conditions to survive 19a: Trends in Biodiversity Action Plan species and habitats 19b: Trends in wild birds population index	C4 & C5.	Requires biological records for priority species (including some formal monitoring). BCT, BTO, BC, CEH, Defra, JNCC, PTES, Roth, RSPB, BWARS, HRS, ORS, BDS. Involves habitat condition monitoring by national agencies.
20: The wider environment is more favourable to biodiversity through appropriate management, reduced habitat fragmentation and increased extent and interconnectivity of habitats 20a: Proportion of land under agri-environment agreement (by scheme), or which is organic or which is in conversion to organic 20b: Proportion of woodland that is certified 20c: Additional indicators to be identified following completion of research into biodiversity indicators (under development)	B1	Partly under development.
21: Sites of international, Welsh and local importance are in favourable condition to support the species and habitats for which they have been identified 21: Percentage of features on Natura 2000 sites in favourable or recovering condition	No direct equivalent.	Involves habitat condition monitoring by national agencies.
22: Our seas will be clean and support healthy ecosystems that are biologically diverse and productive and managed sustainably 22a: Indicators, including coastal zone indicators, to be reviewed in the context of progress of the Marine Bill (under development) 22b: Number of Marine stewardship council certified sustainable fisheries in Welsh waters 22c: Number of fisheries assessed by ICES (International Council for the Exploration of the Sea) and Sea Fisheries Committees to be in safe biological condition - based on stock assessments, fish catches and catch per unit effort (under development) 22d: Input of hazardous substances to the marine environment 22e: Trends in seabird population index	Related to B2, but measured differently. C5 is equivalent to 22e.	Mostly under development. 22e requires biological records for birds within the framework of formal monitoring. JNCC
23: The quality and diversity of the natural and historic character of our landscape and seascape is maintained and enhanced 23: Indicators, measuring quality and diversity,	No direct equivalent.	Under development. Will be assessed through remotely sensed data.

to be selected on completion of CCW landscape characterisation work (under development)		

There is much less overlap between the Welsh biodiversity indicators and the UK biodiversity indicator set than there is between England's biodiversity indicators and the UK set.

Table 9. Scotland's Biodiversity Strategy Indicators. The indicators are split into two sets – those reflecting state and those reflecting engagement. Only the state indicators are presented in this table. The 'Cross-ref' column indicates a relationship with indicators in the UK Biodiversity Indicator set. Indicators which rely, to some extent, on biological records or records of habitat condition are indicated in the final column together with the sources (organisations) from which the data are sourced (sources expanded in Appendix A). Compiled from Scottish Natural Heritage (2013).

Biodiversity State Indicators		
Indicator	**Cross-ref**	**Species/habitats, notes & sources**
S01 Status of biodiversity action plan (BAP) priority species	C4	Requires biological records for priority species (including some formal monitoring). BCT, BTO, BC, CEH, Defra, JNCC, PTES, Roth, RSPB, BWARS, HRS, ORS, BDS
S02 Status of biodiversity action plan (BAP) priority habitats	Much in common with C3	Involves habitat condition monitoring by national agencies
S03 Abundance of terrestrial breeding birds	C5	Requires biological records for birds within the framework of formal monitoring. BTO, JNCC and RSPB
S04 Abundance of wintering waterbirds	C5 (specifically C5c)	Requires biological records for birds within the framework of formal monitoring. BTO
S05 Abundance of breeding seabirds	C5 (specifically C5d)	Requires biological records for birds within the framework of formal monitoring. SMP
S06 Vascular plant diversity	C7	Assessed through vascular plant biological records within the strict monitoring framework of the periodic Countryside Survey. CEH
S07 Woodland diversity	No direct equivalent	Includes biological records collected through formal survey. NIWT
S08 Terrestrial insect abundance: Butterflies	C6	Requires biological records (including some formal monitoring). BC & CEH
S09 Terrestrial insect abundance: Moths	No direct equivalent	Requires biological records (including some formal monitoring). BC & Roth
S10 Notified species in favourable condition	No direct equivalent	Supported by biological records collected/collated to support Common Standards Monitoring. Data from various sources
S11 Notified habitats in favourable condition	No direct equivalent	Involves habitat condition monitoring by national agencies
S12 Otter	No direct	Requires biological records. VWT

	equivalent	& SNH
S13 Freshwater macroinvertebrate diversity	An aspect of B7.	Requires biological records. SEPA
S14 Marine plankton	No direct equivalent	
S15 Estuarine fish	No direct equivalent	Requires biological records. SEPA
S16 Commercially exploited fish stocks	B2	
S17 Non native species	B6	Requires biological records from many sources including, for example, BSBI & BOU

The Scottish Biodiversity Indicator set includes a number of indicators not represented in the UK Biodiversity Indicator set, for example the abundance of moths and the diversity of woodland.

Table 10. Biodiversity indicators for the Northern Ireland Biodiversity Strategy. The indicators are from a larger set covering other aspects of the environment. Only those listed specifically as 'biodiversity indicators' are included in the table. The 'Cross-ref' column indicates a relationship with indicators in the UK Biodiversity Indicator set. Indicators which rely, to some extent, on biological records or records of habitat condition are indicated in the final column together with the sources (organisations) from which the data are sourced (sources expanded in Appendix A). After Northern Ireland Department of the Environment (2013).

Biodiversity indicators		
Indicator	**Cross-ref**	**Species/habitats, notes & sources**
Nature Conservation Designations • Area of Nature Conservation Designations	C1	
Conditions of features in ASSIs • Condition of features within Areas of Special Scientific Interest (ASSI)	No direct equivalent	Supported by biological records collected/collated to support Common Standards Monitoring. Data from various sources
Wild birds • Wild bird populations	C5	Requires biological records for birds within the framework of formal monitoring. BTO, JNCC and RSPB
Wetland birds • Wetland bird populations	C5 (specifically C5c)	Requires biological records for birds within the framework of formal monitoring. BTO
Sites of Local Nature Conservation Importance • Number of Sites of Local Conservation Importance (SLNCI) adopted or proposed in area plans	No direct equivalent	
Tree Preservation Orders • Number of confirmed Tree Preservation Orders (TPO)	No direct equivalent	
Priority habitats • Trend for priority Biodiversity Action Plan habitats	Much in common with C3	Involves habitat condition monitoring by national agencies
Seals • Strangford Lough common seal population, adult and pups	No direct equivalent	Biological records of common seals. NIEA

This report contains some copyrighted information and, consequently, you may only use it for non-commercial research or private study.

Compared to other national-level biodiversity indicator sets and the UK Biodiversity Indicator set, the Northern Ireland biodiversity indicators are very restricted and show every sign of having been developed on an ad hoc basis depending on the available data.

4.3 European and global headline biodiversity indicators

It is useful to view the UK headline biodiversity indicators within the context of European and world headline indicators. Table 11 lists the latest European biodiversity headline indicators, developed and reviewed under a process called Streamlining European Biodiversity Indicators (SEBI).

Table 11. European biodiversity indicators (SEBI 2010) grouped by CBD focal areas. After European Environment Agency (2012).

EU Headline Indicator	SEBI 2010 Indicator
Trends in the abundance and distribution of selected species	1. Selected species groups a. Birds b. Butterflies
Change in status of threatened and/or protected species	2. IUCN red list of European species
	3. Change in status of species of European interest
Trends in extent of selected biomes, ecosystems and habitats	4. Trends in the extent of selected ecosystems in Europe
	5. Change in the status of habitats of European interest
Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance	6. Livestock genetic diversity
Coverage of protected areas	7. Nationally designated protected area
	8. Sites designated under the EU habitats and Birds Directive
Nitrogen deposition	9. Critical load exceedence for nitrogen
Trends in invasive alien species (numbers and costs of invasive alien species)	10. Invasive alien species
Impact of climate change on biodiversity	11. Impact of climate change on bird populations
Marine Trophic Index	12. Marine trophic index of European seas
Connectivity/fragmentation of ecosystems	13. Fragmentation of natural and semi-natural areas
	14. Fragmentation of river systems
Water quality in aquatic ecosystems	15. Nutrients in transitional, coastal and marine waters
	16. Freshwater quality
Area of forest, agricultural, fishery and aquaculture ecosystems under sustainable management	17. Forest: growing stock, increment and felling
	18. Forest: deadwood
	19. Agriculture: nitrogen balance
	20. Agriculture: area under management practices potentially supporting biodiversity
	21. Fisheries: European commercial fish stocks
	22. Aquaculture: effluent water quality from finfish farms
Ecological Footprint of European countries	23. Ecological footprint of European countries

Percentage of European patent applications for inventions based on genetic resources	24. Patent applications based on genetic resources
Funding to biodiversity	25. Financing of biodiversity management
Public awareness and participation	26. Public awareness

Feest (2013) compared the UK headline indicators with the European ones, noting that although the EEA indicators are a pragmatic approach to monitoring biodiversity, they lack organism or species approaches which, he argues, could be implemented at the country level. Feest also points out the lack of representation of freshwater biodiversity in the EEA set and the limited representativeness of the direct indicators of biodiversity (indicators 1-3), in particular the lack of any indicators directly relating to plant biodiversity.

Table 12. Global biodiversity indicators. Note that many of the indicators are including in more than one CBD Ad Hoc Technical Group headline. After Biodiversity Indicators Partnership (2013).

CBD Ad Hoc Technical Expert Group headline	Indicator
Trends in extent, condition and vulnerability of ecosystems, biomes and habitats	Red List Index
	Extent of forests & forest types
	Extent of marine habitats
	Area of forest under sustainable management: degradation & deforestation
	Forest fragmentation
	River fragmentation & flow regulation
Trends in abundance, distribution and extinction risk of species	Red List Index
	Living Planet Index
	Wild Bird Index
	Wildlife Picture Index
Trends in genetic diversity of species	Ex-situ crop collections
	Genetic diversity of terrestrial domesticated animals
Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture	Ecological Footprint
	Status of species in trade
	Wild Commodities Index
	Red List Index
	Living Planet Index
	Wild Bird Index
	Marine Trophic Index
	Proportion of fish stocks in safe biological limits
	Ocean Health Index
	Cumulative human impacts on marine
Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation and underlying drivers	Wild Commodities Index
	Red List Index

	Living Planet Index
	Wild Bird Index
	Water Quality Index for Biodiversity
	Trends in invasive alien species
	Nitrogen deposition
	Loss of reactive nitrogen to the environment
	Ocean Health Index
	Cumulative human impacts on marine ecosystems
Trends in distribution, condition and sustainability of ecosystem services for equitable human well-being	Red List Index
	Biodiversity for food & medicine
	Health & wellbeing of communities directly dependant on ecosystem goods & services
	Nutrition indicators for biodiversity
Trends in awareness, attitudes and public engagement in support of biological diversity and ecosystem services	Biodiversity Barometer
Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives	Trends in invasive alien species
	Area of forest under sustainable management: certification
	Area of agricultural ecosystems under sustainable management
	Number of MCS certified fisheries
	Status of NBSAPS
Trends in access and equity of benefit sharing of genetic resources	Ratification status of the Nagoya Protocol
Trends in accessibility of scientific/technical/traditional knowledge and its application	Status and trends of linguistic diversity and numbers of speakers of indigenous languages
	Index of Linguistic Diversity
	Number of maintained species inventories being used to implement the CBD
	VITEK
Trends in coverage, condition, representativeness and effectiveness of protected areas and other area-based approaches	Management efffectiveness of protected areas
	Coverage of protected areas
	Protected area overlays with biodiversity
Trends in mobilisation of financial resources	Official development assistance in support of the Convention

Developing biodiversity indices at the global scale remains a work in progress (e.g. Mace 2005; Scholes & Biggs 2005; Pereira & Cooper 2006; Jones et al. 2011). Some of those listed in Table 12 are composite indices which integrate indices operating at a regional scale (e.g. the Wild Bird index), whilst others are specific to the global scale. An example of the latter is the Living Planet Index (LPI), developed by WWF International and UNEP-WCMC , which compiles 9000 population trends for 2,600 freshwater, terrestrial and marine vertebrates.

5 The anatomy of a state indicator

Thus far we have examined the multi-layered concepts of indicators in a general sense. Here we examine birds in more detail as an example of how a particularly well-catered for taxonomic group contributes to biodiversity monitoring.

Birds are perhaps the best monitored of all taxonomic groups and, as a result, make a significant contribution as biodiversity indicators at almost all levels. Their public popularity, combined with the relative ease with which they can be identified and surveyed, makes birds an appropriate target for cost-effective, large-scale surveillance by volunteers. Britain has one of the longest traditions of bird surveillance anywhere in the world with time series for many common and widespread species going back to 1970, and some before that. These time series have been developed from volunteer surveys coordinated by a number of organisations including the Joint Nature Conservation Committee, the Royal Society for the Protection of Birds and, especially, the British Trust for Ornithology (BTO), e.g. the Common Bird Census, Breeding Bird Survey, the Waterways Breeding Bird Survey and the Wetland Bird Survey.

Birds are also widely considered to be good indicator species because, in general: they are high in many food-chains and therefore sensitive to environmental changes; their ecology is comparatively very well understood; and their populations trends are thought to reflect wider biodiversity trends.

For each species targeted by regular standardised surveillance, the BTO produces a population index showing an abundance trend over time. The BTO aggregates species trends for a number of landscape types – breeding farmland birds, breeding woodland birds, breeding water & wetland birds, breeding seabirds and wintering wetland birds – each of which can be considered an ‘operational indicator’. It should be noted that all these indicators were widely used to inform academic research, conservation campaigning and conservation management before they were ever used as strategic headline indicators for biodiversity.

When the need became apparent for biodiversity indicators to measure progress against targets arising from the CBD, the pre-existence of robust surveillance programmes and their suitability as indicator species made birds an obvious choice for the development of biodiversity indicators in the UK. The ‘Wild Bird Index’, based on the five operational indicators referred to above, was first pressed into used as a strategic headline indicator in 2000 as one of 15 ‘UK Quality of Life Indicators’ and today these operational indicators are integrated within the UK Biodiversity Indicator set and the three four national-level indicator sets (Table 13).

Table 13. The integration of five bird operational indicators into country-level, UK, regional and global headline biodiversity indicators. The column 'Element' indicates the element of the indicator set to which the operational indicator contributes and the column 'Type' indicates how that element is classified within the typology used by each indicator set.

Indicator set	Element	Type

England Biodiversity 2020 Indicators	5. Species in the wider countryside: farmland	Theme
	Breeding farmland birds	Indicator
	6. Species in the wider countryside: woodland	Theme
	Woodland birds	Indicator
	7. Species in the wider countryside: wetlands	Theme
	Breeding water and wetland birds	Indicator
	8. Species in the wider marine environment	Theme
	Breeding seabirds	Indicator
England Natural Environment Indicators	1. Species in the Wider Countryside	Indicator
	Breeding farmland birds	Measure
	Breeding wetland birds	Measure
	Wintering waterbirds	Measure
	Breeding woodland birds	Measure
	Breeding seabirds	Measure
Welsh Biodiversity Indicators	19: The loss of biodiversity has been halted and we can see a definite recovery in the number, range and genetic diversity of wildlife, including those species that need very specific conditions to survive	Outcome
	19b: Trends in wild birds population index	Indicator
	22: Our seas will be clean and support healthy ecosystems that are biologically diverse and productive and managed sustainably	Outcome
	22e: Trends in seabird population index	Indicator
Scotland Biodiversity Strategy Indicators	S03 Abundance of terrestrial breeding birds	Indicator
	S04 Abundance of wintering waterbirds	Indicator
	S05 Abundance of breeding seabirds	Indicator
Northern Ireland Biodiversity Strategy Indicators	Wild bird populations	Indicator
	Wetland bird populations	Indicator
UK Biodiversity Indicators	C5 Birds of the wider countryside and sea	Indicator
	C5a Farmland Birds	Measure
	C5b Woodland Birds	Measure
	C5c Wetland Birds	Measure
	C5d Seabirds	Measure
	C5e Wintering waterbirds	
EU SEBI 2010 Indicators	Trends in the abundance and distribution of selected species (birds)	Indicator
Global Biodiversity Indicators	Wild Bird Index	Indicator

The extent and quality of bird surveying in the UK ranks among the best in the world, but birds are relatively well-surveyed, compared to other taxa, all over the world. Consequently birds have also been used as indicator species at regional and global levels. In Europe, operational indicators like those described for the UK are aggregated from several countries for the biodiversity indicator 'Trends in the abundance and distribution of selected species (birds)' (Sheehan et al. 2010) and the 'Wild Bird Index' has been named as a global indicator although it is not fully operational yet.

In terms of the proposed Essential Biodiversity Variables (EBVs) (Pereira et al. 2013), the bird indicators discussed here are an expression of the EBV class 'Species Population' and, specifically, the EBV 'Population Abundance'. But in the framework illustrated by Figure 5, EBVs sit between primary observations and the indices (including operational indices) constructed from them. The raw data collected for the bird surveys used to construct the indicators described here are also geo-referenced and could therefore, potentially, be used to construct indicators that express the EVB ‘Species Distribution’.

Birds have been used to illustrate how observations collected through standardised surveys and surveillance programme can be used to express strategic headline biodiversity state indicators at all levels from country to global. But birds comprise a very atypical taxonomic group in this respect: there are *no* other taxonomic groups that are similarly represented and integrated into headline indicators at all levels, much less habitats.

6 Representation of species and habitats by headline indicators

This section presents an overview of the representation of habitats and species in state and impact headline indicators and considers where the major gaps are.

6.1 Species

The explicit representation of specified taxonomic groups in indicators of biodiversity state and/or impact (from the DPSIR model) is infrequent as illustrated by Table 14. The table does not consider indicators that integrate a few selected taxa across diverse taxonomic groups, e.g. those for invasive species or priority species, but only those where an indicator, or a specified component or measure of the indicator, is generated from trends for a related group of taxa (or a single taxon).

Table 14. The explicit representation of various taxonomic groups in state/impact headline indicators at the UK and country levels.

Species	UK	England	Wales	Scotland	Northern Ireland
Birds	C5 Birds of the Wider Countryside and at Sea	5,6, & 7 Species in the wider countryside; 8 Species in the wider marine environment	19b Trends in wild birds population index; 22e Trends in seabirds population index	S03 Abundance of terrestrial breeding birds; S04 Abundance of wintering waterbirds; S05 Abundance of breeding seabirds	Wild bird populations; Wetland bird populations
Bats	C8 Mammals of the wider countryside	5 Species in the wider countryside - farmland			
Otter				S12 Otter	
Common Seal					Strangford Lough Common Seal Population
Fish				S15 Estuarine fish	
Butterflies	C6 Insects of the wider countryside	5 & 6 Species in the wider countryside		S08 Terrestrial insect abundance:	

				butterflies
Moths				S09 Terrestrial insect abundance: moths
Freshwater invertebrates				S13 Freshwater macro-invertebrate diversity
Marine plankton				S14 Marine plankton
Vascular plants	C7 Plants of the wider countryside	5 & 6 Species in the wider countryside		S06 Vascular plant diversity

It is clear that the representation of species and habitats in headline biodiversity indicators at the UK and country level is selective and patchy, mainly because the development of indicators has been opportunistic, capitalising on extant surveillance programmes that have generated robust and repeatable time-series data. Some features of Table 14 are worth highlighting.

- Vertebrates, though not comprehensively covered, are relatively well represented - especially birds.
- Despite comprising the vast majority of all terrestrial species in the UK (estimated at 40,000) and widespread acknowledgement that invertebrates can make excellent indicators of biodiversity (e.g. Simaika & Samways 2011; McGeoch 1998; Gerlach et al. 2013; Underwood & Fisher 2006; Kremen et al. 2007; Settele & Kuhn 2009), invertebrates are relatively poorly represented.
- Plants are poorly represented compared to animals.
- Despite playing a key ecological role in terrestrial ecosystems and having potential as good indicators, fungi are not represented at all.
- Species from freshwater habitats are poorly represented compared to terrestrial habitats.
- Marine species are very poorly represented, despite the key importance of marine habitats to biodiversity and the functioning of the biosphere.

It is important to recognise that a lot of species surveillance/monitoring goes on that does not contribute directly to headline biodiversity indicators. The indicators produced by such activity can be considered as ‘operational indicators’ because although they do not contribute to headline indicators, they yield important indicators for other purposes, e.g. scientific, engagement or campaigning. Operational indicators might not be incorporated into headline indicators for a number of reasons, some of which are outlined below.

- The organisation responsible for the operational indicator does not wish it to be incorporated into a headline indicator.
- There are insufficient resources, either within the responsible organisation, or without, to incorporate the operational indicator.
- There is, as yet, an insufficient time series for incorporation of the operational indicator.

- The long-term sustainability of the operational indicator is unclear.
- The quality of the operational indicator is not considered to be high enough.
- The taxonomic group represented by the operational indicator is already represented in the headline indicator set.
- The operational indicator would not add strategic value to a headline indicator set.

We must remember that the value of good biodiversity indicators is that we can get a good impression of how facets of biodiversity are faring without having to measure the progress of every element. Complete taxonomic coverage is not possible and, thankfully, unnecessary if good indicators are found. Nevertheless exclusion of extant operational biodiversity indicators on the basis of the last two points listed above is highly unlikely given the extremely limited taxonomic coverage indicated by Table 14.

6.2 Habitats

An assessment of the degree to which monitoring of the state of different habitats contributes towards headline biodiversity indicators is difficult. In contrast to species which are almost always classified according to an agreed international standard, there is no single agreed ‘taxonomy’ of habitats. So, for example, some headline indicators deal with habitats classified with respect to the UK Biodiversity Action Plan priority habitats (e.g. the UK Biodiversity Indicator ‘C2 Habitat Connectivity’) whilst others deal with habitats classified with respect to the EU Habitats Directive Annex I (e.g. the UK Biodiversity Indicator ‘C3 Status of habitats of European importance’). There is not always a one-to-one correspondence between habitat as defined by these different classifications.

In addition, in terms of monitoring there is a very close, and rather confounding, relationship between sites and habitats. So for example, the UK Biodiversity ‘component measure’ ‘C1a Condition of A/SSSIs’ comes under the indicator ‘C1 Protected Areas’ but is usually assessed with respect to the condition of the habitats in the A/SSSI (by Common Standards Monitoring). Other habitat indicators that should be independent of protected sites, e.g. the UK indicator ‘C3 Status of habitats of European importance’, and the indicators for England, Wales, Scotland and Northern Ireland which measure the condition of priority or BAP habitats, are not convincingly measured through representative samples in which the sampling units for habitat are selected independently of their relationship to protected sites. But the condition of habitats within protected sites cannot be considered representative of those same habitats beyond the network of directly protected sites.

For UK and country-level indicator sets, specific habitats are rarely considered outside of the context of protected sites. The very few exceptions are listed below.

- UK indicator ‘B3 Climate change adaptation’, which is under development, may include measures on the extent of coastal habitats like saltmarsh.
- UK indicator ‘C2 Habitat connectivity’ includes the UK priority habitats ‘broad-leaved, mixed and yew woodland’ and ‘neutral grassland’ (also included in the England Biodiversity 2020 indicators).
- Scotland indicator ‘S07 Woodland diversity’.

Compared to the biological recording and monitoring of species, condition monitoring of habitats is harder to implement for a number of reasons, including the following.

- It is no simple matter to classify a habitat (since there are many habitat taxonomies) and, regardless of this, assigning a habitat to a class within an agreed classification is difficult. In contrast to most species concepts, habitats do not lend themselves well to traditional classifications – in reality they grade into one another with transitions that defy discrete classifications.
- Consistency in classifying a habitats between different observers is notoriously difficult (e.g. Cherrill & Mcclean 1999) and we might expect consistency in judging the condition of habitats to be similarly poor.
- The concepts of identity and condition, when applied to a habitat, are not entirely independent – for example when the condition of the habitat in an area degrades so much that it loses many characteristic species, the area itself may be judged to be better classified as a different habitat.
- There is no simple basic protocol for recording the presence of a habitat equivalent to the 'who, what, where & when' of the taxonomic biological record.
- There are no widely accepted protocols for assessing habitat condition.

For all of these reasons there is not a large body of data on habitat distribution and condition equivalent to that for species distribution and abundance. In general, the limited data that do exist are generated by a small number of professional ecologists, which also contrasts markedly with data for species distribution and abundance which are mostly generated by volunteers. These are the underlying reasons for the poor representation of habitats in headline indicator sets. And yet Bunce et al. (2013) highlighted the importance of habitats as indicators of biodiversity, emphasising their ecological links to species and arguing that habitats integrate many facets and levels of organisation of biodiversity. Geijzendorffer & Roche (2013) reviewed European monitoring of ecosystem services and concluded that monitoring at a range of scales and particularly at the habitat level provides the best data on the provision of ecosystem services.

Clearly, if measures of the extent and condition of habitats are to realise their full potential as strategic indicators of biodiversity, there is a great deal of development to do.

7 Conclusions

Biodiversity monitoring and biodiversity indicators are closely linked and multi-layered concepts. Within these contexts, the word 'indicator' is widely used in two senses:

1. to refer to organisms targeted by monitoring and whose presence/absence or abundance is held to signal a wider ecological phenomena; and
2. to refer to the actual outputs of monitoring (e.g. an index).

In the UK, the outputs of biodiversity monitoring are important to a number of different audiences which can be characterised as a continuum with biophiles – those interested in biodiversity for its intrinsic value – at one end and policy makers and strategists at the other. Most of the monitoring that contributes towards strategic UK (and country-level) headline biodiversity indicators of state and impact was initiated to service the biophile end of this audience but subsequently adopted, for pragmatic reasons, in headline indicators. The selection of headline indicators in the UK was not the result of an objective evaluation process such as undertaken in New Zealand (Monks & Wright 2013) and, as a result, there are considerable gaps in their taxonomic coverage and representativeness.

Among the most notable gaps in the representativeness and taxonomic coverage in the UK, and at country-level, are:

- lower plants;
- fungi;
- invertebrates;
- all marine taxa.

In addition, there is little, if any, contribution from rigorous habitat condition monitoring outside of the framework of protected sites.

The fact that a group of taxa is not well-represented by strategic headline indicators does not necessarily mean that no monitoring is taking place. In fact a considerable amount of monitoring produces operational indicators which are not incorporated into headline indicators. There are many potential barriers that could account for this and it may be possible to address these to fill some gaps in the representativeness of headline indicators without initiating entirely new monitoring. But there are certainly areas where new monitoring is required.

There is a lot of scope for improving the coverage and quality of invertebrate monitoring. Gerlach et al. (2013) includes an excellent review of high level invertebrate taxa in terms of how they are actually, or could potentially, be used in monitoring. Of the invertebrate taxa, those inhabiting soil may represent a particularly significant gap in our monitoring. There are also plenty of advocates for using lower plants and fungi in monitoring (e.g. Drapeau et al. 2013). The greatest limitation to the use of these taxonomic groups in monitoring remains the difficulty of practical identification – also called the ‘taxonomic challenge’ (Gerlach et al. 2013; McGeoch 1998).

Marine monitoring around the UK is in its infancy. Some general strategic ‘protocols’ for moving forward were recently identified by (Chambers et al. 2013). There are major differences between monitoring in marine and terrestrial habitats, not least of which is that the opportunities for volunteer and citizen science in the marine environment are more restricted because of the inaccessibility of the habitat without specialist equipment and training.

There seems little doubt that advances in systematics and taxonomy and the associated advances in molecular techniques will offer opportunities for improving monitoring of biodiversity over the coming decades, although the assertion of Ji et al. (2013) that techniques such as metabarcoding will allow us to move away from using indicators are probably wide of the mark. It seems more likely that these new techniques will be integrated into the practice of biodiversity monitoring and the development of new indicators as appropriate and just as likely that they will be deployed with the aid of citizen scientists.

The crucial role of non-professionals – whether characterised as volunteer biological recorders, citizen scientists, expert amateurs, natural historians, or whatever – in producing biodiversity indicators over the coming decades is clear (e.g. Thuiller 2007; Danielsen et al. 2013). There is growing interest in the development of analytical methods that allow more robust quantitative indices of change to be drawn from 'casual' biological records (e.g Isaac et al. 2013). But it also appears that volunteer biological recorders are themselves increasingly interested in contributing to structured surveys of the kind from which robust indicators of change are more reliably produced.

The purpose of the Tomorrow's Biodiversity project is to target gaps in the coverage of biodiversity monitoring in the UK with new FSC training and resource development. The FSC cannot itself develop new monitoring programs, but it can support the development of new or existing operational indicators by other organisations which could, in turn, contribute towards strategic headline indicators. The priorities for the Tomorrow's Biodiversity project going forward are outlined below.

- Identify, through consultation and further research, what operational biodiversity indicators exist within the UK that do not currently contribute towards headline indicators.
- Identify, through consultation, barriers to the development of existing or new operational indicators.
- Identify, through consultation, where the FSC could help to overcome such barriers.
- Establish partnerships with other organisations to address some of the barriers in the delivery phase (years 3-5) of the Tomorrow's Biodiversity Project.
- Align the outputs of the Tomorrow's Biodiversity project with the core operations of the FSC in ways that will ensure a lasting legacy beyond the end of the Tomorrow's Biodiversity project.

There are many ways in which we could work with partner organisations to support the development of existing or new operational indicators. In doing so, the FSC must play to its strengths but also be willing to try new approaches where there is a clearly established need. Ways in which the Tomorrow's Biodiversity project can deliver this support include those outlined below.

- Provision of training in taxonomic identification skills.
- Provision of training in habitat survey and assessment skills.
- Provision of training in the operation of survey protocols.
- Provision of training in the use of new tools and resources that can contribute to the operation and management of operational indicators, e.g. online key development and GIS.
- Provision of training and support to others providing training.
- Trailing new ways of providing training and support (e.g. online).
- Development of new resources in support of the development of operational indicators (including but not necessarily limited to ID resources).
- Exploring delivery of such resources through multiple platforms (including paper and electronic).
- Provision of support to others developing new resources.
- Facilitating support and mentoring networks.

This report contains some copyrighted information and, consequently, you may only use it for non-commercial research or private study.

Given the huge gaps in representativeness and taxonomic coverage of headline biodiversity indicators in the UK and at country-level, there is currently potential for almost any operational biodiversity indicator to make a contribution if it meets the criteria for inclusion. The FSC and the Tomorrow's Biodiversity Project cannot directly influence the development of national and UK indicators, but it can target resources on the development of operational indicators that have potential to make a contribution and we can priorities work in the those areas, identified above, for which few operational indicators currently contribute.

8 References

Barnard, S. & Boyes, S.J., 2013. *Review of Case Studies and Recommendations for the Inclusion of Expert Judgement in Marine Biodiversity Status Assessments (JNCC Report No. 490)*, Peterborough.

Bevilacqua, S., Claudet, J. & Terlizzi, A., 2013. Best Practicable Aggregation of Species: a step forward for species surrogacy in environmental assessment and monitoring. *Ecology and evolution*, 3(11), pp.3780–93.

Bibby, C.J., 1999. Making the most of birds as environmental indicators. *Ostrich*, 70(1), pp.81–88.

Biodiversity Indicators Partnership, 2013. The Indicators. *Biodiversity Indicators Partnership website*. Available at: http://www.bipindicators.net/indicators [Accessed December 16, 2013].

Buckland, S.T. et al., 2005. Monitoring change in biodiversity through composite indices. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 360(1454), pp.243–54.

Bunce, R.G.H. et al., 2013. The significance of habitats as indicators of biodiversity and their links to species. *Ecological Indicators*, 33, pp.19–25.

Butchart, S.H.M. et al., 2010. Global biodiversity: indicators of recent declines. *Science (New York, N.Y.)*, 328(5982), pp.1164–8.

Caughlan, L. & Oakley, K.L., 2001. Cost considerations for long-term ecological monitoring. *Ecological Indicators*, 1(2), pp.123–134.

CBD, 1992. Convention on Biological Diversity. Available at: http://www.cbd.int/convention/articles/default.shtml?a=cbd-02 [Accessed May 13, 2013].

CBD, 2010. *Strategic Plan for Biodiversity 2011 – 2020 and the Aichi Targets*, Montreal, Quebec, Canada.

Chambers, C. et al., 2013. *Potential for joined up marine monitoring and data collection between Statutory Nature Conservation Bodies and industry*, Peterborough.

Chambers, L.E., Huges, L. & Weston, M.A., 2005. Climate change and its impact on Australia's avifauna. *Emu*, 105, pp.1–20.

Cherrill, A. & Mcclean, C., 1999. Between-observer variation in the application of a standard method of habitat mapping by environmental consultants in the UK. *Journal of Applied Ecology*, 36(6), pp.989–1008.

Dale, V.H. & Beyeler, S.C., 2001. Challenges in the development and use of ecological indicators. *Ecological Indicators*, 1(1), pp.3–10.

Danielsen, F. et al., 2013. Linking public participation in scientific research to the indicators and needs of international environmental agreements. *Conservation Letters*.

Defra, 2013a. *Biodiversity 2020 : a strategy for England's wildlife and ecosystem services Indicators 2013*, London.

Defra, 2013b. *England Natural Environment Indicators*, London.

Drapeau, V., Feest, A. & Hayward, K., 2013. Standardised Biodiversity Quality Assessment: Lichens and Bryophytes as Bioindicators? *In Practice*, pp.33–38.

European Environment Agency, 2012. *Streamlining European biodiversity indicators 2020: Building a future on lessons learnt from the SEBI 2010 process*, Luxembourg.

Feest, A., 2013. The utility of the Streamlining European Biodiversity Indicators 2010 (SEBI 2010). *Ecological Indicators*, 28, pp.16–21.

Geijzendorffer, I.R. & Roche, P.K., 2013. Can biodiversity monitoring schemes provide indicators for ecosystem services? *Ecological Indicators*, 1, pp.1–10.

Gerlach, J., Samways, M. & Pryke, J., 2013. Terrestrial invertebrates as bioindicators: an overview of available taxonomic groups. *Journal of Insect Conservation*, 17(4), pp.831–850.

Gregory, R.D. et al., 2005. Developing indicators for European birds. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 360(1454), pp.269–88.

Heink, U. & Kowarik, I., 2010. What are indicators? On the definition of indicators in ecology and environmental planning. *Ecological Indicators*, 10(3), pp.584–593.

Hellawell, J.M., 1991. Development of a rationale for monitoring. In *Monitoring for conservation and ecology*. Springer, pp. 1–14.

Hockley, N. et al., 2009. *Biodiversity Indicators for Wales*, Bangor.

Hyatt, E., 2001. Editorial. *Ecological Indicators*, 1(1), pp.1–2.

Isaac, N.J.B. et al., 2013. *Trends in the Distribution of UK native species 1970-2010 Preliminary report to JNCC. JNCC Report No. 488*, Peterborough.

Ji, Y. et al., 2013. Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding. *Ecology letters*.

JNCC, 2012. The Biodiversity Indicators. Available at: http://jncc.defra.gov.uk/page-4233 [Accessed February 21, 2013].

JNCC, 2013. *UK Biodiversity Indicators in Your Pocket 2013*, Peterborough.

Jones, J.P.G. et al., 2011. The why, what, and how of global biodiversity indicators beyond the 2010 target. *Conservation biology : the journal of the Society for Conservation Biology*, 25(3), pp.450–7.

Jørgensen, S.E., Burkhard, B. & Müller, F., 2013. Twenty volumes of ecological indicators – An accounting short review. *Ecological Indicators*, 28, pp.4–9.

Kremen, C. et al., 2007. Terrestrial Arthropod Assemblages : Their Use in Conservation Planning. *Conservation Biology*, 7(4), pp.796–808.

Lambeck, R.J., 1997. Focal Species : A Multi-Species Umbrella for Nature Conservation. *Conservation Biology*, 11(4), pp.849–856.

Lindenmayer, D.B., Margules, C.R. & Botkin, D.B., 2000. Indicators of Biodiversity for Ecologically Sustainable Forest Management. *Conservation Biology*, 14(4), pp.941–950.

Mace, G.M., 2005. An index of intactness. *Nature*, 434(March), pp.2–3.

McGeoch, M. a., 1998. The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews of the Cambridge Philosophical Society*, 73(2), pp.181–201.

Monks, J.M. & Wright, E.F., 2013. *Selection of potential indicator species for measuring and reporting on trends in widespread native taxa in New Zealand*, Wellington.

Niemeijer, D. & de Groot, R.S., 2008. A conceptual framework for selecting environmental indicator sets. *Ecological Indicators*, 8(1), pp.14–25.

Northern Ireland Department of the Environment, 2013. *Northern Ireland Environmental Statistics Report January 2013*, Belfast.

Noss, R.F., 1990. Indicators for Monitoring Biodiversity: A Hierarchical Approach. *Conservation Biology*, 4(4), pp.355–364.

OECD, 2003. *Core Environmental Indicators. Development Measurement and Use.*, Paris.

Pereira, H.M. et al., 2013. Essential biodiversity variables. *Science*, 339(6117), pp.277–278.

Pereira, H.M. & Cooper, D.H., 2006. Towards the global monitoring of biodiversity change. *Trends in ecology & evolution*, 21(3), pp.123–9.

Rapport, D.J. & Hildén, M., 2013. An evolving role for ecological indicators: From documenting ecological conditions to monitoring drivers and policy responses. *Ecological Indicators*, 28, pp.10–15.

Rockström, J. et al., 2009. A safe operating space for humanity. *Nature*, 461(7263), pp.472–475.

Rossi, J.-P., 2011. Extrapolation and biodiversity indicators: Handle with caution! *Ecological Indicators*, 11(5), pp.1490–1491.

Scholes, R.J. & Biggs, R., 2005. A biodiversity intactness index. *Nature*, 434(7029), pp.45–9.

Scottish Natural Heritage, 2013. Scotland's biodiversity state indicators - Scottish Natural Heritage. *Scottish Natural Heritage website*. Available at: http://www.snh.gov.uk/publications-data-and-research/our-changing-environment/scotlands-indicators/biodiversity-indicators/biodiversity-state-indicators-list/.

Settele, J. & Kuhn, E., 2009. Insect Conservation. *Science (New York, N.Y.)*, 325(July), pp.41–42.

Sheehan, D.K. et al., 2010. *The Wild Bird Index – Guidance for National and Regional Use*, Cambridge, UK.

Simaika, J.P. & Samways, M.J., 2011. Comparative assessment of indices of freshwater habitat conditions using different invertebrate taxon sets. *Ecological Indicators*, 11(2), pp.370–378.

Simberloff, D., 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? *Biological conservation*, 83(3), pp.247–257.

Statistics for Wales, 2012. *State of the Environment 2012*, Cardiff.

Van Strien, a. J. et al., 2009. A typology of indicators of biodiversity change as a tool to make better indicators. *Ecological Indicators*, 9(6), pp.1041–1048.

Van Strien, A.J. et al., 2009. A typology of indicators of biodiversity change as a tool to make better indicators. *Ecological Indicators*, 9(6), pp.1041–1048.

Thuiller, W., 2007. Climate change and the ecologist. *Nature*, 448(7153), pp.550–552.

Turnhout, E., Hisschemöller, M. & Eijsackers, H., 2007. Ecological indicators: Between the two fires of science and policy. *Ecological Indicators*, 7(2), pp.215–228.

UK Government, 2012. *National Planning Policy Framework*, London.

Underwood, E.C. & Fisher, B.L., 2006. The role of ants in conservation monitoring: If, when, and how. *Biological Conservation*, 132(2), pp.166–182.

Vačkář, D. et al., 2012. Review of multispecies indices for monitoring human impacts on biodiversity. *Ecological Indicators*, 17, pp.58–67.

Walters, M. et al., 2013. *Essential Biodiversity Variables*, Montreal.

9 Appendix A. Glossary of data providers

This appendix includes all the data providers listed in Table 5, Table 6, Table 7, Table 8, Table 9 and Table 10.

Acronym	Data provider
BC	Butterfly Conservation
BCT	Bat Conservation Trust
BDS	British Dragonfly Society
BOU	British Ornithologists Union
BTO	British Trust for Ornithology
BWARS	Bees, Wasps & Ants Recording Society
CEH	Centre for Ecology & Hydrology
EA	Environment Agency
HRS	Hoverfly Recording Scheme
JNCC	Joint Nature Conservation Committee
NBN	National Biodiversity Network
NIEA	Northern Ireland Environment Agency
NIWT	National Inventory of Woodland and Trees
MBA	Marine Biological Association
ORS	Orthoptera Recording Scheme
PTES	People's Trust for Endangered Species
Roth	Rothamsted Research
RSPB	Royal Society for the Protection of Birds
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage
UKPN	UK Phenology Network
VWT	Vincent Wildlife Trust