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Matching Scales: The impact of ecosystem service scales on a planning and policy environment

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ABSTRACT

There is an increase in the consideration of ecosystem services (ES) within the planning, policy, and research sectors. The increase in sectors working with ES is leading to an increase in scale mismatches, where ecosystem services are being mismanaged, leading to problems. Using a combination of methods these scale issues were investigated. A systematic review of both scientific and grey literature was undertaken which analysed 112 documents and led to a survey of 72 subjects who were working with ES across different sectors, and finally 19 in-depth interviews were undertaken, in order to understand fully the scale issues, and potential solutions being used. The systematic review found that a lot of ecosystem service scientific literature was based on, or had connections with, the global issue of climate change, this was in contrast to the survey that found that both researchers and those in policy are working at a regional spatial scale or below. The in-depth interviews attributed this to many factors including the pressure to publish in high-impact journals, and applying for funding. The survey found that the different sectors are working at different scales, and where they do work at the same scale, the definition they place on that scale term is different. The survey and in-depth interviews found that funding can influence the extent of a project and funding timelines lead into the temporal scale of a project. Funding can encourage collaboration with stakeholders and between sectors in order to pool resources and expertise. Alongside clarity of terms used and expectations for the project, collaboration was also put forward as one of the methods which can alleviate scale mismatches.

Keywords: ecosystem services; scale; policy; systematic review; survey; interview; funding; collaboration.

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1 Introduction

1.1 Biodiversity and Ecosystem Services

An ecosystem can be defined as a community of living organisms in conjunction with the non-living components of their environment (including air, water, and mineral soil), and the way in which these organisms and components interact as a whole.

The word biodiversity is a contraction of the term ‘biological diversity’ which the Convention on Biological Diversity define 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” (Convention on Biological Diversity, no date). Biodiversity can influence and enhance many ecosystem services by being a ‘building block’ for ecosystems (Mooney, 2010). Although UK biodiversity is currently in decline (DEFRA, 2011) it should be conserved as a vital element in ensuring a healthier planet, and to maintain ecosystem services (Convention on Biological Diversity, no date).

The modern-day concept of 'environmental services' emerged in the 1970s (Wilson and Matthews 1970), with the term “ecosystem services”, introduced in the 1980’s by Ehrlich and Ehrlich (1981). Costanza et al., (1997) and Daily (1997) wrote landmark ecosystem service documents and from there it has become the basis for a large and increasing area of science that looks to measure, assess, and value aspects of society's dependence on nature (Lele et al., 2013).

Ecosystem services are described by the UK National Ecosystem Assessment as “the benefits provided by ecosystems that contribute to making human life both possible and worth living” (UKNEA, no date a). These benefits can include pollination, carbon sequestration, water filtration and nutrient retention. Cultural services are another ecosystem benefit described as “non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience” (Alcamo et al.,

2003). Figure 1, which was created using data from Millennium Ecosystem Assessment (MEA), shows the different types of ecosystem services and their benefits.

Figure 1 Ecosystem services wheel (Metro Vancouver, no date)

Each of these processes has often been taken for granted, but as the state of biodiversity and ecosystems decline, it becomes increasingly important to protect the services they provide (DEFRA, 2011), since ecosystem services act as a bridge between human and natural systems, accounting for many positive environmental externalities (Raymond et al., 2013). There are many links between biodiversity and the constituents of human well-being as shown in Figure 2. The strongest link, with the highest potential for mediation by socioeconomic factors is that between provisioning services and the basic materials for a good life, this is ecosystem services at their most basic, the services that give food and shelter and fuel. One of the weakest links is between cultural services and the basic materials for a good life, although it is weak with a low potential for mediation by socioeconomic factors it is still present and still important, and shows that it does exist and there are people that value cultural services in such a way that it has an impact on their basic

ideas for a good life. Regulating services are consistently linked to a medium extent in both values to security, basic materials for a good life and health. Supporting services are the back-bone of all ecosystem services. Ecosystem services are vital in policy due to the extent to which they provide and are intrinsicly linked to security, materials for a good life, health and social relations which are all aspects necessary in providing a functioning society.

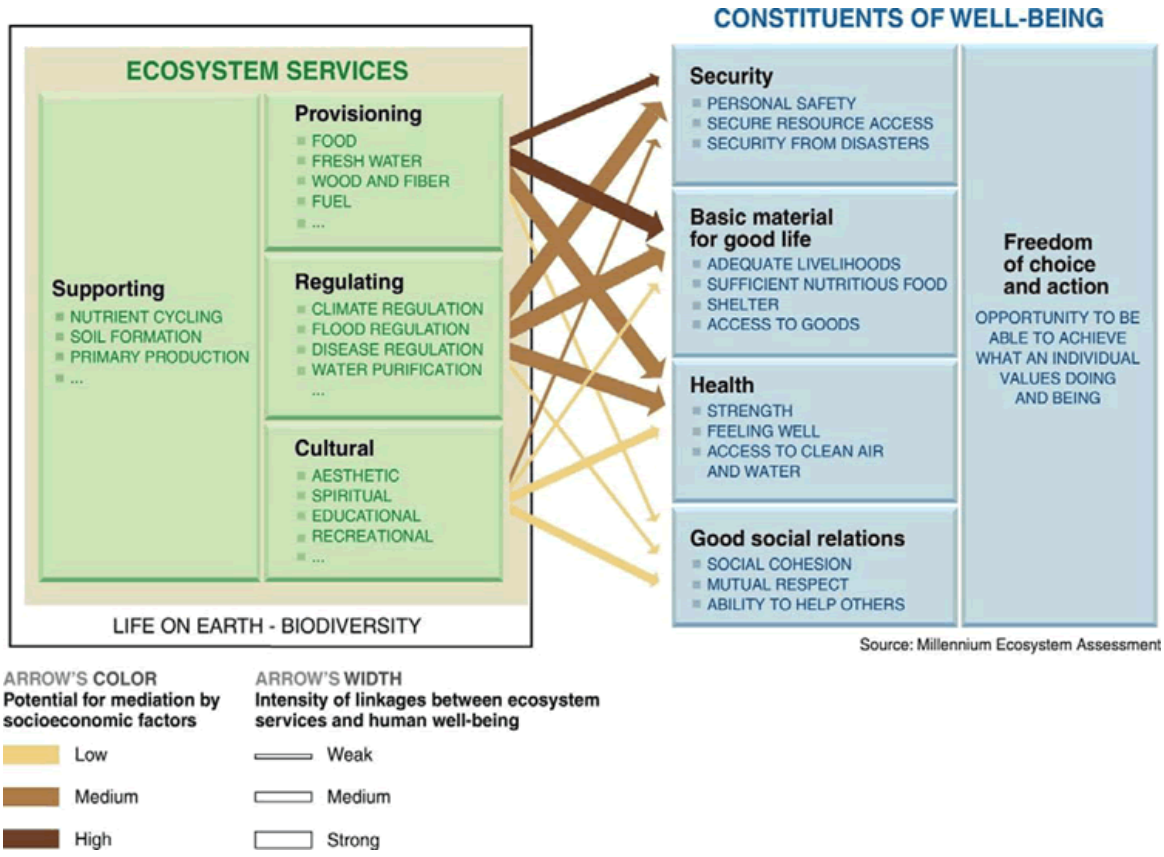

Figure 2 Linkages between Ecosystem services and human well-being (MEA, 2005a)

In recent years, the ecosystem services concept has become important in facilitating collaboration between scientists, professionals, decision-makers, and other stakeholders (Schroter et al, 2014). However, the concept, although accepted by many, is contentious and difficult to define. It attracts much debate, most of which is from those who understand the advantages of the concept but are looking for improvements in terminologies and methods (Lele et al., 2013). Table 1 shows Schroter et al's (2014) assessment of the different points of contention and the ways in which solutions and ways forward are proposed.

Table 1 Points of contention, Schroter et al. (2014)

Critique	Arguments	Counter-arguments	Way forward
Environmental ethics	The ES concept excludes intrinsic value of nature. Nature conservation should be based on intrinsic instead of anthropocentric values.	The ES concept bundles valid anthropocentric arguments. The cultural ES domain includes values with elements of intrinsic values, for instance existence value.	Anthropocentric framing could be used for broad argumentation in support of conservation and sustainable use of ecosystems. Stronger acknowledgment of existence aspects within the cultural services domain could bring different worldviews together.
Human–nature relationship	The focus on ES could promote an exploitative human–nature relationship. This might contradict holistic perspectives of indigenous people.	The ES concept could re-connect society to nature. Nonmaterial values can be covered in the cultural ES domain, to include peoples' values and needs.	The ES concept offers a "platform" for bringing people and their different views and interests together. Attention is needed to move beyond the Western origin of the ES concept.

Critique	Arguments	Counter-arguments	Way forward
Conflicts with the concept of biodiversity	The ES concept might replace biodiversity protection as a conservation goal. There is inconclusive evidence of a "win-win" scenario between biodiversity and ES. ES might not safeguard biodiversity, but instead divert attention and resources.	There are conceptual overlaps between ES and biodiversity. There is a growing body of evidence that biodiversity underpins the ecosystems functions which give shape to ES. Current initiatives based on ES lead to a broad perspective on land management and conservation.	Indirect inclusion of biodiversity in several ES categories can pave the way for potential "win–win" scenarios. Further research and monitoring are needed to clarify the relationships between biodiversity and ES.
ES valuation	The ES concept comprises economic framing. ES assessments often involve economic valuation.	Monetary valuation provides additional information in decision-making processes. ES assessments do not necessarily involve valuation and valuation does not necessarily involve monetization.	Develop both biophysical and sociocultural value indicators of ES to explain human–nature relationships.
Commodification and Payment for Ecosystem Services	The ES approach is based on the assumption that payment for ES will ensure their provision.	Assessing ES in monetary terms does not necessarily equate to using market instruments.	Focus on ES approaches that include nonmarket instruments.

Critique	Arguments	Counter-arguments	Way forward
Vagueness	ES has become a "catch-all" phrase because of its many vague definitions.	Imprecision of the ES concept can spur creativity and refinement of definitions. Use of the ES concept can facilitate multiple societal actors to interact without consensus on the precise meaning and can foster transdisciplinary research.	ES offer common ground for debate and methodological progress in different scientific fields. Use of the ES concept can build bridges between science and practice, enabling for integrated, transdisciplinary approaches to solve "wicked problems."
Optimistic assumptions and normative aims	The ES concept is too optimistic. Ecosystems outputs may not always be beneficial to humans.	Positive terminology shows the optimistic intentions and research interests. ES is one of the many normative concepts used within environmental science. Total value freedom is impossible for science embedded in sociocultural contexts.	Scientists should be explicit and transparent about whether research aims and provided information are normative. ES scientists are challenged to find ways to systematically consider implicit assumptions and perceptions of stakeholders and practitioners on ES and connected values.

There are three main themes within the arguments - ethical considerations; strategies for nature conservation; and the current state of ecosystem services as a scientific approach. The ethical considerations, relating to the interaction of humans with nature are addressed with the idea that ecosystem service concept offers a platform for different views to be addressed and that anthropocentric framing can support sustainable use of ecosystem services. The second type of argument deals with schemes for biodiversity conservation and sustainable use of ecosystems, relating to the science–policy interface. These arguments are countered by saying that biodiversity is indirectly included in most ecosystem services categories. Focusing on the biophysical and socio-cultural indicators of ecosystem service alongside the ecosystem services approaches which include non-market instruments can aid in any issues with ES valuations, PES and commodification. The current state of ecosystems services as a scientific approach is the third argument. This is countered by identifying that ecosystem services offer common ground for debate and progress in different scientific fields and also between science and practice. Any ecosystem service research encompasses both implicit assumptions and perceptions of stakeholder groups. Although the approach of managing and researching the environment through ecosystem services has many contentions there are also many reasons why it is widely used in research and planning and policy practice.

1.2 Scale in ecosystem services

A real difficulty in understanding scale mismatches is the definition of the term 'scale'. As it is not possible to study, model or visualise the environment in detail or with anything like its full complexity, scale becomes a vital tool with which to simplify the selection of data and the sense of the complexity of the information available. Scale, then, is the “window of perception” Levin (1992), and is simply a filter or a measuring tool which enables an agreed association for space and time to be interpreted.

Although the term ‘scale’ is used extensively in environmental science, there is no clear definition, though over the last 30 years a great deal of work has been

done on trying to define scale within the context of geographical and ecosystems study. Nominally, three types of scales have been identified: absolute, relative, and conceptual. Although in 1989 Meentemeyer had a conception of scale as being either absolute or relative, it is now agreed that a conceptual scale, which includes terms such as “local” and “global” (Meyer 1992) is valid.

Gibson et al., (2000) give some useful definitions which provide a starting point for this discussion, as shown in Table 2.

Table 2 Definitions of key terms related to the concept of scales adapted from Gibson et al., (2000)

Scale	The spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon.
Extent	The size of the spatial, temporal, quantitative, or analytical dimensions of a scale.
Resolution (grain)	The precision used in measurement.
Absolute scale	The distance, time, or quantity measured on an objectively calibrated measurement device.
Relative scale	A transformation of an absolute scale to one that describes the functional relationship of one object or process to another (e.g., the relative distance between two locations based on the time required by an organism to move between them).

Regardless of what might be found within a space, absolute scale exists independently of the objects or processes being studied (Gibson et al., 2000). Use of absolute spatial scales include conventional cartography, remote sensing, and mapping sciences in order to locate an object and to measure its

size (Gibson et al., 2000). With absolute scales, hierarchical systems can easily be created, and so when looking at temporal scale, divisions could be Century-Decade-Year-Month-Week; and with spatial scale divisions could be Nation-City-District-Neighbourhood (Gibson et al., 2000). So, although appropriate for inventory, planning, and most mapping and descriptive studies (Meentemeyer, 1989), the concept of absolute space has significant shortcomings for ecosystem services.

Seeing space as relative, is more suitable for understanding ecosystems, and increasing attention is being paid to relative space and time in order to conceptualize the processes and mechanisms which occur in space. Such relative scales are defined by, rather than defining, the objects and processes under study. A relative concept of space regards space as 'a positional quality of the world of material objects or events,' (Harvey, 1969, p. 195, Jammer, 1954). Relative space is particularly important in studies of behavioural geography that focus on individual perception of space, when we need to measure distance in terms of the time and energy needed for an organism to change its position from one place to another. Absolute distance rarely corresponds with the relative distance (Gibson et al., 2000).

There are two further points to consider with seeing space as relative. Firstly, the composition of the ecosystem may consist of migration and commuting patterns, watersheds, or the dispersion of pollutants, for example (Meentemeyer, 1989). Here, scale is defined through forms and functions, processes and rates. One example would be the effort required by an organism to move from one point to another (Turner et al., 1989). There are entire populations of migratory bird species that inhabit and then desert sites across the globe on varying temporal scales, thus varying their spatial scales over time. Secondly, two areas which are next to each other in Euclidean terms, in pure space, may be quite distinct in terms of ecosystem scale. Where, for example, there is a marine conservation area, that prohibits fishing, the stocks of fish will be higher than in the adjacent fisheries, although the conservation area can

also have positive effects on the abundance of fish in the fisheries area (Roberts et al, 2001).

It is important to remember also that the resolution used in any research will have an effect on the data outcomes. Hess et al., (2006) have taken a view of scale within ecological studies defining areas as “grain” and “extent”. Grain is the size of each observational unit, though Gibson et al*.,* (2000) prefer the term “resolution”. This might be a pixel within remote sensing data, or a quadrat at a field site. Extent is the size or temporal length of an entire study, the full remote sensing data set or the entire field study area (Hess et al., 2006). It is interesting to note that researchers working with what might be termed ‘coarse grains’ (or lower resolutions) or across ‘large extents’, such as those at continental or eco-regional scales, have found high, positive correlations between species diversity and overall species richness (Olson and Dinerstein, 1998; Ricketts et al., 1999; Myers et al., 2000; Lamoreux et al., 2006), whereas in reality, conservation planning often occurs at finer resolution or smaller extents (Cooper, 1998; Reid, 1998; Ferrier, 2002). Hess et al. (2006) concluded that the choice of resolution and extent gives inconsistent results from previous studies which examine the effectiveness of using indicator populations to make deductions about other species; that care should be taken when planning is based on data developed at other resolutions or extents; and that planning based on data recorded in other geographical areas should be done carefully, even where this is done with an equal resolution and extent, and the areas are physically near one another.

As noted above, the terms ‘global’ and ‘local’ are used by geographers to show conceptual thinking about scale (Gibson et al., 2000). Meyer et al., see these terms as levels of ‘totality, comprehensives’ and ‘particularity, discreteness, contextuality’ (Meyer et al., 1992, p. 256). This gives rise to the notion that in, for example, physical geography, spatial scale implies a temporal scale; and that in human geography, context is vital in understanding space.

An alternative view of scale is given by Cao and Lam (1997) who describe the four meanings behind scale as used in environmental assessment and monitoring as cartographic scale, observational scale, measurement scale and

operational scale (Cao and Lam, 1997). The four meanings and their definitions are found in Table 3.

Table 3 Definitions of Cao and Lam's four scale meanings (adapted from Lam, 2004)

Cartographic Scale	The ratio between the measurements on a map and the actual measurements on the ground.
Observational Scale	The spatial extent of the study or the area of coverage.
Measurement Scale	The smallest distinguishable parts of an object – a pixel or sampling intervals.
Operational Scale	The spatial extent at which certain processes operate in the environment.

The definition and use of a particular scale has long been identified as a challenge in determining ecosystem goods and services, including scales at which the service is expected to be delivered (Birkhofer et al., 2015), its assessment (Grafius et al., 2016) and its interpretation (Raudsepp-Hearne and Peterson 2016).

The different variations in meaning of scale can lead to confusion and potentially mismatches. As we have seen, 'scale' is a term that is used often but can mean very different things depending on the background and context.

It should be noted that the definitions above relating to spatial and temporal dimensions in ecology, fail to take into account the sociological view of the environment; the concept of representation and organisation (Cumming et al., 2006). Organisational scale takes a view from an individual through to an entire species, and their scales of interaction. Representational scale, however, looks at the groups that have influence, and the individuals acting as representatives of those groups, via laws and policies.

These groups are often working across political divides, especially where an ecosystem takes in parts of more than one administrative area. This is referred to as multi-level governance (MLG) which has been defined as the 'political structures and processes that transgress the borders of administrative jurisdictions, aiming to cope with interdependencies in societal development and political decision-making which exist among territorial units' (Benz 2006). Representational policy then, is governance, which is the application of policy decisions. Traditionally, management of resources was at a top-down level, with governments making and executing decisions based on their interests.

What makes MLG interesting from an ecosystem service perspective is that the participation in the decision-making process is increasingly carried out by non-state organisations (Bache and Flinders 2005). There is also an assumption that systems of governance at these multiple levels are not hierarchical in a traditional top down way (Bache and Flinders 2005), but instead are made up of formally independent, but mutually inclusive levels of governance (Scharpf 1997; Papadopoulos 2005; Paavola 2008). This "shift from government to governance", suggests that one style of representation is being replaced by another, with the traditional hierarchical government approach becoming one of networked collaboration through public-private partnerships, including NGOs for example, often beyond national borders (Pierre 2000, Van Tatenhove et al., 2000).

It is important to address the governance of ecological problems by dealing with cross-scale and cross-level dynamics (Cash et al., 2006) though this can be difficult, particularly with regard to scale issues. Coordinating the management of larger geographic areas covering more than one country is complicated by the varying social relations and institutional frameworks, which have their unique style of representation; and by the very ecosystems themselves (Clark et al., 2010). Large-scale conservation projects work at more complex spatial and temporal scales, and also, importantly, at different legal scales, all of which make them more difficult to define (Clark et al., 2010). Because this large-scale planning and governance works across multiple scales, it is clearly difficult to

see each level, and who is being represented by whom, from the governing body down to the manager of an individual field or public park (Saunders and Briggs, 2002). This leads to potential conflict and tension, and so finding a way to coordinate, and at the same time to decentralise, decision making is essential (Saunders and Briggs, 2002).

One solution for this is a system of participatory governance where citizen engagement is seen as the expected outcome (UNESC, 2007). Spatial scale is important regarding the various players' relationships to the process of understanding the value of ecosystem services (Schmitter 2002; Hein et al., 2006; Hunsberger and Kenyon 2008). Koontz (1999) has shown that people who live closest to the ecosystem service tend to see its economic value, whereas those living further away favour resource conservation (Koontz 1999). Both temporal and spatial scale vary greatly across policy and governance, which alongside the huge variations in scale within ecosystem services, can and does cause issues of scale mismatch.

Where planning is successful, it is usually built through face-to-face interaction whether at the local scale or extended networks (Wyborn and Bixler 2013). Such relationships are the foundation of the trust and tight social networks which are built through personal relationships (Armitage et al., 2009; Wondolleck and Yaffee, 2000), which lead to success in outcomes for ecosystem services. Without shared identity and vision, and especially a sense of place, these outcomes are unlikely (Carr, 2002) whether at local, regional or global level (Wyborn and Bixler 2013). One solution proposed by Marshall (2005) is through the use of "nested arrangements" where the smaller goups of local people, become part of a larger inclusive system, without giving up their autonomy (Marshall, 2005). Thus representational scale allows us to see the interactions between stakeholders in the ecosystem service (Wyborn and Bixler 2013).

The definition and use of a particular scale has long been identified as a challenge in determining ecosystem goods and services, including scales at which the service is expected to be delivered (Birkhofer et al., 2015), its

assessment (Grafius et al., 2016) and its interpretation (Raudsepp-Hearne and Peterson 2016).

The different variations in meaning of scale can lead to confusion and potentially mismatches. As we have seen, ‘scale’ is a term that is used often but can mean very different things depending on the background and context.

1.3 Millennium Ecosystem Assessment

It was a combination of both scientists and policy-makers who identified a requirement for the evaluation of the stocks of ecosystem services across the globe, relating to both finance and conservation needs (MEA, 2005b). In the year 2000, in order to evaluate the consequences of ecosystem change, the Millennium Ecosystem Assessment (MEA) was called for by Kofi Annan, the then United Nations Secretary General. The MEA was initiated in 2001 with contributions from 1360 experts from across the globe (MEA, 2005b). As well as evaluating, the MEA assessed the scientific input needed for ecosystems and their services to be managed sustainably. The five technical volumes and six synthesis reports that make up the MEA were published in 2005. The MEA deals with all the types of ecosystems around the world, whilst also incorporating the needs of the stakeholders and people who interact with and benefit from these ecosystems. The MEA also collected information on those tools and management techniques being used at that time.

The Millennium Ecosystem Assessment’s conceptual framework (2005a) attempted to develop better tools for measuring and mapping Ecosystems services by distinguishing between the four categories of services – provisioning, regulating, cultural and supporting (Figure 2). In recent years it has been the most widely recognised and applied framework (DEFRA, 2007; Haines-Young and Potschin, 2009; National Assembly for Wales, 2012). This tool has proved useful in enabling cross-comparison between different assessments and areas.

1.4 Ecosystem service valuation

The way ecosystems and the services they provide today are valued, stems from an idea developed from the 1970's onwards, expressing the wealth gained from the environment in monetary terms (de Groot et al., 2002). The concept started initially as a way to integrate the natural environment into policy and planning decisions (Helliwell, 1969). Ecosystem service valuation is still seen today as a way to make it more straightforward to incorporate nature's benefits into policy and economic decision making (Lienhoop et al., 2015). Although there is contention in the issue of the commodification of ecosystem services, by not commoditizing there is a risk that ecosystem services will not be integrated into the decision making process. Whilst most economic valuation of ecosystem services often fail to encompass the cultural, and less obviously accountable benefits of ecosystem services, particularly when the values are being used in policy development (Gomez-Baggethun and Martin-Lopez 2014), it is agreed that placing a well thought out, but estimated value on what could be perceived as an invaluable resource enables this resource, via its economic value, to be integrated more easily into the planning and policy context (Kumar et al., 2013). To simplify this integration into planning and policy, the spatial and temporal scales of economic valuation should be at scales relevant for the planning and policy design and intervention (Kumar et al., 2013).

It is difficult to wholly assess the importance of ecosystem services, as they are an intricate part of our natural environment, and attempts to assess their financial value have found that they can contribute twice as much to human well-being as gross domestic product (Costanza et al., 2014). There are some ecosystem services that have direct market values, thus assigning market values can be easier, but these don't include the farther reaching benefits of an ecosystem service (Farber et al., 2002). For example, the market value of clean water provided by a private water company doesn't take into consideration the psychological benefits to the people who live in the local area where a reservoir might be used for recreational purposes. (Lienhoop et al., 2015).

The values of different ecosystem services don't always come directly from products such as timber or clean water, and so the interpretation lies with the organisation making the valuation. Some indirect benefits of ecosystem services are found in agriculture, with insect pollination being vital to 20% of cropland in the UK (Breeze et al., 2011). Carbon storage in soils and trees is vital for climate change mitigation (Glenday, 2006). Freshwater ecosystems provide drinking water, help produce healthy fish stocks, and are used in farming and industry, as well as being areas of recreation (Liquete et al., 2011). Cultural services hold varying levels of importance to different groups, from recreational use through to health benefits such as Eco-therapy (Mind, 2007), which can relieve pressures on the National Health Service. Cultural services are measured with qualitative, rather than quantitative data, including questionnaires and opinion groups (Norton et al., 2012), so the value of a site will vary between individual responses as their perceptions will be different according to their personal values.

The UK government Department of Food and Rural Affairs (DEFRA) introduced guidelines on valuing ecosystem services to help other government departments, and environmental impact is embedded into the decision making process from the start (DEFRA, 2007). The simplified version of the Ecosystem Approach guidelines are to:

- Establish the environmental baseline
- Identify and provide qualitative assessment of the potential impacts of policy options on ecosystem services
- Quantify the impacts of policy options on specific ecosystem services.
- Assess the effects on human welfare
- Value the changes in ecosystem services

The ecosystem approach has been adopted in some decision making by the UK government Department of Food and Rural Affairs (DEFRA, 2007).

Monetary quantification is not favoured across the board in ecosystem services. There are those who believe that such economic valuation can be limiting and lead to an underestimation of the relationship between people and the

environment. It becomes purely financial, to the detriment of the ecosystem service itself (Raymond et al., 2013). Valuation techniques can also be uncertain due to knowledge gaps in ecosystem processes, human preferences, and the technicality of the process of valuation (TEEB, no date a).

1.5 Ecosystem service conservation and policy

The conservation, sustainability, and sustainable use of ecosystem services can be enabled by policy and decision making. When the benefits of ecosystem services are fully harnessed and integrated into policy and planning decision making, then they are more likely to be recognised as an asset and used sustainably. There are many different ways of integrating ecosystem services into planning and policy decisions, for example through the economic valuations discussed above, or by conservation designations, or by the ecosystem approach.

In order to attempt to manage the natural environment there are specific legal designations which can be applied to areas that have particular value either locally or at a larger scale. A site may be designated for many different reasons depending on its scientific, conservation, historical or cultural value. By conserving and controlling the natural environment, this feeds back into the quality and quantity of ecosystem services that a natural area can provide. Natural England, who are the government's adviser for the natural environment in England, have a designations strategy which enables appropriate management of these sites across England. This strategy tracks all designations and ensures that they are managed to fulfil their designated goals (Natural England, 2012). By designating an area there are stricter more extensive rules on the change of land-use, particularly within planning permissions (DCLG, 2016). Within the UK there are different levels of designation, depending on the origin of the legislation. National designations are: Sites of Special Scientific Interest (SSSI), National Nature Reserves (NNR), and Local Nature Reserves (LNR). The European designations fall under the Natura 2000 networks, and are called Special Protection Areas (SPA) or

Special Areas of Conservation (SAC) and global designations are the Ramsar convention on wetlands, and OSPAR marine protection sites. Designating conservation sites requires extensive work in maintaining the site to the conservation standards for which it was designated, it is more than simply designating with signs and fences (JNCC, 1994).

The UK National Ecosystem Assessment (UK NEA) took place in 2009 and concluded with a report in 2011. The project was undertaken by different government organisations, academics, NGOs, and private sector institutions, to report on the benefits provided by the UK natural environment to society and continuing economic prosperity. The UK NEA is used as a basis to ensure that the UK are meeting their wider global and European obligations in environmental conservation and management. The assessment helps feed into other ecosystem service policy projects by providing information on how the natural environment is benefitting the UK. The NEA provided the research and evidence that led to the publication of the government's Natural Environment White Paper, which set out government pledges and targets for the natural environment in the UK for the following 50 years. The white paper identifies that a healthy natural environment is the foundation of sustained economic growth and personal well-being. The fact that this has been set out in an official government report is a great step forward for ecosystem services in the UK.

The Natural Capital Committee (NCC, no date) are an independent advisory group which was set up by the Government in 2012 after the Natural Environment White Paper was published (H.M.Government, 2011). The NCC are tasked with achieving the Government's statement in the White Paper to be "the first generation to leave the natural environment of England in a better state than it inherited". The NCC produce an annual report on the state of natural capital in the UK, identifying at risk environments which require attention along with forthcoming research areas, in order to ensure that the Government is accountable to this statement. They also help develop measures for natural capital, and methods for companies to incorporate natural capital accounting to

their businesses, and also for natural capital to be integrated into government decision making.

The Natural Capital Initiative is a national forum in the UK that brings together decision makers from academia, policy, business, and civil society to engage in multi- and cross-disciplinary discussion on embedding natural capital ideas into policy and practice (Natural Capital Initiative, no date).

1.6 Measuring and mapping ecosystem services

Birkhofer et al. (2015) identified four main difficulties for ecologists in ecosystem service research which all relate to the identification and analytical process of measuring ecosystem services (Table 4). The relationships within and between ecosystem services and human users are complex, and this is where the difficulties arise.

Table 4 Four challenges in ecosystem service research, Birkhofer et al., 2015

Challenge	Sub-challenge	Opportunities
3.1. Understanding anthropogenically modified systems	(i) Identifying human impact on service-providing units and ecosystem services (ii) Considering matrix effects in modified landscapes	Consideration of relationships between biodiversity and ecosystem service provision and management interventions Identifying effects of anthropogenic interventions on service-providing units at different spatial scales
3.2. Assessing ecosystem services	(i) Assessing relationships between services and measures usually quantified in ecological studies (ii) Accounting for dynamics and uncertainties in models of service provision	Identifying ecological measures that are reliable indicators of ecosystem service provision Evaluation of uncertainty, integration of evolutionary aspects and human impacts into process-based models and socio-economic models
3.3. Analyzing relationships between ecosystem services	(i) Understanding if relationships between ecosystem services are indirect or direct (ii) Solving issues with the visualization and statistical testing of relationships between multiple services	Performing studies that model direct and indirect effects, experimental test for relationships and developing mechanistic models Accounting for non-linear relationships when visualizing or analyzing relationships between services
3.4. Considering appropriate spatial and temporal scales	(i) Up scaling from experimental plots to scales relevant for management of most ecosystem services (ii) Understanding temporal dynamics of service provision to develop sustainable management and conservation strategies	Coupling research on mechanisms for service provision with conservation-oriented research Utilizing existing long-term studies and promoting the need for such research projects

Biodiversity is complex and thus the ecosystem services derived from it are often measured by the more obvious features in order to estimate the less observable (Vermeulen and Koziell, 2002). This traditional approach to measuring and mapping ecosystem services has attempted to codify and simplify highly complex systems (Bennett et al., 2009). The reasons for this can be seen partly as the requirement for policy makers to have achievable targets

with which to show the value of system, and to demonstrate accountability and performance. This can be seen with targets such as the 2050 carbon emissions reduction targets, which are rigid, even though there are known uncertainties in the carbon cycle (Meinhausen et al., 2009). Some scientists feel they are unattainable and leading towards “dangerously misguided policies” (Anderson et al., 2008). From a practical standpoint, the inherent complexities of ecosystems services and their interdependencies lead to a simplistic approach in assessment. Only some specific services are measured, and these often in isolation from the much wider context, as is becoming clear from our understanding of the complex interactions between services and their wider contexts (Bennett et al., 2009).

This approach does not take into account the thresholds and complex non-linear realities in the real world where a relatively small additional change may signify dramatic change in a system (Haines-Young and Potschin, 2010). As O'Neill (2011) argues, this leads to the undervaluation of the commodification of nature, where its elements are subjected to a simple exchange value.

Haines-Young and Potschin (2009) found that in practice there have been substantially different definitions and measurements of specific services. This was not only as a result of the difficulty in categorizing services and the simple delineation between functions and services which are by their nature interrelated and interdependent, but also of the variations in context, including geographical and temporal scales (Alcamo et al., 2003; Haines-Young and Potschin, 2009).

Nontheless, three complementary but distinctive perspectives have been identified for the assessment of ecosystem services (Potschin and Haines-Young, 2011). Firstly, the habitats perspective, in which the distinctive role of habitats in relation to ecosystem services provision and their multifunctional characteristics is identified; secondly, the services perspective, where ecosystem services are linked to societal benefits/opportunities and problems; and thirdly, the place-based perspective which considers how human well-being

and place-making is affected by the health and future development of specific geographical areas (Haines-Young and Potschin, 2010).

Although the complexities of nature and ecology are difficult to assess, particularly in ecosystem services, there are tools, guidelines and methods used which attempt to do this. The way in which ecosystem services are mapped and measured plays an important role in scale mismatches within ecosystem services. The resolution and extent of data can have an impact in the results which are used in decision making.

Sophisticated tools such as InVEST (Integrated Valuation of Environmental Services and Trade-offs, no date), ARIES (ARtificial Intelligence for Ecosystem Services, no date), NEAT (National Ecosystem Approach Toolkit, no date) and TESSA (Toolkit for Ecosystem Service Site-based Assessment, no date) use existing biophysical models or bespoke modelling environments. InVEST is a group of modelling tools which can map, measure and value ecosystem services (Natural Capital Project, no date). ARIES is designed to measure the societal benefits of the natural environment in a way that takes into account the dynamic complexity of nature, whilst keeping models simple enough to be used effectively (ARIES, no date). NEAT provides visual tools, based on GIS applications, which can be easily used to assess and value ecosystem services and benefits, making them useful for stakeholder engagement (NEAT, no date). TESSA is a tool which can be used to compare models of a site, before and after conversion to agricultural use. For example. TESSA deliberately excludes some of the more specialist knowledge of ecosystem services so that it can be used by non-specialists such as policy-makers (TESSA, no date). These tools use biophysical information alongside the location and activities of people to create map outputs.

The underlying data and models being used to research ecosystem services can cause confusion, as data from different scales can give different information about ecosystem services from within the same areas. For example, Grafius et al., (2016) used both 5m resolution land use/land cover data and 25m land use/land cover data to analyse identical areas of Luton, Bedford and Milton

Keynes in the UK to determine the flow and quantity of selected ecosystems services (carbon storage, sediment retention, pollination) and found that simply using input data at these two spatial scales resulted in significant differences in the assessment. However, it is important to bear in mind that the cost of fine scale data sets is likely to be much more expensive than coarse scale data, even if the results are likely to be more reliable. Grafius et al., (2016) found that when selecting the data to use in analysis, it is critical to consider the service which is to be modelled and its specific sensitivities. It is vital that the process of data selection is informed by the questions being researched, alongside the characteristics of the landscape study site, to determine the most appropriate scales of inquiry. Figures 3 and 4 show the differences in spatial patterns of ecosystem services as a function of these different input datasets.

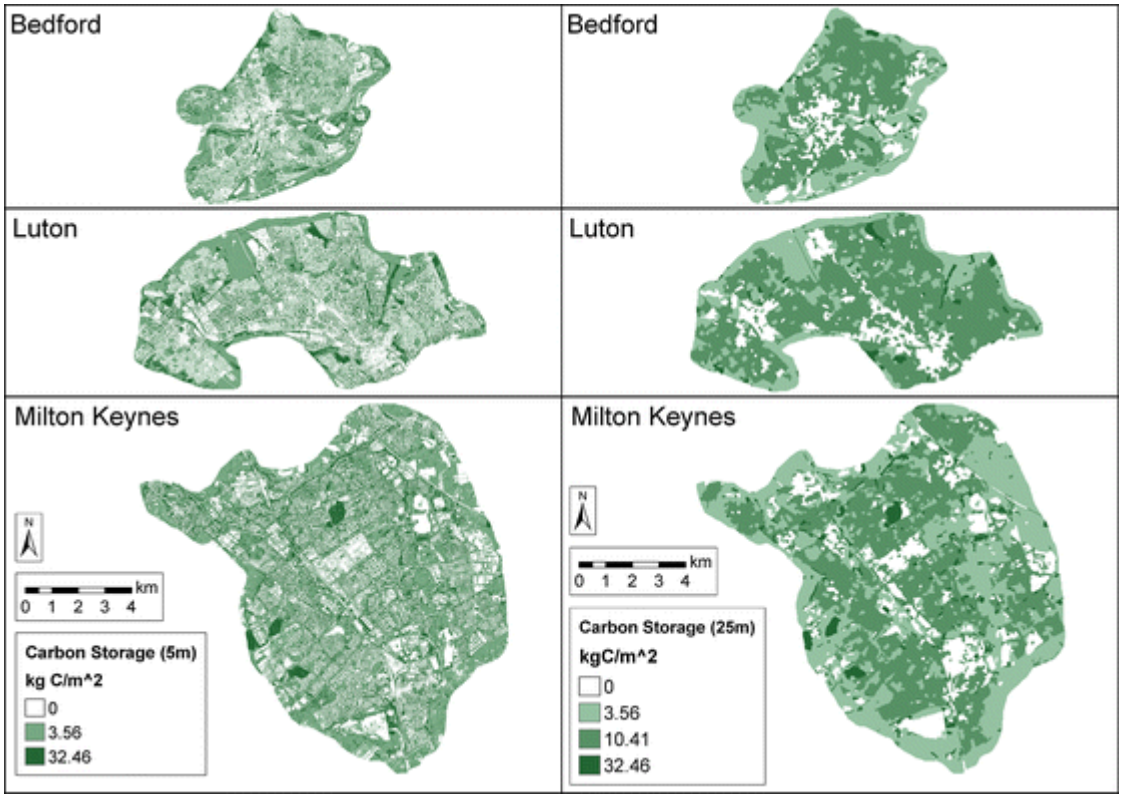

Figure 3 Modelled potential carbon storage in Bedford, Luton and Milton Keynes UK (kg C m²), based on 5m versus 25m resolution land use/land cover

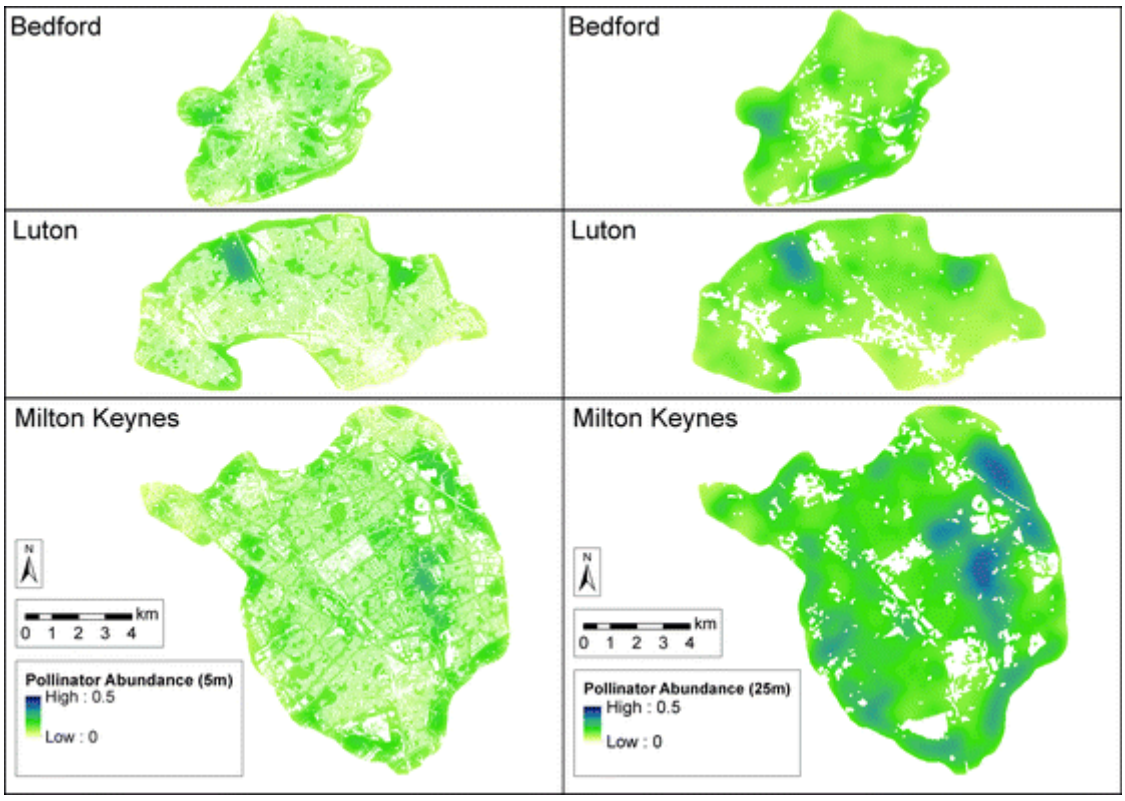

Figure 4 Relative index of pollination service provision in Bedford, Luton and Milton Keynes UK, based on 5m and 25m land use/land cover

The tools used in order to make the decisions and policies that encompass ecosystem services can frequently be the cause of the mismatch, as the tools are rigid and often can't flex to fit different scales. The MEA has collated the tools which are most commonly used in environmental management as seen in Table 5. The Table shows the ease with which each tool can be adapted and amended to fit the issues in environmental management and the scale at which they can be accurate.

Table 5 Tools used in environmental management (MEA, 2005a)

					Scale of Application		
Method	**Optimization**	**Equity**	**Thresholds**	**Uncertainty**	**Micro**	**National**	**Regional and Global**
Cost-benefit analysis	+	+	–	+	✓	✓	✓
Risk assessment	+	+	++	++	✓	✓	✓
Multi-criteria analysis	++	+	+	+	✓	✓	
Precautionary principle[a]	+	+	++	++	✓	✓	✓
Vulnerability analysis	+	+	++	+	✓	✓	

[a] The precautionary principle is not strictly analogous to the other analytical and assessment methods but still can be considered a method for decision support. The precautionary principle prescribes how to bring scientific uncertainty into the decision-making process by explicitly formalizing precaution and bringing it to the forefront of the deliberations. It posits that significant actions (ranging from doing nothing to banning a potentially harmful substance or activity, for instance) may be justified when the degree of possible harm is large and irreversible.

Legend:

++ = direct application of the method by design

+ = possible application with modification or (in the case of uncertainty) the method has already been modified to handle uncertainty

– = weak but not impossible applicability with significant effort

Cost-benefit analysis compares and calculates the benefits and costs of a project. However on a large scale project, with multiple environmental impacts reaching into the future, Almansa and Martinez-Paz (2011) found that the tool can't be used effectively or at least requires adaptations (Almansa and Martinez-Paz, 2011). Multi Criteria Analysis (MCA) is widely used in environmental management as it can rank project alternatives according to the costs and benefits, and also the involvement of stakeholders. Multi Criteria Analysis based decisions are often better received as they can incorporate public opinion and ideas (Huang et al., 2011). The Precautionary Principle (PP) was named as a major part of International Union for Conservation of Nature (IUCN) policy, as a way of taking action on environmental events before waiting for full scientific analysis (JNCC, no date). The PP is made more effective within the environmental sector when the alternatives are thoroughly assessed as new solutions can be found, rather than just problems being identified. This enables

precautionary plans to be put into place, and also puts more pressure on those creating the environmental risks (Tickner and Geisner, 2004).

The tools and management processes that are currently used in order to manage the natural environment can cause mismatches in scales as they don't always have the flexibility to incorporate the inherent complexity and unpredictability of the natural environment. This can lead to decisions being made on outputs from a tools that cannot fully encompass the scales within the natural environment. For instance, using cost-benefit analysis as a tool in ecosystem services management can lead to some of the benefits of an ecosystem being lost if a different benefit is the focus of the management (POST, 2013). Incorporating the complexity of the natural environment into the decision-making process is a key challenge (Mace et al., 2012).

Scale mismatches are a global problem which will continue to cause issues until they are challenged and changed. Bakun and Broad, (2003) show that when ecosystem services are managed at the wrong scale, and inflexible tools are used to manage a fluid issue, negative environmental and social impacts are created. Where a management plan is set in place for an area which has temporal fluctuations in species abundance or diversity, such as areas where fish abundance changes during an El Niño event, (Bakun and Broad, 2003) there are a set of methods and targets that cannot be met, causing a mismatch between management and the natural scales.

Planners are not able to fully encompass the scale at which an ecosystem functions as they are restricted to political boundaries, whether this be country boundaries, or regional boundaries within a country. Even when environmental management decisions are informed by the best scientific and technical inputs, their success falls to the political and institutional framework in which they are applied (Harding, 2006), and when representation is spread across various different institutional frameworks further mismatches can occur. The ecosystem services provided by one area of freshwater ecosystems are often spread across different local government divisions, so governance needs to ensure that

the freshwater ecosystem can be managed in a way that it continues to provide reliable service levels (Keen, 2005).

The mismatch of ecosystem service scales and environmental management and policy scales has been the focus of many research papers. There have been different ideas as to why a mismatch occurs, and also different ways to try and resolve the issues caused by the mismatch, as set out below.

1.7 Reasons behind scale mismatches

The interaction between science and policy is vital in the decision making process, yet it is often found that the research and policy communities have limited communication, and contrasting aims that inhibit them making a connection (Posner et al., 2015). Scientists and policy makers have a disconnect derived from a perceived lack of understanding of the other party (Weichselgartner and Kasperson 2010). As a result of this Sutherland et al. (2013) identified twenty advice points to enable policy makers and their advisors to interpret scientific claims. Due to widespread publicity of this article, Chris Tyler of the Parliamentary Office of Science and Technology countered with an article published in the Guardian newspaper detailing twenty key points that scientists should understand about those involved in policy making. Their twenty key points are presented in Tables 6 and 7.

Table 6 Summary points from Sutherland et al. (2013)

Nature – William Sutherland
Difference and chance cause variation
No measurement is exact
Bias is rife
Bigger is usually better for sample size
Correlation does not imply causation
Regression to the mean can mislead
Extrapolating beyond the data is risky
Beware the base rate fallacy
Controls are important
Randomization avoids bias
Seek replication not pseudo replication
Scientists are human
Significance is significant
Separate no effect from no-significance
Effect size matters
Study relevance limits generalisations
Feelings influence risk perception
Dependencies change the risks
Data can be dredged or cherry picked
Extreme measurements may mislead

Table 7 Summary points from Tyler 2013

Guardian – Chris Tyler
Making policy is really difficult
No policy will ever be perfect
Policy makers can be expert too
Policy makers are not a homogenous group
Policy makers are people too
Policy decisions are subject to extensive scrutiny
Starting policies from scratch is rarely an option
There is more to policy than scientific evidence
Economics and law are top dogs in policy advice
Public opinion matters
Policy makers do understand uncertainty
Parliament and government are different
Policy and politics are not the same thing
The UK has a brilliant science advisory system
Policy and science operate on different time scales
There is no such thing as a policy cycle
The art of policy is a developing science
'Science Policy' isn't a thing
Policy makers aren't interested in science per se
'We need more research' is the wrong answer

There are many direct responses to Sutherland et al. (2013) in the Tyler (2013) list, although Tyler has not written these as a clear point by point rebuttal. Both sides use the awareness that they are only human, and Sutherland et al. (2013), use this point to identify that scientists want to promote their work. Tyler

(2013), however, uses this to explain that mistakes and bad decisions can sometimes be made.

Both sides identify that not everything is always as precise or flawless as the other side might like to think. Sutherland et al. (2013) identifying that ‘No measurement is exact’ and Tyler (2013) making the point for the policy side that ‘No policy will ever be perfect’. The expectations of scientists and stakeholders when meeting in advisory bodies diverge due to their different needs and perceptions (Sarewitz and Pielke, 2007). It is important from the outset to clearly define any points which could be misunderstood or misinterpreted, or else a project may, for example, be of great scientific benefit, but not adapted to the needs of policymakers.

The two points that Sutherland et al. (2013) make which relate to the issue of scale are ‘Extrapolating beyond the data is risky’ and ‘Study relevance limits generalisations’ which identify that it is not always possible to ‘scale up’ results either temporally or spatially; and ‘Bigger is usually better for sample size’ where it is believed that the more data is available, the more accurate the results. Scale is mentioned by Tyler (2013) in ‘Policy and science operate on different time scales’, which directly highlights the scale mismatches that occur between policy and science, which may be having an impact on the natural environment.

Traditionally, policy for environmental issues has been under the control of government regulation. It is rare for issues of scale to be addressed, though this does occur (Goldthau, 2014). Even then, delegation of responsibility may not be appropriate for the scale of the project, often being delegated down to a local area which is not able to take decisions where the environmental needs cross political boundaries. There have been, within the last ten years, efforts to overcome the mismatch between ecological and political boundaries, for example delineating by use of physical boundaries such as watersheds.

Highlighted by the above arguments is the need for, from the outset, a science/policy interface on ecosystem service research projects, as the outcomes of ecosystem service projects have a direct implication on policy-

relevant factors such as flooding and pollination. There is a real need at all levels, not just in larger or official policy committees, to increase mutual understanding. Neßhöver et al. (2013) have identified that in the field of biodiversity across Europe, new scientific knowledge has begun to influence policy, and policy perspectives have begun to be included in research processes. These new lines of communication often continue after the end of one specific project.

Another issue surrounding matching the scales of policy and ecosystem services is double counting. Double counting can occur when the process of an ecosystem service is valued separately from the benefit of that same service (Hein et al., 2006), an example being biodiversity and carbon sequestration in forestry. This is an issue because it can undervalue or disregard one ecosystem service in favour of another and cause management decisions which fail to incorporate one of the services, meaning it may be detrimentally affected and could potentially disappear.

Many ecosystems deliver multiple ecosystem services, which can make it complicated to create a management plan or policy that doesn't create trade-offs between one service and others. The diversity of fine scale ecosystems may be missed when policies delivered by centralized government agencies apply a "one-size-fits-all" outlook (Cumming et al., 2006). Management decisions made at the landscape scale often do not fully encompass the full stock of ecosystem services which are present (Raudsepp-Hearn et al., 2010) Ecosystems such as rivers need to be managed wisely in order to ensure that the full range of services that they provide - water for irrigation or domestic supply, power generation and their intrinsic biodiversity values (Tickner et al., 2017).

It is also possible that mismatches occur through what are known as ecosystem services trade-offs. Here, either intentionally or not, the provision of one ecosystem service is reduced as a consequence of the increase in use of another. These trade-offs may be seen along axes of spatial scale, where the effect of the trade-off is determined either locally or at a greater distance;

through temporal scale, where slow or rapid effects take place; and, by the likelihood that the managed area will be able to return to its original state if land management is stopped (Rodriguez et al., 2006). When the effects of a trade-off occur at a different scale to the benefits of the preferred ecosystem service, the decision maker may not witness or comprehend the trade-off as it is out of their realm of influence. This is the point at which the scale mismatches occur.

Cavender-Bares et al., (2015) created a framework in order to recognise and highlight the sustainability of trade-offs in ecosystem services. The perspectives and needs of different stakeholders may contrast sharply with different expected and realised outcomes from a management project. The trade-off occurs in the interplay between the provision of ecosystem services on the one hand, and biodiversity on the other. Theoretical models are used to determine such a trade-off by considering cultural, regulatory and support services. Commonly, management practices could be seen to benefit all the stakeholders in an ecosystem service whilst enhancing both provisioning and regulatory services. In one analytical study by Ewing and Runck (2015), an increase in both corn production and enhanced water quality was understood to be feasible, even with existing technology and clear management.

The data used in order to create policies and value the ecosystems can create mismatches, as the data is often scale dependent, and if a lower resolution dataset is used there can be inaccuracies as to real quantities and values of ecosystem services (Konarska et al., 2002). Using 1 km resolution land cover data and 30m land cover data, all of the US states were compared on ecosystem service valuation. Only one state, New Mexico, had lower ecosystem service value in the 30m resolution than in the 1km data (Konarska et al., 2002). It is far more difficult to obtain high resolution data to use in research, and thus it is often the lower resolutions from which decisions are made. However, high resolution data spanning a large area may lose finer details such as anomalies and overall patterns (MEA, 2005a). These details can be useful in seeing just how complex ecosystem services are; mapping and analysing them can take more than one measure; and finding and using all of

the data for all of the elements of a service, at the correct scale, is often difficult (Naidoo et al., 2008). These factors can all be contributory factors in management decisions not encompassing the full picture, meaning ecosystem services are being undervalued and undermanaged.

Boundaries are difficult to see within ecosystem services as the beneficiaries of each service can be far and wide, and even reach into the future, making them spatially and temporally fluid. With policy and decision making there are often set spatial boundaries within local authorities, and the decision makers are often under short temporal constraints (Bai et al., 2011). It is highly unusual for political boundaries to be in line with environmental demarcations, such as watersheds, as political control is defined by town, county, or local authority areas. (Salzman, 2005). This is an imbalance which can cause difficulty for accurate and effective long term policy making. These boundaries can be an important factor in ecosystem valuation, as any change in representational boundaries can have significant effects on the valuation of services in an area (Troy and Wilson, 2006), for example in marine areas, especially where the shoreline and territorial waters may be included (Troy and Wilson, 2006).

There are very few published case studies that have identified and solved the problem of scale mismatches (Cumming, et al., 2006). Changing the scale and type of data used to create the policies and management techniques can lead to more accurate results in analysis (Konarska et al., 2002). Developments in ecological science have made it easier to manage ecosystems at a larger scale (Wyborn and Bixler, 2013), as these fall in line with the larger scales that policy and legislation cover. These developments could be used to have more effective large scale management. Collaborative efforts between governments and other decision making organisations can increase the scale of management to closer match those of the natural environment (Wyborn and Bixler, 2013). It is clear that there needs to be a change in the way that ecosystems are managed in order to include both temporal and spatial scales, and these changes need to occur at an institutional level (Cumming, et al., 2006).

1.8 Definition of the problem

Within the environmental and ecosystem service sector an issue is emerging of mismatching scales. This issue presents itself in spatial and temporal contexts, which are influenced by funding, organisational power and targets. This mismatch in scales is multidimensional and applies to the natural scales of ecosystem services; the scales at which scientific research is undertaken; planning and policy-making scales; and the interaction of these scales at different institutional levels. Ecosystem services are complex and the planning, policy and research sectors surrounding them reflect this.

1.9 Aims and objectives

The aim of this research is to understand the extent, occurrence, and nature of problematic scale mismatches within ecosystem service planning, policy, and research in order to gauge and potentially alleviate their effects on the integration of ecosystem services into such policy, planning and research outcomes.

The objectives are to:

1. Assess the extent and circumstances in which scale mismatches occur
2. Determine the reasons behind those scale mismatches which are problematic
3. Interpret the causes of and current solutions for scale mismatch problems.
4. Identify practical solutions to reduce or resolve scale mismatch problems.

In order to tackle the aim and objectives, a combination of research methods from social science, ecology and medical research were employed.

Chapter 1 (this chapter) is the introduction and sets out the justification for the research, and the aims and objectives of the research question. Key concepts and an introduction to the challenges associated with scale mismatches are identified.

A systematic review of the terminology used in ecosystem service research is presented in Chapter Two and was used to gather in depth information on how, when, why and where ecosystem service scale was being researched, and where mismatches occurred.

Using evidence taken from the systematic review, an online survey was created to reach a wide and varied audience of scientists, policy makers and the public who had experience working with ecosystem services. The survey questions set out to identify the more intricate details of the ecosystem service scale mismatches, and the source of these issues. The development of this survey and the results found are found in Chapter Three

In Chapter Four the survey was then followed up with in depth interviews with key figures in ecosystem service research, practice, and policy. The interviews delved deeper into the issues and inconsistencies unveiled by the survey.

Finally, the research was investigated collectively in Chapter Five in order to uncover the overarching synthesis and themes and to draw conclusions and ensure all of the aims and objectives were met.

2 Systematic review of ecosystem service scale and policy.

2.1 Introduction

2.1.1 Ecosystem services

Ecosystems and the services they provide have encountered huge changes over the last fifty years, more than any other period in history, which will have repercussions reaching far into the future (Daily et al., 1997; Alcamo et al., 2003; Vihervaara et al., 2010). This is associated with anthropogenic pressures such as population growth, industrial expansion, and agricultural expansion. The consequence of this is a worldwide decline in biodiversity and ecosystem services (Chapin et al., 2000; MEA, 2005a).

Ecosystem service research is broad, and a simple search for the presence of the term 'ecosystem service' in an article title, abstract or keywords on ScienceDirect, a platform with a wide range of peer reviewed scholarly literature (Elsevier, no date), returned 4,697 articles. There is a lot of information on ecosystem services, and a systematic review enabled the collation and analysis of this information. Not all of the articles were relevant to the research question around scale, and the benefit of a systematic review is that it enabled the narrowing down and focusing on the more relevant articles and literature. The project focussed on the issues surrounding scale in ecosystem services, which stem mainly from mismatches in the spatial, temporal or organisational scales of ecosystem management. Scale mismatches are a global problem which will continue to cause issues until they are challenged and changed, as discovered previously in Chapter One (1, 1.6).

2.1.2 Systematic Review

A systematic review is a review of a clearly formulated objective that uses systematic and explicit methods to identify select and critically appraise relevant research and to collect and analyse data from the studies which are included in the review (Moher et al., 2009). Systematic reviews are different from traditional literature, narrative, or critical reviews as they are led by a systematic protocol

in order to encompass all of the literature available on a topic, in a way that can be simulated and repeated (Hemingway and Brereton, 2009). A systematic review attempts to bring the same precision and robustness to reviewing research and evidence as is expected in the production of the original research (Hemingway and Brereton, 2009).

Systematic reviews have more often been used in medical literature and healthcare policy, where they evolved from the original process of meta analysis, after Dr. Archie Cochrane called for health care practitioners to engage in a more evidence led approach to medicine in 1972 (Cochrane, no date). This call was taken up by professors at Oxford University and led to the beginning of the Cochrane Collection in 1992. The Cochrane Collection is a database of healthcare based systematic reviews, which are performed following their rigid protocols (Cochrane, no date). Systematic reviews are used alongside meta-analyses in order to keep those in the medical field abreast of the wide range of medical literature (McGowan and Sampson, 2005). There are around 20,000 medical journals, producing upwards of 2 million articles per year (Hemingway and Brereton, 2009). This large number of articles, alongside the ease of access of any specific one, makes it difficult to get complete and robust information on a particular topic. The systematic review process can help by accurately summarising a very wide topic into just one thorough, comprehensive, and rigorous paper, which gives those in an already high pressure, time sensitive sector (such as health care) the opportunity to access up-to-date information (Hemingway and Brereton, 2009).

The use of systematic reviews is on the increase, as they use a systematic and predefined methodology covering all appropriate literature, presenting it in a way that enables them to be read and interpreted by scientists, policy makers and consumers (Gopalakrishnan and Ganeshkumar, 2013). There are many prescribed processes that can be used, and some journals which only publish systematic reviews have their own prescribed methodology and also more wide ranging protocols. The two most prevalent in the UK are the Cochrane review protocols and the PRISMA protocol. Both of these have been designed for use

in medical literature. As a result of the success of these robust protocols, systematic reviews have now started to become more prevalent wherever they can be used to aid decision making, becoming a recognised standard for appraising, assessing and synthesising available data (Collaboration for Environmental Evidence, 2013).

Again, drawing from methodologies in the health sector, specific guidelines for CEE systematic reviews (SRs) for application to environmental management (CEE, 2013) have also been informed from practice in social sciences and education (Gough et al., 2012). With an underlying philosophy of transparency and independence, the rigour and objectivity applied at various points in the systematic review process sets them apart from other recently published but more traditional reviews (Roberts et al., 2006). CEE has a conviction that using a robust procedure will enhance the practice and policy in environmental management by identifying and providing a strong evidence base (CEE, 2013). Regardless of the project being undertaken, from the innate curiosity of an individual researcher to global policy development, it is important to use the best available evidence, and using a systematic review ensures that such evidence is both relevant and valid (CEE, 2013).

Systematic reviews in ecology are useful as they look at different aspects of this wide ranging field, and work to formulate answers to a broad question. There are many varying ways of measuring and analysing the natural environment, which is one of the key reasons that make systematic reviews in ecology more challenging, as conflicting scales and methods make direct comparisons of the information available difficult (Bilotta, et al., 2014). Ecosystems and their services are interconnected with the habitat, other species and also humans. Therefore reviewing research that is from ecology, land management and social science can help create the broad answers needed to inform future planning, policy and decision making. Using a systematic review can help build a picture of the socio-ecological environment, specifically in areas where environmental interactions can be disruptive (Bhattacharya-Mis and Lamond, 2014). Bhattacharya-Mis and Lamond, (2014) found that in areas where flooding is

both regular and devastating, a systematic review of the literature can collate both social data, on where people remember previous flood events and the levels of devastation, and the ecological data which can predict areas at risk of future flooding. This can build a broad and all-encompassing base of data with which planning, policy, and further research decisions can be made.

Within the ecology field, literature reviews are currently widely used and often provide the evidence used for making conservation and management decisions, but these reviews are not as thorough as systematic reviews as they don't follow such robust protocols. This less thorough approach was found to lead to lower quality reports that are often prone to bias due to unreliable inclusion and exclusion criteria (Roberts et al., 2006). In a study comparing 73 Cochrane methodology systematic reviews with 73 ecology reviews of literature (Roberts et al., 2006), it was found that when reporting inclusion and exclusion criteria, all 73 Cochrane studies defined inclusion/exclusion criteria for the identification of relevant studies. This compared to just twenty of the ecology reviews. Only one ecology review documented the reasons behind the inclusion and exclusion criteria, in comparison with 70 Cochrane reviews (Roberts et al., 2006). The work of the CEE then, has enabled researchers in the environmental field to introduce the robust framework, increasing integrity of ecological systematic reviews. Making a few relevant adaptations from the health care systematic review protocol can lead to a well-rounded systematic review of ecology which can then be used to inform planning and policy decisions (Bilotta et al., 2014).

A systematic review was used in this project in order to create a solid knowledge base regarding the policy/planning environment, researchers and environmental stakeholders use of, and ideas about, the term 'scale' in ecosystem services. A systematic review was used as further research alongside a standard initial literature review because the work needed to be robust and the conclusions drawn needed to be unbiased and to encompass all the relevant information, in order for the project to feed into further work. It enabled identification of all the relevant and reliable research on scale and how it is used to support the delivery, conservation, and management of ecosystem

services. A systematic review was chosen as the method to gain the information needed for the project as a whole, as they are widely recognized as being a good source of information, not just for scientists, but for policy and decision makers as well (Gopalakrishnan and Ganeshkumar, 2013). A lot of the learning behind the methods for the systematic review came from medical literature, where, as we have seen, systematic reviews are prevalent.

2.2 Research aim and objectives

The overarching aims and objectives of the entire research project are set out below.

The aim of this research is to understand the extent, occurrence, and nature of problematic scale mismatches within ecosystem service planning, policy, and research in order to gauge and potentially alleviate their effects on the integration of ecosystem services into such policy, planning and research outcomes.

The objectives are to:

1. Assess the extent and circumstances in which scale mismatches occur
2. Determine the reasons behind those scale mismatches which are problematic
3. Interpret the causes of and current solutions for scale mismatch problems.
4. Identify practical solutions to reduce or resolve scale mismatch problems.

The systematic review is setting out to help meet the overall aim of the research project, specifically understanding the extent of occurrence, and nature, of problematic scale mismatch within planning, policy, and research. Through a systematic review it is hoped that an understanding of the nature of scale mismatch will be identified assessed and the reasons behind it determined, helping to provide solutions which will be uncovered from the articles.

2.3 Materials and Methods

2.3.1 PRISMA and Cochrane

An edited version of the medical journals' PRISMA flow diagram was used in order to structure the systematic review. PRISMA is used mainly in healthcare to summarize the benefits and harms of healthcare intervention. The PRISMA protocol was created by a group of 29 review authors, methodologists, clinicians, medical editors, and consumers (Moher et al., 2009). It was designed not only so that it can be easily used by researchers, but also to create robust studies that can be interpreted by the end user. The PRISMA report identifies that some modifications to the flowchart and the checklist, in order to focus on a different question, will still enable to user to get a full and comprehensive review (Moher et al., 2009). This ability for modification, alongside its robust and easy to follow protocol is the reason why it was chosen to be used in this systematic review. The Cochrane reviews that are also prevalent in medical literature have very robust and specific protocols that are split into 5 specific areas (Cochrane, no date). However, none of these would be appropriate for answering the question in this systematic review because they relate specifically to medicine.

Alongside the PRISMA method, guidelines from the Collaboration for Environmental Evidence were also used. CEE was used as it is a branch out from the Cochrane process, so it is robust, but it is also adapted in order to be used for environmental evidence (CEE, 2013). The CEE guidelines and PRISMA work well together as they both have their own strengths, CEE with its thorough and well thought out process for setting the question for the review (CEE, 2013), and PRISMA ensuring a robust study and avoiding bias, with their easy to follow protocol.

Publication bias is difficult to avoid (Moher et al., 2009). During this systematic review it was found that as the questions being asked of the literature were not focussed on the results of experiments, but rather on the prevalence of specific words and topics, publication bias would not be too much of a threat to the accuracy of the review.

2.3.2 Sources

The systematic review process includes a comprehensive search for all available and potentially relevant evidence and to ensure it is prejudice free. Three resources were used to search for articles: ABI/inform, a comprehensive and diverse research business database; Ebsco-environmental complete, a database specifically for resources in agriculture, ecosystem ecology and energy; and Google Scholar, a large database with a vast range of information relating to researchers and policy/planning makers. These particular databases were chosen as they are widely available to, and likely to be used by, those in research and policy, so their current thinking may well be informed and influenced by articles contained within them.

2.3.3 Inclusion and exclusion criteria

In order to avoid bias, and to ensure thorough analysis, inclusion and exclusion criteria were applied at different stages until the articles for data synthesis were obtained. These filter the findings to be manageable, focused and specific. No papers were excluded by date, as it was the timeline of the way research has progressed that is being investigated.

Inclusion criteria:

1. All regions/countries or continents (To get a full global picture).

2. The use of scale within biodiversity and ecosystem service (Either biodiversity or ecosystem services as they are interlinked and the basis of the question).

3. The various habitat types present across landscapes.

Exclusion criteria:

1. Article is not English language (If no translation could be found then the paper was excluded as it would be impossible to analyse fully)

2. Scale is used outside policy/planning and research context (The question being answered revolved around the research and planning/policy environments so anything outside this was deemed superfluous).

3. Same article in different databases (Each included article was only analysed and counted once).

4. Articles with title and abstract but without access to the full article (If access was unable to be attained through Cranfield University's subscriptions it was not able to be read in full and thus could not be included in the systematic review).

2.3.4 Keywords and Search Strings

Before the Systematic Review was started a background study of the literature was analysed to find the different words, themes and fields that would need to be searched in order to create a robust study. A literature review that had previously been performed at the beginning of the wider study set out in Chapter One, of which this systematic review is a part, was used. This search resulted in the following keywords:

ecosystem, ecosystem services, landscape services, natural environment, natural services, ecological services, scale, spatial scale, spatial pattern, temporal scale, temporal pattern, policy, management

Search strings were then formulated using Boolean operators and other research tools and copied into the selected databases. By a process of scoping, an initial review of several documents relating to the keywords, the search strings start broad and are then narrowed down to give more detailed answers to the research questions. The initial strings are from the broader literature searches, and as the review continued the strings forked into either spatial or temporal scale.

The strings that were used in the search are:

- Strings 1 – “ecosystem service*” OR “nature’s service*” OR “environmental service*” OR “landscape service*”
- Strings 2 – “temporal scale*” OR “time scale*” OR timescale* OR “spatial scale*”
- Strings 3 – (manag* w/3 “natural resource*”) OR “socio-ecological system*” OR “natural capital AND scale*”
- Strings 4 – “government polic*” OR “decision mak*” OR “policy mak*”\

The Boolean operator OR gives a broader result, where any paper with any of the keywords will be found (Worldox, no date). Where there is an asterisk at the end of a word, such as “ecosystem service*”, the search will include variations of the word including service, services, serviced. However, the inclusion of the quotation marks will ensure that the exact phrase is searched for. In string 3, the w/3 creates a search for the terms manag* and “natural resource*” within a proximity of 3 words of each other (Worldox, no date). The Boolean operator AND was used to combine strings.

Each string on its own is not relevant to the research as they are too broad, so they were combined to narrow the search. The combinations were: strings 1 AND 2, to find overall ideas of scale in ecosystem services; strings 2 AND 3, to get ideas of the different words used in ecosystem services and their scale; and strings 1, 2 AND 4, to understand the planning and policy aspects of ecosystems service scale. Using the strings enables consistency across the results by using the same words and search terms, rather than just performing three different searches.

2.3.5 Literature selection

Where the search unveiled irrelevant articles it was easy to spot this from their titles. The terms being searched included scale which has many meanings, the search turned up papers discussing fish scales and weighing scales, which are easy to identify as being irrelevant. The next step in the selection of literature to be analysed was to read the abstracts of each of the articles where titles that

suggested they may be useful in the analysis. After the articles had been selected by their abstracts, they were then read in full. Also, the reference lists of the papers were reviewed to include potentially suitable articles.

2.3.6 Data Extraction

The information collected from each of the papers selected to be read in full was guided by a combination of the PRISMA and CEE methods. Following the tick box method of the PRISMA guidelines and the critical appraisal CEE procedure, a table was made which was completed by reading each of the papers and extracting the relevant information which can be found in Appendix A. The purpose of the systematic review was to determine different perceptions of scale, and its various uses in ecosystem service research, so the actual data used in each of the papers was not necessarily of use. The review was focussed on the language used within the papers and the general themes identified. This is one of the adaptations made from the PRISMA and Cochrane guidelines, as the intended output of the review was different from most systematic reviews, where the results of the papers are analysed to answer a question.

Where there were papers that did not have all of the data that was necessary to complete a table, as much information as possible was extracted and as long as over 50% of the shaded aspects of the table (Appendix A) was complete the paper was included in the study. Any less than 50% and the paper was excluded as it would not ensure the robustness of the study. After the data was collated and the initial results and patterns identified, the papers were then analysed further to ensure that the context and further flows were identified correctly before conclusions were made. This was done by reading the full text of the paper, in order to get the flow of the research and ensure that although the information had been extracted, it wasn't taken out of context. Using the data extraction tables, the articles were read and searched for solutions to mismatch problems, and the reasons behind them. These reasons could be part of the overall theme of the research, or they could have been suggestions put forward in a conclusion for the reasons behind scale mismatch. The article

could be focussed on testing or utilising one specific solution, or it could have put forward ideas on what the solution could be, or needs to include.

2.4 Results

2.4.1 Article Distribution

A total of 2941 papers were found within the initial screening and were reviewed during the process, of which 112 papers were used in assessing how scale supports the delivery of different ecosystem services. The returns from the search strings from the different search engines are shown in Tables 8-10. Google Scholar (Table 10) returned the most articles that were included in the study, although the differences between the total number of articles returned and the final amount selected is the highest compared to ABI/INFORM (Table 8) and EBSCO (Table 9).

Table 8 String combinations in ABI/INFORM

Search strings	Total Number of articles	Number selected on initial screening (title and abstract)	Number selected on second screening (full text)
String (1 AND 2)	9	7	6
String (2 AND 3)	16	4	2
String (1 AND 2 AND 4)	2	2	1

Table 9 String combination in EBSCO – environment complete

Search strings	Total Number of articles	Number selected on initial screening (title and abstract)	Number selected on second screening (full text)
String (1 AND 2)	91	17	15
String (2 AND 3)	3	3	1
String (1 AND 2 AND 4)	16	10	8

Table 10 String combination in Google scholar

Search strings	Total Number of articles	Number selected on initial screening (title and abstract)	Number selected on second screening (full text)
String (1 AND 2)	2630	97	73
String (2 AND 3)	140	5	2
String (1 AND 2 AND 4)	34	8	4

The breakdown of articles according to their habitat showed: aquatic – 25; terrestrial – 49 and terrestrial and aquatic – 38 as displayed in Figure 5.

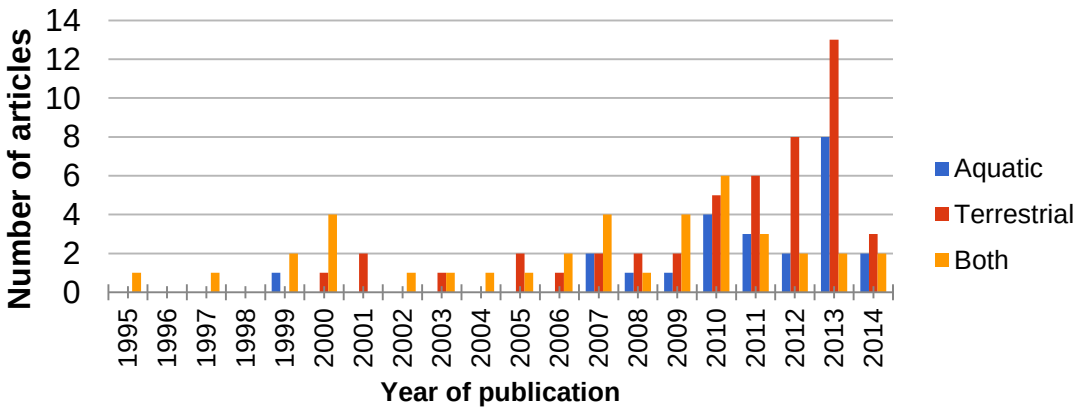

Figure 5 Distribution of articles over time by habitat

Figure 5 shows the most active year for articles to be published that fall within the context of the systematic review was 2013. The review was undertaken in 2014 so it has not been possible to follow pattern of increase in articles. However, the significant increase in both terrestrial and aquatic articles coincided with the publication of the Natural Environment White Paper (H.M. Government, 2011) and the conclusion of the National Ecosystem Assessment in 2011 (UKNEA, 2011). The two year time lag is explained by the time required

to do the research and then publication on what has become the forefront topic of ecosystem services.

As we have seen in Chapter 1, there are many different ways of describing scale, however most of them fall into a temporal or spatial context. Figure 6 shows the breakdown of spatial, temporal, and spatial and temporal articles whilst Figure 7 shows the distribution of articles over time, separated into scale context.

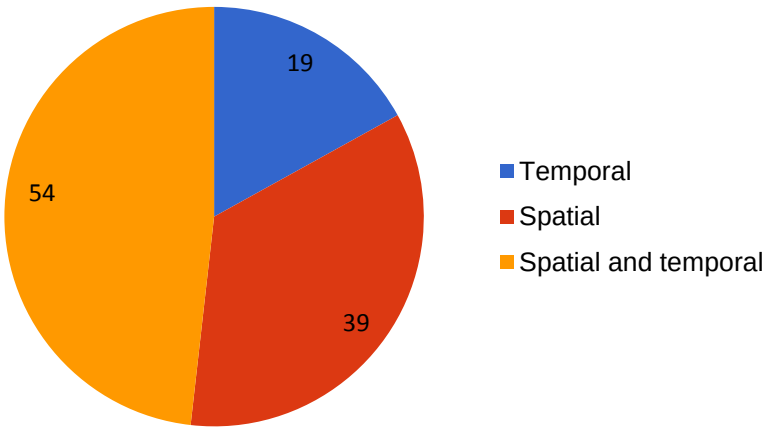

Figure 6 Breakdown of spatial, temporal, and spatial and temporal articles

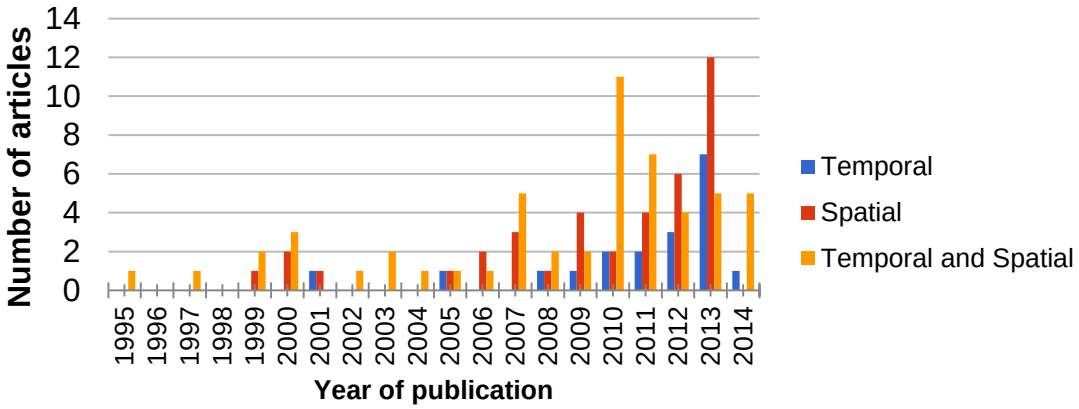

Figure 7 Number of articles separated by scale context

Figure 7 shows that articles that reference both temporal and spatial scale which been consistent from the beginning of ecosystem service research that is relevant to this review. Researching in an exclusively spatial context has increased year on year from 2005, whilst for a temporal context this increase started later in 2008, and has been present in fewer articles. The focus shift from the combined study to the separate could be a move toward more detailed scale analysis, and also a recognition of the issues and problems that are present in scale terminology in ecosystem services, and the importance of dealing with them in detail.

Analysing the trend in the various articles showed that the articles were from 27 countries, in three regions (EU, Western North America and North America). Figure 8 shows the breakdown of the countries and articles in the study.

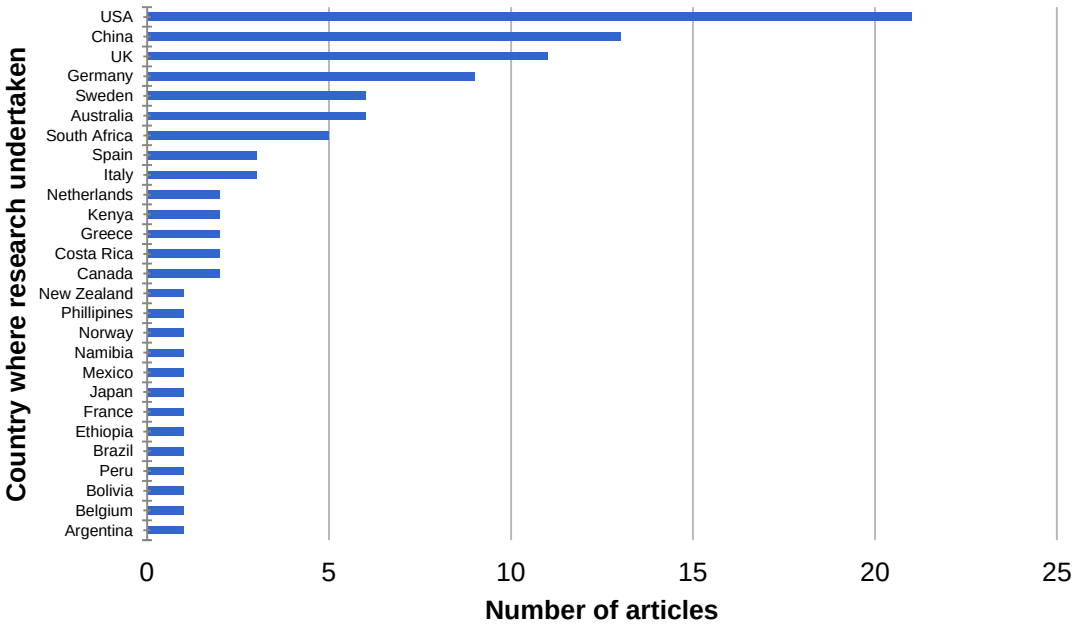

Figure 8 Number of articles by country

The research most relevant to the systematic review is taking place in the USA, followed by China and then the UK. Overall there are 27 countries represented in the review. The country identified is where the research was undertaken.

2.4.2 Identification of methodologies

An important part of the discussion on scale in ecosystem service research and policy is the methods used to acquire the data, as this is how the research conclusion is drawn, and on which the policy is then based. In order to investigate this, the papers were split into articles based on spatial scale and those based on temporal scale. The spatial scale articles were then analysed independently of the temporal scale ones in order to find the methods which were used in the articles.

In the 53 spatial scale articles used for this research, four basic study methods were employed descriptions of what they are comprised of are shown in Table 11, some articles used a combination of all four. The methods were: literature/research, field sampling/expert knowledge, modelling/simulation, and valuation/calculation.

Table 11 Methods identified and composition

Method	Composition
Literature/research	Obtain results based on deductions made from other research, such as systematic reviews and review papers
Field sampling/expert knowledge	Research undertaken at field sites or by experts in lab conditions
Modelling/simulation	Using a tested, or introducing a new modelling or simulation tool
Valuation/calculation	Based on estimation of spatial patterns of the ecosystem

Figure 9 shows that the literature methodology was the most prevalent, featuring in 16 out of 53 articles, with field sampling/expert knowledge also quite prevalent within the studies appearing in 14 out of the 53.

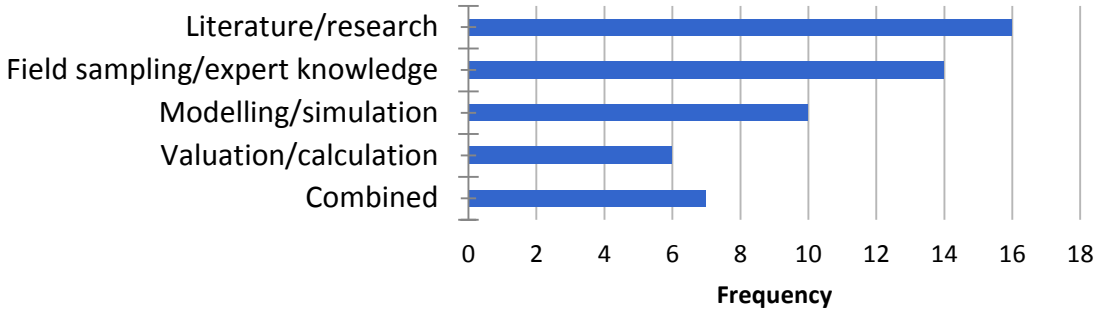

Figure 9 Research methods used in the 53 spatial scale articles

Table 12 shows the distribution of the research methods by region. Prominent in the Table is the higher use of literature/research methodology in Europe whereas in the USA almost all the methods are used. Articles with field sampling/expert knowledge occurred about fourteen times with the basis of findings hinging on onsite measurements. Modelling/simulation had about ten occurrences. This was relatively hypothetical and largely addressed management practices for the ecosystem under various anticipated conditions. An example of a model method used is the Integrated Valuation of Environmental Services and Trade-offs (InVEST, no date). The calculation method (frequency 6) is based on estimation of spatial patterns of the ecosystem. Finally, there was combined method (frequency 7) which involved the mix of other methods to arrive at a result.

Table 12 Distribution of research methodology across the three most represented countries in the systematic review

	Research methods				
Country	Literature/ research	Field sampling/expert knowledge	Simulation/ modelling	Calculation	Combined
USA	5	6	2	-	4
Europe	8	2	-	2	-
China	-	1	2	-	-

2.4.3 Working with scale

Figure 10 highlights some of the different words used for spatial scale by both the research articles and the planning/policy articles. The figure also shows how the frequency of use of these words has changed over time, with the use of ‘large’ or ‘multi/multiple’ scale increasing. The increase in articles discussing matters at ‘large’ scales shows the more wide reaching global scale of science and research. The increase in research done at ‘multi’ or ‘multiple’ spatial scales is a positive move towards turning away from the ‘scaling up’ of research, where research from a specific scale is then used to apply to, and make assumptions about, larger and smaller scales of the same environment.

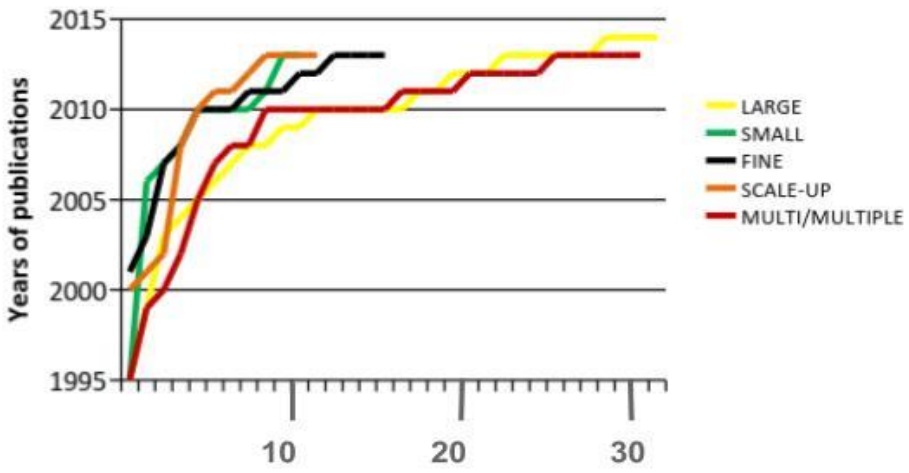

Figure 10 Scale term usage within articles over time

2.4.4 Terminology

The variability in terms used for scales reflects the complexity of the natural ecosystem services to which they are applied. It is also important to consider the context, as ecosystem service research can be discussed either with respect to the natural system, or by the service they provide, or the end user. These can change the scale at which the work being done is considered, thus requiring different terms to describe them. The terms used are often linked to the recipient, and used in order to reach the intended audience.

The systematic review found that the frequently used ‘large’ or ‘multi’ scale describes the regular variations of processes involved in obtaining services from the ecosystem. Some of the explanations of scale terms by authors include: (Scholes et al., 2013) “multi-scale means doing a study at several scales, essentially simultaneously”; Governance scale (Hein et al., 2006) is the “hierarchically organized institutions/administrative levels at which decisions on the utilization of capital, labour and natural resources are given”, “fine scale was defined as the smaller than the minimum resolution of the assessment, community scale as where the local people assert their territorial domain” (Tomich et al., 2010), while James et al., (2000), defined “sub-regional scale as

the scale at which local, political and planning decisions are made and, as such, it is the scale which influences directly the development of landscapes".

However complex, 'local', 'regional' or 'global' scale were used in 85% of articles. Though there are no clear demarcations of their use, the planning and policy sector use 'local' to describe county, community, village, state; 'regional' to depict countries with close boundaries and 'global' for all the countries on planet Earth. On the other hand, researchers' use of 'local and regional' refers to where an experiment, monitoring or assessment is being carried out or where the results of the experiment are experienced. They agree with the policy and planning sector on the use of 'global'.

'Multiple scale' is the assessment of the ecosystem at various spatial and temporal scales, simultaneously. The review has shown that multiple scale research is going to provide policy makers and planners with the best information they need to make decisions. Multiple scale assessment shows a better problem definition; improved analysis of scale dependent processes; improved studies of different cross-scales; and gives a better understanding of the causality including improving the accuracy and reliability of findings (Scholes et al., 2013). Although there can be 'multiple temporal scales' and 'large temporal scales', when the term 'multi scale' or 'large scale' are used they refer to spatial scale for the majority of stakeholders involved in an issue.

2.4.5 The nature of scale mismatch.

Not every paper analysed had a strong point in a particular direction. There were some papers which discussed the problems surrounding scale, and some which discussed a particular project or idea and only briefly made reference to there being an issue with scale. There were some papers that are quoted twice; these are where there are two different ideas or solutions being presented. Table 13 shows the reasons behind the scale mismatches in ecosystem service management and policy, and Table 14 presents the solutions found.

Table 13 Reasons for scale mismatches

Authors	Summary point
Martin-Lopez et al., 2009	where action is taken/where results seen
Satake, 2008	where action is taken/where results seen
Cumming et al., 2006	where action is taken/where results seen
Hein et al., 2006	where action is taken/where results seen
Gret-Regamey et al., 2013	where action is taken/where results seen
Martin-Lopez et al., 2009	stakeholder knowledge
Hein et al., 2006	stakeholder knowledge
Skourtos et al., 2010	stakeholder knowledge
Cortner et al., 1998	stakeholder knowledge
Ahlborg and Nightingale, 2012	stakeholder knowledge
Ribeiro et al., 2008	data collection/use methods
Busch et al., 2012	data collection/use methods
Dick et al., 2014	data collection/use methods
Norgaard, 2008	data collection/use methods
Barbour et al., 2005	data collection/use methods
Felipe-Lucia et al., 2014	data collection/use methods
Helfenstein and Kienast 2014	data collection/use methods
Boykin et al., 2013	data collection/use methods
Brody 2003	research/management/policy different scales
Brody et al., 2004	research/management/policy different scales

Table 14 Solutions to scale mismatches

Authors	Summary Point
Martin-Lopez et al., 2009	multi-scale approach
Scholes et al., 2013	multi-scale approach
Barbour et al., 2005	multi-scale approach
Pegg And Taylor, 2006	multi-scale approach
Gret-Regamy et al., 2013	multi-scale approach
Konarska et al., 2002	standardized, unified framework
Maltby, 2003	standardized, unified framework
Dick et al., 2014	standardized, unified framework
Hermann et al., 2014	standardized, unified framework
De Groot et al., 2002	standardized, unified framework
Valles-Planells et al., 2014	standardized, unified framework
Childress et al., 2002	standardized, unified framework
Cortner et al., 1998	closer relationship between science and policy
Norgaard 2008	closer relationship between science and policy
Cumming et al., 2006	closer relationship between science and policy
Fisher et al., 2009	closer relationship between science and policy

2.4.1 Notable Finding: Climate change

A notable finding from the systematic review was the high frequency of articles discussing the search terms in the context of climate change. This was not something that was investigated, nor part of the aims of the study, but rather a pattern that was identified at the full text reading stage. Climate change was discussed for many different reasons in relation to scale. Firstly, the way in

which it is going to shape the future of ecological systems, where current and future research need to look at climate change as it creates shifts in ecosystems (Dearing, 2012; Maltby, 2013; Haase et al., 2014; Forst, 2009). Secondly, the policy and framework development shift that is occurring due to climate change, and attempts to mitigate its effects in ecosystems (UNEP 2011; Duraiappah et al., 2014; Scholes et al., 2013; Tomich et al., 2010; Satake, 2008; Huacka et al., 2013; Quintero, 2009; Gret-Regamy et al., 2013; Foley et al., 2010; Izquierdo and Clark, 2012). Thirdly the type and extent of ecosystem service research being undertaken in a changing climate (Skourtos et al., 2010; Helfenstein and Keinast, 2014; Boykin et al., 2013; Xu et al., 2014). Finally, the way in which climate change mitigation methods are affecting ecosystems (Busch et al., 2012).

2.5 Discussion

The increase in articles discussing large or multi/multiple scale can be seen as a problem in planning and policy, where something that has been found to have worked in one area is then rolled out as a management decision. However, the effects of doing this at different scales have not been taken into consideration. This usually occurs because of a shortage of relevant data (Green et al., 2005). As a consequence, regional or individual studies to monitor global scale changes in biodiversity have sometimes been scaled up inappropriately (Green et al., 2005). Temporally, it can be useful for time scales to be applied to the different types of ecosystem services in order to integrate them into policy and planning timelines and budgets. The Millennium Ecosystem Assessment, affirms the benefits of ecosystem services based on the temporal scale ranges from ‘immediate short to medium term’ (provisioning services) to ‘indirect medium to long-term’ (regulatory services), ‘direct long-term’ (cultural services) and to ‘indirect long to very long term’ (supporting services) (Skourtos et al., 2010). These time scales can be contradictory or conflicted within a landscape where many ecosystem services are acting at once, which means this move towards multi/large scale will be better focussed to encompass them due to being able to incorporate and comprehend multiple scales within the research

and policy. Understanding these temporal scales can make it easier for those in both research and policy to prioritise specific research projects, acknowledge limitations, and manage resources. Multiple scale studies may also be increasing due to the move towards more interdisciplinary studies around ecosystem services, and also the development in knowledge of the intricacies of ecosystem services and their interactions. In conclusion, it is important that care is taken when dealing with upscaling policy decisions from smaller scale research projects, though this is happening already with the move towards large, multi and multiple scale projects.

2.5.1 From research to policy

Within the research articles analysed, the data and information obtained came predominantly from climatic data, archaeological findings, fieldwork, anthropological activities, maps and historical studies. The extensive and varied areas from which evidence is collected for the articles in the systematic review indicates that there is a wealth of information available to enable the planning and policy sectors to implement their recommendations to ensure sustainability at the different temporal and spatial scales which are represented in the different areas of data collection. These implementations include programmes such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), EU biodiversity strategy 2020, and The Economics of Ecosystem and Biodiversity (TEEB). IPBES is an independent, intergovernmental body comprised of 94 United Nations governments who agree that more needs to be done to strengthen the relationship between science and policy regarding ecosystem services and biodiversity (IPBES). The EU biodiversity strategy 2020 aims to halt biodiversity loss and restore habitat. The strategy aims to increase the EU's contribution to averting global biodiversity loss (EU Commission, 2011). TEEB is a global initiative which is researching and highlighting the economic benefits of the environment, which will help governments and decision makers to incorporate ecosystem services more easily into their plans (TEEB, no date a). It can be seen then that the interdisciplinarity of the ecosystem services sector may be causing

miscommunication of scale issues and so it must be ensured that policy and planning decisions are made with interdisciplinary knowledge.

2.5.2 Mismatches: reasons and solutions.

2.5.2.1 Reasons behind scale mismatches

Mismatches were seen across many of the research papers and these were identified and amalgamated into four groups, shown in Table 9: where action is taken/where results are seen; stakeholder knowledge; data collection/use methods; and research/management/policy different scales.

Five papers identified ‘where action is taken/where results seen’ as the reason behind mismatches in scale (Martin- Lopez et al., 2009; Satake, 2008; Cumming et al., 2006; Hein et al., 2006; Gret-Regamey et al., 2013). This is mainly due to the complexity of ecosystem service provision and use. Ecosystem services are provided at one scale, but can often be delivered or used at a different scale. With cultural services, for example, this can mean that people travel long distances in order to enjoy a specific environment (Martin-Lopez et al., 2009). Through regulation of services the globally important services of carbon sequestration and clean air can be drastically affected by deforestation at the local scale (Satake et al., 2008). This complexity causes decisions to be made at one scale, though the effects of those decisions happen elsewhere. Cummings et al., (2006) explain that scale mismatches occur “when the scale of environmental variation, and the scale of social organization in which the responsibility for management resides, are aligned in such a way that one or more functions of the social-ecological system are disrupted, inefficiencies occur, and/or important components of the system are lost.” It can be seen then, that scale mismatches are defined as the mismatch between where actions are taken and where results of those actions are seen.

The idea of 'stakeholder knowledge' being the most important reason for scale mismatches in ecosystem services and decision making was found in five papers (Martin-Lopez et al., 2009; Hein et al., 2006; Skourtos et al., 2010; Cortner et al., 1998; Ahlborg and Nightingale, 2012). This could be

stakeholders' knowledge of the value of specific ES, which can differ from stakeholder to stakeholder, and means that decisions made about the ecosystem service will work for some, but not others (Martin-Lopez et al., 2009). Stakeholder knowledge is also susceptible to change when applied at different scales (Skourtos, et al., 2010). The collection of data from local stakeholders can also cause scale issues, as different stakeholders hold different levels of knowledge, which can be contradictory if they are experiencing the local area at different scales (Ahlborg and Nightingale, 2012). So it is evident that although stakeholders can be difficult to work with, they do alleviate scale mismatches by bringing in information that might not be available. On the other hand stakeholders are where mismatches occur, as they are the people who are benefitting from the services, but their scales of interaction with the ecosystem services can vary, both temporally and spatially. When they visit a nature reserve, for example, they need to consider how far they will travel to get there. Getting them onside and harnessing their knowledge alleviates these mismatches.

The specific tools and techniques used in collecting and employing data to make scale dependent decisions in ecosystem services was identified as being the most important reason for the occurrence of scale mismatches, appearing in eight of the papers read (Ribeiro et al., 2008; Busch et al., 2012; Dick et al., 2014; Norgaard, 2008; Barbour et al., 2005; Felipe-Lucia et al., 2014; Helfenstein and Keinast, 2014; Boykin et al., 2013). Ribeiro et al., (2008) highlight that it is difficult to make conservation and management decisions in areas with high fragmentation, as data needs to be collected at the scale of the entire landscape in order to create an accurate picture of the area. The current methods used to analyse ecosystem services across the landscape are only as accurate as the data available (Helfenstein and Kienast, 2014). Comparing locally identified ecosystem service data to EU derived ecosystem service data in order to analyse the same sites, it was shown that the total ecosystem service index of the same site was different even with the same data (Dick et al., 2014). This confirms that the data used to research ecosystem services,

especially when it is going to be used for policy and planning decisions, needs to reflect the scale at which the decision will have an impact.

The idea that research, management and policy all interact at different scales was identified in two of the papers analysed (Brody, 2003; Brody et al., 2004). Brody et al. (2004) discuss the idea that local jurisdiction and decisions do not always align with the extent of an ecosystem and the subsequent management decisions made can often be ineffective. Therefore, if decisions made by policy and planning have consequences beyond their realm of influence or knowledge there can be a scale mismatch between where action is taken and where results are seen.

2.5.2.2 Solutions

There were three types of solution identified across fifteen different papers analysed (Table 10). The three solutions were; to use a multi-scale approach; to have a standardized unified framework or method; and, to increase communication with stakeholders.

The multi scale approach was identified by four papers (Martin-Lopez et al., 2009; Scholes et al., 2013; Barbour et al., 2005; Pegg and Taylor, 2006; Gret-Regamy et al., 2013). Scholes et al., (2013), identified that ecosystem service assessments have no specific correct scale at which to be performed and thus require multiple scales for accurate analysis (Scholes et al., 2013). Looking across both spatial and temporal scales can help understand and plan for large environmental disturbances (Barbour et al., 2005). Understanding species diversity at various scales can enable better investment of time and resources in the recovery of biodiversity (Pegg and Taylor, 2007). Integrating local stakeholder knowledge data into large scale land-use maps can reduce uncertainty and provide more accurate ecosystem service values (Gret-Regamy et al., 2013). For this reason, the multi scale approach is gaining recognition and its use as identified by this study may drastically ease scale issues.

A standardized unified framework was the solution found in seven papers (Konarska et al., 2002; Maltby, 2003; Dick et al., 2014; Hermann et al., 2014;

De Groot et al., 2002; Valles-Planells et al., 2014; Childress et al., 2002). Although not all of the papers suggested a specific style or type of framework, some had ideas on what this framework should include. De Groot et al., (2002), suggest a framework with checklists to assign economic, socio-cultural and ecological values to ecosystem services. Incorporating the three different aspects of valuation enable more accurate cross-scale management and policy decisions to be made. Hermann et al., (2014), created a framework to assess five landscape services (regulation, habitat, provision, information and carrier) across three scales. One of the issues present when creating so many models and frameworks is that each one comes with copyright, ownership and distribution problems (Childress et al., 2002) which hinder it being becoming standardized and unified. So the solution of a standardised unified framework is more towards an 'ideal' situation where if every interested party would collaborate in its creation it would work. However, in a real world situation this would be difficult, especially due to the intricate nature of ecosystems services, and the way in which the natural environment and its complexities differs from place to place, and also how policy and planning decisions are subject to different regulations and rules from place to place.

A solution for the scale mismatch problem, by enhancing the relationship between those working in science and research, and those who work in ecosystem management and policy development, was identified in four papers (Cortner et al., 1998; Norgaard, 2008; Cumming et al., 2006; Fisher et al., 2009). These problems all require action, and the collaboration among managers, scientists and the public will enable the opportunity to discuss, explore and resolve these issues (Cortner et al., 1998). Institutions often find it difficult to adapt to new arrangements of collaboration and interdisciplinary research is required to understand such difficulties (Cummings et al., 2006) in order to work towards a resolution for scale mismatches. This requires the scientists who conduct the research to work closely with the institutions who are making decisions about the environment. The relationship between those who value and trade in ecosystem services and those in ecosystem service governance, also needs to be strong to ensure stocks of ecosystem services

remain protected (Norgaard, 2008). As set out above, there are many reasons why collaboration is difficult (different terminology, different disciplines, different legislative boundaries, stakeholder difficulties) but working together, which can be easily implemented, could decrease those issues slightly and be a good solution to scale mismatches.

2.5.3 Climate Change

Although the time scale for climate change is measured over centuries, (Steffen, 2011) it is a strong theme behind the articles that were part of this review, which highlights the integrated nature of ecosystem services and climate change mitigation. In order to be able to face the challenges that climate change is bringing, and will continue to bring in the future, ecosystems need to be resilient and adaptable. This means that policy and planning decisions need to ensure that the ecosystems we have are sustainable. The large number of papers discussing climate change shows that although the current stocks of ecosystem resources are beneficial now, the temporal scale of research is stretching far into the future. Temporally, researchers are attempting to take care of future generations of people who need decisions to be made now to protect the environment for their future, indeed, to ensure that there is a future. In conclusion, climate change is driving more research in the space of ecosystem services, which will in time ensure that scale mismatches become resolved, whereas at the moment the increase in work in the area may be causing wider mismatches since we're not at all sure of how each other sector works, and it is imperative to work together on this interdisciplinary issue that is having globally devastating effects that will in some arenas be irreversible over time.

2.6 Conclusions

In summary, the systematic review to understand the extent of occurrence, and nature, of problematic scale mismatch within planning, policy, and research has brought to light a number of issues. The interdisciplinarity of the ecosystem services sector may be causing miscommunication of scale issue which can be alleviated by ensuring that policy and planning decisions are made across

interdisciplinary knowledge. It is vital that the data used to research ecosystem services, specifically when it is going to be used in policy and planning decisions, needs to reflect the scale at which the decision will have an impact. In addition, if decisions made by policy and planning have consequences beyond their realm of influence or knowledge, this can cause a scale mismatch between the where the action is undertaken and the area where the results can be seen. In a similar fashion, the solution of a standardised unified framework leans more toward an 'ideal' situation, although in the 'real world' this is difficult unless collaboration is possible between every interested party. Total collaboration is necessary as all aspects of the intricate nature of ecosystems services, including how policy and planning decisions are subject to different regulations and rules, need to be taken into consideration.

Although stakeholders can be difficult to work with, they do mitigate scale mismatches by bringing in information that might not be available elsewhere. Stakeholder involvement is identified as being a key aspect for both the reason why scale mismatches occur and also ways in which they can be resolved. When stakeholder engagement is carefully planned, fully integrated into the research project, and closely managed, it can ensure the success of a project, with results which can be readily and easily integrated into policy and practice. Therefore, getting them onside and harnessing their knowledge can help to reduce scale mismatches.

Finally, climate change being a strong theme throughout the articles reviewed reflects the current global issue that the scientific and policy making communities are facing. The large number of articles and research papers in this area is ensuring there is a robust science and policy making position, in order to move forward to attempt to reduce carbon emissions, and to map and measure the effects and solutions of climate change. The global scale issue of climate change is influencing the scales at which research is being tackled, with more large and multi-scale research projects being undertaken, as identified by this study in Figure 10, which shows that this solution is currently being taken on board, and going forward may drastically ease scale issues and also rectify

the climate change issue. This is a positive move as it is widely recognised that the larger a dataset is, with more repetitions or across a larger landscape, the more accurate the results are (Sutherland et al., 2013).

3 A survey to investigate scale mismatches within the ecosystem services community

3.1 Literature Review

Within a given landscape, biodiversity is capable of stabilizing ecosystem services, providing the full spectrum of provisional, supporting, cultural and regulating services (Alcamo et al., 2003). Each of these services have often been taken for granted as they belong to no one, but continue to be used and harnessed by all. As the state of biodiversity, and ecosystems declines, it becomes more important to protect the services they provide (H.M. Government, 2011). Humans are pivotal in the delivery of ecosystem services which its processes and functions provide (Fisher et al., 2009). In order to stem the decreasing rate of ecosystem services supply worldwide, taking into account the impacts of human activities, various conservation measures have been introduced at different scales to ensure their sustainability (Egoh et al., 2007).

In order to properly research, manage and plan for ecosystem services there are many aspects which need to be considered. There is a high potential for problems, whether through miscommunication in terminology, or through the different perceptions of scale by institutions and research projects, which can lead to scale mismatches. One of the most comprehensive ways to investigate where, when and how these issues may occur is to ask the practitioners themselves. A survey of those working with ecosystem services will aid in the identification of the reasons behind scale mismatches, and help work towards developing solutions.

3.1.1 Three exemplar ecosystem services

The research was focussed on three particular ecosystems services in order to give concrete examples of mismatch in scale. By limiting the study to pollination, water infiltration and carbon sequestration there was a direct focus to the data, bringing clarity to the methods of the research and the analysis of the data. This survey aimed to investigate, within the three ES, the impact of

scales used in the provision of ecosystem services on those scales used in planning and policy administration.

3.1.1.1 Pollination

Pollination is a process which is of huge importance in the UK to farmers, with 20% of UK cropland dependent on insect pollination (Breeze et al., 2011). Although pollination is of broad interest in current affairs, it is not accounted for within local council plans, but seen merely as a positive by-product of well managed, biodiverse environments. The main threats pollination faces are changes in land-use, pesticides, habitat fragmentation, agricultural practices and invasive non-native plants and insects (Kearns et al., 1998). There has been much in the media about the issues of the decline of 'bees' worldwide. This decline has highlighted the problems that pollinators currently face in the world.

3.1.1.2 Scale

There are many elements to consider when thinking about the scale of pollination. The smallest distance which can be considered is the foraging distance of a single pollinator, which itself is decided by the quality and proximity of forage availability, communicated via the waggle dance (Schurch et al., 2015). Three of the main insect pollinators are set out below in Table 15 edited from Grafius et al. (2016).

Table 15 Flight distances of pollinating species

	Honey bees	**Bumble bees**	**Butterflies**
Foraging distance (m)	1000	1500	200

Connectivity plays a huge part in the scale at which pollination can naturally function. Where there are corridors between patches of pollen rich plants such as crops, this can increase the flight distance for pollinators. Grafius et al. (2016) identify that the best habitat profile for pollination to occur is 'continuous green spaces'. This, alongside the physical flight distance of

pollinators, leads to the conclusion that pollination functions at a local scale, with local being farm or green space. This is reiterated in Andersson et al.'s (2014) paper which identifies pollination as working at a 'local' spatial scale, and a seasonal temporal scale.

3.1.1.3 Water Infiltration

Water Infiltration into the soil, and then on to groundwater, has become more of a forefront issue in the UK as climate change causes flooding to affect thousands of homes across the country (Smith et al., 2014). This is an issue with huge political associations, as people are looking for someone to blame. Water infiltration has two main benefits for humans, firstly it prevents flooding when water is stopped from running off and is instead is absorbed into soils. This, alongside the cleansing process of filtration, leads to increased abundance in drinking water availability.

3.1.1.4 Scale

Andersson et al. (2014) break down water infiltration into the different aspects which make up the process, with flood control, drinking water distribution and water quality enhancement. All of these services are identified as occurring at a 'local' scale, but the benefits are scalable up to regional due to their management procedures (Andersson et al., 2014).

3.1.1.5 Carbon Sequestration

C-sequestration is here defined as the ability of the terrestrial system to remove carbon from the atmosphere via photosynthesis and sequester it in the soil or deeper in the Earth's surface. It is therefore a function of the type and quantity of plant communities. For instance, plant residue from woody vegetation is far more recalcitrant than that from herbaceous plants. As 95% of the UK's carbon stock is found in soils (Ostlea et al., 2009), policy decisions should be focused not just on reducing carbon emissions, one of the main causes of global climate change (Solomon et al., 2009), but also on removing atmospheric carbon.

3.1.1.6 Scale

The intrinsic link between carbon sequestration and climate change shows that the scale at which carbon sequestration has an impact is global. The process of carbon sequestration can go from just one tree to a landscape of peat bog, to the entire Amazon rainforest. Grafius et al. (2016) found that carbon storage was most prevalent in areas with high tree density. There is no direct link between the source of emissions and where carbon is sequestered, meaning that the scale of carbon sequestration can be seen as global. The service of carbon sequestration requires no connectivity in order to function, which means that all trees and soils and areas of peat could count towards one global network of carbon sequestration.

3.1.2 Terminology

Terminology is an important factor in attempting to move ecosystem services from the exclusive realm of science and into the planning and policy environment. The terminology used across this field has many synonyms, such as ‘nature’s services’, ‘nature's benefits’, ‘ecosystem services’, ‘ecosystem benefits’, ‘natural capital’, and ‘natural assets’, all of which could be used interchangeably. This should not be a problem for those in the industry who already have a grasp of the ways in which the words can be used, but to those who are new to working with ES, it may cause confusion. A number of the large scale projects surrounding ecosystem services and planning, policy and economics have their own specific glossaries of terms (TEEB, no date b; UKNEA, no date b; National Capital Initiative, no date b). These glossaries can ease some confusion, but when it comes to the perceived scale given to the terms used, there is possibly less clarity. For example, the meaning of “long term” to a scientific researcher is not necessarily “long term” to a someone involved in policy or planning.

3.1.3 Institutional Scales

Examining the scale at which ecosystem services are delivered, and the scale at which they are both managed and have planning and policy decisions placed

on them, can give an idea of how to better integrate ES into planning and policy decisions. It is important to define the spatial and temporal scale boundaries in relation to ecosystem service research (Alcamo et al., 2003; Dick et al., 2011). Ecosystem services are provided at definite ecological scales and are used at various institutional scales. It is often the case that a specific area provides different ecosystem services at different institutional scales. The De Wieden wetlands in the Netherlands, for example, provide reeds and fish as both employment and resources at the local, municipal scale; recreational use at the local and regional scale; and nature conservation which is important for both national and global scales. The complexity associated with ecosystem services provision and utilization opens the possibility of mismatch between the creation of ecological scales and the institutional scales of management (Martín-López et al., 2009).

3.1.4 Research scales

Research which develops a spatio-temporal scale within itself will incorporate the functional roles of most species and give a more accurate picture of the system (Winfree, 2013). Similarly, the spatio-temporal scope of ecosystem function research, when based on a smaller scale, may not be representative of ecosystem delivery for services in a large landscape. Land use decisions, such as the selection of crop rotations, deforestation measures, design of protection sites, among others, usually occur on multiple scales from hectares to several thousand square kilometres (Seppelt et al., 2013). The ineffective integration of ecosystem services into decision-making could result from a mismatch in scales between the ecosystem function/processes and the output of such policy. (Gillson and Willis, 2004; Carpenter et al., 2009). An understanding of the use of scale will ensure continued, improved monitoring and experiments which describe biodiversity changes, and the impact of those changes over time (Vellend et al., 2013).

3.2 Surveys

There are many different ways in which to collect information from your intended audience, with the two most used being surveys and interviews. The

most challenging difference in performing a survey over an interview is that here the respondent is tasked with interpreting and understanding each question without prompts from an interviewer (Harris, L. and Brown, G., 2010).

Surveys have been used for data collection for hundreds of years, with the most substantial advances in survey practice being the use of random sampling in the 1940s and telephone surveys in the 1970s (Dillman, 2007). It is now seen that the internet is the most significant advance in survey data collection, with 89% of the UK going online frequently (Office for National Statistics, 2014). Online surveys can reach a large audience with less labour, and a lower cost for the surveyor.

3.2.1 Online Surveys

There are many advantages to creating an online survey, the first being the large network of people that the survey is able to reach, this network can include targeted groups, where people with similar interests gather (Wright, 2005). It is also possible to advertise the survey via social media, to a specific audience if it is available online. This large network makes it easy for the surveyor to reach people in a short amount of time, and also hosting a survey online can be a lot less expensive than printing and distributing paper surveys, or the man hours of conducting telephone surveys (Wright, 2005). In comparison to paper surveys, web-based surveys not only have a better response rate, they also cost a lot less to the researcher in both time and money (Greenlaw and Brown-Welty, 2009).

3.2.2 Ecosystem services and surveys

The intrinsic relationship between humans and ecosystem services has been researched using various methods, one of which is the survey. In Spain surveys have been used to establish that there is a clear understanding in the general population that ecosystems provide services and benefits (Martin – Lopez et al., 2012).

As ecosystem services are managed and used by humans, survey research can establish a broad picture of the way that they are integrated into research,

policy and management. Surveys are also used to garner public perceptions of ES. For example, a survey was undertaken by Camps-Calvet et al. (2016) of users of urban gardens in Barcelona, Spain in order to establish the importance they attribute to specific ES. The survey found that cultural ecosystem services are the most highly valued and recognised ecosystem services by urban garden users. The survey also established that the beneficiaries of ES provided by urban gardens in Barcelona are mainly elderly, low-income and migrant communities.

Surveys have been used to research the implementation of ecosystem services into policy in South Africa (Wilcock et al., 2016). The survey by Wilcock et al. (2016) was able to establish that ecosystem service practitioners have insufficient data, both spatially and temporally for them to provide well rounded policy and practice decisions. The services that are their main focus, and the scales at which they concentrate their work, were also uncovered.

3.3 Aims and Objectives

The overall aims and objectives for the research project are set out below.

The aim of this research is to understand the extent, occurrence, and nature of problematic scale mismatches within ecosystem service planning, policy, and research in order to gauge and potentially alleviate their effects on the integration of ecosystem services into such policy, planning and research outcomes.

The objectives are to:

1. Assess the extent and circumstances in which scale mismatches occur
2. Determine the reasons behind those scale mismatches which are problematic
3. Interpret the causes of and current solutions for scale mismatch problems.
4. Identify practical solutions to reduce or resolve scale mismatch problems.

The survey was formulated to understand the ways in which scale mismatches occur within planning, policy and research. By gathering the opinions of those in the industry, the survey also aimed to gauge the effects of scale mismatches on the planning, policy and research sectors, in order to enable evaluation and potential alleviation of those effects.

3.5 Methods

3.5.1 Research

Extensive research went into the design of the survey, as it was to be aimed at a wide audience. It was imperative that the survey be understood by groups of people who work in science, policy and planning and so Bryman's (2008) rules for an effective survey were followed (Table 16).

Table 16 Bryman's (2008) design rules for an effective survey or questionnaire

Design Rule
Avoid ambiguous terms in questions
Avoid long questions
Avoid double-barrelled questions
Avoid very general questions
Avoid leading questions
Avoid questions that are actually asking two questions
Avoid questions that include negatives
Avoid technical terms
Does the respondent have the requisite knowledge?
Make sure there is a symmetry between a closed question and its answers
Make sure the answers provided for a closed question are balanced
Do not rely too much on stretching people's memories
Forced choice rather than tick all that apply

3.5.2 Focus

The survey focused on those who work with ecosystem services, either directly or as a by-product, in order to identify the scales at which they have influence, their research is conducted, or their decisions have impact. During survey design, input from various groups was sought, in order to ensure usability, accuracy and relevance for each group. Advice gained from colleagues at the University of Sheffield led to a discussion of the questionnaire with a few members of the target audience before it was sent out. The questionnaire was discussed with researchers, PhD students and council land managers, as these were typically people who were easily accessible, and so could discuss the project without contaminating the pool of people required for completing the research survey.

Many people with concerns for privacy may not wish to divulge personal information and so for the success of a survey it was important to reduce as far as possible the need for this information. Where it was needed for accuracy, however, then it was important to confirm that confidentiality will be maintained (Dillman, 2007). In the case of the survey for this project it was possible to make the respondents' answers completely anonymous to respect privacy. In order to ensure that respondents felt comfortable with the anonymity of the survey, they were only asked to identify the sector in which they worked and not their exact job role. The data that the survey was going to provide for analysis was only to be separated via the sectors, so this would not affect the subsequent analysis. Through Qualtrics survey software, the respondent only needed the link to access the survey, and the survey would not request personal or identifiable information.

3.5.3 Software

The survey was hosted by Cranfield University and created using Qualtrics software. Qualtrics was chosen as the survey software because it enables the designer to host different question types, from sliding scales to pictures and rankings; and also because it can be manipulated in such a way as to show results depending on the responses to specific questions, thus easing the

process of grouping the respondents by different factors, such as their answers to previous questions, their professional sector, or length of service in their industry.

3.5.4 Accessibility

The survey was aimed at professionals who have busy and demanding jobs, so keeping the survey short was vital. Advising the respondents that the survey could be completed in 15 minutes or less was deemed to be important in order to maximise responses. The shorter and easier a survey looks, the more respondents will be willing to fill it out, and the longer a survey is, so the response rates drop (Heberlein and Baumgartner, 1978). It is also beneficial to have surveys which are carefully structured with questions which are easily answerable as response rates will improve (Dillman et al., 1993; Dillman, 2007). At the beginning of the survey the time that it should take will be declared, so the respondent will have an understanding of the length of commitment needed.

As the participants are completing the survey without an interviewer present, some of the terms that are less general were predefined in order to reduce any confusion. Giving definitions for some of the words also ensured that the participants were answering questions in an appropriate manner, as the meaning of the question was made clear. Survey questions need to be clear as to how the respondent is to answer, explaining either within or after the question. There can be many variables and so techniques such as ensuring that ranks or scales are clear, explaining how to record their response or whether the respondent is allowed to select one or more answers (Bryman, 2008) can help the end result of the survey.

Varying the type of questions asked, and using pictures as visual guides would keep the participants interested and increased the chance that they would complete the questionnaire.

3.5.5 Pilot

A pilot study was performed with eight participants, a representative target group (Aldridge and Levine, 2001). The pilot study participants included 1

landscape architect, 2 PhD students, 2 Postdocs, 1 town planner, an environment manager from the Environment Agency and a member of the BESS knowledge exchange team. They were chosen because links had already been established with them and they would be willing to go through the survey and give constructive feedback. From the pilot study, some changes to the questionnaire were made in regards to wording, definitions and clarification of instructions. The introductory paragraph was made more informative in order to refocus the participants after they had made the decision to take part in the questionnaire. The definition for carbon sequestration was deemed complicated, and made easier to understand. The titles of the sections which contain questions 13, 14 and 15 and 18, 19 and 20 were simplified and formatted in bold, in order to clarify the difference between them as some pilot participants had thought that questions 18, 19 and 20 were a repeat of 13, 14 and 15.

3.5.6 Specific ecosystem services

In order to create focus within the survey responses, and have the participants draw on experiences within their day-to-day work, the survey discussed three specific ecosystem services. Pollination, water infiltration and carbon sequestration were used as examples because each of them provide services at different scales, and are important at different institutional scales. They are also all widely discussed and regularly at the forefront of media attention, which suggests a higher probability that the survey participants will have heard of them and, indeed, have some knowledge of them.

3.5.7 The Survey

The final survey is found in Appendix B. Below is Table 17 which maps the reasoning for the questions and sections.

Table 17 Survey questions reasoning, excluding instructions 4, 9, 12, 17 and 21

Question number	Reasoning
1	Introduction and main details
2, 3	Predefined terms and Map defining regions
5, 6, 7	Respondent identifiers
9	Scale words
10, 11	Temporal and spatial scale words meanings
13, 14, 15	Ecosystem service function scales
16	Tool identification
18, 19, 20	Policy scales
22	Ecosystem service consideration
23, 24, 25	Ecosystem service relevance
26	Ecosystem service importance
27, 31	Communication between sectors
32, 33	Extra ideas and comments

3.5.8 Ethics

Once the questions had been finalised the survey was submitted to the Cranfield University ethics committee as any piece of research that will have impact or interaction with the public requires confirmation that it is not going to have ethical consequences. The ethics committee confirmed that there was nothing within the survey that would cause any ethical issues.

3.5.9 Distribution

To begin with, the survey was sent out to 104 potential participants who had been mined from the contacts of those working on the BESS project. BESS is a

research consortium looking at how the biodiversity of towns and cities contributes to human well-being (Bess-Urban, no date) and thus had contacts in local councils, environment charities, planners and policy makers. After about 47 responses, 45% of the initial 104 sent out, it was decided to distribute more widely, in order to gain more responses. Using various social media, such as Twitter and Facebook, and specifically focussing on those that might reach sectors that hadn't yet been represented, the link was sent to different groups on Facebook, with retweets requested from relevant groups on Twitter. The survey was retweeted by the President of the British Ecological Society, prominent ecology and environment bloggers and environment labs and research groups. The Facebook groups were private network areas for researchers working in ecosystem services.

3.5.10 Analysis

Analysis of the results was undertaken through clear charts and graphs in order to compare and contrast the sectors. More in depth analysis was provided using Bayesian Belief Networks.

The Bayesian belief network approach looks at the extent of a belief that something will happen, rather than the actual probability that it will happen. Prior probabilities can be calculated for each event without the cost and complications that come with running repeated trials (Heckerman, 1997). Using belief bar nodes it can be found, just by looking at the structure of the network, whether a particular node has any influence on another node.

A Bayesian belief network is a graphical model which represents a set of random variables and their conditional dependencies. (Krieg, 2001). The programme Netica was used in the research as it was available at Cranfield University and had all of the necessary features for the research. Figure 11 shows the graphical representation of a Bayesian belief network in Netica (Norsys, no date). The belief bar nodes represent variables and the arrows represent the Bayesian probabilistic relationships between these variables (Krieg, 2001).

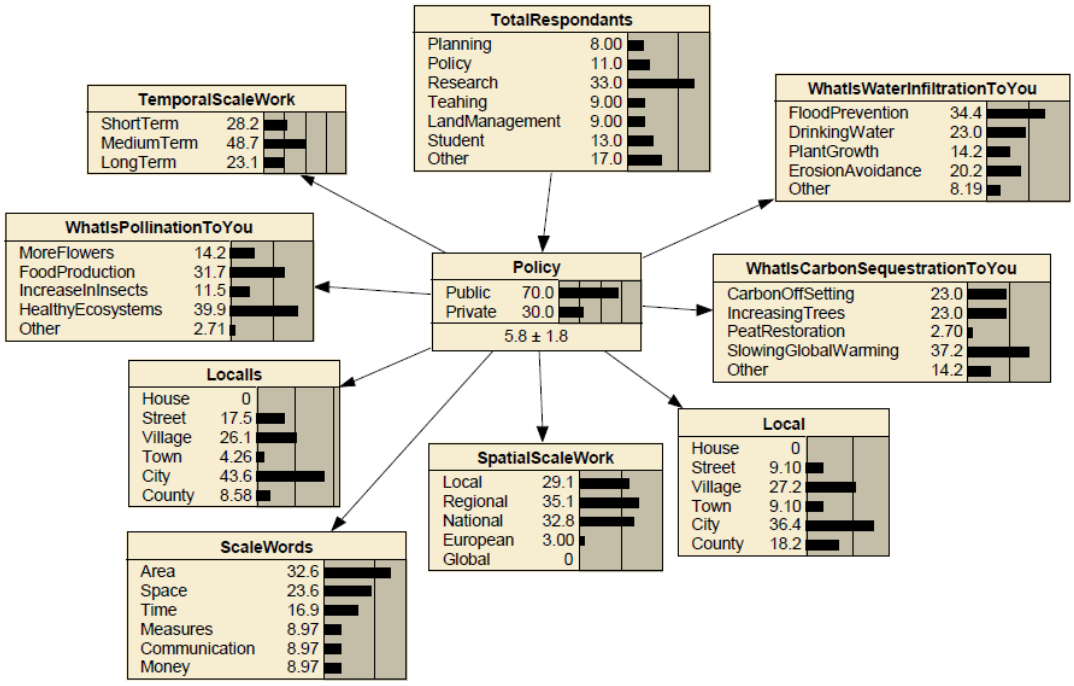

Figure 11 Graphical representation of a Netica Bayesian belief network using the policy sector results

The nodes at the top of the diagram have a higher tendency to influence the lower nodes, as shown by the causality arrows. (Norsys, 1995)

Within Bayesian belief networks it is possible to perform sensitivity analysis, which looks at how sensitive a result is to the evidence available (Jensen et al., 2005). Sensitivity to findings can identify which factor exerts the most influence on another. Dlamini (2010), for example, used sensitivity analysis to discover which factors have the highest influence on wildfire occurrence. Key criteria or key management interventions which should be researched accurately can be identified through sensitivity analysis (Dlamini, 2010).

In order to analyse the survey data, Bayesian belief networks were to be used to fully map and find the decision variables of the responses, but due to respondents identifying as belonging to more than one sector it became difficult to intricately separate the variables in the nodes. It was possible, however, to

perform sensitivity to findings, which was used to identify the response given which had the most influence on a particular sector.

3.6 Results

3.6.1 Respondents

After being open for five months in total, all attempts to gain more respondents had been used and the flow of respondents had stopped. There were a total of 72 respondents to the survey. Figure 12 shows that those in research were the most represented. Some of the respondents worked across more than one sector, as the survey allowed for them to check more than one box. The least represented sector was the planners, although with seven respondents they were only one less than the teachers and land managers and three less than the policy sector. Although the research sector was better represented than the other groups, the way in which the analysis was performed, by working in percentages where necessary, aimed to avoid any bias appearing in the results.

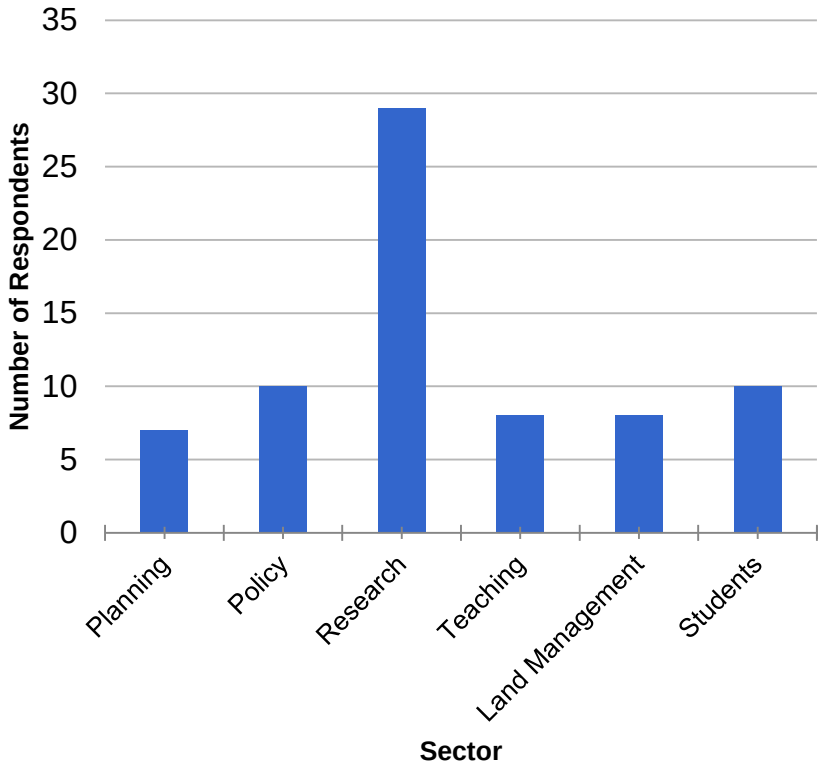

Figure 12 Total respondents by sector

For the discussion and interpretation of the results of the survey, it is only the respondents from the research, planning and policy sectors that were used. This was because the main crux of the research is based on these sectors. The other sectors were selected within the survey sectors, as different avenues were initially being investigated, but which were not subsequently deemed necessary to follow.

Figure 13 shows that research had the highest number of respondents who had worked in their sector for over twenty years. In research the majority of respondents had worked in the industry for 3-10 years, while in policy and planning the majority have worked in the industry for 11-20 years.

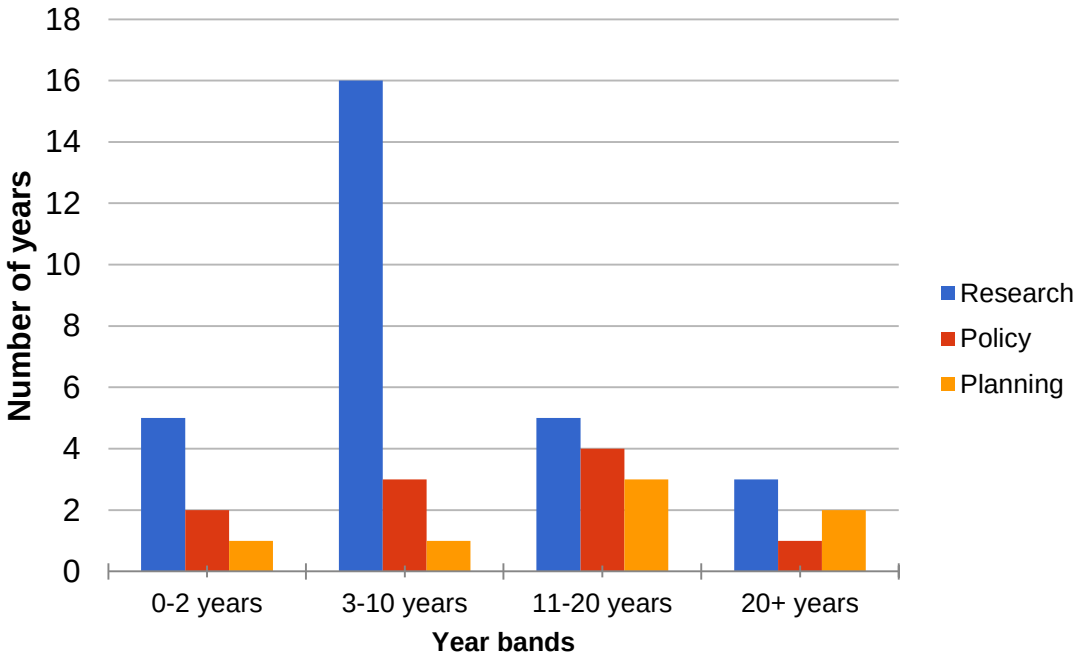

Figure 13 Length of time in which respondents have been working in their industry

3.6.2 Scales worked

Figures 14 and 15 show the spatial and temporal scales at which the respondents identified that they worked. Those in research identify as working at the regional or global scale, while policy-makers identified at a regional or national level. For planning it was quite evenly spread from local through to national, with one respondent each identifying as working at a global scale.

Each of the different sectors clearly identified that they predominantly work to a medium term temporally.

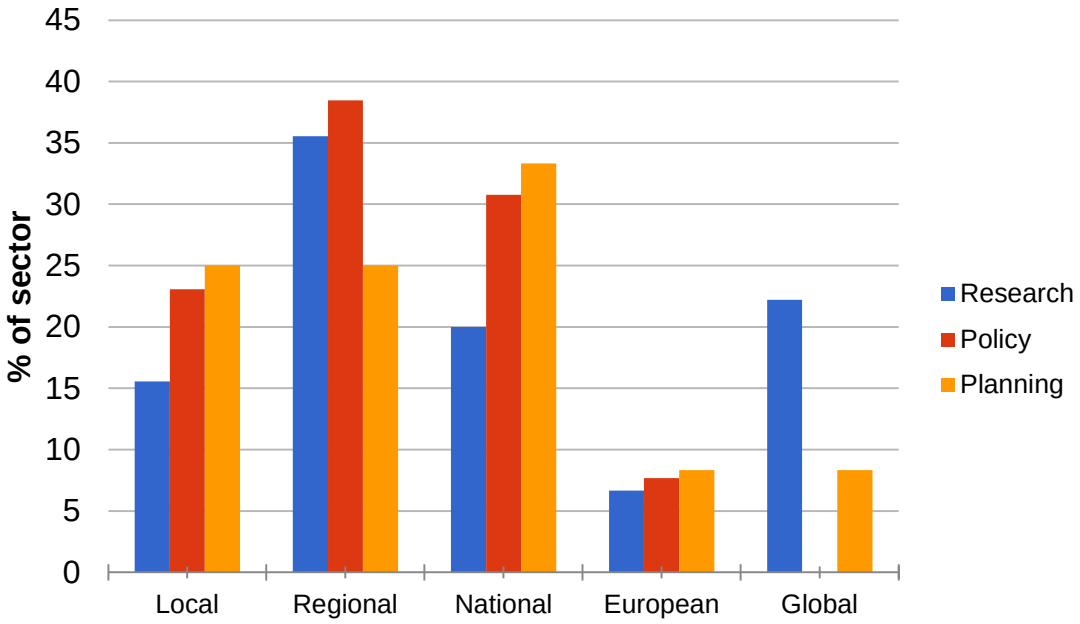

Figure 14 Spatial scales worked at by sector, as percentage of whole sector

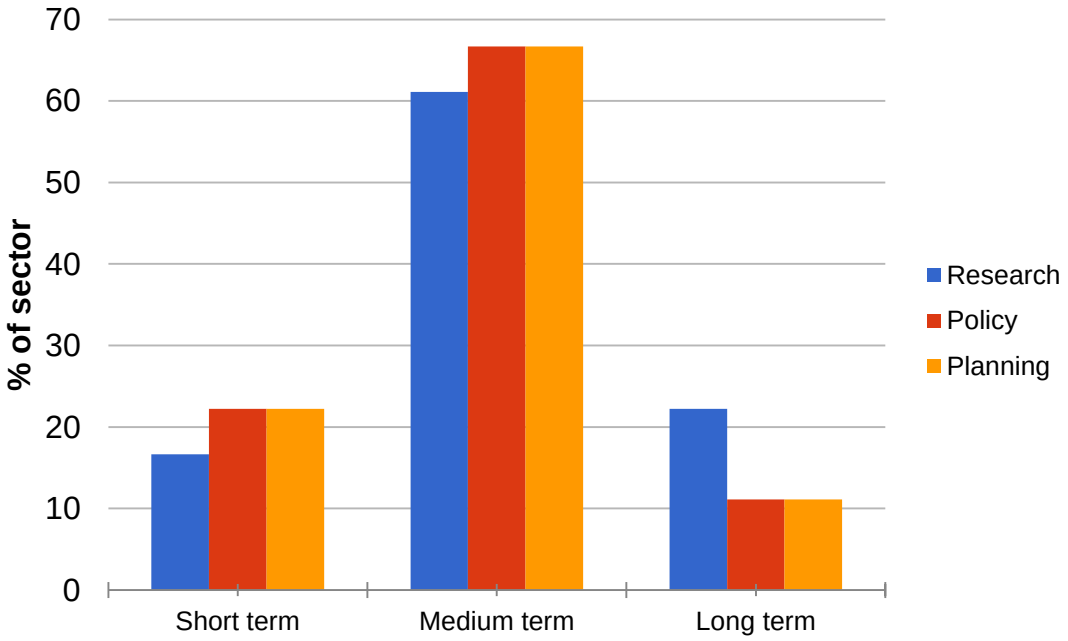

Figure 15 Temporal scale at which the respondents work, as percentage of whole sector

3.6.3 Terminology

As we have seen in the systematic review (2, 2.4.4), the different words used in ecosystem service research can make it difficult for the different sectors to communicate effectively. Terminology and the many meanings that a word can hold can cause confusion. Table 18 shows the meanings that each sector gives to the different scale terms used.

Table 18 Meanings of scale terms to each sector

Sector	Short term	Medium term	Long term	Local
Policy	Weekly	Yearly/decade	Half century	City
Research	Weekly	Decade	Half century	County
Planning	Yearly	Decade	Half century	City/Town/Village

For ‘short term’, weekly was the meaning identified by policy and research whilst planners identified it as yearly. Researchers and planners identify decade as being the meaning of ‘medium term’, whilst those in policy also identified decade, alongside yearly. Those in policy, research and planning identify ‘long term’ as meaning a half century. Planners found it difficult to find a definite answer for the term ‘local’, and responded with city, town and village. Those in policy identified city as being the meaning of ‘local’, and research identify county. Figures 16 to 18 show the different responses to the meanings of the temporal scale terms by sector.

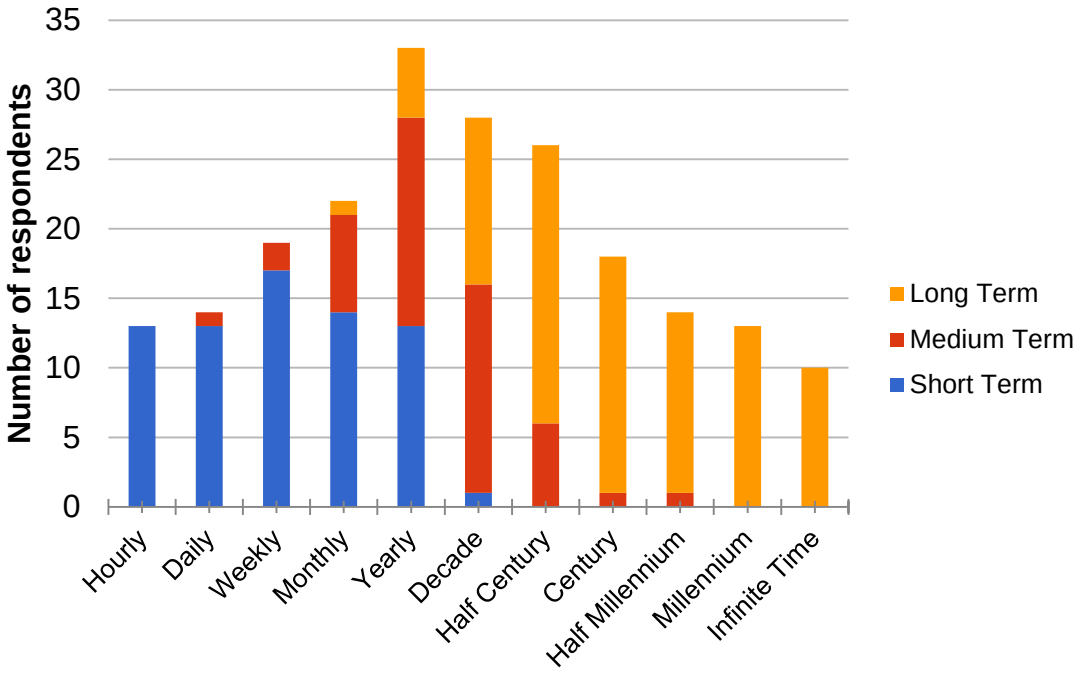

Figure 16 Research sector temporal scale terms meaning

As displayed in Figure 16, it is only ‘hourly’, ’millennium’ and ‘infinite’ time that have no ambiguity as to their scale meaning. This is reflective of the different backgrounds of science represented within the survey. Ecosystem service science is broad and can cover the individual life span of an insect, through to the carbon sequestered deep within the earth's surface. The area of expertise of the respondent will reflect how they view both spatial and temporal scale. Each of the temporal scale terms were ascribed between six and eight different meanings, which would definitely lead to confusion if not properly defined.

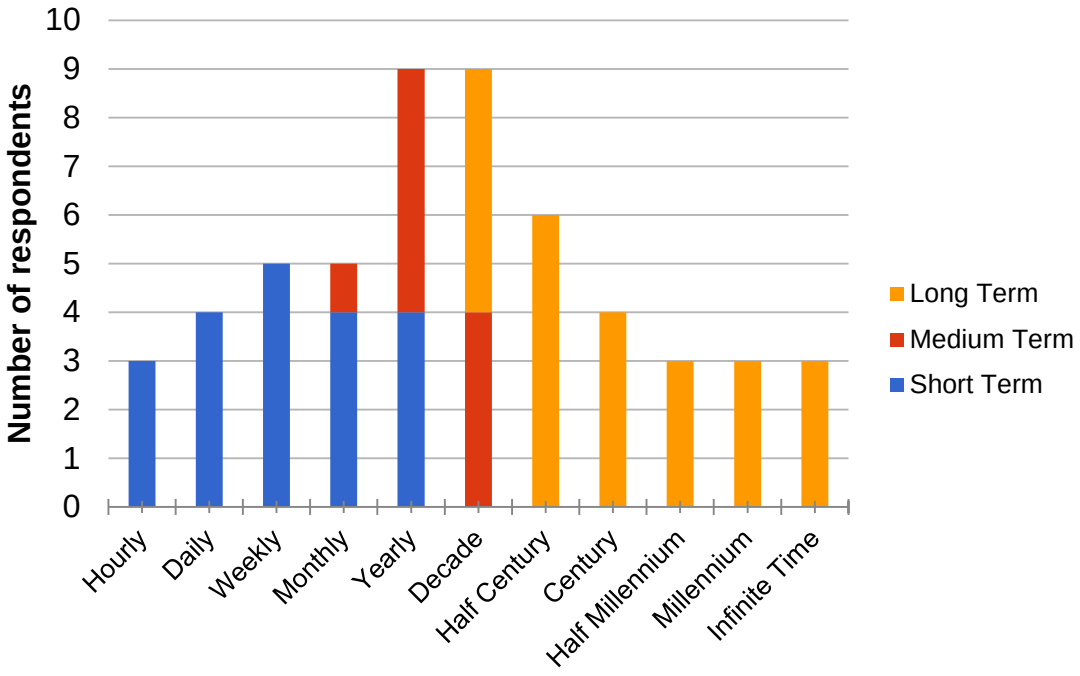

Figure 17 Policy sector temporal scale meaning

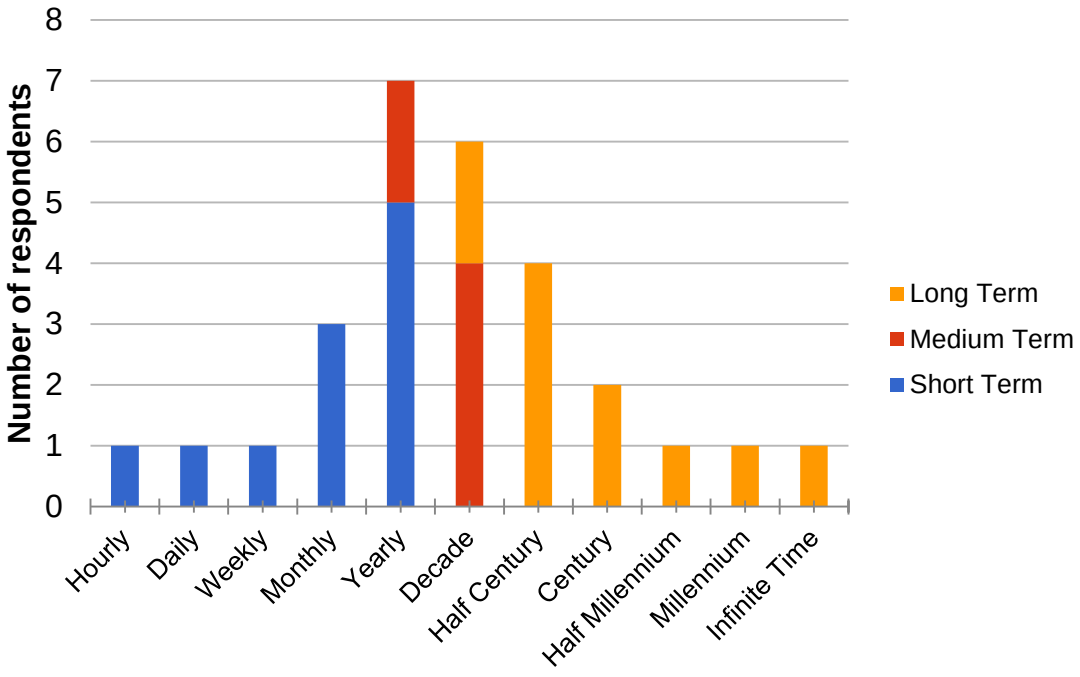

Figure 18 Planning sector temporal scale meaning

There is less ambiguity within the policy and planning sectors about the meanings behind temporal scale, with only ‘monthly’, ‘yearly’ and ‘decade’ being assigned to more than one scale term. This then shows the ambiguity of ‘long term’ and ‘short term’, with ‘long term’ being assigned six time-frames from decade to infinite time, by both sectors and short term assigned five time-frames from hourly to yearly.

The respondents were also asked what the term ‘scale’ meant to them. They were presented with a list of widely recognised scale terms which had been collated during the initial literature review (1, 1.1-1.7). Their responses are shown in Figure 19.

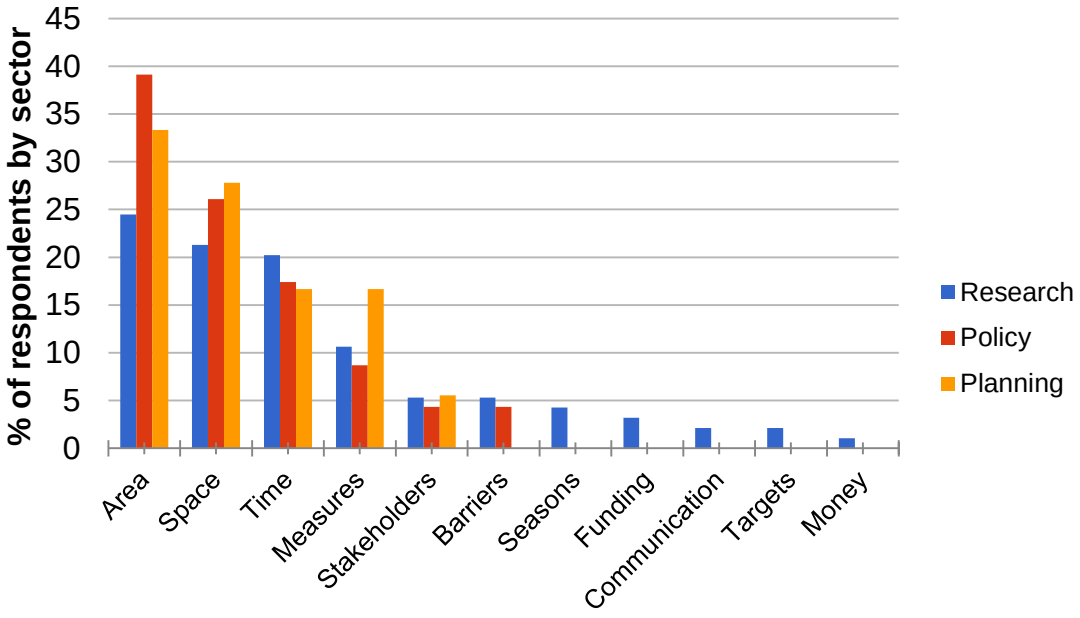

Figure 19 Scale terms identified by sectors

‘Area’, ‘space’ and ‘time’ are the three scale terms most identified by all the sectors. Researchers identified all the terms as being relevant. Those in policy and planning only identified six and five terms respectively. Each of the three sectors identified two spatial scale terms more than the first temporal scale term. Despite the field of work of both policy-makers and planners, it was only the researchers who identified the non-temporal and non-spatial terms as being relevant to scale.

3.6.4 Ecosystem service consideration

The respondents were asked to identify how often they considered pollination, carbon sequestration and water infiltration within their day-to-day roles, and also which service they thought was most important, hectare for hectare. They were then given breakdowns of the services within each ecosystem services and asked to select which they considered the most important.

Figure 20 shows that carbon sequestration is the service that was most frequently considered every day and pollination was the least regularly considered, having the highest number of people identify that they never consider it, or only consider it once or twice a year. Water infiltration is considered significantly ‘once or twice a week’ and ‘month’. Each of the services are considered at one time frame or another by the different respondents. Those who identify that they never consider a particular service most likely work in a specific sector with one of the other services, for example a policy maker or researcher focussed entirely on pollination.

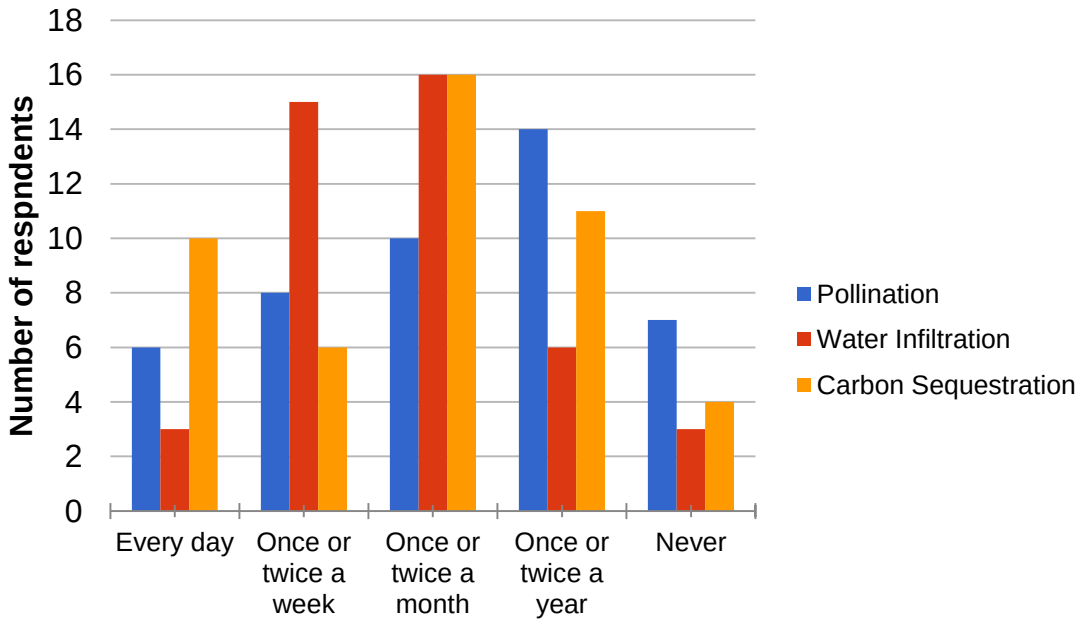

Figure 20 Total respondents ecosystem service consideration

3.6.5 Ecosystem Benefits

Each of the three exemplar ecosystem services provides a wealth of benefits. A few of each of the services benefits were listed and the respondents were asked to identify which is the most important aspect of each services. Figures 21 to 23 show what the different sectors identified as being the most important factors.

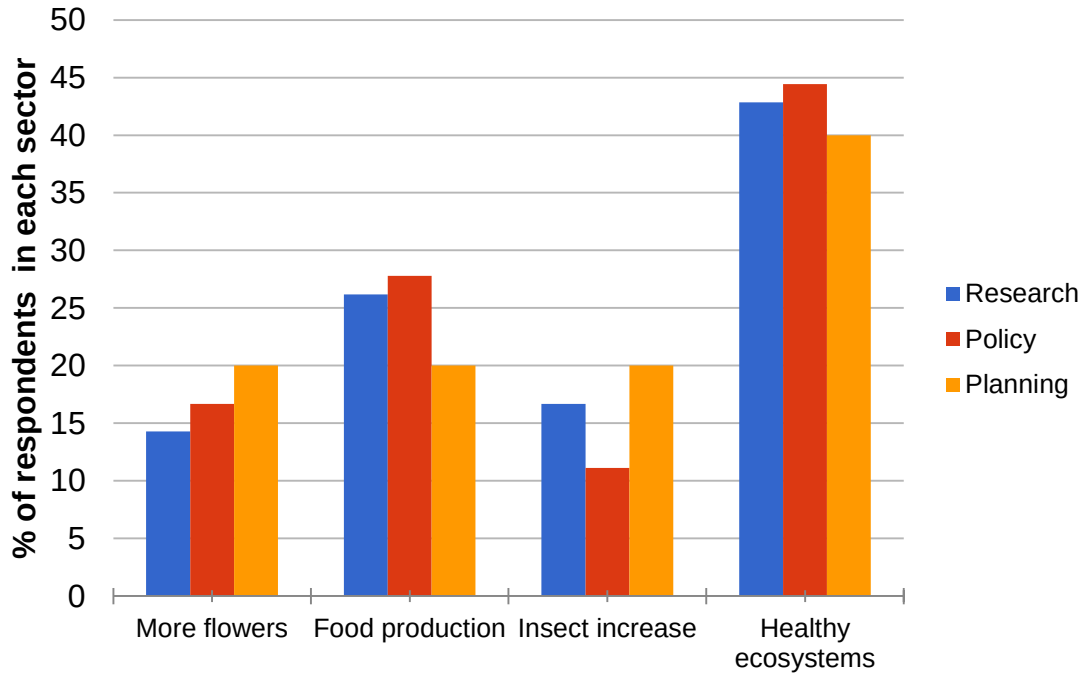

Figure 21 Most important aspect of pollination

There was a large majority in each of the sectors who identified that 'as representative of healthy ecosystems' is the most important aspect of pollination. This is interesting, as pollination has links to food security and production, which is a forefront topic in policy and research, and also the important topic of the decline of bees and insect pollinators in the UK, whereas a healthy ecosystem may encompass both of those factors and thus be important in sustainability across all of the important aspects. Those in policy and research identified 'food production' as being the second most important aspect of pollination, and planners give equal importance to the remaining aspect.

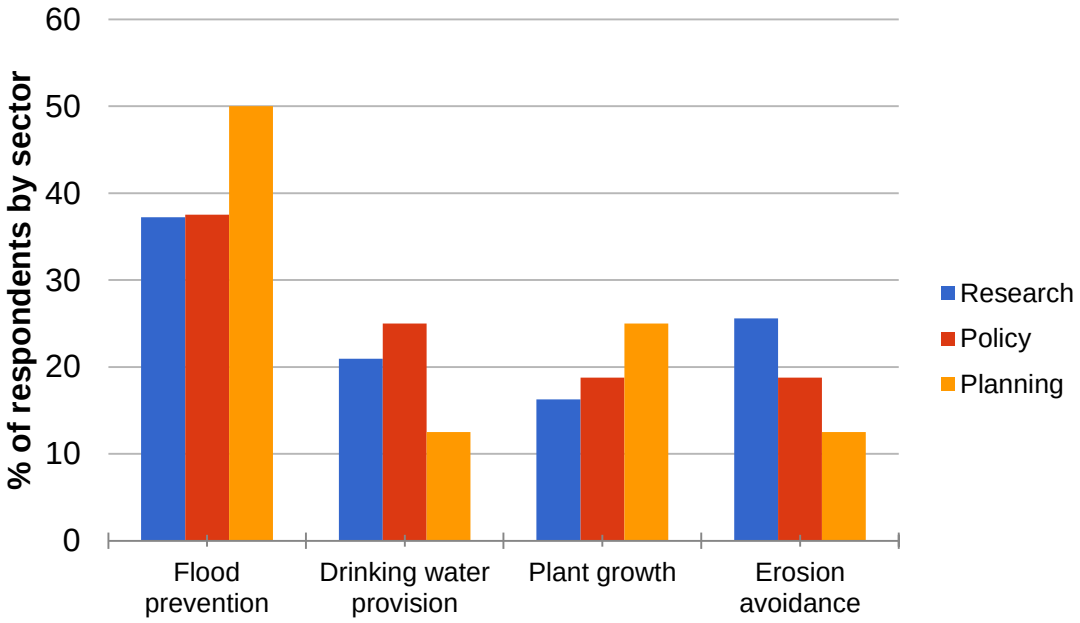

Figure 22 Most important factor of water infiltration

As in Figure 21, there is a majority in one aspect in Figure 22, which for water infiltration was flood prevention. Flood prevention is being thoroughly researched due to the occurrence of 'once in 100 year' flood events in the UK; and how to be best equipped to deal with the events and their aftermath; and what policy decisions need to be taken and what planning need to happen or change. Plant growth was the least important to those in research. The second most important to those in research was erosion avoidance, whilst this was the joint least important to those in policy and planning.

There was a general consensus identified in Figure 23 that across all of the sectors, slowing global warming is the most important goal of carbon sequestration. Climate change was identified in the systematic review (2, 2.4.6) as being a driver behind a lot of the policy and research literature within the field of ecosystem services. This reflection shows that here is an issue which is being comprehensively considered by all sectors. Planners saw carbon offsetting, increasing trees, and peat restoration as equally important, but for researchers and policy-makers there was much less interest.

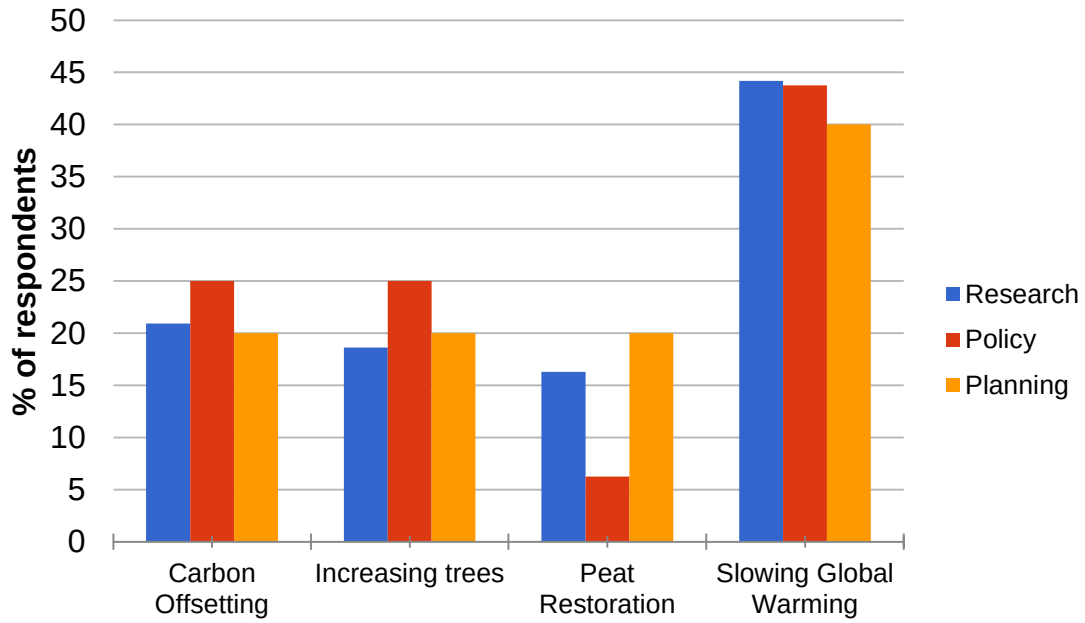

Figure 23 Most important aspect of carbon sequestration

3.6.6 Ecosystem service natural and policy scales

It is important to understand the scales at which ecosystem services are perceived to be naturally functioning by those who work with them, as this will influence the decisions being made surrounding them. For the same reason it is equally important to know the scale at which they believe that the policy for those natural services is applied. Tables 19 to 21 identify these natural and policy scale perceptions for each of the ecosystem services.

The highlighted figures in these tables show the highest frequency response for each variable, in order to enable easy comparison.

Table 19 Perceived natural and policy scales of pollination

Pollination	Total		Research		Policy		Planning	
Scale	*Natural*	*Policy*	*Natural*	*Policy*	*Natural*	*Policy*	*Natural*	*Policy*
Local	32	13	13	7	6	3	4	2
Regional	18	8	9	4	2	1	1	0
National	8	26	5	11	0	5	0	3
European	3	9	1	2	0	1	0	0
Global	4	2	2	0	1	1	1	0
Short Term	19	24	10	12	1	3	2	4
Medium Term	22	24	10	10	3	5	2	1
Long Term	22	6	11	2	5	1	2	0

For pollination, the ‘natural’ spatial scale at which is functions has been identified by all of the sectors as ‘local’, and the policy spatial scale is identified as ‘national’ by all the sectors. It is less defined at the spatial scale, but all of the sectors identify ‘long term’ as being the natural temporal scale of pollination. The policy temporal scale is split between ‘short term’ and ‘medium term’, with research and planning identifying ‘short term’ and policy identifying ‘medium term’.

Table 20 Perceived natural and policy scales of water infiltration

Water Infiltration	**Total**		**Research**		**Policy**		**Planning**	
Scale	*Natural*	*Policy*	*Natural*	*Policy*	*Natural*	*Policy*	*Natural*	*Policy*
Local	17	14	7	5	1	5	2	1
Regional	37	23	18	12	7	4	3	2
National	8	19	5	7	1	2	1	2
European	3	6	1	3	0	0	0	0
Global	2	0	1	0	0	0	0	0
Short Term	9	17	5	11	1	3	0	3
Medium Term	31	32	15	12	3	5	4	2
Long Term	26	9	12	5	5	1	3	0

In the research field, water infiltration is perceived at both the spatial and temporal scales where there is a match between the ‘natural’ and policy scales, with ‘regional’ and ‘medium term’. There is only one other instance where there is a match of perception: planners with the natural and policy spatial scales matching at regional.

Table 21 Perceived natural and policy scales of carbon sequestration

Carbon Sequestration	Total		Research		Policy		Planning	
Scale	*Natural*	*Policy*	*Natural*	*Policy*	*Natural*	*Policy*	*Natural*	*Policy*
Local	10	7	4	1	1	1	0	0
Regional	15	5	6	3	2	2	2	1
National	20	27	10	14	2	2	1	3
European	6	12	4	5	0	0	0	1
Global	21	4	13	3	3	3	4	0
Short Term	2	6	2	2	0	0	0	1
Medium Term	15	26	6	15	2	2	2	4
Long Term	44	19	23	8	7	7	4	0

The only sector who perceive that the natural spatial and temporal scales of carbon sequestration to be the same as those scales at which policy is created for carbon sequestration are those in policy, with global and long term. Research and planning sectors both perceive the policy scales of carbon sequestration to be national and medium term and the natural scales to be global and long term.

3.6.7 Sensitivity to findings

Using Bayesian Belief Networks to analyse the data, it was possible to obtain the 'sensitivity to findings', highlighting which response to the survey is the one which most clearly identifies each user within their sector. This gives an idea as to what is most unique and important to each sector. Table 22 shows the top

three variables obtained through the ‘sensitivity to findings’ for each of the different sectors.

Table 22 Top three sensitivity to findings results by sector

Sector	First	Second	Third
Policy	Local	Water infiltration meaning	Temporal scale worked at
Planning	Local	Temporal scale worked at	Pollination meaning
Researchers	Pollination meaning	Spatial scale worked at	Carbon sequestration meaning

The Bayesian belief networks also aid quantification of the most common responses for each sector, shown in Table 23. The figures relate to the likelihood (0 being impossible, 1 being certain) that the person in that sector would pick the answer shown. Each of the aspects shown are the one with the highest majority.

Table 23 Most common response to question 'What is the most important aspect to each of the following ecosystem services?' by sector using Bayesian belief networks (0-1)

Sector	Pollination	Carbon Sequestration	Water Infiltration
Policy	Healthy ecosystem (0.40)	Slow global warming (0.37)	Flood prevention (0.34)
Planning	Healthy ecosystem (0.36)	Slow global warming (0.36)	Flood prevention (0.39)
Research	Healthy ecosystem (0.40)	Slow global warming (0.42)	Flood prevention (0.35)

There is a strong consensus across all of the sectors in all three representative ecosystem services as to what is the most important aspect of each of the services. For pollination, the most important aspect is the representation of a healthy ecosystem, for carbon sequestration the most important aspect is the slowing of global warming, and for water infiltration the most important aspect is flood prevention.

3.6.8 Natural scales

It is difficult to know at what scales ecosystem services function naturally, and there are many processes and programmes that attempt to measure ecosystem services. Ecosystem services are provided at a wide variety of spatial and temporal scales (Hein et al., 2006) so defining the scales and their interactions is difficult. Consideration of global as a 'natural' scale is still coarse resolution both in terms of space and time, rendering it impractical for policy and management decision-making (Tallis et al., 2012). There is also the argument that ecosystem services are the utilisation of the natural environment by humans, thus meaning that their 'natural' scale is difficult to determine as it is inherently linked to the beneficiaries (Norton et al., 2016). Within the survey,

participants were asked at which scales they believed the three ES functioned at a natural scale and also at which scales they believed the policy surrounding the ecosystem service is created. Although there is much ambiguity about natural scales Andersson's work (2104) has been used as a comparative tool to analyse the results of this survey. The ‘natural’ scales of ecosystem services were taken from Andersson et al. (2014). Andersson et al. define spatial scale as the relevant scale at which ecosystem services are produced and temporal scale as the timing of ecosystem service production. This could be constant, seasonal or related to individual or even unique events (Andersson et al., 2014). As this paper was published after the survey was completed the same spatial scale words are not used, so direct comparison is not possible. Hence the main conclusions can only be drawn from the temporal scale information.

Table 24 shows Andersson et al.’s (2014) determination of the spatial and temporal scale that ecosystem services function at ‘naturally’ alongside the scales at which respondents identified the ecosystem services function at ‘naturally’ and the scales at which policy is made for them.

Table 24 Andersson et al.’s (2014) determination of the spatial and temporal scale

Ecosystem service	**Andersson Spatial**	**Andersson Temporal**	**Survey Natural Spatial**	**Survey Natural temporal**	**Survey Policy spatial**	**Survey Policy temporal**
Carbon Sequestration	Regional	Constant/ Seasonal	National	Long	National	Medium
Water infiltration	Local/ Regional	Constant/ Event	Regional	Medium	Regional	Medium
Pollination	Local	Mobile/ Seasonal	Local	Medium/ Long	National	Short/ Medium

It is difficult to make any comparisons with the temporal scale as it is in very different measures. There is consensus between Andersson and the 'natural' and policy scales identified by the survey that water infiltration is a regional process. The 'natural' scales match at 'local' for pollination, but the overall scale identified for policy was 'national'. The survey identified a match in policy and natural scales for carbon sequestration as national, but Andersson identifies it as being a regional process.

3.7 Discussion

Overall, when discussing the spatial scale at which they work, all the respondents identified the finer scales of local and regional, whilst temporally, each sector identify that they work at a medium term scale. One of the interesting aspects to the time scale factors is what 'medium term' means to each sector, as people across sectors identify it as yearly or decadal, which are wholly different. This then leaves space for mismatches in temporal scale. Although the sectors are using the same term to describe the temporal scale at which they work, they do not identify that the meaning behind the term 'medium' is different for each of them.

3.7.1 Natural scales and policy scales

When ecosystem services are managed at the wrong scale it can cause negative environmental and social impacts (Bakun and Broad, 2003), and the survey data suggests that this is happening. Focusing on the individual service scales it is possible to identify that there is a clear difference between the natural spatial scales of pollination and the spatial scales at which the policy for pollination is applied. This difference is highlighted in Table 19, where 'local' is identified as the natural spatial scale of pollination and 'national' is identified as spatial scale of the policy. This shows that there is a clear mismatch between the perceived natural and policy scales of pollination, which could have an impact on the decisions made within the policy realm for pollination.

‘Global’ and ‘long term’ are identified overall, and also within each sector separately, as the scales at which carbon sequestration naturally functions. The respondents to the survey as a whole, and also when broken down into their sectors, identify the policy scale as ‘national’ and ‘medium term’. Although this shows that there is a mismatch in scales between the natural and the policy scales, it also shows that most people in the industry, and within the different sectors, are aware of this mismatch. By being aware of the mismatches between natural and policy scales it is possible to mitigate problems that may be caused by it.

3.7.2 Sensitivity to findings

Table 22 shows the analysis of the sensitivity to finding results for each of the sectors. From the Table it can be seen that the meaning behind the term ‘local’ was significantly different for those in planning and those in policy, compared to other sectors, and to each other. This is going to lead to significant scale mismatches due to the word ‘local’ being so commonly used. It is often an assumed word so people don’t specify what it means in the context of their research or policy. The scale at which a sector works, either temporally or spatially appears at least once in each of the sectors’ unique responses. This makes it clear that the sectors are all working at different scales. Working at these different scales can augment scale mismatches, and be the lead cause of them, yet there are also many circumstances where working at conflicting scales is necessary, depending on what specific research or policy are being worked on. The interaction between science and policy is vital in the decision making process, yet can often be limited (Posner et al., 2015), and it is important to overcome this and create open channels of information, as this is a scale issue that can easily be planned for, so long as it is identified as such.

3.7.3 Local

‘Local’ is an interesting term in scale mismatch issues in ecosystem services as it is used regularly in papers, reports and discourse. Within each of the three sectors there were respondents who identified as working at the ‘local’ scale (Figure 14), though when compared to Table 18 this shows that this is not

straightforward, as all of them working at the same scale. Table 18 shows that the sectors identify ‘local’ with completely different meanings. ‘Local’ is a commonly used word, which means that it often isn’t predefined, and whereas in discourse it is possible to explain or question, when reading a printed document it can easily be misconstrued. This could then lead to extreme mismatches in scale, if management decisions or the research read to help shape those decisions are applied in a different manner to that intended. Improvements in the use of terminologies within ecosystem services are necessary (Lele et al., 2013). The inconsistencies in the meaning of ‘local’ highlight the communication discrepancies that are felt across the fields.

3.7.4 Important aspects within ecosystem services

Across the survey, respondents believe that the most important aspect of pollination is that it is a representation of a healthy ecosystem. Slowing global warming is the most important factor within the service of carbon sequestration, which is reflected Figure 23. The most important feature of water infiltrations is flood prevention; this is clear in the breakdown of each of the sectors and overall in Figure 22. The priorities across all sectors concur, which shows that although there is the same line of thinking, which is positive, it could also make it difficult to fully manage ecosystem services. If everyone has the same priorities, this will mean that those priorities are developed, worked on and met, although this could also potentially be at the expense of other aspects. Water infiltration is important for flood prevention, but is also vital for providing clean and healthy drinking water. Both of these services require completely different management plans, at different scales, yet are provided by the overarching service of water infiltration. Management plans for ecosystem services need to be carefully developed in order to manage the different services provided by the same ecosystem process (Tickner et al., 2017). Scale mismatches may therefore occur when one aspect of a service is overlooked in favour of another.

3.7.5 Ecosystem service consideration

Figure 20 shows that carbon sequestration is mostly considered once or twice a month, by all the sectors. Water infiltration either once or twice a week once or twice a month. Pollination is considered once or twice a year.

The most important aspect of carbon sequestration was identified as ‘slowing global warming’ (Figure 23). Global warming and climate change are some of the most contentious environmental issues at the moment, with many policy and research articles within ecosystem services focussing on the issue (2, 2.4.6), so it will be integrated into many environmental decisions on a regular basis. For this reason, carbon sequestration is the most highly considered of the three ecosystem services in the survey. There are many targets and legislative processes related to climate change, and mismatches could occur when trying to apply and meet these larger scale targets as some scientists feel they are unattainable (Anderson et al., 2008), particularly when those in the industry are working at a regional scale.

Pollination is considered by most of the sectors on an annual or twice yearly basis, which reflects the agricultural regimes of sowing and harvesting crops. In the policy sector, pollination is considered more often, as they need to deal with issues in the media regarding the combative issues of neonicotinoids, and the regulatory decisions to restrict their use in order to protect pollinators. This mismatch in scales relates to the different perspectives of the sectors, which means that although there is technically a mismatch, it may not have a negative effect and is merely a matter of process.

Flood prevention was identified in Figure 22 as being the most important aspect of water infiltration. This link with flooding requires that water infiltration is thought of regularly - weekly or monthly. Flood events occur mainly over the winter in the UK, but the work to prevent them occurs all year round, including not just the infrastructure but also the research behind prevention and prediction.

Climate change is a prevalent issue in scale mismatches, as it is a global scale, long term problem, though solutions are considered on a local scale, and short term time frame. Figure 15 shows that there is a lack of focus on the long term scale. There are many policy targets focussed on climate change, such as the 2050 carbon emissions reduction targets, which are rigid, even though there are known uncertainties in the carbon cycle (Meinhausen et al., 2009). Ecosystem services are at the forefront of the climate change issue, as both carbon sequestration and carbon capture feature within many different ecosystem services. This lack of focus on the long term will likely create mismatches.

3.8 Conclusions

Across all three of the exemplar ecosystem services of water infiltration, pollination and carbon sequestration within the survey, it was identified that the perceived scales, of what might be considered natural, are different from the scale at which the policy for the services is applied. ‘Natural’ services are seen as longer term, and covering a wider spatial area. This is the main issue for scale mismatches throughout ecosystem services. This scale mismatch is clearly identified by ecosystem services practitioners, and this is something that will need further investigation using in depth interviews, where respondents will be able to put forward case studies and further justification of their use of terminology.

Although there are scale mismatches present, there is some optimism in noting that all sectors have the same focus on each of the individual ecosystem services, and the priorities within. Due to this, enhanced communication and collaboration should be possible. For pollination, this important aspect is ‘representative of a healthy ecosystem’; for carbon sequestration, it is ‘slowing global warming’; and for water infiltration, it is ‘flood prevention’.

The negative side to all sectors having the same priorities is that there may be some aspects of each of the services which are left neglected. However, if the management plan is in place for the aspects which are considered important, then the service should receive the level of management and conservation required.

Throughout the responses, there is a strong climate change theme when discussing ecosystem consideration and important aspects of the services. Carbon sequestration is the most frequently considered ecosystem service, and the most important aspect of carbon sequestration is the slowing of global warming. Yet climate change is a long term issue, and most respondents identified as working at only the medium term. Equally, it is also a global problem, though again the only sector working at a global scale with any significance are researchers, whose impact is limited to their ability to persuade policy makers in their decision making. This highlights the mismatches present between the scale of ecosystem service practitioners and the services with which they work.

4 In-depth interviews to understand scale mismatches in ecosystem services.

4.1 Introduction

Interviews are one of the most frequently used methods of qualitative data collection (Opdenakker, 2006). The previous work undertaken in this research project involved a systematic review and a survey. The systematic review investigated the use of different ecosystem services and scale terms surrounding ecosystem services within published literature and grey policy literature. This led to the development of a survey, where the systematic review data was used to ask questions of those working in ecosystem services research, policy and practice. Using interviews alongside these methods in order to discern understanding is a common approach (Posner et al., 2016; Sales-Rosa and Sanchez, 2016; Camps-Calvet et al., 2016). Leading on from this previous research to qualitative interviews will enable a "deeper picture" to be realised (Silverman, 2006). The qualitative interviews will allow the participants' own perspectives and principles to form part of the research outcomes (Byrne, 2004).

Face-to-face and telephone interviews enable the interviewer to understand the tone of the interviewee and they can also enable the interviewer to see the social cues of the interviewee (Opdenakker, 2006). By performing a qualitative interview, the interviewee is seen more as a 'participant' rather than a 'subject', as they are involved in the processes of sculpting the interview as and when different topics arise (King, 1994).

There is substantial evidence to demonstrate the benefits of qualitative data collection, frequently through the use of interviews, in a broad range of subjects and applications (Bryman, 2008). Within ecosystem services research, interviews have been used to collect qualitative data to provide greater explanation of the issues through surveys and other means of data collection (Ostrom, 2009; Brown, 2013; Scholte et al., 2015; Swapna et al., 2016; Barclay et al., 2017).

The aim of this research is to understand the extent, occurrence, and nature of problematic scale mismatches within ecosystem service planning, policy, and research in order to gauge and potentially alleviate their effects on the integration of ecosystem services into such policy, planning and research outcomes.

The objectives are to:

1. Assess the extent and circumstances in which scale mismatches occur
2. Determine the reasons behind those scale mismatches which are problematic
3. Interpret the causes of and current solutions for scale mismatch problems.
4. Identify practical solutions to reduce or resolve scale mismatch problems.

The interviews undertaken in this research were developed from previous research (Chapters 1, 2 and 3), and set out to meet aspects of the aims and objectives above. The interview questions and subsequent analysis will determine the reasons behind problematic scale mismatches, and discover the extent of the problems caused by scale mismatches. There are questions which aim to assess the extent and circumstance in which scale mismatches occur and this information will be used to attempt to develop strategies to solve mismatch issues.

4.2 Method

4.2.1 Questionnaire design

As in other research in this field (Posner et al., 2016), a survey (3, 3.5.7) was used to inform the questions for the interview. In order for the survey to be accurate and constructive, Posner et al. (2016) used a pool of participants for the survey which was as similar as possible to that intended for the interviews. The interview questions in this project were informed by an extensive survey which was used for data collection in its own right, and thus it was well

conceived and detailed. Leading on from the survey, specific topics were selected which would give supporting evidence through a comprehensive overview in order to answer both the questions of the project as a whole, and the interview project within itself.

Predominantly open questions were used in the survey meaning that the variety of responses could not be pre-empted or pre-coded. Although closed questions can often increase response rates, they also lack the depth, detail and accuracy needed for this study (Griffith et al., 1999). Open questions can enable the respondent to bring in issues that they feel are related, but have not yet been covered (O'Cathain and Thomas, 2004). The questions were used to answer the specific points of the aims and objectives, whilst making sure that all additional information was recorded for analyses. The interviews were designed to be semi-structured. Semi-structured interviews are used when it is clear what needs to be asked, and specific issues need to be addressed, but the interviewee may have further details or different points to make that wouldn't be addressed in set questions (Hatton Macdonald et al., 2013). The semi-structured interview process ensures that the same questions are answered by each interview participant, but it also enable those questions to be moulded and adapted to fit the interviewees' previous responses and depth of knowledge (Galletta, 2013). The question script was written in such a way as to be the same for face-to-face interviews, telephone interviews and Skype interviews. Having one script to be used in all situations ensured consistency. The justification and intention behind each question can be found in Table 25. Although the script stayed predominantly the same the questions were marginally different for each participant group. The questions for those in policy are presented in Appendix C and for research in Appendix D.

Table 25 Interview questions justification and intentions

Question	Intentions	Justification
1	To understand the depth of knowledge and understanding of the respondent.	Broad opener is important to set the theme of interviews.
2 & 2a	Identification of any scale mismatches specific to their line of work.	
3 & 3a,b,c	To understand current practice in overcoming scale mismatch issues and see how they compare to those identified in the systematic review.	Developed from the results of the systematic review (2, 2.4).
4	To understand the scale at which the scientists' research is undertaken and the scale of influence of policy-makers' decisions.	This was slightly different for the different sectors as they have different ways of working
5	To further develop the issue of terminology that was uncovered in the survey, using the terms that caused contention in the survey responses.	Developed from results of survey (3, 3.7) to confirm whether terminology is really an issue.
6	Following on from the survey the interviews delved deeper into the important aspects of the three exemplar ecosystem services.	The same exemplar services as used in the survey (3, 3.5.6) in order to enable synthesis and comparison in the results.
7	To find the influences behind decisions taken within the realm of scale.	This was slightly different for the different sectors as they have different ways of working.
8	This question explored the findings of the systematic review; that a lot of research is focused on the global/large scale, whilst the survey respondents identified as working at a medium term/regional scale.	This questions was developed from the results of both the systematic review (2, 2.4) and the survey (3, 3.7) in order to enable synthesis of the three pieces of research.

4.2.2 Pilot

An initial pilot was used to gauge timings, as the interviews were intended to be only 30 minutes long, as this is the optimum time for an interview (Bryman, 2008). The pilot also helped with the flow of the interview, ensuring the interviewer knew where and what prompts were likely to be needed. There were two pilot participants. The first had only basic knowledge of the subject, and gave advice on the clarity of the questions, and was conducted via Skype to ensure feasibility. The second had excellent knowledge and experience, and asked relevant questions and gave a good idea of timings. This interview was performed face-to-face. The pilot process also indicated that there would need to be a brief definition of ecosystem services at the beginning, as there are many different ways of working with ecosystem services without knowing, or using the exact term 'ecosystem services'.

4.2.3 Key informant sample

The invitation for the interviews began with stakeholders in the F^3UES BESS project, (Fragments, Functions, Flows and Urban Ecosystem Services), a research consortium looking at how the biodiversity of towns and cities contributes to human well-being (Bess-Urban, no date). These were mainly scientists, well connected with policy-makers and NGOs, and so were in a good position to recommend other participants.

In addition, the BESS programme mailing list was used. Biodiversity and Ecosystem Service Sustainability (BESS) is a research programme looking at the functional role of biodiversity in key ecosystem processes, thus ensuring that the participants receiving the invitation were already knowledgeable about the issues being broached. Each respondent to the invitation was then further scrutinized via a discussion of their role to ensure their relevance to the project.

In total, 19 respondents were interviewed. There are extensive notes for all 19 interviews, although of these only 18 transcripts were able to be transcribed due to a recording device malfunction. There were six policy/management respondents working in organisations such as the Environment Agency, the

Parliamentary Office of Science and Technology, the Department for Environment, Food and Rural affairs and the Joint Nature Conservation Committee; six NGO respondents, who worked with organisations such as the World Wildlife Fund, the Parks Trust, and Surrey Nature Partnership; and seven science respondents who all worked with ecosystem services, two of whom work specifically with scale, from institutions such as the University of York, the Centre for Ecology and Hydrology in Exeter, and Manchester University. This broad sample of respondents were all regularly working with ecosystem services, or had a wide-ranging understanding of them and the way they are used in policy and science. It can be seen that they were a very representative group. Most of the UK based respondents worked at a local and national level or above.

Saturation of ideas occurred at this point in the study, where fewer new ideas were coming into the project, and it felt well rounded with the 19 respondents. Saturation is the point where diminishing returns occurs in a qualitative sample (Ritchie et al., 2003). Charmaz (2006) suggests that saturation might happen more quickly in a more "modest" study than one that is aiming to span disciplines. Jette et al., (2003) suggested that expertise in the chosen topic can reduce the number of participants needed in a study. With the guidance and expertise of colleagues and supervisors, it was possible to identify when saturation had occurred through the even distribution of respondents from each sector, their level of expertise, and the homogeneity of responses.

As ideas and responses became more and more repetitive, recruitment for respondents slowed. The majority of the respondents were from organisations in the UK as most of them were contacts of contacts. As interviews needed to be either face-to-face or via Skype, it was much easier to recruit within the same time-zone, with only one respondent being interviewed by Skype from the USA.

4.2.4 Recording

Using a Dictaphone to record the interviews enabled the interviewer to be focussed on the conversation and not just the note taking. However, note taking

alongside recording is helpful to keep track of the interview and to ensure that it stays on topic. Also any points made could be examined as required, further into the interview. Notes also help when the recording had stopped and the interviewee may come up with some final thoughts (Bryman, 2008). Recording the interviews and then transcribing them, ensured that the intonation of what was said could be interpreted alongside the words used. The recordings and transcripts also allowed for the data to be re-examined to ensure no bias by the interviewer (Bryman, 2008). The recordings were transcribed by an outside agency and then proof-checked in order to confirm accuracy. For data analysis, it was important to ensure that key words such as 'ecosystem' hadn't been split into 'eco system' so that it could be used as a search term, particularly when relying on digital analysis. This was an issue which had occurred through using an outside agency, who had no experience of working within the environmental field.

4.2.5 Data Analysis

The data analysis was started by splitting the interviews into sectors and responses to each question. All of the responses for each question were gathered and then they were split into three groups based on the sector in which the respondents worked. The three sectors were 'policy' 'science' and 'NGO'. Collating the questions into the sectors enabled comparisons to be made, whilst also ensuring the anonymity of the respondents.

4.2.5.1 Thematic content analysis

The next process in the analysis was coding, a very common method to analyse qualitative interview data. It is defined as ''tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study'' (Miles and Huberman, 1994). There are three processes involved in developing the codes with which to code the data. The first involves the literature and existing theory surrounding the project, and any questions that need asking of the data regarding theory. The second evolves from the aims and hypothesis of the research project; and the third involves reading the transcripts and picking out clusters of data (Ryan and Bernard, 2003). As the codes develop, a

codebook is created where each code has a title, inclusion and exclusion criteria, a short overview, a more in depth description, and examples (MacQueen et al., 2007). The data is examined using the codes, and whenever relevant information is uncovered it is extracted and placed into the codes table. Each quote is given a reference relating to the sector of the respondent and the line within the transcript where the quote is found (s = Science, p = Policy, n =NGO). For example, ‘s18’ relates to the 18th line of text in the science sector transcript.

4.3 Results

4.3.1 Respondents

There were 19 respondents overall who provided in-depth detailed interviews. They were from three sectors, with six from policy/management, seven from science and six from NGOs. Having the three sectors represented was important to ensure that the data collected was well-rounded. Each of the sectors had different motivations for the protection and use of ecosystem services, and would have different ideas of where problems and issues lie.

From the policy sector those interviewed were looking at ecosystem services from different perspectives including conservation, economics, and informing politicians and the public. The scale of influence was also varied from local government through to larger national government agencies. This enabled the project to have ideas and opinions from different sides of the issue.

The science sector respondents were from a variety of research backgrounds, including modelling, soil science, marine science and social science, but all within an ecosystem service or environmental science capacity. This allowed for a wide breadth of experiences to be captured, through working with scale, policy and management at different levels and to different extents.

The NGOs represented different habitats, from across the UK and further afield. The sites the NGO’s are involved in varied from networks of urban parks, through entire peatland landscapes, to the interest of habitat and species conservation UK wide. This meant they had different levels of interest in, and

interaction with, the policy and management of the environment and ecosystem services.

4.3.2 Thematic content analysis

Overall there were 10 codes identified (Table 26), some of which relate directly to the aims and hypothesis; some of which are enabling development of issues identified in the survey; and some of which were identified as the transcripts were read. Those that do not correspond with a direct question are identified as non-direct responses (NDR). The first column refers to the codes that were either predefined or developed as the transcripts were read. The same interviewer undertook all of the interviews, which enabled the easier identification of topics materialising at the interview stage. The second column elaborates on the idea behind the code, and the question it is asking of the transcripts. The justification column explains why that particular code is valuable to the research, and in some cases how the code was developed. In some cases there are example quotes in order to aid the reader's understanding of the justification.

Table 26 Codes used for thematic analysis and their justification

Code	Overview	Justification
Extent	To what extent ecosystem services are considered within their role	This will show how integrated ecosystem services are within the sectors.
Science (NDR)	When the respondent mentions science sectors	To identify the breadth of sciences involved "eco-toxicology" (s30) "modelling" (s17)
Scale Terms	Discussing the other terms involved in scale issues	To identify to what extent terminology increases scale issues
Collaboration (NDR)	Mentions of teaming up and collaborating with other groups	Collaboration influences the scale of a project, and could ease scale mismatches.

Code	Overview	Justification
Money (NDR)	Any points or references to funding and money	Recurring point in responses “schemes for funding” (p87) “funding is always a challenge” (n55) “money is important” (s455)
Solutions Used/Proposed	Any proposed or currently in practice solutions to scale issues	To uncover the potential solutions to scale mismatch problems
Scale Issues	Identified ecosystem services issues surrounding scale	To define which scale issues are most prevalent
People (NDR)	References to people, constituents or the public	Recurring point in responses “listen to what people are saying” (p214) “engaging people” (n74) “work with local people” (s68)
Other ES terms (NDR)	Terms referring to ecosystem services	To identify to what extent terminology increases scale issues

Code	Overview	Justification
Climate change (NDR)	Discussions surrounding climate change	Recurring point in responses “in terms of climate change and woodlands, the trees that grow now will be trees in 200 years’ time” (p591) “the classic example is climate change which is a global problem but actually studies … are looking [at] national” (s472)
Evidence	References to where and how evidence is gathered for research and policy decisions	Recurring issue in responses "look through the academic literature" (p883) "light reviews which we conduct in-house" (p864) "We tend to commission quite a lot of research, so we'll use various experts." (n581)

The data in Table 27 show that the most frequently mentioned themes overall were Scale Issues, and Collaboration was the most frequently mentioned NDR. For the respondents who work in policy, the most frequently mentioned theme was ‘Scale Terms’ and NDR theme was ‘Collaboration’. Collaboration was also the most frequently mentioned NDR theme, alongside ‘People’, for NGO respondents, though the most frequently mentioned overall theme was ‘Scale Solutions’. The science respondents most frequent theme was ‘Scale Issues’ and NDR theme was ‘Money’.

Table 27 Frequency of each code found within the interviewees responses

Code	Overview	All Responses	Response from Policy	Responses by Science	Responses by NGO
	Number of respondents (n)	*(n= x)*	*(n= x)*	*(n= x)*	*(n= x)*
Extent	To what extent ecosystem services are considered	14	8	6	--
Science	When the respondent mentions the science sector	3	3	--	--
Scale Terms	Discussing the other terms involved in scale issues	52	42	3	7
Collaboration	Mentions of teaming up and collaborating with other groups	36	25	3	8
Money	Any points or references to funding and money	30	17	6	7

Code	Overview	All Responses	Response from Policy	Responses by Science	Responses by NGO
Solutions Used/Proposed	Any proposed or currently in practice solutions to scale issues	65	37	9	19
Scale Issues	Identified ecosystem services issues surrounding scale	69	36	15	18
People	References to people, constituents or the public	24	13	3	8
Other ES Terms	Terms referring to ecosystem services	8	5	--	3
Climate Change	References to climate change	14	10	2	2
Evidence	Where evidence is gathered from	16	11	2	3

During the process of coding, five overarching themes were brought to light and used to group the codes. These five themes were Restrictions, Terminology, Scale Issues, Scale Solutions, and Climate Change. The themes and all of the corresponding quotes are found in Appendix E. The overarching themes were used to structure the following results.

4.3.3 Theme: Restrictions

4.3.3.1 Code: Extent

In the analysis for this study, the extent to which interviewees considered that they work with ecosystem services was determined. The respondents across all sectors were not necessarily those whose roles had a clear link to ES. They had been chosen because they work with the environment, whether directly in hands-on research or management, or indirectly via planning and policy.

For policy-makers, the extent to which they work with ecosystem services was echoed across the sector as regular and increasing: “we are restoring ecosystem services so we deal with it all the time” (p19), “certainly an increasing area of work” (p22), “quite a lot” (p11), “a lot” (p13), “on a daily basis” (p16). Overall, it can be seen that policy-makers have a clear understanding of the link between working with the environment and working with ES.

This extent was also reflected in science: “more or less entirely really” (s8), “a lot” (s6), “pretty much completely” (s3). However, there were two respondents who said that they only worked with ES “indirectly through their work with the environment, not really investigating an ecosystem per se” (s34), “indirectly they can be linked back to ecosystem services” (s20), showing that this link is viewed less directly in this field.

NGOs generally said that their work within the environmental sector provided a direct or indirect link to ES: “Indirectly I work with ecosystem services” (n27), “To a degree, it’s just that we don’t often call them that” (n20), “I think that everything really, in a way, is about ecosystem services” (n5), whilst another identified that they were more involved with ES “A large extent, I would say most of all my work has a relationship with ecosystem services” (n3).

4.3.3.2 Code: Evidence

Those in policy-making gather their evidence from a host of different sources such as searching academic literature “from all the scientific journals, from publications from research that’s been performed, relationships from different academics and institutions” (p876); “we do systematic views, of peer reviewed information” (p887, p884, p877, p876, p850); conferences and workshops (p878); or commissioning their own research “we commission people to do the work” (p888).

Policy-makers may also perform their own in-house research; “It may be through light reviews which we conduct in-house” (p864); “we had evidence folks within the Environment Agency” (p837). This can then lead to less than appropriate science being used to inform policy decisions which may be put into practice. NGO’s commission research externally; “We tend to commission quite a lot of research” (n581) and internally “we will also commission our consultants” (n568).They also ask experts for evidence “so we'll use various experts“ (n584).

Scientists discuss the external limitations of the data that is gathered; “data can limit what your initial plan was” (s396), and how funding and the data available can hinder the research process, “who's funding it and what they want” (s393).

4.3.3.3 Code: Collaboration

Collaboration between sectors is discussed regularly within the interviews. Policy-makers work with academia; “we work with academics” (p889) “talk to the partners that we work with and certainly the university sector” (p884), (p877, p861, p851, p846, p842). They also collaborate with economists “We’ve got economic consultants” (p845), government agencies “they are commissioned by the Scottish government to do research in this area” (p851), “Mapping and Assessing of Ecosystem Services working group...at the European Commission” (p316) (p67, p289). With the private sector “we work in partnership with...private consultancies” (p861), “a consultant and other specialist partners” (p847), “But it might be that there might be other water quality benefits of peatland restoration could be attractive to water companies”

(p101) (p845, p96). Policy-makers also work with NGOs “local level led by an NGO, an environmental NGO” (p847); and with users “we work with local stakeholders” (p109), “we hold workshops with the stakeholders” (p289), “somebody basically did a GIS tool where you can work with stakeholders” (p370).

Scientists collaborate with other academics (s413) and government agencies (s10). NGOs collaborate with scientists “one of the key relationships that we have here in Surrey is the Surrey university” (n158); policy-makers “The other probable main source of information is Natural England” (n603); and end-users “We have a Heathland Forum where the people who are managing the sites on a day to day basis, meet up once a year” (n590), “a kind of stakeholder engagement project which is trying to bring together the main sectors” (n11). Scientists discuss collaboration less than the other agencies, but this could be because they are the party which is often asked to join a collaboration, as they have the knowledge and expertise for the research side of a project. Evidently, ecosystem services cannot be managed and researched by scientists alone. Ecosystem services are interdisciplinary, not just through the different branches of science, but also with the end-users, managers and policy practitioners.

The collaborations are recognised as a step toward the inter-disciplinary approach to ecosystem services research and management; “how are we taking an interdisciplinary approach?” (p786). Communication and collaboration links enable the flow of information through the different sectors involved in ES research. This flow of information is vital in enabling understanding at all levels. Both policy-makers and NGOs discuss some of the processes of stakeholder engagement, examples being “they get all the landowners to sit round posting notes on bits of the land” (p289); they “hold workshops with the stakeholders” (p367).

There can be things which can inhibit the initiation of the collaborative process: “often the university is less focused on the smaller scale stuff so again we might use them for bigger scale pieces of work” (n574); “listen to what people are

saying within that process, which takes longer" (p213); and things are "incredibly complex because it involves people as well as ecology" (s245).

4.3.3.4 Code: Money

Funding may be hindering the science/policy interface as those in policy know what they need from the science, but don't necessarily have enough money to fund a project; "I work out what I can do for the money and do that" (s399); "as big as we can afford" (s354). The origin of the funding can also have an effect on the research; "whose funding it and what they want from the project" (s393). Funding can affect the science that goes into policy; as policy-makers say, "we are able to articulate what scientific data is needed but we are not always able to [do it], again, because our funding and time to actually collect that data" (p418).

NGO's work on what is "practical and affordable" (n687) as there isn't always adequate finance for them to do their work to the widest extent, "very rarely is there sufficient funding" (n55). Often NGO's will collaborate in order to try to gain funding; "We work alongside organisations such as the Wildlife Trust and the RSPB...We work together on funding bids to get more resource" (n333-335).

Within a policy context, creating a valuation of ES helps to integrate them into decision making "putting monetary values on ecosystem services" (p61); "mainstream value in decision making" (p67); "peatlands codes, which is a way of quantifying carbon savings from restoring peatlands" (p91); "natural capital accounting" (p252, p101, p63). The value of all the services from a habitat need to be considered in order to create best value. NGOs consider that making a valuation can help communicate important messages. When trying to protect or conserve a habitat "it's difficult to continuously communicate that there's environmental issues and concerns without being able to put a kind of figure to it really" (n165).

4.3.4 Theme: Terminology

1.4.3.1 Scale Terms

When it comes to scale terms, there are two main factors that need to be considered; clarification and context. Across all three sectors there is consensus that when discussing scale terms there should be clarification as to the units of scale, both temporally and spatially. Clarifying exactly what is meant by the scale terms is important to policy-makers “we normally have to define” (p679), “you need to have clear objectives or clear kind of statements of intent which are attached to those different terminologies” (p624). From science “I think local definitely needs defining. Long-term is a similar thing” (s237). And from NGOs “I think language in general can be difficult, so I would say yes it was important to make it clear” (n387). Policy-makers speak of being cautious about definitions, “I spend a lot of my life dealing with the difficulties of definition given these are all lay terms they are all open to abuse” (p629). Scientists are more direct about the need for clarity in all cases as “it’s really important to define what you mean” (s217), and policy-makers discuss the specific process “‘longer term’ I would actually put in brackets how many years I meant, that’s just where we are coming from. We tend to be ultra-cautious” (p638).

Defining terms needs to be done on a case by case basis, as there are those stakeholders across the different sectors who would believe they already understand terminology: “Most people understand that short term is the next three years” (n406), “most people have an idea of what short-term means really. In the next three years or something” (p597), “local is a fairly well understood context” (n389) which can cause even more obstructions to communication than if a stakeholder or researcher simply doesn't know “actually their understanding is different to yours, causing problems further down the lines” (n389). Aggravating this issue is that lack of agreement amongst the respondents about the depth of the problem. Some people in policy-making feel that there will never be an agreement on the terms used and so see “no hope of ever seeking or calling an agreement” (p671). Some of the terms themselves can be more

case specific than the definitions, such as the “human experience scale” (s365), which will be dependent on which humans are involved in the research project.

When discussing scale terms, in addition to clarity there needs to be a consideration of the context, as two parties may well know what a specific scale term means in one context while having different understanding in another: “I think any of them [scale terms] can be pretty context-dependent” (s230), “it depends in which context you're looking” (p601). This can lead to confusion down the line. The importance of context was discussed across each of the three sectors and can apply to either the people involved or the ecosystem service under discussion. It is important, therefore, at the start of a joint project, to ensure that terms are defined and recorded. Without this consensus, a range of problems can occur including lost time/time wasting; “it takes more time to work out when there is no clear definition or people haven’t specifically said what the time scale is” (s241); confusion “you know if scientist and let’s say farmers, we are talking about two completely different things” (s211); and funding “short- and long-term can mean different things to different people, so if I'm talking to potential funders, for example, short- and long-term definitely mean different things to them than to me in terms of experimental duration” (s245). The context must take into account all parties, hence “Long term, say, to an MP would be more than 5 years, to most other people they are thinking 25 years and [for] scientists [it] would be more than 100” (p633). Thematic context includes the implied idea behind a concept, so “long term, [if] you’re talking about something climate...changing, [a] technical term, like you know I’m thinking in my head probably at least 50 years. If I’m talking long term in terms of countryside produce in [the] environment I’m thinking 5-10 years” (p675).

4.3.4.1 People

During the interviews, the concept of ‘people’ was interpreted as any stakeholder, whether they saw themselves as such or not. As one policy-maker put it, you “work in terms of stakeholder engagement, so you have to do something a lot more local...to allow people to relate and engage and approve it” (p588). Another said “I could get the local Oakley environment group to do

something about the river flowing through the village, [but] Bedford, [which] is most probably three miles / four miles away, could I get those village people to engage with the river flowing through Bedford? A few, but mostly not" (p529). And again, when "dealing with an MP ... they think of constituency... so if you can aim at that sort of scale its means much more" (p486).

From the NGO sector there was a view that "it's quite difficult to make people feel that they have a sense of belonging to that kind of large, Celtic seas' scale especially if you're a fisherman that only fishes in, I don't know, the Severn Estuary or something. Then it just doesn't have that same sort of relevance necessarily" (n75).

Working locally is important but there are difficulties involved. "If you try and tell people to stop playing football, because it's a nice bit of grass and we want to leave it long, locally they can't see that, but it makes perfect sense at the level we are looking at. That is where you get those mismatches potentially coming in, that is where tensions occur" (n418).

Public engagement can be made more challenging by a lack of public knowledge making it difficult to develop their understanding "when you are talking about ecosystems service to make it real you have to use case studies" (p486), "I think that just asking people the questions 'well who benefits?' helps people to think about the benefits that extend beyond their immediate surroundings" (p277), "They know they like it but they don't know why" (n224), "a lot of the general public, generally don't understand that it can be a positive transformation" (n197), "they may not understand initially but a proportion can be brought on the journey" (n217), although this awareness is increasing "the general public have developed over the last 4 years an increasing awareness" (s282).

In the interviews 'feelings', well-being and 'happiness' were referred to: "quite difficult to make people feel that they have a sense of belonging" (n75); "people's cultural associations there, what they feel their local environment is and not wanting it to change too much" (n97); "Natural capital has a very strong focus on social well being" (p145); "important in terms of the happiness of urban

residents and having landscapes" (s312); " if your city has a...lot of urban green space...can tie in with...how happy your residents are likely to be" (s321). The public can influence and make their own trade-offs "so a lot of people go 'pollinators', everyone goes 'bees! aren't bees great. Actually there's a lot more pollinators out there, you know, that are very, very critical, and you know, who's monitoring those?" (p752) Or, "you might be a [bird-watcher] or an anthropologist. and then you'll think about birds and you would go anywhere to see bird but then you might trample on plants or not care about them unless they relate to your specific species" (p535). If you can build into your policy or practice something that people can easily recognise as something that will make them 'feel happier', then there will be more engagement from the public. This happiness can then be counted within natural capital processes.

4.3.4.2 Other Ecosystem Service terms

It is most likely, because they were talking to a researcher whom they knew to have an understanding of ecosystem services, that throughout the interviews the scientists mainly referred to ecosystem services directly as 'ecosystem services'.

However, ecosystem services can also be discussed using different terms, which might relate to their benefits "One of the things I struggle with is the term because people talk about ecosystem services, rather than food production or clean water" (p32), " it's just that we don't often call them [ecosystem services]. We still operate in a world of 'green infrastructure' and, obviously, 'biodiversity of habitats'" (n20). Or ES might be discussed as the processes through which they are managed, "looking at say, ecosystem services through a lens of green infrastructure" (p148), "green infrastructure" (n21). Equally ES might be discussed through the ways in which they can be measured; "I work in the area of natural capital" (p15). The different terms used are shown in Table 28. Within the science arena, Ecosystem Services are discussed mainly by directly using the term Ecosystem Services, or by a direct reference to the service being provided.

Table 28 Other ecosystem service terms identified in the interviews

Other Ecosystem Service terms
Green infrastructure
Clean air
Clean water
Food production
Natural capital
Biodiversity of habitats

Those in policy-making and NGOs know that there are a host of terms which can be used to infer ecosystem services, especially in order to communicate to different audiences. The words could change depending on the topic under discussion. For example, monetary value as 'natural capital' (p16); or integrating ecosystem services into a management plan, as 'green infrastructure' (p148). These other terms are used either to narrow thinking to specifics, or to widen the concept under discussion. The terms don't negatively impact understanding for the user or reader, but rather enable communication. This can be the case whether discussing a particular service with someone who has an understanding of it, or by talking in terms of economics or management in order to communicate with specialists in those areas, or even talking more broadly, by relating to people's local areas, so enabling public understanding.

4.3.5 Theme: Scale Issues

The scale issues that were identified in the interviews by both the respondents and the guided interview Question Three (Appendix C and D) have been grouped into five categories which link the different themes to the scale issues

discussed. The first four categories are the same as those identified in the systematic review (2, 2.4.5) and the fifth is natural scales which was established during the analysis of the transcripts. The frequency of references to each of the scale issues are in Figure 24.

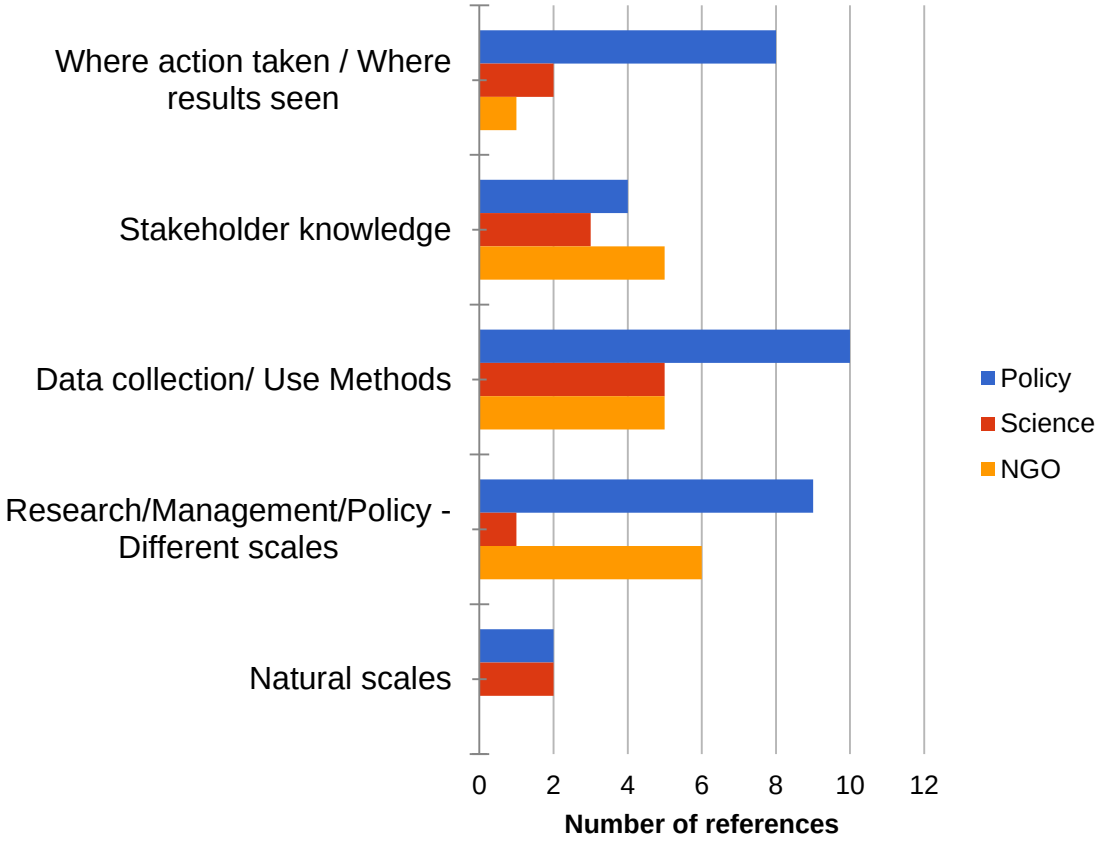

Figure 24 Frequency of references to different scale mismatch issues

Policy-makers find that the data produced by ecosystem service research is difficult to work with as the scale is too fine; “I almost find that the research that we read, it’s such a local and fine scale that we have difficulty extracting how that would impact the work we do” (p1075). There also needs to be more research into the process after research, to enable policy integration at different scales, as these quotes show: “I don’t think that there is nearly enough work done on how you take research outputs and translate them into public policy” (p912); “how [do] you do anything at the international scale because it’s really, really hard? The institutions just don’t exist and you look how the struggles have gone on over stable development and climate change, and you see it will have

its work cut out for it" (p174). There are some who see that accurate tools do exist, along with methods of data collection, but it is in the interpretation where the downfall happens; "we can show that our mapping and assessing of the assets themselves is very, very accurate, but there seems to be a disconnect in terms of 'what does this mean?', in terms of 'how I decide to manage that individual parcel of land [e.g.] for grazing, or 'where is it, are we going to want to put riparian buffer strips?', so on and so forth, so we've had issues with scalability there" (p129). Transferring the research from science into policy and practice is where problems can occur: "I don't think that there is nearly enough work done on how you take research outputs and translate them into public policy" (p912). Some projects are not transferrable - neither the policies produced (p87), nor the scale of the indicators within them, hence "how does that relate to the condition of natural capital more locally, [when] a lot of the indicators are not scalable." (p367).

Regional differences in the UK mean that there are always going to have to be regionally specific management plans; "peat is only in certain places. Sometimes very isolated places and therefore there is a regional challenge there" (p989). "You can't just pull one central lever and ... get results" (p963). The natural scales themselves can lead to mismatches. It is complicated to simultaneously manage for different ecosystem services in one landscape "we work with multiple eco systems all the time...different scales for different services are really apparent" (p200).

Policy-makers can only influence the area over which it they have control. "The local Council, doesn't equate to an environmental catchment. So therefore the Council is able to decide something within the boundaries of its influence" (p46)

Public stakeholders mainly consider the services which they can see directly affecting themselves. "[We talked to] local stakeholders and we asked them to think about the benefits [of] taking services from the area, and it was quite noticeable that they thought about the ones that they'd benefitted from themselves, like food productivity and wildlife, but they didn't think very much at

all about the carbon sequestration benefit, and they saw flood regulation as a dis-benefit because it was a benefit to areas downstream and not to them".

Stakeholder knowledge is often different to the way in which a scientist, or policy professional would approach an issue but this doesn't mean that it is incorrect "so individuals, stakeholders like farmers, have a very specific agenda and it's very difficult to (although they sort of already understand ecosystem services in a completely different sense to which scientists do), it's probably hard for them to have to think about taking into account ecosystem service delivery in their management, and also their income is outside of a localised cycle, so I could look at ecosystems services but ultimately the main services of production for the farmers in the catchment was completely divorced from local levels as it depends who's buying their meat, and that could be China" (s438).

The publishing possibilities for good journals are affected by the scale of a study. "If you want to be in one of the big impact journals the larger the scale you are at, the more [likely] you are to get published" (p1060). So the scale at which the study is made may be lead not by what is necessary, or by 'natural' scales, but by the external pressures put on researchers looking for publication.

4.3.6 Theme: Scale Solutions

The scale solutions which were identified in the interviews by both the respondents and the guided interview Question Four (Appendix C and D) have been grouped into five categories which link the different themes to the scale solutions discussed. The frequency of references to each of the scale issues are in Figure 25.

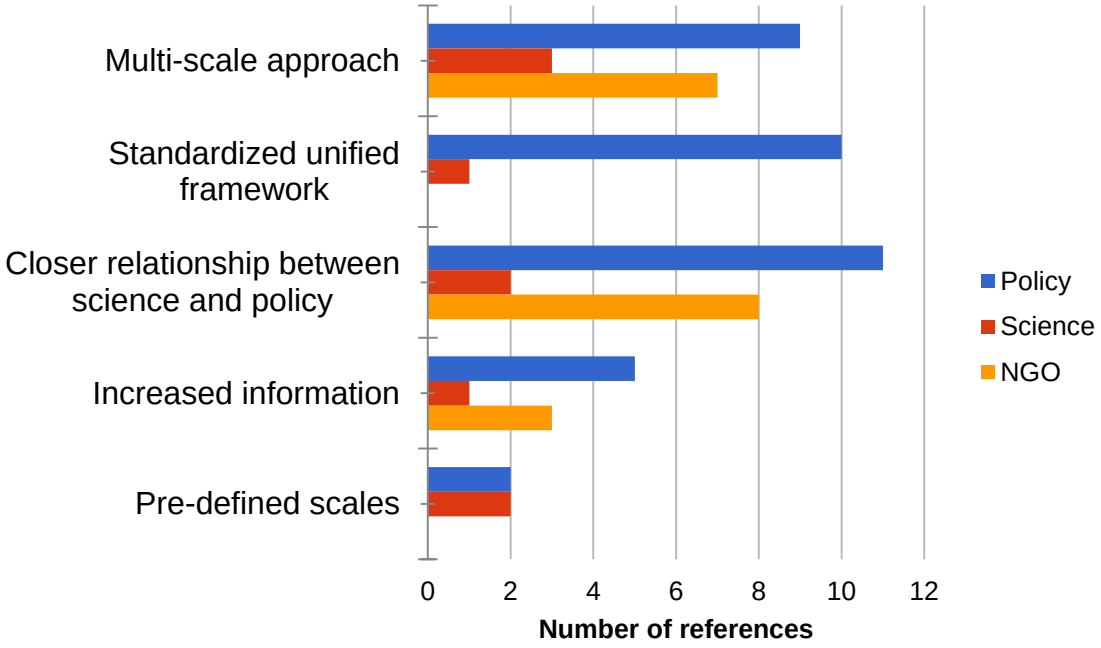

Figure 25 Frequency of references to different scale mismatch issues

It can be seen from the interviews that when working with the environment, nothing can be looked at in isolation and thus a multi scale approach may be necessary. Everything can have wider effects, so it is important to see a project in the context of this wider environment. “When we are working on a site we are constantly going up to what we call a 40,000 level and looking at that site and content and the region” (p179). When involving stakeholders it is important to take a multi scale approach. ”[We] tried to work with stakeholders at a national scale, policy stakeholders who are interested in the results at a local scale, for local stakeholders who might be interested in the results” (s58) as each stakeholder, depending on their scale of involvement will have different opinions, investments and ideas. They also have different influences, and thus it is important to ensure that they are presented with the right data, at the right scale. “If you produce data for different scales it is more or less useful, so data produced at national scale may not be that useful [for] local level stakeholders as they do not have the power” (n127). The boundaries of influence of an agency can have an effect on how much they can do; “the regional area

boundaries of the Environment Agency and Natural England are going to be harmonised" (p1122), and this could lead more cohesion between the two agencies, as the data will be directly applied at the correct regional scale.

Although a standardized unified framework may be a great way to move forward, with ecosystem service management it may not be easy, as "it becomes difficult to standardise these things" (p248). Introducing a national scale dataset for ecosystem services may alleviate scale issues by "asking how they are using existing data and then ensuring how we take that information. So what the user requirements are, and then integrate that into national data-sets moving forward, but also how we can then take that to make sure that the existing data is either more user-friendly, but more importantly, more discoverable to these users" (p339). Not only will a standardized unified framework make it easier to communicate between and among scientists and policy-makers, it will also aid in the process of changing the scale of research. For example, "the RSPB's energy for nature project, where they, on their wetland reserves, they create a lot of biomass waste which they are now looking to turn into marketable bio-products – a circular economy thing there. That has been piloted at a local level, but if you can get the framework right, and the scheme right, it could potentially be scaled up elsewhere" (p239).

In order to alleviate the issue of the disconnect between researchers and policy practitioners there should be someone to work in the middle; "people should have those integrated roles" (p55). There also needs to be someone to enable the research that has been fed into policy, which can then be applied in practice as "there may not be any clear guidance or clear view exactly of how that policy translates into delivery" (p1113). Bringing together the different agencies involved in a project, "... let's bring the Environment Agency, bodies like the water company, those companies, let's bring them together" (n240), can increase the connectivity of the agencies. The relevant parties in a project need to be involved in all aspects of the project "What we've got to do is take our stakeholders with us. That is a long-term project." (n439).

Pre-defining the scale at which a project is going to be undertaken will alleviate many of the scale issues which come about from confusion or misinterpretation. “It’s really important to define what you mean in all cases because otherwise it does generate misunderstanding” (s217). Predefinition in a project not only applies to the scales, but also to the terms, especially when the discussion involves a variety of stakeholders. “That piece of work looking at trying to communicate what ecosystem services are too many stakeholders and at the moment the term means different things to a lot of different people ... particularly on the marine side the definition we have been working with ... so they are looking to develop those definitions to make them something that makes sense” (p431). Defining time scale is also important; “being specific about what time horizon we're talking about does help, so that we're all kind of on the same page” (p598).

In general, the more information there is, then the easier it will be to alleviate scale issues by “trying to find additional or higher-resolution data to resolve an issue” (s137), or “increasing scientific data” (p262). Combining different types of data will also help increase information “to integrate Earth observation data with existing data to kind of improve decision making” (p329). The increase of information will then lead to better understanding “and the more we understand [about] the optimum way to design areas of green structure, to deliver eco systems services, [and] deliver those benefits, the better“ (n33).

4.3.7 Theme: Climate change

Those in policy-making positions see climate change as a representative of many of the scale issues present in decision making, both spatially and temporally. Global agreements and targets to limit CO_2 emissions may well be made, but policy-makers feel that actions need to take place more locally as “there are international agreements which are trying to address the whole carbon and climate change question, which seems sensible, but when it comes to more regional outreach, more land-use related issues, within Scotland, we do have a difficulty “ (p997-1000). One of the respondents from the policy sector suggested that the international institutions needed to respond to the problem of

climate change don't yet exist. The IPCC and the UN have wide membership, but not every country has signed up to the targets set by these bodies. This demonstrates that scale issues can be seen in environmental management, as, although climate change is affecting the globe, from a political perspective there is no way of getting every country on board to try and solve the issue.

Additionally, the notion that climate change is seen as a long-term problem by policy-makers, described as "probably at least 50 years" (p673) because "in terms of climate change and woodlands, the trees that grow now will be trees in 200 years' time" (p591).

When it is only the next election which is the long-term target of politicians, it is difficult for them to focus on what policy-makers would describe as long term plans. Even for those governments which do sign up to the targets for the reduction of carbon emissions, there is then the problem of cascading down to regional areas in order for action to be taken. For example, budgets are not equal across the UK for councils, and some councils have other, more pressing priorities than focussing on long term changes to mitigate climate change.

In science, research is also generally carried out at a national scale, whereas the issue is global: "the classic example is climate change which is a global problem but actually studies … are looking [at] national" (s472). However a more pressing problem may be that due to the publishing bias, relating research work to climate change mitigation can often mean publication in a more high impact journal, which as one of the respondents stated, holds more 'currency' "you don't publish, you don't get a job, basically...it's kind of the currency...so it's a lot of pressure to do [work] that's wider and has a relevance across the world, or across the continent or something" (s456) . This leads to scale issues where a project which is undertaken at a small, field scale is then being cascaded up to deal with the global issue of climate change in order to gain that all important place in a high impact journal.

4.4 Discussion

The discussion is structured around the five overarching themes and subsequent codes that were developed and identified in Appendix E, Quotes from interview transcripts organised by theme: Restrictions, Terminology, Scale Issues, Scale Solutions and Climate Change.

4.4.1 Restrictions

The increase shown in this research, both in the overall consideration of ecosystem services and the in holistic view of the integrated nature of ecosystem services, is evidence that ecosystem services are becoming more mainstream in the thinking and action of policy-makers, research professionals and NGOs. The integration of ecosystem services into the many different sectors across science and policy may come with communication and terminology problems, which in turn could lead to problematic scale mismatches. Schroter et al. (2014) see ecosystem services as the process through which the different sectors can be brought together into collaborative work.

Those in policy remark that they regularly source information from published academic literature, but this data may not always be at the correct scale, or it may have biased findings, due to the limitations placed on researchers through funding and availability of data in the published literature.

Within ecosystem service research, it is often necessary to have scientists with highly specific knowledge, but they are not always accessible if an organisation looks only to in-house researchers. The evidence gathered to provide the data for a policy or practice decision can have huge implications on the decisions made using that evidence (Hein et al., 2006). The commissioner of the research can affect the scale of the project, potentially causing mismatches, depending on their own needs.

The findings suggest that collaboration with the policy sectors is vital in producing well rounded policy decisions which can be applied at the appropriate scales to the ecosystem services at which they are aimed. Those in policy were

involved in the greatest collaboration across sectors, and also with local people, which will help the making of well-rounded policy decisions. Practical involvement in a project will also help toward a feeling of ownership, which can make users feel more invested, thus helping the success of a project. There are many different processes involving stakeholders in projects, and what would be considered most effective will differ from project to project, though the majority start at least with a simple meeting and consultation. Collaboration between agencies can increase the size of a project, linking up many local agencies to create a larger scale landscape project through the facilitation of communication, negotiation, and feedback (Prager et al., 2012). This links back to the systematic review (2, 2.4.3) where many published articles are increasingly related to working at the 'large' or 'multi' scale. Working with ecosystem services will always involve people, which adds extra layers of complexity to research and decision making. People, often unpredictably, expand and contract both the spatial and temporal scales of a project (Koontz, 1999) through processes such as their willingness to travel, organisational structures, and expectations.

It was found in responses from all sectors that to some extent funding directly affects the scale of research. Scientists argued that it is the finance which affects how big a project can be, or how many replicates can be carried out. They appear to want to go as big as they can, which is reflected in Sutherland et al.'s (2013) comment "Bigger is usually better for sample size", and their restrictions nearly always come in the form of money, which is the main driver behind the scope of a research project with scientists asking, "how big you can make it from a price?" (s480).

The results identified that a bias may be present in science, which could occur through funding, as the needs of the funder are often required to be reflected in the research undertaken, which may mean that the focus is different to what would be most beneficial. The lack of funding for NGO's is forcing them to work together, which has the benefit of protecting and conserving more species, as the aims of many NGO's are species or habitat specific. Valuing ecosystem

services can help open up lines of communication between sectors. It can also help integrate ES into the decision-making process. Both policy-makers and NGOs discuss valuation as a tool for communication and integration.

There is much contention around the issue of ecosystem service valuation (Costanza et al., 1997; de Groot et al, 2002; Lienhoop et al. 2015; Gomez-Baggethun and Martin-Lopez 2014; Kumar et al., 2013), but if both the people making the policies and the people defending the environment think they are necessary, as was uncovered in the research, then it may well be the best way forward.

The research shows that clarifying scale terms at the outset of a project, and discussing the scale of the project with the stakeholders from the start, will ensure a smoother running project. A researcher may work on many different projects, for which the scale terms will take on different meanings, depending on the stakeholders, so defining them will ease the confusion.

As seen in the results, one of the most substantial influences on the scales of ecosystem service research, policy, and practice, is the people; the stakeholders, end users or constituents. Stakeholders are known for their influence on the scales of ecosystem service research and policy (Cavender-Bares et al., 2015). It is difficult to get people on board with a project which has no direct influence on their day to day life, though it is also not easy to bring people round to an idea which is going to change their local area, whether beneficial or not.

This level of engagement requires an understanding that many of the interviewees consider that the general public lacks, or which at least should be taught before progress can be made with a new project. For a project to be successful, it is vital to get the local people and stakeholders involved, but local people can often get in the way of a larger landscape scale project, by not accepting change in their area through having a classic ‘not in my backyard’ perspective. However, nimbyism can occur even when the people have a deep knowledge and understanding of the widespread benefits of ecosystem services. The public make regular ecological ‘trade offs’ (Cavender-Bares et al.,

2015) and can have a huge influence on the policy, practice and natural processes of ecosystem services. Working with stakeholders in all sectors, and the general public, has an influence on the scale of ecosystem service consideration in both policy and practice.

4.5 Scale issues and solutions

The most prevalent scale issue, across all sectors was data collection/use methods. For policy-makers this is an issue regarding the scale of the data they need to use, which if too fine cannot be used accurately for their purposes. This is interesting, as within the research it was found that those in scientific research feel that it is important to have data which is representative of local scales, so this is an issue which can be resolved in a way that could work well for both parties.

Another issue for those in policy is the lack of information on how to translate the science into policy, and the processes surrounding this. The natural processes themselves can lead to mismatches. It is hard to simultaneously manage for different ecosystem services in one landscape as it is not possible to include, in its totality, the full stock of ecosystem services present (Raudsepp-Hearn et al., 2010). Policy-makers only have a pre-defined area of influence so they are only able to make decisions within their boundaries.

There are some solutions to scale mismatches that are more realistic than others. The solution most discussed, and the most likely to occur, is that of building relationships between science and policy. This will ensure that decisions are made with both sectors in mind and that are practical and applicable. Attempting to build a standardized unified framework would be too contentious, as the input from too many different sectors, with different opinions, would be needed to develop it; whereas if those sectors just set out to work together collaboratively, on a case by case basis, then the results would be more advantageous.

4.6 Conclusions

The research shows that the extent to which people are working with ecosystem services is increasing, which reflects the increase in scientific and policy articles on this area which was found in the systematic review (2, 2.4.1). This increase in working with ecosystem services requires a wide evidence base for decision making. It was found that both policy and NGO sectors often gather their evidence 'in house' and this could be an area where scale mismatches may become prolific, as the evidence will either be gathered by, or research undertaken by, 'non-experts'. In providing evidence, scale needs to be seriously considered where findings are published, as there are factors identified by the respondents such as publishing bias and the notion that 'upscaling' research will increase the chances of publication. Where the research is undertaken 'in-house' this could lead to bias within the sector. The gathering of the evidence for policy decisions can lead to collaboration, when not undertaken 'in-house'. The respondents identified that collaboration could be with a range of parties, from local communities to professionals such as economists, and these wide collaborative efforts can lead to data and evidence being gathered from across different scales, and from people with different views and ideas. This idea of collaborative efforts being developed as a process through which to solve scale issues was referred to in the responses from all sectors, although there were times where collaboration was deemed a necessity. Working together, particularly for the NGO's, was necessary in order to gain funding and to use existing funding in the most cost-effective way. Funding is therefore drawing those groups together, whereas for research and policy it is affecting the extent and outcomes of research. The evidence suggests that whoever is funding the research, what their intentions are, how much finance they are providing, what return they might want to see on their investment, and when they want to see that return, all have an effect on both the spatial and temporal scale of a piece of research, or a policy decision.

Two of the most highly discussed scale issues were research/management/policy at different scales; and, the data collection/use methods. Both of these highlight the issues of retrospectively applying changes

to policy or planning where a policy is constantly evolving. There are difficulties in making changes, for example, buffer strips in agriculture, or meeting new and evolving CO_2 emissions targets. Scale mismatches are occurring due to ever changing scales of policy and planning decisions. By encouraging a closer relationship between science and policy, scale mismatch issues can be eased.

Climate change was found to be exacerbating all of the most difficult scale mismatch issues, whilst also forcing the sectors to resolve issues as and when they occur. Climate change is causing fast paced changes to the targets and goals for CO_2 reduction, renewable energy technologies, and agricultural practices, throughout all of which ecosystem services are vital. These fast-paced changes are causing reactive practices, but also forcing sectors to work together.

5 Synthesis of findings

The research project set out to discover whether, and to what extent, scale issues play a role in scale mismatches in ecosystem service research, planning and policy decisions. The following chapter sets out how this was undertaken and the findings of the research.

5.1 Overarching research aims and objectives

The aim of this research was to understand the extent, occurrence, and nature of problematic scale mismatches within ecosystem service planning, policy, and research in order to gauge and potentially alleviate their effects on the integration of ecosystem services into such policy, planning and research outcomes.

The objectives were to:

1. Assess the extent and circumstances in which scale mismatches occur
2. Determine the reasons behind those scale mismatches which are problematic
3. Interpret the causes of and current solutions for scale mismatch problems.
4. Identify practical solutions to reduce or resolve scale mismatch problems.

A combination of research methods from social science, ecology and medical research were employed to fully explore these aims and objectives.

5.2 Research Projects

5.2.1 Literature review

The initial review was undertaken in order to understand the full landscape of the literature in regards to ecosystem services and scale. It was established that ecosystem services are vital natural processes which make human life on earth possible. The literature review found that there are many different ways in which ecosystem services and scale interact, and where scale has a significant impact

on ecosystem services. The areas where the impact is most problematic is within the planning, policy and research sectors.

5.2.2 Systematic Literature review

After an initial literature review, a systematic review of ecosystem service scientific and policy literature gathered in-depth information on how, when, why, and where ecosystem service scales were being researched, and where mismatches occurred. In terms of the scales used within policy and research, the systematic review found that the usage of the terms ‘large-’ or ‘multi-’ scale were being used more frequently. Themes that repeatedly occurred with respect to reasons and solutions for scale mismatches were uncovered and can be found in Table 29.

Table 29 Reasons and solutions for scale mismatches uncovered in the systematic review

Reasons for mismatches	Solutions to mismatches
where action is taken/where results seen	a multi-scale approach
stakeholder knowledge	a standardized, unified framework
data collection/use methods	closer relationship between science and policy
research/management/policy different scales	

5.2.3 Survey

A survey of scientists, policy makers and members of the public, all of whom had experience of working with ecosystem services was undertaken. The survey questions uncovered the more complex details of ecosystem service scale mismatches, and the sources of these issues. Mismatches were revealed between the scale at which ecosystem service practitioners work, and the services with which they work. Carbon sequestration was found to be the most frequently considered ecosystem service, and the most important aspect of carbon sequestration was the slowing of global warming. Yet climate change is

a long-term issue, though most respondents identified as working at only the medium term. Although there are scale mismatches present, there is some optimism in noting that all sectors have the same focus on each of the individual ecosystem services. For pollination, the most important aspect is 'representative of a healthy ecosystem'; for carbon sequestration, it is 'slowing global warming', and for water infiltration it is 'flood prevention'. As all sectors are in complete agreement, enhanced communication and collaboration should be possible.

5.2.4 In-depth interviews

The survey was then followed by in-depth interviews with key figures in ecosystem service research, practice, and policy. The qualitative interviews allowed the participants' own perspectives and principles to become part of the research. It was found that scientists are generally only able to work on a project which is undertaken at a small, field scale. This is then being cascaded up to deal with the global issue of climate change, in order to gain that all important place in a high impact journal. Communication and collaboration links enable the flow of information through the different sectors involved in ES research and this flow of information is vital in enabling understanding at all levels. Introducing an intermediary may help to alleviate the issue of the disconnect between researchers and policy practitioners.

5.3 Synthesis

In order to synthesise and extract conclusions from this research, questions encompassing the aims and objectives were posed. These questions were then used to elaborate and discuss the findings on the research and the ways in which they meet the aim and objectives. The questions were:

- How do practitioners understand and utilise scale in ecosystem services?
- What are the difficulties surrounding communicating scale issues both within and between different practitioner sectors?
- Which processes are exacerbating scale mismatches?
- Which practical solutions can alleviate scale mismatches?

5.3.1 How do practitioners understand and utilise scale in ecosystem services?

There were many different interpretations uncovered in this research as to what are the ‘natural scales’ of ecosystem services. The initial literature review (1, 1.7) showed that the process by which the scale of an ecosystem service is measured, or how it is interpreted, can vary the ‘natural scale’ hugely, both spatially and temporally (Grafius et al., 2016). Within the systematic review there were no articles that put forward clear numbers or data of natural scales for ecosystem services, but rather they showed the different ways of measuring ecosystem services, and defined the extent of influence of management decisions (2, 2.4.2). It is not the natural scales that cause the mismatches; it is the processes by which they are interpreted and managed (2, 2.4.5).

Integrating the scales applied to natural ecosystem services into policy and practice comes from the research methods, and the tools used to measure them. The survey showed the respondents’ perceptions of 'natural' spatial scales of ecosystem services to be different from the spatial scales at which they perceived the policy decisions for those services is created at (3, 3.7.5).

The decision as to which of these tools to use, in order to undertake a study, or at which spatial and temporal extent research should be undertaken, is not led by the ‘natural’ scale of the service. Rather, it is led by the restrictions placed on the researcher (4, 4.3.3 restrictions). Funding restrictions can lead to the use of less detailed resolution data (4, 4.3.3); or the need to publish might lead someone to extrapolate results to reach a wider temporal scale (4, 4.3.5). Policy decisions are not led by natural scales, they are restricted to jurisdictions or led by global targets.

Ecosystem services are “the benefits provided by ecosystems that contribute to making *human* life both possible and worth living” (UKNEA, no date a). They don’t exist outside of the notion of ‘society’, as without humans they are just the processes of the natural world. It is only by their management, utilisation, and

the way in which humans harness them, that they become ecosystem services. This means that it is that people don't look to the 'natural' scales of the services when thinking of and discussing scale issues and problems, but rather to the management schemes, policy restrictions and research extent.

5.3.2 What are the difficulties surrounding communicating scale issues both within and between different practitioner sectors?

The terms used during scientific research and the creation of policy and practice are simultaneously both simple, due their regular use in discussions on a daily basis, and complex, due to the various potential meanings behind them. This was clearly demonstrated in this research project. The literature review found that there are many different ways to talk about scale, and many varied terms can be used (Cao and Lam, 1997; Cumming et al., 2006; Gibson et al., 2000)

In the systematic review, for example, it was found that local, regional or global scale were used frequently in articles without being defined. The planning and policy sectors use 'local' to describe county, community, village, state; with 'regional' to depict countries with close boundaries; and 'global' for the whole planet. Researchers' use of 'local and regional', however, referred to where an experiment, monitoring or assessment was taking place, or where the results of the experiment are experienced. Their use of 'global' is the same as in the policy and planning sectors. (2, 2.4.4).

In the survey, 'local' was described as city by those in policy; as county by those in research and land management; and by those in planning it was city, town and village (3, 3.7.3). Although the data suggests that they are working at the same scale (3, 3.7.2), it is clear that, when the meaning behind the term is investigated, this is not the case.

This was highlighted as an issue in the survey, though during the interviews it was considered something which can easily be resolved by predefining terms on a case by case basis (4, 4.3.6). Clarifying exactly what is meant by scale terms was important to policymakers, science researchers, and NGOs. One of

the most interesting aspects of the interviews regarding scale terminology was the number of respondents who highlighted that many scale terms had obvious meanings. This is where the problem stems, as they don't consider ambiguities in meaning, and thus don't feel the need to create or consult a glossary.

Terminology issues were highlighted across the entire research project. During further discussion in the interviews, it was clear that although it is an issue, it is something which could be overcome simply by predefining the terms at the beginning of the project (4, 4.3.6). There is a clear problem with the lack of consistency in the use of the different words involved with scale.

There can be issues of communication through formal journal articles, where research is adapted so that it has a better chance of being published. This research may well then be used to make planning and policy decisions and, as the data used has not been correctly communicated, it will not be accurately interpreted.

Some terms are used to explain issues and processes to different sectors in a way that will aid understanding. For example, 'natural capital' is a term and a process through which ecosystem services can be integrated into valuation and accounting methods (H.M.Government, 2011); and 'green infrastructure' is a process by which ecosystem services can be included in planning and management schemes, particularly in urban areas (4, 4.3.4.2).

There is a clear solution that has also been put forward by multiple parties, across all sectors: that of predefining the terms at the beginning of a project or report.

5.3.3 Which processes are exacerbating scale mismatches?

The systematic review found a strong theme of climate change was present in the articles (2, 2.4.1). This was also found in the survey, as carbon sequestration was the ecosystem service which is given the most consideration. The most important aspect of carbon sequestration was the need to slow global warming (3, 3.7.5). Within the interviews, climate change was the most talked

about environmental problem, without any prompting from the interviewer (4, 4.3.7).

This shows that this vast, long term, global scale issue is at the forefront of the thinking of scientists, planners and practitioners (UNEP 2011; Duraiappah et al., 2014). In the survey, the respondents, across all sectors, identified that they work at either a short or medium term temporally, and a local, national or regional scale spatially. There is a clear disconnect here, which will be having an influence on the goal of climate change mitigation.

However, although climate change is a huge issue which is leading to the destruction and loss of biodiversity and ecosystem services (Dearing, 2012; Maltby, 2013), it is also drawing the research and policy communities together. Scientists are undertaking research which is then being extrapolated to a global scale in order to relate to the "buzz" term of climate change, to gain both publication and funding. This can then be incorrectly interpreted by outside agencies. In order to avoid this, communication and collaboration are key to avoiding the onset of scale issues. One of the main issues highlighted in the interviews was the lack of a methodology to embed research into policy. By ensuring that there is an integrative role present, where the science-policy interface occurs, misinterpretation of the research goals would be avoided.

The systematic review found that there is an increase in the number of research projects using a larger, or multi-scale approach (2, 2.4.3). According to Sutherland et al (2013), the larger a project is, whether through collecting or using more data, the more robust it is, but also the more expensive it will be, which will consequently require a higher amount of funding. The survey shows that only three of the respondents think that funding is a scale term (3, 3.7.3). However, when the question was reversed in the interview, and the respondents were asked what affects the scale of their research the response was often money or funding (4, 4.3.3). Hence, the scale of research being undertaken is directly affected by the amount of money available, as are the number of replicates which can be carried out. Often scientists appear to want to scale up their research, and the restrictions are nearly always financial.

Raising of finance from external bodies can also create a bias in scientific research, as the needs of the funder may be reflected in the research, thus changing the focus of research away from what might be most beneficial. Finally, funders are often not the ones with the expertise necessary to define the appropriate scale for a research project.

Those with the money hold the power: the power to control the extent of a research project, or the extent of a management process. Funding will affect both the spatial and temporal scales, which can, and indeed are, causing scale mismatches.

5.3.4 Which practical solutions can alleviate scale mismatches?

There are many different ways in which 'people' who utilise ecosystem services have been described throughout the research project; constituents, the public, stakeholders. Each way of describing them corresponds to their different influences. 'Stakeholders' is used for those who have a direct influence or involvement in a project, such as a farmer or landowner. The survey showed that stakeholders are a 'scale term', such is their influence on scale, particularly for those who work in policy. 'The public' refers to those people who have no direct involvement in the project, other than being unidentified end-users. Public individuals often have strong opinions, although they are not always consulted. 'Constituents' are those between these two; those who may pay for a project indirectly through taxation, and therefore feel they have a right to a voice. Ecosystem services can initiate collaboration between scientists, professionals, decision-makers, and other stakeholders (Schroter et al., 2014).

Within both the systematic review and the interviews, stakeholders are identified both as a cause of scale issues, and also as a way of easing them. Within the systematic review, stakeholder involvement was seen as a key reason for scale mismatches to occur, but also key in the resolution of these issues (2, 2.4.5). It has been shown that where stakeholder engagement is carefully planned, the success of a project will improve, and policy and practice can be thoroughly established. As was shown in the interviews, without constituent and

stakeholder involvement, the success of a project cannot be guaranteed. However, constituents can often block large, landscape scale projects by refusing to accept changes in their area (4, 4.3.5). This can happen even when the constituents are knowledgeable about the widespread benefits of ecosystem services.

As in Martin-Lopez et al. (2009) it was found within this research that although they can often make a project more complicated, stakeholders have an important role in helping to inform and shape research and policy. Their local knowledge can ensure the success of a project (4, 4.3.6). The stakeholder's perspective is often different to the way in which a scientist or policy professional would approach an issue, but this doesn't mean that it is incorrect. Early and extensive collaboration with all stakeholders involved in ecosystem services, across all sectors, including the local communities, economists, planners and most importantly researchers and policy professionals, will lead to resolutions of scale mismatches.

In the initial literature review, the techniques used in ecosystem service valuation were highlighted as a potential factor in scale mismatches (1, 1.5). They presented as a potential mismatch due to their tendency to undervalue some services whilst overvaluing others (Hein et al., 2006). Within the systematic review, valuation techniques were put forward as a part of the standardized unified framework solution, whereby if the value of ecosystem services was measured in the same way, then it would clarify the integration of the values into planning and policy decisions (2, 2.4.5). The interviews showed that within a policy context, creating a financial valuation of ecosystem services helps to integrate the services into the decision making process (4, 4.3.6). This could be the valuation of benefits within an ecosystem service, but may also be the placing of a value on the impact of using such resources for financial gain. The total value of all of the services from a habitat need to be considered in order to create best value, and also to attract potential sponsors or investors.

NGOs consider that making a financial valuation can help communicate important messages. When trying to protect or conserve a habitat it is deemed

necessary to show financial costs and benefits for the project. Although there was some contention identified within the initial literature review, (Costanza et al., 1997; de Groot et al., 2002; Lienhoop et al., 2015; Gomez-Baggethun and Martin-Lopez 2014; Kumar et al., 2013),

Many articles showed that ecosystem services are better integrated into planning and policy decisions when they have been assigned economic values (4, 4.3.6). Throughout the research this issue came up regularly. The people making the policies, the scientists doing the research, and those defending the environment all thought that valuation was a necessary process to ease the integration of ecosystem services into planning, policy, decision making, and communication. Financial valuation was, therefore, seen as the best way forward.

5.3.5 Summary overview

Table 30 gives an overview of each of the questions and where the conclusions have been drawn from. The summary findings and implications highlight what is important and how this it is having an effect.

Table 30 Questions, findings and implications relating to the synthesis of the research

Question	Synthesis	Finding	Implications
How do practitioners understand and utilise scale in ecosystem services?	Literature review - Ecosystem services are vital natural processes which make human life on earth possible and they are increasingly being integrated into planning and policy decisions. Systematic review - Different methods of defining and investigating data give divergent results. Survey - Distinct 'natural' scales are identified by various practitioners. Interviews - Research will be done at a scale relevant to funding and influence.	That the 'natural' scales used to make planning and policy decisions are often determined by the way in which they are researched or analysed.	This is one of the more unresolvable issues in scale mismatches, as scale, a concept which has been shown to be difficult to define, is used inconsistently. So trying to define 'natural' scales is equally difficult, if not more so. There needs to be an understanding of the extent of 'natural' scales, how they are being defined in each individual case, and from where the data to define them came.
What are the difficulties surrounding communicating scale issues both within and	Literature review – There are communication and misunderstanding issues between science and policy.	The discussion around terminology is only really a problem when people assume they already understand the meaning of scale.	Terminology - there is much ambiguity, but it is imperative that people ask for clarification or read the glossary in order to completely understand a scale term,

Question	Synthesis	Finding	Implications
between different practitioner sectors?	Systematic review - There are many terms used by practitioners, both scale terms and technical terms. Climate change was referenced in a large number of articles, as it is currently a hot topic by which to frame discussions. Survey – There is disagreement around the different scale terms and technical term meanings. Interviews - Scale terminology can be clearly explained. The only issues occurred when the respondents 'knew' what the scale terms were, with no level of ambiguity. Research is more likely to get into a high impact journal if it is on a 'hot topic'.	The issue of researchers tailoring research to high impact journals can also create problems in communicating scale.	particularly in cases where they are informing policy, planning or further research decisions. Scientific literature can be misleading to those researching for policy or planning, if scientists are tailoring their research to fit a popular narrative.

Question	Synthesis	Finding	Implications
Which processes exacerbate scale mismatches?	Literature review - Scale itself as a concept has many different meanings and interpretations. Systematic review - Climate change is a driver behind many papers. Survey - Funding wasn't highlighted as being a scale term. Climate change was important across all sectors. Interviews - Funding was highlighted as a scale issue. Funding affects the extent of research. Climate change can lead to misleading data being used in planning and policy decisions.	Finance, and the amount of funding available, can have a serious impact on the scale of a project and its collaborators. Funding has become a scale term. Climate change was widely discussed within the research and this is exacerbating scale issues as decisions are being made reactively, and researchers want to deliver the buzz word "climate change".	Climate change is a growing issue within ecosystem services, so those scale issues which are associated with it will likely increase. The choice of resolution, or the extent of the field site determined most useful, can become irrelevant if funding isn't available to carry out the project at that scale.
Which practical solutions can alleviate scale mismatches?	Systematic review - Stakeholder engagement and collaboration between policy and science was found to be a method for mismatch alleviation.	Collaboration is key to highlighting scale issues. Collaboration must take place at the outset of a project. Stakeholders are key, both for their knowledge and their participation.	Ensuring that engagement and collaboration are employed can help smooth the process of integrating ecosystem services in policy and planning.

Question	Synthesis	Finding	Implications
	Survey – All sectors agree on the most important aspects of particular ecosystem services, which may ease collaborative efforts. Interviews - stakeholders need to be onside otherwise nimbyism can become part of the problem. Collaboration is important. Valuation is contentious, but is a language that can be spoken by all stakeholders.	The process of valuing ecosystem services has been found to be contentious. In the interviews, it was found that valuation can be a useful tool, as many aspects of ecosystem service management involve a financial aspect. Stakeholders can be both the root and solution of a scale mismatch.	Although valuation is contentious, money is a universal language which all sectors can understand and effectively communicate through.

5.4 Practical and informed strategies for the alleviation of scale mismatch effects on the integration of ecosystem services into policy, planning and research.

5.4.1 Collaboration

The survey highlighted that people working with ecosystem services are working at different spatial scales, and even where they do identify as working at the same scale, their definitions differ.

Working at different scales isn't necessarily going to cause scale issues, however. Often the issues are simply created by the lack of communication between the sectors. Rather than merely reading and interpreting policy documents or research papers, increased communication and collaboration between sectors can ease scale issues, especially where no definition of terms is supplied.

There is a disconnect when scientists feel that they have to tailor their research to a larger scale for it to be accepted for publication in a high impact journal. This can lead to that information being considered unsuitable to a more regional scale based policy decision. Those in policy also identify that the intricate level of detail in research can also be unsuitable for regional policy decisions. Collaboration at the outset of a project could alleviate this issue.

Stakeholder collaboration is also identified as being vital for a successful research project or policy process within ecosystem services, as it is the stakeholders' investment which can both introduce local knowledge, and lead to acceptance of the project. Any increased well-being is also beneficial for policy-making. Funding has been identified as being a major issue in the matter of scale issues, and collaboration both within and between different sectors could mitigate this by pooling resources and expertise.

5.4.2 Clarity

An interesting factor to come out of the research is the effect which funding has on the scale of a project. Funding can influence the extent of a project at both temporal and spatial scales. Funding timelines lead into the temporal scale of a project, as goals and targets need to be met in order to secure funding for the next round, meaning that the temporal scale of results is on the funder's schedule, not necessarily the schedule which would be most advantageous for the process. Spatially, funding can impact the size of a study site, the number of stakeholders involved, and the number of repetitions that can be performed. Funding can also affect the quality of the data used, as fine resolution, more detailed, data is more expensive. Thus if lower resolution data is used, intricate but high impact details may be missed. Understanding and making clear the aims and objectives of both the funder and the research which is to be undertaken given the limitations of funding, can ease mismatches in expectations and thus lead to a reduction in scale mismatches.

Table 31 highlights the suggested scale terms which it is necessary to define at the outset of any ecosystem service project. This list of terms, which should always be referred to in order to avoid scale mismatches, has been gathered from throughout this research project and should be used as a guide when dealing with any stakeholders; or when interpreting any research; and during interdisciplinary meetings.

Table 31 Scale terms definitions list

Terms necessary to define
Local
Regional
Large Scale
Medium Scale
Small Scale
Natural Scale

5.5 Conclusion

Ecosystem services are so complex that those who work with them are very likely to be working at different scales, both temporally and spatially. It is important to recognise where the mismatches can occur, and to mitigate for them. Scale mismatches occur within and between all sectors working with ecosystem services, and are due to misinterpreting either data or terms.

Climate change research is increasing, and the threat to ecosystem services of climate change is growing, so the ecosystem service community are at a pivotal point where problematic scale mismatches can, and will, have tremendous impact, especially where planning and policy decisions need to be made rapidly.

Many solutions were identified within the research, but they were deemed impractical due to time and development constraints. The practical and easily applicable solutions identified of pre-defining terms, and collaborating, will enable the alleviation of scale mismatch issues.

Appendix A **Data extraction table for the systematic review**

Journal or source title	
Article title	
Author(s)	
Date, country,	
Context	
Objectives	
Method	
Result	
General notes	
Conclusion	
Scale relevance	
Scale Mismatch/ Solution Identified	

Appendix B **Survey Questions - Qualtrics hosted survey**

Investigating scale in the ecosystem services planning and policy environment

1 Welcome! The purpose of the questionnaire is to understand what the term “scale” means to those who work in the area of ecosystem services, biodiversity, conservation, sustainable development and planning. Data from this questionnaire will be used in my PhD. My PhD has two main objectives, the first is to develop understanding of the "scale" at which biodiversity supported ecosystem services functions. The second is to develop understanding of the scale at which planning and policy decisions are made, and what the implications of this are for biodiversity supported ecosystem services. Thank you for taking the time to fill in this questionnaire. If you know of anyone who may also have valuable insight into this topic, please forward it on to them. If you have any additional comments you would like to make, these would be greatly appreciated. Please send them to me either by return email, or in the final box of this questionnaire. Thank You Zoe Holden

2 Predefined Terms for this questionnaire. Ecosystem - A combination of living organisms and their environment Ecosystem services - the benefits provided by ecosystems that contribute to making human life possible and pleasurable Regional scale - See map below National scale - England/Scotland/Wales European scale - Europe-wide Global scale- The whole world Pollination - the transport and transfer of pollen to enable fertilization and reproduction of plants Carbon Sequestration - The natural extraction and storage of carbon dioxide from the atmosphere Water Infiltration - The process by which water enters the soil

3

4 About you The data you give in this questionnaire is anonymous. However, in order for the data analysis to be more useful to us, could you please identify a few basic facts about yourself.

5 Which sector do you currently work in?

- ❑ Planning (1)
- ❑ Policy (2)
- ❑ Research (3)
- ❑ Teaching (4)
- ❑ Land Management (5)
- ❑ Student (6)
- ❑ Other (7) _____

6 Do you work in the Public or Private Sector? Skip this question if you are still studying, unless you are currently doing a PhD. If you are doing a PhD, then please relate this question to your funding organisation.

- ❍ Public (1)
- ❍ Private (2)

7 How long have you been working in your current sector? You can include various job roles, so long as they have been within the same sector

- ❍ 0-2 years (1)
- ❍ 3-10 years (2)
- ❍ 11-20 years (3)
- ❍ 20+ years (4)

8 The terms relating to Ecosystem Services scale

9 Scale – With reference to your current sector, what does the word "scale" mean to you? Please pick 3-5 of the terms below which relate to your idea of scale. Add "others" if there are any not listed that better fit your idea.

- ❑ Area (1)
- ❑ Money (2)
- ❑ Time (3)
- ❑ Targets (4)
- ❑ Space (5)
- ❑ Barriers (6)
- ❑ Communication (7)
- ❑ Stakeholders (8)
- ❑ Funding (9)
- ❑ Seasons (10)
- ❑ Measures (11)
- ❑ Other (12) _____
- ❑ Other (13) _____
- ❑ Other (14) _____

10 When discussing temporal scale, phrases such as 'short term, medium term and long term' are often used. From the perspective of your current job please select a word or words from the rows which most reflect your idea of the phrases in time-spans in column 1.

	Short Term (1)	Medium Term (2)	Long Term (3)
Hourly (1)	❑	❑	❑
Daily (2)	❑	❑	❑
Weekly (3)	❑	❑	❑
Monthly (4)	❑	❑	❑
Yearly (5)	❑	❑	❑
Decade (6)	❑	❑	❑
Half Century (7)	❑	❑	❑
Century (8)	❑	❑	❑
Half Millennium (9)	❑	❑	❑
Millennium (10)	❑	❑	❑
Infinite Time (11)	❑	❑	❑

Q39 What temporal scale do you think most typifies the activities of the sector you currently work in?

❑ Short term (1)
❑ Medium term (2)
❑ Long term (3)

11 Local - With reference to the perspective of your current sector, what is local? Please select the pictures by clicking on it below to show which one best shows your idea of 'local'.

	Off (1)	On (2)
County (7) City (8) Street (9) Village (10) Town (11) House (12)		

Q38 What spatial scale do you think most typifies the activities of the sector you currently work in?

- ❑ Local (1)
- ❑ Regional (2)
- ❑ National (3)
- ❑ European (4)
- ❑ Global (5)

12 NATURAL SCALES

13 What spatial and temporal scales do you think are most important for effective provision of POLLINATION services? Choose one response for spatial scale and one response for temporal scale.

- ❑ Local (1)
- ❑ Regional (2)
- ❑ National (3)
- ❑ European (4)
- ❑ Global (5)
- ❑ Other (10) _____
- ❑ Short Term (6)
- ❑ Medium Term (7)
- ❑ Long Term (8)
- ❑ Other (9) _____

14 What spatial and temporal scales do you think are most important for effective provision of WATER INFILTRATION services? Choose one response for spatial scale and one response for temporal scale.

- ❑ Local (1)
- ❑ Regional (2)
- ❑ National (3)
- ❑ European (4)
- ❑ Global (5)
- ❑ Other (10) _____
- ❑ Short Term (6)
- ❑ Medium Term (7)
- ❑ Long Term (8)
- ❑ Other (9) _____

15 What spatial and temporal scales do you think are most important for effective provision of CARBON SEQUESTRATION services? Choose one response for spatial scale and one response for temporal scale.

- ❑ Local (1)
- ❑ Regional (2)
- ❑ National (3)
- ❑ European (4)
- ❑ Global (5)
- ❑ Other (10) _____
- ❑ Short Term (6)
- ❑ Medium Term (7)
- ❑ Long Term (8)
- ❑ Other (9) _____

16 Do you use any specific computer software or “tools of the trade” to conduct your work on ecosystem services?

17 POLICY

18 From your own experience, at what spatial and temporal scale do you think that policy relating to POLLINATION services is created Choose one response for spatial scale and one response for temporal scale.

- ❑ Local (1)
- ❑ Regional (2)
- ❑ National (3)
- ❑ European (4)
- ❑ Global (5)
- ❑ Other (10) _____
- ❑ Short Term (6)
- ❑ Medium Term (7)
- ❑ Long Term (8)
- ❑ Other (9) _____

19 From your own experience, at what spatial and temporal scale do you think that policy relating to WATER INFILTRATION services is created Choose one response for spatial scale and one response for temporal scale.

- ❑ Local (1)
- ❑ Regional (2)
- ❑ National (3)
- ❑ European (4)
- ❑ Global (5)
- ❑ Other (10) _____
- ❑ Short Term (6)
- ❑ Medium Term (7)
- ❑ Long Term (8)
- ❑ Other (9) _____

20 From your own experience, at what spatial and temporal scale do you think that policy relating to CARBON SEQUESTRATION services is created Choose one response for spatial scale and one response for temporal scale.

- ❑ Local (1)
- ❑ Regional (2)
- ❑ National (3)
- ❑ European (4)
- ❑ Global (5)
- ❑ Other (10) _____
- ❑ Short Term (6)
- ❑ Medium Term (7)
- ❑ Long Term (8)
- ❑ Other (9) _____

21 WITHIN YOUR INSTITUTION

22 Within your institution, how often do you consider the following Ecosystem Services in your day to day work.

	Pollination (1)	Water Infiltration (2)	Carbon Sequestration (3)
Every day (1)	❍	❍	❍
Once or twice a week (2)	❍	❍	❍
Once or twice a month (3)	❍	❍	❍
Once or twice a year (5)	❍	❍	❍
Never (4)	❍	❍	❍

24 Pollination is defined as - Transport of pollen to allow fertilization by any natural pollinatorWhat benefit does pollination provide in your sector?

- ❑ More flowers (1)
- ❑ Food production (2)
- ❑ Increase in insects (3)
- ❑ A representative of healthy ecosystems (4)
- ❑ Other - please specify (5) _____

23 Carbon sequestration is defined as - The storage of carbon dioxide from the atmosphere in the landscape What benefit does carbon sequestration provide in your sector?

- ❑ Carbon Off-setting (1)
- ❑ Increasing trees (2)
- ❑ Peat Restoration (3)
- ❑ Slowing Global Warming (4)
- ❑ Other, please specify (5) _____

25 Water Infiltration is defined as - The process with which the landscape absorbs water What benefit does water infiltration provide in your sector?

- ❑ Flood prevention (1)
- ❑ Drinking water provision (2)
- ❑ Plant growth (4)
- ❑ Erosion avoidance (5)
- ❑ Other - please specify (6) _____

26 Hectare for hectare which ecosystem services holds most value in your line of work? Please drag and drop to rank the three listed below with the most important at the top, and the least at the bottom.

_____ Pollination (1)

_____ Carbon Sequestration (2)

_____ Water Infiltration (3)

27 COMMUNICATION The level of communication between those working in planning, policy, research and land management may affect the scale of the decisions made. Please answer these questions according to the sector you work in and identified in the “About You” section of this questionnaire.

28 PLANNING: How often do you discuss any issues relating to ecosystem services with those that work in policy, research or land management?

- ❍ Constant discussion and communication (1)
- ❍ Discuss all issues as and when they arise (2)
- ❍ Only discuss pressing issues (3)
- ❍ Never (4)

29 POLICY: How often do you discuss any issues relating to ecosystem services with those that work in planning, research or land management?

- ❍ Constant discussion and communication (1)
- ❍ Discuss all issues as and when they arise (2)
- ❍ Only discuss pressing issues (3)
- ❍ Never (4)

30 RESEARCH: How often do you discuss any issues relating to ecosystem services with those that work in planning, policy or land management?

- ❍ Constant discussion and communication (1)
- ❍ Discuss all issues as and when they arise (2)
- ❍ Only discuss pressing issues (3)
- ❍ Never (4)

31 LAND MANAGEMENT: How often do you discuss any issues relating to ecosystem services with those that work in planning, policy or research?

- ❍ Constant discussion and communication (1)
- ❍ Less than Once a Month (2)
- ❍ Once a Month (3)
- ❍ Never (4)

32 Further Comments

33 If you have anything to add, or any ideas that you feel relevant please include them here

Q37 Thank You for taking the time to complete this questionnaire. Please click through to submit.

Appendix C **Policy and Management in-depth interview questions**

Questions – Policy and Management

1. To what extent do you feel you work with ecosystem services?
2. Within your work, when working with ecosystem services have you ever come across an issue that you can equate to being caused by scale mismatches?
    a. Examples?
3. Have you previously tried to resolve policy/management and environmental scale mismatches via any of these processes?
    a. Increasing communication with stakeholders?
    b. Using a multi-scale approach?
    c. Increasing the scientific data used to aide in the policy decision process?
4. At what scale do you think your decisions have an impact?
5. When discussing scale, do you find that any of the following words can have different meanings?
    a. Local
    b. Long term
    c. Short term

6. Within your role what are the most important aspects of the following ecosystem services?
    a. Carbon Sequestration
    b. Pollination
    c. Water infiltration
7. Where do you get the research that you base your advice/decisions on?
8. My research has shown that there is a contrast between the scale that policy/management workers believe they work at, and the scale that most published policy on scale matters is performed at
    a. Expand?

Appendix D **Science and Research in-depth interview questions**

1. To what extent do you feel you work with ecosystem services?
2. Within your work, when working with ecosystem services have you ever come across an issue that you can equate to being caused by scale mismatches?
    b. Examples?
3. Have you previously tried to resolve environmental scale mismatches via any of these processes?
    a. Increasing communication with stakeholders?
    b. Using a multi-scale approach?
    c. Increasing the scientific data used to aide in the policy decision process?
4. At what scale do you think your research is performed at?
5. When discussing scale, do you find that any of the following words can have different meanings?
        a. Local
        b. Long term
        c. Short term
6. Within your role what are the most important aspects of the following ecosystem services?
    a. Carbon Sequestration
    b. Pollination
    c. Water infiltration
7. How do you decide at which scale you are going to carry out research?
8. My research has shown that there is a juxtaposition between the scale that researcher believe they work at, and the scale that most published science on scale matters is performed at
    a. Expand?

Appendix E **Quotes from interview transcripts organised by theme**

1. Restrictions

Money	"putting monetary values on ecosystem services." (p61)
	"There is a challenge there in applying values which are based upon spatially specific or local studies and then applying them more widely at a national scale for example" (p78)
	"incentivise sponsors to invest – what's the benefit to them" (p96)
	"Possibility that local business might want some kind of affiliation with a local environment or where their staff and customers might be, branding of particular products" (p101)
	"although our client may not have the resources to affect changes outside of the site we are working" (p412)
	"we are able to articulate what scientific data is needed but we are not always able to again because our funding and time to actually collect that data" (p418)
	"who are the beneficiaries? what are the market mechanisms within that that is actually generating revenue? who is paying for that? who is receiving that revenue?" (p735)
	"getting as big as we can afford and as many replicas we can afford but that's how ecological the design works so you just do as much as you can" (s354)
	"who's funding it and what they want from the project." (s393)
	"i work out what i can get money for...and i do that" (s399)
	"I guess a lot of it is funding and how big can you make it from a price really." (s478)
	"money is important in the sciences as well, the grant proposals and making sure you have funding." (s455)

	"publication does tie in with that pretty heavily, but yeah, when i used the term 'currency' i didn't specifically mean money by it. you don't publish, you don't get a job, basically" (s456)
	“funding is always a challenge because there’s, very rarely is there sufficient funding to do the sort of work you need to do” (n55)
	“it's difficult to continuously communicate that there's environmental issues and concerns without being able to put a kind of figure to it really” (n165)
	"We work together on funding bids to get more resource to do what we need to do." (n333)
	"valued the benefits or the carbon sequestration benefit of the woodland in Surrey in the region of 60 million annually, so there is a huge financial benefit for the carbon sequestration" (n487)
	"And if that matches the policy great, but if doesn’t then we won’t put it into that scheme. So if the policy is land management scheme...this chunk of money, is going to go and fund that particular scheme" (n690)
Collaboration	“So that means working with other government departments “ (p67)
	"to get a business sponsor or investor into peatlands restoration, what are the benefits of peatlands restoration, well in terms of carbon savings they are kind of global but if you are going to incentivise people, incentivise sponsors to invest – what’s the benefit to them" (p96)
	“we hold workshops with the stakeholders from the various agencies, so that's the Statutory Nature Conservation bodies, the Environment Agencies, Scottish Environmental Protection Agency” (p289)
	"[stakeholder] interaction they get all the land owners to sit round posting notes on bits of the land" (p367)
	"how are we taking an inter-disciplinary approach? how are we bringing not just the kind of carbon scientists and the foresters, how are we bringing the pollinator scientists, you know, and the botanists and the pedologists and you know, the people that understand soils and soil

structure,... they shouldn't be considered in isolation" (p786)

"James Hutton Institute, SRUC, they are commissioned by the Scottish government to do research in this area" (p851)

"we work in partnership with other research organisations, so that could be anything from academia through to private consultancies, to say industry bodies" (p861)

"relationships from different academics and institutions" (p877)

"We undertake research using the specialist's organisations" (p881)

"talk to the partners that we work with and certainly the university sector and also agencies" (p884)

"work with academics" (p889)

"they'll be collaborative, things like Biodepth and Ecofinders where you have these consortia across Europe or the UK" (s413)

"the whole links between natural capital and ecosystem services is incredibly complex because it involves people as well as ecology" (s423)

"working closely with local authorities" (s10)

"stakeholder engagement project which is trying to bring together the main sectors across the Celtic seas to look at policy implementation and looking at sort of sustainable solutions to their activities" (n11)

"key relationships that we have here in surrey is the surrey university, we are constantly working with them trying to underpin what we are doing with the good robust evidence" (n158)

"often the university is less focused on the smaller scale stuff so again we might use them for bigger scale pieces of work" (n574)

"We have a Heathland Forum where the people who are managing the sites on a day to day basis, meet up once a year" (n590)

"So my ecologists work closely with the Natural England Officer responsible on a site basis, responsible for, sites of special scientific interest. And there's osmosis, a flow of information between them"

	(n603)
	"subscribe to a lot of networks" (n622)
Evidence	"we had evidence folks within the Environment Agency" (p837)
	"published literature" (p850)
	"light reviews which we conduct in-house" (p864)
	“conferences and workshops” (p878)
	"look through the academic literature" (p883)
	"do systematic views" (n887)
	“we will use our own commissioned research and also commissioned research that other agencies use as well” (p890)
	"depends on what the project is whose funding it and what they want from the project" (s393)
	“so i guess sometimes data can limit what your initial plan was” (s396)
	“we will also commission our consultants to do one off pieces of work” (n568)
	“We tend to commission quite a lot of research, so we'll use various experts.” (n581)
	"we are sort of a global organisation so we'll draw on people across the world really" (n584)
Extent	“a lot” (p11, p13)
	“daily basis” (p16)
	“Increasing” (p22, p25)
	"pretty much completely" (s3)
	"a lot" (s6)
	“more or less entirely really” (s8)
	“Indirectly I work with ecosystem services” (n27)

	“large extent” (n3)

2. Terminology

Scale Terms	"local is a word that government departments like to use because it sounds nice but actually i’m not sure how helpful it is once you get further down" (p574)
	“local certainly has different meanings because to some people it just means in the immediate surroundings of where they live, whereas to others a local authority” (p583)
	"people have a general idea of what we mean by longer-term. so most people would be thinking about sort of 25-50 years" (p591)
	"most people have an idea of what short-term means really. in the next three years or something" (p597)
	"it depends in which context you're looking" (p601)
	"other people may say that, you know, local refers to the decision making process, so i suppose yeah, you have to contextualise these things" (p606)
	"local can be very, very fine scale but it can also go up to i would say what is actually quite a high level grain in terms of, say, catchment area" (p611)
	“short-term planning is a lot more focussed, and there is a lot more kind of, i think, monitoring and assessment related to short-term, short-term goals because they're much more quantifiable” (p617)
	"you need to have clear objectives or clear kind of statements of intent which are attached to those different terminologies to ensure that you don't have that ambiguity of meanings between the different audiences or stakeholders" (p624)
	"local is definitely going to have different meanings for different people, local to some people will mean their immediate community to others it will be say their area of a local authority so there’s quite a lot of give and take in there" (p630)

"short term that's probably the least likely for people to misunderstand" (p635)

"local impacts or about local restoration its typically thought of at the community scale however you define community whether it's a small town or a neighbourhood so i think that term it sometimes has different meanings but i would say more or less people grasp that sort of meaning for local" (p641)

"i think long term and short term certainly in some ways it's a generation thing, i think younger generations may have a different meaning for long term then older generations" (p644)

"i find that restoration you have to think on long term and i mean generations and generations and so sometimes i think that's misconstrued that long term might be more than 3 years to 10 years when really in restoration were talking more about 25 – 50 years" (p646)

"[scale terms] all have different meanings depending on the person you are talking to. and the context within the conversation you are having" (p655)

"short term and long term are really interesting as again on the perspective whether you are coming from the human perspective of if you are thinking about the trends you might see natural variability or the environment which have been operating for decades if not for 100s of years" (p658)

"so we were talking about getting an oil or gas installation of renewable energy development they are referred to as temporary say maybe 20 years and then they are removed from the environment so they consider to have a short term but temporary affect" (p662)

"long term, you're talking about something climate, climate changing, technical term, like you know i thinking in my head probably at least 50 years, if i'm talking long term in terms of countryside produce in environment i'm thinking 5-10 years, so it depends on the context on the things yours discussing" (p675)

"we have national and local, local could mean our area team which is

the region i sit in i'm basically York office you know it's basically the whole of Yorkshire which is massive isn't it, and then staff within in that would then talk about locally and that might mean you know a national park or a parish" (p680)

"i think to a farmer local to a farmer means farm scale or maybe a cluster of farms in a community where as i'm talking about a plot" (s211)

"really important to define what you mean in all cases" (s217)

"long term wasn't used we didn't get hung up with specifics there" (s225)

"i think any of them can be pretty context-dependent" (s230)

"a city planner, or works for a city council, they're mostly going to be concerned with the scope of that single city both spatially and across time" (s231)

"long-term is a similar thing as sometimes 3 years is quite a long time but if you are looking at long term data that is normally over 10 years so again it definitely needs clarifying" (s237)

"if you are looking generally it can kind of cause problems, so i guess it takes more time to work out when there is no clear definition or people haven't specifically said what the time scale is" (s241)

"that human experiential scale because i was working with landscape architect and there was a lack of evidence at that scale" (s365)

"use long term, as in very long term so we would be talking about 20, 30, 40 years which is quite short term for that environment but we would certainly be talking about that sort of time scale if we are talking long term" (n382)

"Short term we'd be probably talking within about three years, and then would often use medium terms to describe the period in-between" (n385)

"make it clear that the stake holders that you're working with understand what you mean when you use certain phrases and terms because it's very often it's a case that you assume they understand and

	actually there understanding is different to yours" (n387)
	"You can have a region that's the size of, kind of, a county, or you can have a whole sort of regional sea which is a whole sea basin" (n395)
	"Most people understand that short term is the next three years, generally, medium term is beyond that and long term is way beyond that" (n406)
	"local, and because we operate in the city scale that's what I mean in terms of the Parks Trust. But if you go and talk to a Parish Council in one of the areas of Milton Keynes, local to them is just their patch" (n411)
	"local is a fairly well understood context" (n379)
Science	"modelling" (s22)
	"eco-toxicology" (s32)
People	"Considering the will of the elctorate" (p7)
	"Natural capital has a very strong focus on social wellbeing" (p144)
	"But then really understanding what it is that stakeholders want in terms of those kind of more nuanced benefits, those health and social benefits, requires a very different approach" (p157)
	"Well, people started off being worried about air, but then the way you cleared up the air was to trap the pollution and discharge it into water. Then people were worried about water" (p216)
	"I think that just asking people the questions 'well who benefits?' helps people to think about the benefits that extend beyond their immediate surroundings" (p277)
	"going to users, asking how they are using existing data and then ensuring how we take that information" (p339)
	"i think people do think about a very local expression of environment" (p529)
	"I could get the local Oakley environment group to do something about

the river flowing through the village, [but] Bedford, [which] is most probably three miles / four miles away, could I get those village people to engage with the river flowing through Bedford? A few, but mostly not and, so I think people do think about a very local expression of environment"" (p529)

"you might be…an ornithologist. and then you'll think about birds and you would go anywhere to see bird but then you might trample on plants" (p535)

"people relate to different expressions of the environment and then will have a different view on what local is" (p537)

"work in terms of stakeholder engagement, so you have to do something a lot more local...to allow people to relate and engage and approve it" (p588)

"the general public have developed over the last 4 years an increasing awareness regarding the value of pollination" (s282)

"terms of the happiness of urban residents" (s312)

"how happy your residents are likely to be" (s321)

"it's quite difficult to make people feel that they have a sense of belonging to that kind of large, Celtic seas scale" (n75)

"Sometimes it's down to, you know, how livestock interacts with people" (n88)

"what they feel their local environment is and not wanting it to change too much" (n95)

"Because a lot of the general public, generally don't' understand that it can be a positive transformation" (n197)

"But actually, they may not understand initially but a proportion can be brought on the journey" (n217)

"They know they like it but they don't know why" (n224)

"It's clearly important to have that discussion, let's bring the stakeholders in" (n234)

	"If you try and tell people to stop playing football, because it's a nice bit of grass and we want to leave it long. Locally they can't see that but it makes perfect sense at the level we are looking at" (n418)
ES Terms	"Natural Capital" (p16) "green infrastructure" (p148) "green infrastructure" (n21) "biodiversity of habitats" (n21)

3. Scale Issues

	"the local Council, doesn't equate to an environmental catchment. So therefore the Council is able to decide something within the boundaries of its influence" (p46) "projects which address or try to develop schemes for funding for protection of ecosystems are not necessarily transferable" (p97) "we can show that our mapping and assessing of the assets themselves is very, very accurate, but there seems to be a disconnect in terms of 'what does this mean?', in terms of 'how I decide to manage that individual parcel of land'so i.e. for grazing, or 'where is it, are we going to want to put riparian buffer strips?', so on and so forth, so we've had issues with scalability there" (p129) "how you do anything at the international scale because it's really really hard, the institutions just don't exist and you look how the struggles have gone on over stable development and climate change and you see it will have its work cut out for it" (p174) "scale aspects are the bit we struggle with in the marine environment in the ecosystem services across these huge geographic scales so when you get managers at one end talking about management and how that impacts it can make it very difficult to try and quantify what the impact is" (p193) "we work with multiple eco systems all the time, so the work we do for

them is often looking at places or designated sites, different scales for different services are really apparent" (p200)

"i don’t think that there is nearly enough work done on how you take research outputs and translate them into public policy" (p912)

"think maybe the challenge for peatlands will be in scale, whereas trees grow everywhere, peat is only in certain places. sometimes very isolated places and therefore there is a regional challenge there. for people in certain parts of the country it’s very important and for others really on their radar" (p989)

“i almost find that the research that we read it’s such a local and fine scale that we have difficulty extracting how that would impact the work we do” (p1075)

"the larger the scale you are at the more you are to get published" (p1060)

"in england we have a very specific problem in that we do not have a land use planning system any more we had the regional spatial strategies which would have been where people could have worked at a regional level but that got swept away" (p1065)

"the turn over time of bacterial community could be in the order of minutes to seconds really, whereas plants you’re looking at a season, so it’s quite hard to know how to characterise the two at the same time in an effective way" (s43)

"there can be mis-matches in terms of - especially the scale at which an - a given ecosystem service might operate and the scale of what data we have available to try and model or conceptualise how that ecosystem service might work, or how various factors affect it" (s92)

"gis data into lots of spatial variables and things, so i guess maybe one of the problems is that a lot of that data is kind of for the uk so i guess it is kind of a coarser scale" (s101)

"you may be talking to someone who's a city planner, or works for a city council, they're mostly going to be concerned with the scope of that single city both spatially and across time, what long-term means is going to be pretty dependent on what sort of scope everyone's dealing

with" (s231)

"we think it is very important to have data that is representative to local scales and we actually work at a one kilometre scale but the one kilometre scale is a sample of the national scale that is relevant to statistics so we actually think this really localises data and gives a good understanding of what's fundamental for them being able to extract to the national level to make predictions or make judgements about eco systems services or the national capital to analyse" (s358)

"the classic example is climate change which is a global problem but actually studies … are looking [at] national and maybe across Europe and things but I imagine there is probably not a lot of stuff that addresses kind of global stuff and its more individual pockets to feed a global" (s472)

"so individuals stakeholders like farmers have a very specific agenda and it's very difficult to although they sort of already understand ecosystem services in a completely different sense to which scientists does it's probably hard for them to have to think about taking into account ecosystem services delivery in their management and also their income is outside of a localised cycle so i could look at ecosystems services but ultimately the main services of production for the farmers in the catchment was completely divorced from local levels as it depends who's buying their meat, and that could be China" (s438)

"there's often a lack of data particularly at the more local level but even the sort of county level there is often a lack of the type of data you need in order to make informed decisions" (n53)

"I think there is not always enough data available on, wider information, when developments are done and clearly there are requirements to assess the impact on developments and wildlife and there are records held, generally held at a county level" (n117)

"In the planning process in the way I perceive it a development application comes in and Natural England, which are a national agency, they tend to work in regional offices, but those regions are very large. They are consulted but they don't have the information. The level they are operating at, at such a broad scale they haven't got the time or resources to really get done to the detail" (n133)

"whenever I talk to academics and probably its reciprocated, we talk different languages, and the way we talk is really quite different, I think there is quite a mismatch" (n675)

“If you try and tell people to stop playing football, because it’s a nice bit of grass and we want to leave it long, locally they can’t see that, but it makes perfect sense at the level we are looking at. That is where you get those mismatches potentially coming in, that is where tensions occur” (n418)

"I do feel that people who make policy and people who get pulled into national policy decisions. Whether they are academics who are pulled into advice politicians or whether they are civil servants working inside the body. They tend to be people who specialise in doing that sort of thing. Now personally I go to CPD events, and people who do work and look at case studies and do research, and they fly all over the world doing it and its really interesting. And they’ve met this politician and that politician and the Secretary of State and had this discussion with him or her and so forth and is really a completely different world. And I can’t really see how that connects down" (n665)

4. Scale Solutions

“we are constantly going up to what we call a 40,000 level and looking at that site and content and the region and how it relates its relationship to the region geographically” (p179)

"the RSPB’s energy for nature project, where they on their wetlands reserves they create a lot of biomass waste which they are now looking to turn into marketable bio products – a circular economy thing there. That has been piloted at a local level, but if you can get the framework right and the scheme right it could potentially be scaled up elsewhere" (p239)

"It becomes difficult to standardise these things. But if you can prove the concept, I guess, then the level of scale" (p248)

"to integrate Earth observation data with existing data to kind of improve decision making" (p329)

"actually going to users, asking how they are using existing data and then ensuring how we take that information. So what are the user requirements are, and then ingrate that into national data-sets moving forward, but also how we can then take that to make sure that the existing data is either more user-friendly, but more importantly more discoverable to these users" (p339)

"eco system services are to many stake holders and at the moment the term means different things to a lot of different people and particularly on the marine side the definition we have been working with have come again with requirements and it can become very difficult to transfer them across in something that's meaningful on the marine side so they are looking to develop those definitions to make them something that makes sense" (p431)

"specific about what time horizon we're talking about does help, so that we're all kind of on the same page" (p598)

"the regional area boundaries of Environment Agency and natural England are going to be harmonised where we are working, and the area team have the same boundaries, announced by the state, and you know the issue of not so much temporarily but the issue of geography is listed because you know the Environment Agency rightly because of their role looks at catchment and water sheds natural England are also very much interested in landscapes and we've got a system of looking at the country to 159 different national character areas based on the geology and landscape, so the new boundaries are sort of trying to take account of the catchments and also take account of the natural England or us doing our geography, so the issue of conflicting spatial scales is an ongoing one" (p1122)

"national policy, its passed onto other organisations and there may not be any clear guidance or clear view exactly of how that policy translates into delivery, and so i think you get inevitable discrepancies there between issues of scale both temporarily and spatially and you know the policy effects in the first place, and i just think that's the way that these things work" (p1113)

"but we think it is very important to have data that is representative to local scales" (s358)

“Trying to find additional or higher-resolution data to resolve an issue” (s137)

"it’s really important to define what you mean in all cases because otherwise it does generate misunderstanding" (s217)

"the more we understand the optimum way to design areas of green structure, to deliver eco systems services, deliver those benefits, the better" (n33)

"So let’s bring the Environment Agency, bodies like the water company, those companies, let’s bring them together. In this area we have a drainage board that focuses on drainage, so let’s bring them in. And let’s focus on future planning and future areas of development focusing on eco systems. I don’t think that’s quite happening as much as it should" (n240)

“My colleagues here have been here twenty years; they know their patch really well. They should be getting in and talking to the national agencies to make that” (n245)

"What we’ve got to do is take our stakeholders with us. That is a long-term project. We have to plan it long-term. It’s not going to happen overnight. And the eco system benefits will come in the long-term. It’s having that long-term view. And I think it comes back to that planning strategically. We are creating something that will be here for ever more. This is, and we have to think about the way that is funded in perpetuity. It’s not just a short term thing. " (n439)

“so for us in example in the county you’ll have policy that’s developed in the county level that we will try to implement at a county level but we also have local policies developed by local authorities” (n642)

5.Climate Change

“well obviously it’s a climate change question, really kind of break it down into what processes can optimise carbon sequestration” (s271)

“carbon sequestration specifically is important in terms of global climate

change” (s316)

“the classic example is climate change which is a global problem but actually studies … are looking [at] national and maybe across Europe and things but I imagine there is probably not a lot of stuff that addresses kind of global” (s472)

“we've got clear interests in sort of climate change” (n499)

“the importance of the marine environment in addressing climate change or absorbing carbon” (n501)

"international scale because it’s really really hard, the institutions just don’t exist and you look how the struggles have gone on over stable development and climate change" (p175)

"so there was multi-party agreement on climate change and so there was multi-party sign up to carbon budgets and then it’s a matter of looking at how do you establish within a parliament or the life of the council in the context of a longer term direction." (p540)

"a lot of things are cost beneficial, they are just not affordable, and there is quite a difference between the two of those...we would take into account climate change and have estimates" (p550)

"if you're saying that you think that climate change is going to have this effect so you will have to do this to mitigate and then adapt." (p556)

"in terms of climate change and woodlands the trees that grow now will be trees in 200 years’ time, so we need to be thinking a lot further ahead" (p591)

"talking long term, you’re talking about something climate, climate changing, technical term, like you know i thinking in my head probably at least 50 years" (p673)

"there are international agreements that are trying to address the whole carbon and climate change question which seems sensible but when it comes to more regional outreach, more land-use related issues within Scotland, we do have a difficulty" (p997)

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