A methodology for ecosystem services assessments across multiple scales

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Statement of Originality

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged. This thesis has not been submitted for any other degree or purpose.

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20 October 2016

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Abstract

The goods and services received from ecosystems (e.g. clean air, clean water, regulating climate, sense of place) are referred to as ecosystem services. People (stakeholders) receive and manage ecosystem services in different ways, rates, magnitudes and scales. This research is premised on the notion that to manage natural resources sustainably for ecosystem service provision we need to mainstream ecosystem services into all stakeholder decision making and a *framework* is required to meet this purpose.

The most utilised framework is the one supporting the Millennium Ecosystem Assessment (MA). Since the MA's release in 2005 there has been exponential growth in ecosystem services research and framework development; there exists no systematic or agreed framework from which to assess ecosystem services across sites, ecosystems, catchments, regions or nations. A lack of analysis of existing initiatives, particularly the drivers underpinning the choice of process applied to develop frameworks and why information and tools differ, hinders the ability to make informed decisions on a framework's relevance, transferability and scalability to purpose, or what is required to develop a more relevant framework. The use of different frameworks by stakeholders limits the use of assessment outcomes by others, and therefore the ability to inform natural resource management, planning and policy at different scales.

To better understand the drivers behind the choice of *methodology* applied in programs, this research analyses ecosystem services assessment methodologies and schools of thought developed in different contexts with a specific focus on geo-jurisdictional scales. In this research a methodology includes the *process* to develop a framework, and the *information* and *tools* supporting the framework.

To analyse methodologies, a three pronged research approach was applied. *Document reviews* ensured this research drew on an existing body of knowledge and broad range of methodologies. *Applied research* was used to develop a regional scale framework in South East Queensland (SEQ), Australia, capturing and creating an understanding of constraints and opportunities that arise in everyday practice. *Multiple case study analysis* with semi-formal interviews was used to analyse frameworks developed at national and multi-national scales (i.e. for the US and UK).

This research provides: (a) a new understanding of the drivers, motivations and contexts that influence how ecosystem services assessment initiatives are shaped; and (b) findings and Recommendations for use by those working in the ever-expanding field of ecosystem services, that will enable them to adopt, adapt or develop assessment methodologies (process, information, tools) in a more sophisticated and explicit manner.

This research reveals the factors influencing the initiation of the program, the culture of coordinating organisations and the resources available strongly influenced the process applied to develop frameworks; the information incorporated in frameworks was influenced by the culture of nations, mandates of coordinating organisations, the existing evidence-base, and the need to integrate assessment outcomes with current natural resource initiatives; and the resources available and capacity of framework users influenced the tools developed. A major finding is the high influence the process applied has on the type of information and tools incorporated in frameworks. Hence, to develop an appropriate methodology for ecosystem services assessments across multiple scales the creation of scientific and political space that allows different knowledge systems to inform each other is required.

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Acronyms and Abbreviations

CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CSIRO	Commonwealth Scientific and Industrial Research Organisation
COWB	Constituents of Well-being
DEFRA	Department for Environment, Food and Rural Affairs
DPSIR	Drivers, Pressures, State, Impact, Response
EMAP	Ecological Monitoring and Assessment Program
EPA	Environmental Protection Agency
ERC	Ecosystem Reporting Category
ES	Ecosystem services
ESRP	Ecosystem Services Research Program
ESRC	Economic and Social Research Council
ESSG	Ecosystem Services Steering Group
ESWG	Ecosystem Services Working Group
EU	European Union
FEGS	Final ecosystem goods and services
FES	Final ecosystem services
GIS	Geographic Information Systems
HHWB	Human Health and Well-being
HUCS	Hydrologic Unit Codes
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
LoE	Line of Enquiry
LWEC	Living with Environmental Change
MA	Millennium Ecosystem Assessment
MYP	Multi-Year Plan
NERC	Natural Environment Research Council
NRM	Natural Resource Management
NSESD	National Strategy for Ecological Sustainable Development
ORD	Office of Research and Development
PCAST	The President's Council of Advisors on Science and Technology
RLOSAC	Regional Landscape and Open Space Advisory Committee
SEEA	System of Environmental-Economic Accounts
SEQ	South East Queensland
SEQC	SEQ Catchments Ltd
SNA	System of National Accounts
TEEB	The Economics of Ecosystems and Biodiversity
UK	United Kingdom
UK NEA	United Kingdom National Ecosystem Assessment
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Program
UNEP-WCMC	United Nations Environment Program - World Conservation Monitoring Centre
UNSD	United Nations Statistical Division
US	United States
WRI	World Resources Institute

Chapter 1

Introduction to ecosystem services concepts and issues

The current rate of biodiversity loss and ecosystem degradation resulting from anthropocentric activities far exceeds that ever recorded in the history of the Earth (MA 2005a; Layke 2009; Butchart et al. 2010; Worldwatch Institute 2012). Population growth, associated resource consumption and land conversion are placing significant pressures on the capacity of ecosystems to continue to support biodiversity and provide the life-supporting ‘goods’ and ‘services' on which human well-being depends (e.g. clean air and water, regulating climate, providing food and timber, generating a sense of place - to name a few) (Costanza et al. 1997; MA 2005a; WRI 2007; DEWHA 2009). These contributions from ecosystems that positively influence human well-being are commonly and collectively referred to as ‘ecosystem services’ (Costanza et al.1997; de Groot et al. 2002; MA 2005a; Daily and Matson 2008; Fisher et al. 2009; Maynard et al. 2010).

All people on Earth are beneficiaries of ecosystem services and therefore stakeholders to their provision. We all receive goods and services and impact on their provision in different ways, at different rates, in different magnitudes and at different (temporal and spatial) scales. But people often take them for granted, or are unaware they are even receiving them (MA 2005a). Even when aware, however, the limited understanding of ecosystem services concepts and tools by these stakeholders; and how to implement these concepts and tools in their decision making; has limited the concept’s application as a proactive tool to natural resource management (NRM) (Daily et al. 2009; Maynard et al. 2010, 2012). For too long (particularly in highly developed nations) ecosystem services have gone unidentified, unrecorded and therefore undervalued (Daily et al. 2009; Maynard et al. 2010). Many natural resources are finite, once these goods and services have been lost they can be prohibitively expensive to replace, if replaceable at all (MA 2005a; Maynard et al. 2010, 2012).

As the provision of ecosystem services traverses multiple (ecological, social and temporal) scales, and stakeholders receive benefits and manage ecosystem services in different ways, conducting ecosystem services assessments and developing effective policies and programs to sustainably manage their provision is complex and problematic (Cork 2002a; MA 2005a; WRI 2007; Australia21 2012). Conducting multi-scale assessments would allow for the environmental, social and economic costs and benefits of natural resource degradation and management to be incorporated into relevant policies and programs; and transparent links between national economic systems, markets, state and local government planning, resource use and protection, conservation policies and programs, investments and incentives, and on-ground property management and planning. The Millennium Ecosystem Assessment (MA) supports the conducting of multi-scale assessments stating (MA 2005a, p. 8):

> *A full assessment of the interactions between people and ecosystems requires a multi-scale approach because it better reflects the multi-scale nature of decision-making, allows the examination of driving forces that may be exogenous to particular regions, and provides a means of examining the differential impact of ecosystem changes and policy responses on different regions and groups within regions.*

This PhD research is premised on the notion that to manage natural resources sustainably we need to mainstream ecosystem services into stakeholder decision making; and to mainstream ecosystem services into decision making a 'framework' is required that enables stakeholders to conduct ecosystem services assessments. By providing information, guidelines and tools for stakeholders (users) to work with, a framework provides a basic structure to solve or address complex issues (MA 2005a; Reid et al. 2006a; WRI 2007; Nahlik et al. 2012). The consistent application of a coherent framework would enable practitioners and decision makers to monitor and evaluate ecosystem service provision over long time frames, set targets, clearly state objectives, communicate findings and coordinate actions. The MA (2005a, p. 34) describes an ecosystem services framework as:

> *... a logical structure for evaluating the system, ensures the essential components of the system are addressed as well as the relationships among those components … and highlights important assumptions and gaps in understanding.*

The multi-stakeholder and multi-scale nature of ecosystem services suggests that to sustainably manage for ecosystem service provision it is not sufficient to develop a framework for single scale applications (e.g. an ecosystem, a catchment, region or nation), or for a specific sector or organisation to apply (e.g. catchment management organisation, utility agency, government). A multi-scale framework (rather than single-scale framework) would allow for nested, interlinked, but semi-independent assessments to be conducted at various scales and levels of organisation (MA 2005d; Reid et al. 2006a; Ash et al. 2010). To develop a multi-scale framework the following research question must be answered: w*hat is an appropriate methodology to enable ecosystem services assessments across multiple scales?* A *methodology* is defined in this thesis as: a framework that consists of *information* and *decision support tools* (tools) suitable for ecosystem services assessments; and the *process* (the series of actions) applied to develop the framework as well.

Globally the most notable and applied of all methodologies is the one supporting the MA (Nahlik et al. 2012). Coordinated by the United Nations Environment Program (UNEP) and developed by over 1300 of the world's leading natural and social scientists, the MA (2005d, p. x) states one of its intents is to be used 'as a framework and source of tools for assessment, planning and management'. Since its release in 2005 the MA framework has been adopted inter alia by the World Resource Institute in their Action Agenda (WRI 2007); the World Business Council for Sustainable Development in developing business solutions (WBCSD 2011, 2012); the Ramsar Convention in the Changwon Declaration on human well-being and wetlands (Secretariat Ramsar 2008); and strategies supporting missions of the Convention on Biological Diversity (CBD) and the Intergovernmental Panel on Climate Change (IPCC) (to name a few) (Fischlin et al. 2007; CBD 2013).

Key components of the MA methodology are its multi-sector approach to stakeholder engagement and the multi-scale technical design of the framework. In the MA (2005d), the flexibility of the framework developed at the global scale allowed for assessments at smaller geographic and jurisdictional scales to be tailored to users' needs. Findings from different scale assessments informed and benefited other assessments at smaller and larger scales (i.e. bottom-up and top-down) (MA 2005d). They say it was clear from the 'exploratory phase of the program' that developing just a global scale framework and conducting a global scale assessment would be insufficient because ecosystems and their processes are ‘highly differentiated in space and time’ (MA 2005d, p. 31); and because ‘causes, impacts and responses to ecosystem change vary at different scales’ (Reid et al. 2006a, p. 6). The MA (2005d, p. 10) states that ‘full multi-scale assessments provide a powerful basis for evaluating the robustness and persistence of [assessment] findings across scales’; and the process of developing the framework and conducting assessments built stakeholder capacity to apply ecosystem services concepts.

Since the MA’s release there has been exponential growth globally in ecosystem services research and framework development (Fisher et al. 2011; Costanza and Kubiszewski 2012). Chapter 2 provides a review of other methodologies and schools of thought on ecosystem services and assessments since the MA’s release. It shows some methodologies have been developed for small scale assessments (e.g. soil management); some for specific decision making contexts (e.g. national environmental-economic accounting); and others have been developed for use in multiple decision making contexts (e.g. land-use and NRM planning). Regardless of the purpose or scale however, since 2005 ecosystem services programs aimed at developing a framework for assessment, planning and management have either adopted or adapted the MA methodology, or developed a completely new methodology with no resemblance to the MA at all.

In this research, the 2005 release of the MA methodology is used as a benchmark to describe more recent schools of thought underpinning processes, information and tools (methodologies) for ecosystem services assessments and the drivers of similarities and differences across them. Figure 1.1 presents the MA’s schematic of the ecosystem services concept which is the most well-known of all ecosystem service conceptual diagrams developed to date. The overall framework developed under the MA builds on and guides the expansion of the ecosystem services concept; it develops the concept into something more detailed and useful for stakeholders (e.g. business, industry, community, government, non-government, Traditional Owners and researchers) to apply.

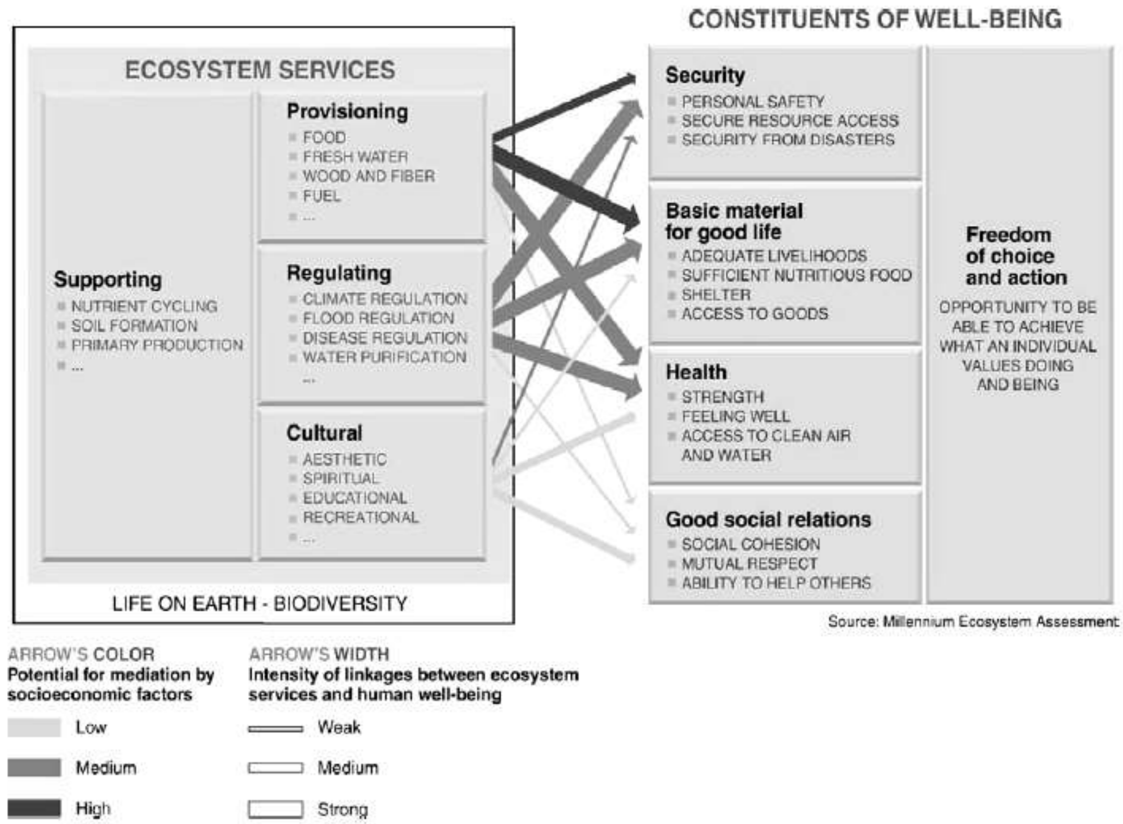

Figure 1.1: The ecosystem services concept from which the MA framework builds on (extracted from MA 2005a, p. vi).

On the left of the MA schematic, four categories of ecosystem services (Supporting, Provisioning, Regulating and Cultural) and examples of goods and services under each category are provided (these are discussed further in Chapter 2). Biodiversity is shown as underpinning the provision of ecosystem services important to human well-being by the box encompassing them. On the right hand side are five categories of Constituents of Well-being (COWB) (Security, Basic Materials for Good Life, Health, Good Social Relations and Freedom of Choice and Action), and examples of the various constituents under each category (also discussed further in Chapter 2). Arrows between categories of ecosystem services and COWB show the intensity of linkages between the two and the potential for mediation by socio-economic factors such as markets, education, and having access and transportation to areas providing services. According to Cork (2002b, p. 8):

> *… the concept of ecosystem services attempts to place the relationship between people and nature into the same service-based framework that we*

> *face in our everyday relationships with businesses, government and voluntary organisations ... the ecosystem services approach treats the service-based relationship between humans and the natural environment as the starting point for planning of all … economic activity, and focuses on collecting the information necessary for the full range of ecosystem services to be considered.*

This human-centric focus on nature has been the main criticism of an 'ecosystem services approach' to managing natural resources (Hansen 2011). Many argue the intrinsic value of biodiversity will be lost through attempts to value biodiversity for ‘our’ own sake rather than for that of ‘its’ own; that nature is too important to be valued; and that nature cannot be reduced to a financial commodity (MA 2005a; McCauley 2006; Simpson 2011; Ingham et al. 2012). Certainly, the value people place on biodiversity is evident in traditional methods of nature conservation which generally have focused on the protection of rare, endangered and threatened species or ecosystems (Ingham et al. 2012; Pittock et al. 2012; IUCN 2015). This research does not delve into the pros and cons of each approach (biodiversity or ecosystem services) nor does it suggest these approaches are mutually exclusive. The benefits of each approach have already been argued in academic literature (Ingham et al. 2012) as well as in colourful popular press by George Monbiot and Tony Jupiter in the Guardian (Juniper 2012; Monbiot 2012) and Richard Conniff in Yale Environment 360 (Conniff 2012).

At the global scale, the importance of ecosystem services to sustainable development is well recognised and has been endorsed by world leaders and emphasised in many international policies and programs from as far back as the 1987 ‘Brundtland Report’ (WCED 1987). In 2012 the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was established to provide ‘scientifically sound’ and ‘relevant’ information to support 'more informed decisions on how biodiversity and ecosystem services are conserved and used around the world’ (IUCN 2013; Diaz et al. 2015; IPBES 2015). As a follow-up to the MA (2005a), at the time of writing this thesis IPBES (2014, 2015) is conducting global and sub-regional assessments on the status and trends in biodiversity and ecosystem services. The achievement of the Sustainable Development Goals which provides a plan ‘for people, planet and prosperity’ (recently developed and agreed to by countries signatory to the UN), will fundamentally depend on the provision of ecosystem service (UN 2015, p. 1).

Slowly, attention has turned from global scale programs developing ecosystem services frameworks and conducting assessments to (multi)national scale initiatives. In recognition of the importance of ecosystem services to sustaining national economies and the limited ability to account for these goods and services in traditional accounting methods (e.g. the System of National Accounts), the UN Statistical Division (UNSD 2012) has used ecosystem services as the framework for the revision of the System of Environmental-Economic Accounts (SEEA). In parallel, the World Bank coordinates the Wealth Accounting and the Valuation of Ecosystem Services (WAVES 2014) partnership that aims ‘to promote sustainable development by ensuring natural resources are mainstreamed in development planning and national economic accounts’. There are numerous case studies showing the contribution of ecosystem services to national job growth, for example, Ecuadorian job growth since the protection placed on the Galapagos Islands archipelago and the expansion of the eco-tourism and recreational sectors (Environmental Systems Research Institute 2011). National scale ecosystem services programs and assessments have been initiated in the United States (EPA 2008), England (Haines-Young and Potschin 2008), Switzerland and Austria (Otts and Staub 2009; Staub et al. 2011), the UK (UK NEA 2011b), and New Zealand (Townsend and Thrush 2012), to name a few.

There is hope in the fact that the release of these global and (multi)national scale programs and assesments has often followed with legislation mandating the development of assessment tools and including ecosystem services into decision making. For example, within only a few months of the release of the United Kingdom National Ecosystem Assessment (UK NEA) the British Government released a White Paper stating their commitment to a ‘green economy’ and ‘safeguarding the environment for the benefit of future generations’ (UK Government 2011, p. 2). As well, in order to halt the loss of biodiversity and ecosystem services and meet obligations under the CBD, the European Union’s Biodiversity Strategy to 2020 (EU 2013, p. 7) calls upon Member States to:

> *Map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020.*

The most recent landmark moment for ecosystem services occurred on the 7th October 2015, when the Obama Administration released Memorandum M-16-01 providing 'direction to agencies on incorporating ecosystem services into Federal planning and decision making' (Executive Office of the President of the United States 2015, p. 1). The Memorandum refers to two key messages from a report developed by the United States President's Council of Advisors on Science and Technology (PCAST 2011, p. 7):

> *First, the economic and environmental dimensions of societal well-being are both indispensable, as well as tightly intertwined. Second, … the government … must not fail to address the threats to both the environmental and the economic aspects of well-being that derive from the accelerating degradation of the environmental capital - the Nation's ecosystems and the biodiversity they contain - from which flow "ecosystem services" underpinning much economic activity as well as public health, safety, and environmental quality.*

Although by nature a multi-scale framework would allow ecosystem services assessments to be conducted at different scales (e.g. local, regional and catchment) and for different purposes (e.g. land-use planning, accounting, State of Environment reporting, Multi-lateral Environmental Agreements), this research responds to the research question from the position of developing a multi-scale framework at the national scale (e.g. for Australia) (WRI 2007, p. 35). Outcomes of assessments would inform 'national implications [of changes in ecosystem services] and the potential decisions that might be taken nationally' (Reid et al. 2006a, p. 8). Based on lessons learnt from the MA, the WRI (2007, p. 35) contextualises the role of national institutions and policies in sustainably managing for ecosystem services provision; and the importance of coordinated institutions and coherent policy making across multi-scales:

> *The Assessment* [i.e. the MA] *points to the importance of ensuring policy coherence … international conventions must be coherent with national policies and these in turn must be coherent with local policies. National institutions are often the pivot between local or regional institutions and international ones. The priority they give this role greatly influences the ability to design and carry out coherent policies.*

It is thought the findings developed through this research will have applicability to all nations (and other geo-jurisdictional areas) grappling with how to develop information and tools for ecosystem services assessments. However, the three programs analysed in this research were coordinated in highly developed nations and some findings may be less relevant to those in less developed nations. Although not often required, when ‘context’ is required to provide an example or better communicate an issue, Australia is used because it is my home nation. Using Australia to highlight key findings is also useful as at the core of Australia’s National Strategy for Ecological Sustainable Development (NSESD) is the concept of ecosystem services (Australian Government 2013a); and due to Australia’s recent commitment to contribute to achieving the global Sustainable Development Goals (UN 2015).

Australia’s NSESD aims to protect biodiversity and maintain ecological processes so to enhance individual and community well-being for current and future generations (Australian Government 2013a). Other key documents across the environment and agricultural portfolios of the Australian Government and States of Australia contain the words ‘ecosystem services’ (Cork 2002b), including national and state biodiversity strategies and various State of Region and Environment reports (Australian Government 2008, 2012; Queensland Government 2008; DEWHA 2009). Chapter 2 introduces a few of the local to regional scale programs in Australia using ecosystem services as an approach to improve NRM. A review paper developed by Graymore (2006) identified a wide variety of other institutional contexts in which policy and management decisions are made involving natural resources and ecosystem services in Australia. The list below includes Graymore’s (2006, p. 10) list (in italics), and then builds on these examples (non-italics):

- *Global scale initiatives such as control of greenhouse gas emissions*
- *Management of special areas of international and national significance,* including Multilateral Environmental Agreements and Conventions (e.g. World Heritage Areas, Ramsar sites, IPBES, CBD)
- *Formulation and implementation of state policies and regulations for specific ecosystems, environments or key issues* (e.g. biodiversity, wetlands, native vegetation, water quality, air quality, waste management)
- *Regional strategic plans*
- *Land-use zoning*

- *Dedication and management of conservation areas*
- *Local environmental plans*
- *Development control plans*
- *Integrated catchment management*
- *Environmental protection policies, programs and projects*
- *Environmental and social impact assessments*
- *Development approval processes*
- *Incentive systems for environmental protection and/or enhancement*
- Business and industry sustainability and reporting
- Social and community planning
- Eco-labelling and consumer awareness programs
- National environmental-economic accounting

Cork (2002a) and Australia21 (2012) suggest the concept of ecosystem services provides an integrative mechanism to assess and communicate the environmental, social and economic dimensions of NRM, and a tool to guide integrated policies and programs in these areas. The Australian Government (2013a) states the development of the NSESD demonstrates their belief that a coordinated approach to sustainable development is required. A coordinated approach is required because of ‘the need to look at management of Australia's ecological and economic resources on a regional, national and international basis, and the significance of potential threats to our environment and economy if we do not take action’ (Australian Government 2013a). To date however, information has not been identified, collated, adopted or developed to systematically and consistently incorporate ecosystem services into any of these programs (Australia21 2012).

A large body of research has been conducted to better understand the use and uptake of ecosystem services approaches in Australia. A literature review and interviews with NRM practitioners conducted by Plant and Ryan (2013, p. 44) revealed an ‘ecosystem services toolbox combined with clear national and regional policy drivers’ is required to remove barriers to the adoption of this approach. Pittock et al. (2012) say the little success in using ecosystem services to facilitate strategic dialogue within and among governments at state and national scales has contributed to a failure to implement important policy commitments fundamental to the health of Australia’s ecosystems. As well, Pittock et al. (2012, p. 118) describe other barriers to the uptake of ecosystem services in Australia such as: the disempowerment of voluntary and regional NRM institutions by changing ‘mandates, form and funding’; intergovernmental agreements lacking incentives for implementation and penalties for non-compliance; and an ongoing ecological debate that sees biodiversity and socio-economic benefits as separate issues.

It is now clear the ‘business-as-usual approach’ to NRM is unsustainable (WCED 1987; Balmford and Bond 2005; MA 2005a; Djoghlaf 2010; TEEB 2010). In the opening address of the 10th Conference of the Parties to the CBD, Executive Secretary Ahmed Djoghlaf (2010) asked us to apologise to our children for our failure to meet the agreed 2010 targets and reduce the loss of biodiversity. As represented by the box encompassing ecosystem services in Figure 1.1 the MA recognises biodiversity as underpinning the functioning of ecosystems and therefore the provision of ecosystem services. If current trends of biodiversity loss and ecosystem degradation are to be reversed we need to rapidly advance information and tools to forecast and quantify ecosystem service provision; and priority must be given to mainstreaming ecosystem services into all sectors of decision making (MA 2005a; WRI 2007; Cowling et al. 2008; Daily and Matson 2008; Daily et al. 2009; Layke 2009; Maynard et al. 2010).

Across the globe much has been achieved in terms of defining and classifying (Daily 1997; de Groot et al. 2002; MA 2005a; Boyd and Banzhaf 2007; Wallace 2007; Fisher and Turner 2008; Fisher et al. 2009), measuring (Chan et al. 2006; Layke 2009; Fisher et al. 2011; Ausseil et al. 2013) and valuing ecosystem services (Costanza et al. 1997, 2014; Farbier et al. 2002; Raymond et al. 2009; Morrison and Hatton-MacDonald 2010; TEEB 2010; Bateman et al. 2013). The MA is but one, without doubt the most prominent, of all ecosystem services frameworks currently available. Chapter 2 reviews the MA methodology and other schools of thought developed since its release providing the current state of knowledge on information and tools that allow for the identifying, measuring and valuing of ecosystem services. Despite all this endorsement and research, however, there is still an ongoing challenge (in Australia and elsewhere) to conduct and demonstrate ecosystem services assessments.

Definitions, classification schemes, data, information and decision support tools vary across the many existing ecosystem services frameworks (Australia21 2012). These frameworks were developed by various stakeholders from different disciplines and cultures, to address specific issues, and for application at different scales and by different users. As Chapter 2 shows, there exists no systematic or agreed framework from which to consistently assess ecosystem services across sites, ecosystems, catchments, a region, state or nation. A lack of analysis of existing initiatives, particularly the drivers underpinning the choice of process applied to develop the frameworks and why the information and decision support tools differ across these frameworks, hinders the potential for researchers and decision makers to make informed decisions on an appropriate framework to adopt or how to develop a more relevant one (MA 2005a; Brunckhorst et al. 2006; Cowling et al. 2008).

Through document and literature reviews, applied research and multiple case study analysis this research identifies key drivers (e.g. scientific, political, historical, scalar) that have provided constraints, or that have led to explicit or implicit choices, that determined the type of process applied to develop a framework and the information and tools to support it. In this research, determining the basis from which the constraints and choices were made have informed a set of Recommendations from which researchers can use to determine an appropriate new methodology to develop; or these Recommendations can be considered when assessing the potential to adopt or adapt an existing methodology; or researchers can use these Recommendations to assess the appropriateness of a methodology already developed and that they currently use.

The central question to this research is: *what is an appropriate methodology to enable ecosystem services assessments across multiple scales?* Hence it is important to identify what issues or topics this research does 'not' address. As previously discussed, this research does not debate the differences between biodiversity and ecosystem services approaches. The focus is greater on geographic, jurisdictional and spatial scales of framework development and application and does not discuss temporal scales of ecosystem service provision. This research analyses methodologies at the scale of program development (e.g. regional, national); projects or specific studies conducted within these programs are beyond the scope of this research. As well, time and budget only allowed case studies to be analysed up until the date of this research, hence any follow-up and second stages of these programs is outside the scope of this research. Finally, the actual application of the information and decision support tools (frameworks) and the outcomes of assessments as a result of their application are also outside the scope of this research. This research does not address these issues primarily due to time and financial resources, but also because they have already been comprehensively discussed by other researchers.

Chapter 3 provides the research approach to answering this question. To break the research into more tractable components the analysis of existing methodologies and schools of thought was undertaken using three Lines of Enquiry. The first Line of Enquiry focuses on the *process* (the series of actions) applied in programs to develop a framework for ecosystem services assessments. This includes identifying factors underpinning the initiation of programs; the role of government and stakeholders in the development of frameworks; the resources required to develop a framework; and how programs were structured. The second and third Lines of Enquiry focus on the *information* (i.e. biodiversity, ecological processes, ecosystem services, valuing ecosystem services) and *decision support tools* (i.e. conceptual frameworks, scenarios, maps, dynamic models, websites and reports) supporting different frameworks.

Chapter 3 also provides the rationale for adopting a three pronged research approach and it describes each approach. It begins by discussing the first approach, *document and literature reviews*. Unlike many other PhD theses, in this thesis the document review is primarily provided in Chapters 1 (Introduction to ecosystem services concepts and issues) and 2 (Methodologies for assessing ecosystem services), rather than after the chapter describing the research design. This order was preferable as outcomes of the document review were used to design the research and provide direction by identifying sub-questions and topics requiring further analysis under each Line of Enquiry. These three Lines of Enquiry were used to analyse different methodologies and schools of thought through the three research approaches.

The other two prongs of this research were *applied research* and its application at the regional scale in South-East Queensland (SEQ, Australia); and *multiple case study analysis* and its application to a national scale program in the United States (US) and a multi-national scale program in the United Kingdom (UK). The three Lines of Enquiry were used to analyse the SEQ, US and UK programs and to delve deeper into the drivers underpinning the choice of methodologies developed. Chapter 4 provides the outcomes of the research in SEQ; and Chapters 5 and 6 the outcomes of the US and the UK case studies. Weaknesses within each research approach were strengthened through the combined use of the three approaches.

Documents and literature pertaining to the SEQ, US and UK programs are discussed extensively throughout their relevant chapters, extending the document review beyond these introductory chapters into the entire thesis. During the course of this research I (co-)authored a number of peer reviewed publications and developed a website describing the SEQ methodology. Rather than include a separate table in this chapter, I refer you to Table 3.1 which lists these documents as primary SEQ literature used as data in this research. I also co-authored a publication on the 'State of ecosystem services in Australia' (Pittock et al. 2012) and this is used to provide context to this research. An Issue Paper I contributed to the UN SEEA is discussed in Section 2.2 and used extensively in this research when describing ecosystem services frameworks at local to regional scales in Australia (Maynard and Cork 2011).

This triangulated approach to research (document and literature reviews, applied research and multiple case study analysis) provided a challenging experience insisting I play multiple roles throughout the research. To conduct document and literature reviews I performed the role of desktop analyst. As applied researcher and Project Manager for the SEQ Ecosystem Services Project I interacted with stakeholders to develop a real-world regional scale ecosystem services framework for NRM and planning. To better understand the reasoning behind the methodology adopted in SEQ, any intrinsic biases, and the potential to develop a methodology for use across multiple scales and purposes, I then acted as interviewer of Leads who were developing ecosystem services frameworks for the whole of the US and UK.

Chapter 7 presents the key findings of this research providing comparisons and contrasts between the methodologies developed in SEQ, US and the UK. It describes the constraints and opportunities provided by drivers influencing respective programs; and how these drivers influenced the types of processes applied and the information and tools that were developed. Based on the experiences of these three programs, and by comparing and contrasting these to the MA experience and other methodologies and schools of thought as described in the literature, this chapter provides Recommendations for determining an appropriate methodology for ecosystem services assessments across multiple scales.

Chapter 8 concludes this research with discussion on the strengths and weaknesses of the research approach in terms of the research outcomes. It re-examines the key findings from Chapter 7 and highlights areas of specific importance to developing a multi-scale framework at the national scale (e.g. for Australia). Areas for future research are discussed as well as my contribution to academic knowledge. The following chapter continues the review of literature (Line of Enquiry 1) by focusing on methodologies and schools of thought for ecosystem services assessments.

Chapter 2

Methodologies for assessing ecosystem services

Chapter 1 discussed the concept of ecosystem services and provided an example, the schematic (Figure 1.1) developed in the MA to communicate ecosystem services to stakeholders (e.g. business, industry, community, government, non-government, Traditional Owners, researchers and communities). It described how the provision of ecosystem services are fundamental to the well-being of people and how these relationships are diverse, complex and context dependent. Although contention exists between conservation approaches traditionally focused on biodiversity and those more anthropocentric of focus (i.e. ecosystem services), an ecosystem services approach is endorsed by many world leaders as an appropriate approach to sustainable development and the management of natural resources.

Chapter 1 also listed a wide variety of institutional contexts across a nation in which policy and management decisions are made involving natural resources. The WRI (2007) described the pivotal role that national institutions play in ensuring policy coherence across scales of organisation, providing rationale for developing a multi-scale framework at the national scale. In order to develop this framework the following research question must be answered: w*hat is an appropriate methodology to enable ecosystem services assessments across multiple scales?* In this research a methodology consists of *information* and *decision support tools* (a framework) that would enable ecosystem services assessments to be conducted; as well as the *process* (the series of actions) to develop the framework.

This chapter builds on the introduction to ecosystem services concepts and issues by providing a review of literature further describing the global scale MA methodology (Section 2.1). The exponential growth in ecosystem services research since the MA's release in 2005 (Fisher et al. 2011; Costanza and Kubiszewski 2012), makes the MA methodology a good benchmark to compare and contrast other methodologies and to identify drivers behind the choice in methodological change from the MA. This chapter therefore reviews a wide range of documents and literature describing ecosystem services initiatives and schools of thought since the MA's release; and highlights key changes from the MA methodology and the drivers underpinning them (Section 2.2).

The literature reviewed in Chapter 1 and this current chapter have informed the development of three Lines of Enquiry that are described in Chapter 3. Three methodologies developed in different countries (Australia, US and UK); at different scales (regional, national and multi-national); by different coordinating organisations (non-government and government); and with differing resources (budgets, number of employees, expertise) were analysed using the Lines of Enquiry (see outcomes in Chapters 4, 5 and 6). Different research approaches (i.e. document reviews, applied research and multiple-case study analysis) were applied to analyse the three methodologies. Background to these case studies and the different research approaches are also provided in Chapter 3. To set the benchmark from which recent methodologies have been developed and the case studies are analysed, the MA methodology is described below.

2.1 The MA methodology

The MA's unique approach to developing a framework and conducting assessments is particularly relevant to this research which does not aim to determine an appropriate methodology for single scale or sector specific assessments, but a methodology that enables assessments to be conducted by multiple stakeholders across multiple scales. Section 2.1.1 describes the process applied to develop the MA framework. Section 2.1.2 describes the information and tools developed to support it.

2.1.1 The process to develop the MA framework

The MA was called for by the UN Secretary-General in 2000 in response to the Parties signatory to the four major global ecosystem-related conventions: the CBD; the Convention to Combat Desertification; the Ramsar Convention; and the Convention on Migratory Species and Wild Species (MA 2005a; Reid et al. 2006a; Ash et al. 2010). The goal of the MA (2005a, p. 28) 'was to establish the scientific basis for actions needed to enhance the contribution of ecosystems to human well-being without undermining their long-term productivity '. An overview of the process applied to develop the MA framework is summarised in Appendix 1, Column 2. Although the process applied to develop frameworks in SEQ, the US and UK are also summarised in this table they are discussed later in their relevant chapters (Chapters 4, 5 and 6).

The MA was coordinated by the UN in which close to 200 nations are signatory (UN 2014b)[*]. Specifically, it was coordinated by the UNEP who is 'the voice for the environment within the UN system' and the 'world's foremost intergovernmental environmental organisation' (UNEP 2013). It was governed by a 15 person multi-stakeholder Assessment Panel and Board with representatives from 'international organisations, governments, business, non-government organisations and indigenous people' (Reid et al. 2006a, p. 3). A Secretariat with offices in Europe, North America, Asia and Africa supported the program which ran for a four year period (MA 2005a). The program cost approximately US$24 million, plus more than US$7 million of in-kind support (MA 2005b). Funders of this global scale program were mostly non-government international organisations. Funding was mostly provided by national governments for sub-global assessments.

Figure 2.1 highlights the multi-scale process and examples of users of the framework (information and tools) at three different scales: regional, sub-regional and local. As previously mentioned, the framework development and assessment process was coordinated by UNEP at the global scale ('Global MA Process'). Outcomes of the application of the framework aimed to meet the needs of decision makers from the four major ecosystem-related conventions. The intended application of the framework and the audience for assessment outcomes was broad however; it extended across countries, disciplines and users hence the breadth of experts and decision makers participating in the MA process.

The multi-scale design of the MA framework enabled nested ecosystem services assessments to be conducted at different scales (MA 2005d). Many more scales, however, were identified and assessed in the MA beyond just the three presented. Reid et al. (2006a) and Ash et al. (2010) explain that to facilitate better decision making at all scales 34 local, watershed, regional and national scale assessments (called 'sub-global assessments') were included as core project components. Note, the terminology applied (i.e. regional, sub-regional and local) are arbitrary terms and spatial scales will be defined differently depending on cultures, countries, disciplines etc. Of importance is the ability to nest different scale assessments so findings feed both bottom-up and top-

[*] Australia, the US and UK are all Member States to the United Nations – see Sections 3.2.2.1, 3.2.3.1, 3.2.3.2 (UN 2014b).

down (double arrows) therefore contributing to more detailed, robust and complete findings (MA 2005d).

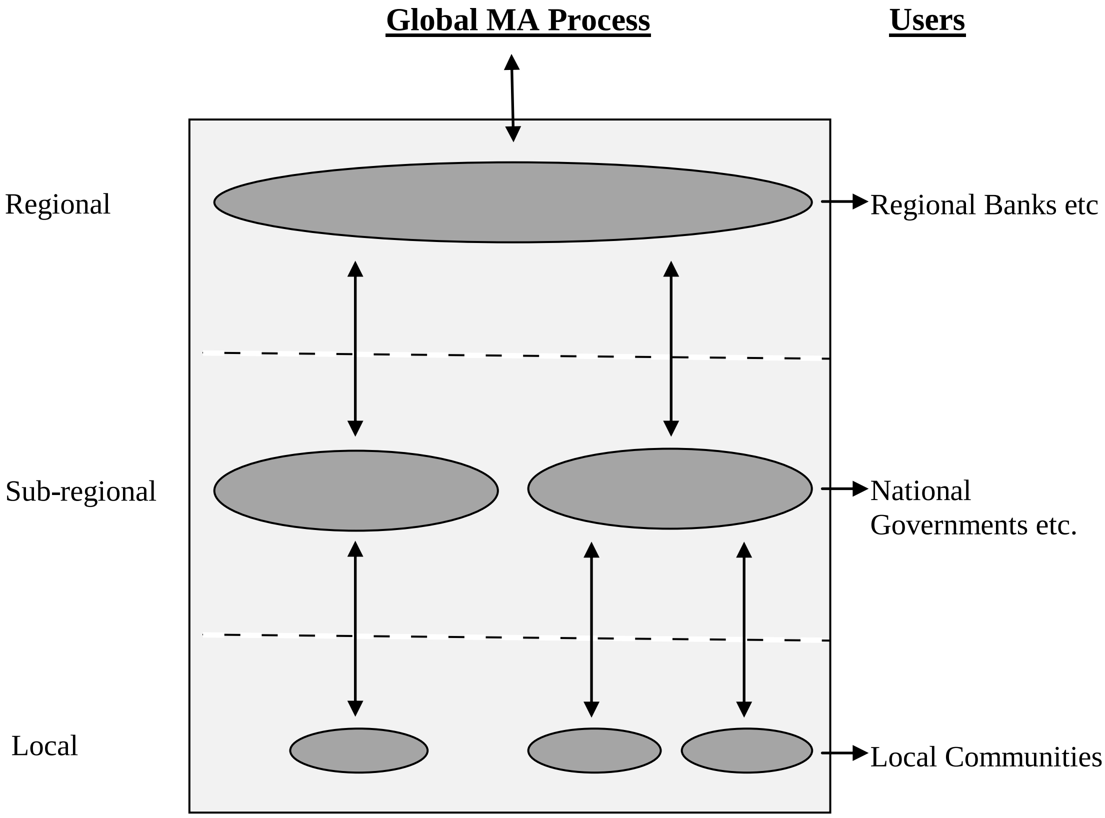

Figure 2.1: The MA's nested multi-scale design (reproduced from MA 2005d, p. 31).

Sub-global assessments were not chosen to be representative samples of ecosystems, regions or nations (MA 2005d). Rather, they were chosen based on the interest and available resources of the proposed coordinating organisation(s) and designed to meet the needs of decision makers in these areas (Reid et al. 2006a; Ash et al. 2010). To meet minimum assessment standards and contribute to the global scale assessment all sub-global assessments were required to meet the following criteria (MA 2005d, p. 33):

- *use the MA conceptual framework;*
- *user engagement; and*
- *adherence to MA policies.*

More than 1300 expert natural and social scientists working at different scales from 95 countries contributed to developing information and tools and conducting assessments under the MA. In the process of selecting experts due regard was given to geographic and gender balance and the inclusion of Indigenous and local knowledge. Experts were structured into four Working Groups: Condition and Trends, Scenarios, Policy Responses and Multi-scale Assessments (MA 2005a, 2005b, 2005c, 2005d). Eighty Review Editors composed of government representatives and other experts oversaw the scientific review of reports (in two rounds) and ensured all comments (from approximately 850 individuals) were appropriately addressed by the Authors (MA 2005a). The following section describes the information and tools supporting the MA framework developed through this process.

2.1.2 The information and tools supporting the MA framework

The generation of new primary knowledge was not an aim of the MA (2005a). The MA (2005b, 2005c, 2005d p. vii) aimed to 'add value' by 'collating, evaluating, summarising, interpreting and communicating' existing scientific (including peer-reviewed literature, data sets, scenarios and models) and other knowledge systems (held by different sectors, practitioners, communities and Indigenous people) in a new form. The information underpinning the MA framework follows closely that developed by the CBD enabling the MA to better integrate with existing global environmental policies and programs, and policies and programs supporting them at different scales (e.g. national scale policies and programs of UN Member States) (MA 2005a).

'Biodiversity' is defined by the CBD (1992, p. 5) as: *the variability among living organisms from all sources, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are a part; this includes diversity within species, between species and ecosystems*. The MA (2005a, p. 62) recognises an 'asymptotic relationship between biodiversity and ecosystem functioning'. Some species make unique contributions to ecosystem functioning important to the delivery of ecosystem services (MA 2005a). However, many species contribute to other ecosystem functions making species substitutable (MA 2005a). Of concern to ecosystem service provision is 'the possibility of significant losses of function … as more species are lost and as redundancy is reduced' (MA 2005a, p. 62). The importance of biodiversity in maintaining ecosystem services is shown by the box encompassing these in Figure 1.1.

‘The Ecosystem Approach’ underpinning the CBD aims to shift the focus of policy making and delivery away from siloed approaches to NRM (such as the conservation of air, water and soil) into more holistic or integrated approaches based on whole ecosystems (SCBD 2004; MA 2005a). The Ecosystem Approach is built on 12 Principles, including Principle 5: the conservation of ecosystem structure and function in order to maintain ecosystem services (SCBD 2004). The MA therefore uses ‘ecosystems’ as the spatial unit for assessing ecosystem services using their framework. Article 2 of the CBD (1992, p. 5) defines an ecosystem as: *a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit.* The MA (2005a, p. 51) says ‘[eco]systems’ have ‘strong interactions among components of the system and weak interactions across its boundaries; discontinuities of strong interactions become boundaries’. Although the size and location of ecosystems is highly important these features are secondary when conducting systems analysis (MA 2005a).

Box 2.1 presents 10 Reporting Categories, the units for assessing ecosystem services at the global scale using the MA (2005a) framework. Humans are recognised as an integral and often dominant part of these ecosystems (MA 2005a). As ‘ecosystem services’ are defined in the MA (2005a, p. 49) as *the benefits people obtain from ecosystems*, without people there are no actual ecosystem services. The MA (2005a, p. 53) states they use overlapping categories ‘because this better reflects real-world biological, social and geophysical interactions, particularly at these relatively large scales’. For example (MA 2005a, p. 53):

Box 2.1: *Assessment units applied in the MA (2005a, p. 53) at the global scale.*

At the global scale surrogate ‘ecosystems’, termed Reporting Categories, are the units used to assess ecosystem services using the MA framework. These ecosystems represent all ecosystems across the globe, they include: Marine, Coastal, Inland Water, Forest, Dryland, Mountain, Island, Polar, Cultivated and Urban. Each Reporting Category contains a number of more defined natural or human modified ecosystems better suited to the scale of sub-global assessments. The location and size of Reporting Categories was spatially defined by grouping more defined ecosystems with similarities in ‘climatic conditions, geophysical condition, dominant use by humans, surface cover, species composition, resource management systems and institutions’ under each Category.

> *... it is helpful to analyse an area dominated by forest* land cover as a single *ecosystem even if it contains some freshwater and agricultural areas within it, rather than analysing the forest, agriculture, and freshwater ecosystems separately, this allows for a more holistic analysis of these interactions.*

Figure 1.1 presented the four categories of ecosystem services in the MA. Provisioning Services (i.e. *the products obtained from ecosystems*) such as food, timber and fibre are the most recognised of ecosystem services due to their economic contribution. They are predominately derived from highly modified and human dominated ecosystems and their value is generally represented in existing markets (therefore regularly measured and recorded). It is much harder to measure and determine the value of Regulating Services (i.e. *the benefits obtained from the regulation of processes*) and Cultural Services (i.e. *the non-material benefits people obtain from ecosystems*) as they are generally derived from landscape functions; there are no established markets; and their values are often highly dependent on people's location, perceptions, experiences, age, culture and education (MA 2005a). Supporting Services (i.e. *ecosystem services necessary for the production of all other ecosystem services*) do not directly provide benefits to people, but are those goods and services recognised as necessary for all other ecosystem services to be derived (MA 2005a).

Twenty-four ecosystem services are assessed under the Provisioning, Regulating and Cultural Categories and seven Supporting Services are also identified. These ecosystem services are derived, received, measured and valued by people in different ways (e.g. economically, culturally, individually, collectively) and at different scales (e.g. in-situ, catchment, regional, national or global; minutes, years, decades or centuries). Through these multiple interacting pathways we can see that humans influence ecosystems and in turn are influenced by changes in ecosystems (MA 2005a). The MA (2005a) and Bennett et al. (2009) say the full range of ecosystems and ecosystem services need to be assessed to make ethical and informed decisions. Costanza et al. (2011, p. 2) states 'the full range of ecosystem services must be considered to prevent creating dysfunctional incentives and to maximise net benefits to society'

The concept of ecosystem services presented as Figure 1.1 shows these ecosystem services contributing to human well-being which is comprised of many experiential constituent parts. The MA (2005d, p. 379) defines ‘human well-being’ as: *a context and* *situation dependent state, comprising basic materials for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind and spiritual experience*. For assessment purposes it describes five categories of Constituents of Well-being (COWB): Security, Basic Materials for Good Life, Health, Good Social Relations and Freedom of Choice and Action. Figure 1.1 provides some examples of the various COWB under each category. These categories and constituent parts were based on outcomes of research conducted by Narayan (2000) who surveyed poor people from 23 countries asking them to discuss good and bad aspects of their life.

At the heart of the MA is its conceptual framework which builds on the schematic of the ecosystem services concept. The conceptual framework, presented as Figure 2.2, aims to guide the concept of ecosystem services (Figure 1.1) into a usable and consistent format that all researchers developing aspects of the framework could follow (MA 2005a). It aimed to provide consistency of approach to applying the MA framework and conducting assessments (e.g. sub-global assessments); and to help guide those reporting on assessment outcomes (MA 2005a; Ash et al. 2010). The conceptual framework provided a shared vision and language (terminology) across disciplines and stakeholder objectives allowing assessments at different scales to be interlinked and outcomes to feed both bottom-up and top-down. The MA (2005a, p. 34) says ‘given the complex interactions between ecosystems and human well-being a prerequisite for both analysis and action is agreement on a basic conceptual framework’.

Similar to Figure 1.1, the position of biodiversity in Figure 2.2 is again made clear by the box encompassing ecosystem services. 'Human Well-being and Poverty Reduction’ are indicated in the upper left hand box of the diagram so to emphasise the primary focus on these issues' (MA 2005a, p. 36). In Figure 2.2 the top right hand box identifies 'Indirect Drivers of Change’ in ecosystems (e.g. demographics, science and technology, cultural and religious values) which, as identified in the bottom right hand box, 'Directly’ drive changes in ecosystems (e.g. through land-use, species introductions, technology, external inputs, harvesting and extraction). At this level the conceptual framework is strongly related to the Drivers-Pressures-State-Impacts-Responses (DPSIR) framework applied internationally in environmental reporting and policy analyses (Ash et al. 2010; State of Environment Committee 2011).[*] The MA builds on

[*] Including the Australian Government’s State of Environment Report (State of Environment Committee 2011).

the DPSIR framework however by including feedback loops and assessments across multiple temporal and spatial scales (Ash et al. 2010).

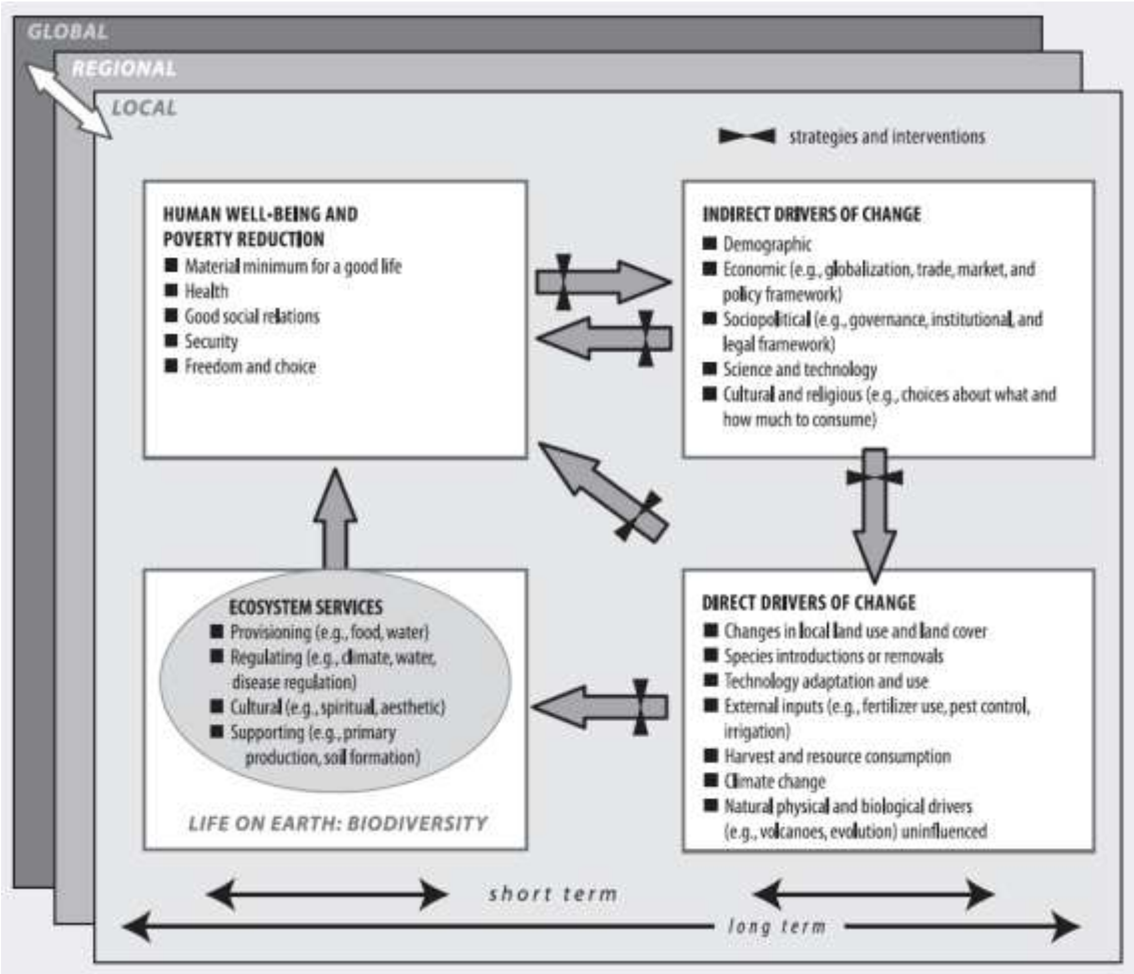

Figure 2.2: The conceptual framework underpinning the MA methodology (extracted from MA 2005a, p. 37).

The MA conceptual framework shows how resulting changes in ecosystems and therefore ecosystem services affect human well-being. These cross-scale interactions between people and the environment are highlighted at the regional, national and global scales; as well, in short and long term timeframes. Arrows indicate the causal interactions among components of the framework and the general direction of the interactions (MA 2005a). Black cross bars indicate intervention points where the dynamics can be altered by people (MA 2005a).

Below is the set of questions the MA used to identify what type of data and information was required to support the framework and to conduct assessments of the conditions, trends and trade-offs in ecosystem services at the global scale (MA 2005e, p. 40). The MA did not provide the data and information to stakeholders to conduct sub-global assessments. It recognised that across the globe the availability and reliability of data, and the applicability of methods to collect and develop the data, was variable across ecosystems, ecosystem services and assessment regions (MA 2005e). However, stakeholders at sub-global scales agreeing to the three criteria for sub-global assessments (Section 2.1.1), and who collect and/or develop data and information to answer the questions described below, could tailor the global scale MA framework to suit their specific contexts and decision making purposes:

- *What are the current spatial extent and condition of ecosystems?*
- *What are the quality, quantity, and spatial distributions of services provided by the systems?*
- *Who lives in the ecosystem and what ecosystem services do they use?*
- *What are the trends in ecosystem condition and their services in the recent (decades) and more distant past (centuries)?*
- *How does ecosystem condition, and in turn ecosystem services, respond to the drivers of change for each system?*

As mentioned in Chapter 1, the MA (2005d, p. x) states one of its intents is to be used 'as a framework and source of tools for assessment, planning and management'. However, similar to the data and information developed, beyond providing the conceptual framework the tools to conduct assessments were not provided to stakeholders for use in their sub-global scale assessments. The data sources, analytical approaches and tools used to derive information and conduct assessments at the global scale were described in large technical documents for the purpose of recording the approach and guiding stakeholders conducting sub-global assessments (these technical documents are discussed shortly). In short, the data sources, analytical approaches and tools applied at the global scale included:

- **Remote sensing and geographic information systems (GIS):** primarily satellite imagery ranging from 10 m – 8 km resolution was used. This was the primary data source for identifying the extent and condition of ecosystems;

- **Inventories of ecosystem components:** these were most commonly used to provide data on the amount and distribution of ecosystem services, species and demographic information (human demographic information was derived from census data);

- **Numerical simulation models:** these were used ‘to describe interactions among components of the system’ and ‘examine assumptions and responses to driving forces’ (MA 2005e, p. 48);

- **Indicators of ecosystem condition and services:** indicators were used in many ways including: ‘as surrogates for difficult to measure characteristics of ecosystem condition’; ‘to incorporate several measured quantities into a single attribute as an indicator of overall condition’; ‘to communicate effectively with policy makers regarding trends in ecosystem conditions and services’; and ‘to measure the effectiveness of policy implementation’ (MA 2005e, p. 49);

- **Indigenous, Traditional and Local Knowledge:** used primarily to provide information on ecosystem condition and trends; and

- **Case studies of ecosystem responses to drivers:** case studies were used to generate ‘general principles about ecosystem responses to drivers in different locations and under different biophysical conditions’ (MA 2005e, p. 53).

An important set of tools developed under the MA methodology are its scenarios. The MA states ‘scenario development is a way to explore possibilities for the future that cannot be predicted by extrapolation of past and current trends’ (MA 2005c, p. 225). They are ‘plausible, provocative, and relevant stories about how the future might unfold … scenarios are not forecasts, projections, predictions or recommendations (MA 2005c, p. 2). Outcomes of these scenarios fed back into the frameworks development providing important information where otherwise information did not exist. The four scenarios chosen took the perspective of someone in 2050 looking back at events occurring in the world since 2000, they included (MA 2005c):

- **Global Orchestration:** focused on global cooperation. Cooperation to improve social and economic well-being and to protect and enhance public goods (e.g. education, health and infrastructure);

- **Order from Strength:** explored citizens, businesses and governments becoming more inward focused in response to terrorism and the breakdown of global cooperation. As a result the world becomes more compartmentalised;

- **Adapting Mosaic:** in this scenario society is interested in learning about socio-ecological systems through adaptive management. An element of this scenario is learning about balancing different forms of capital (natural, human, built etc.); and

- **Techno Garden:** society focuses on ‘natural capitalism’ in this scenario – developing profit from working with nature. The reliability and supply of ecosystem services is improved through strengthened markets and institutions.

As mentioned previously the data sources, analytical approaches and tools developed to conduct assessments, as well as the design of the MA framework and lessons learnt from its development and application, are written into five technical volumes (A Framework for Assessment; Current State and Trends; Scenarios; Policy Responses; and Multi-scale Assessments). Each volume ranges from 395 pages to 918 pages each. One synthesis document brings together and summarises the five technical reports for decision makers (MA 2005f). Five other synthesis reports focus on specific issues or are tailored for specific stakeholders (i.e. Biodiversity Synthesis; Desertification Synthesis; Opportunities and Challenges for Business and Industry; Wetlands and Water Synthesis; and Health Synthesis) (MA 2005a). These documents are available for purchase in hard or paperback versions and they are freely available on a dedicated website.

Since the MA’s release in 2005 many new and existing institutions, policies, plans and programs are applying or integrating ecosystem services into their objectives (WRI 2007; EPA 2008; Haines-Young and Potschin 2008; Staub et al. 2011; UK NEA 2011b; WBCSD 2011; Townsend and Thrush 2012; UNSD 2012). Some global scale institutions, policies, plans and programs such as the IPCC, the CBD and Ramsar have adopted the MA framework without change (Fischlin et al. 2007; Secretariat Ramsar

2008; CBD 2013). Elements of the framework have also been adopted in a wide variety of other contexts - for example, determining impacts on bird species of projected land-cover changes due to climate and land-use change (Jetz et al. 2007) and assessing potential health issues associated with acid sulfate soils (Ljung et al. 2009). Of those policies, plans and programs that adopted the MA framework (i.e. used the information and decision support tools), rarely is the rationale provided for its adoption over other frameworks. Generally, those who adopted the MA discuss the process applied to develop the framework, particularly the involvement of over 1300 natural and social scientists from around the world and its coordination by UNEP as justification for using the framework.

Outside of those policies, plans and programs that adopted the MA framework, the growth in ecosystem services research since the MA's release has led to new schools of thought on how to develop information and tools for ecosystem services assessments; and what these information and tools should look like. For example at the national scale, England's assessment of terrestrial ecosystems (Haines-Young and Potschin 2008) and New Zealand's assessment of coastal ecosystems (Townsend and Thrush 2012) used the MA methodology as a foundation, adapting the MA information and tools to suit local contexts and to include more up-to-date or local knowledge and data. Other programs such as the US Environmental Protection Agency's Ecosystem Services Research Program acknowledge the MA but the process applied under their program and the information and tools developed show little resemblance to the MA methodology at all (EPA 2008).

As Chapter 1 mentioned, much has been achieved in terms of defining and classifying, measuring and valuing ecosystem services. However, much of this information is yet to be combined, structured and integrated into comprehensive and credible frameworks for (multi-scale) ecosystem services assessments. Where frameworks have been developed a lack of analysis into the drivers underpinning the information and tools, and the process to develop these, hinders researchers and decision makers from making informed decisions on which framework to adopt, adapt or how to develop a new ecosystem services framework from scratch. The following section reviews documents and literature key to describing research advances and new schools of thought on ecosystem services since the MA. It highlights key methodological changes from the MA and where information was available, the drivers underpinning these changes.

2.2 Other methodologies and schools of thought

The literature shows, that of those initiatives that adapted or dismissed the MA methodology, the major methodological change has been in the information supporting the framework. Specifically, researchers and users say its lack of economic analysis and inability to robustly conduct such analysis hinders the use of the framework (Boyd and Banzhaf 2007; EPA 2008; Fisher and Turner 2008; Morrison and Hatton-MacDonald 2010; TEEB 2010; Johnston and Russell 2011; UK NEA 2011b). The MA purposely did not focus on the economics of ecosystem change, but rather on the 'human well-being' dimensions of service provision and more specifically the link between ecosystem services and poverty alleviation (MA 2005a; TEEB 2010). Butler and Oluoch-Kosura (2006, p. 1) say ‘human well-being … depends critically upon the human institutions that govern relationships between human individuals and groups, and also between humans and ecosystem services’.

To address the issue of economic analysis, in 2007 the Environment Ministers attending the G8 +5 conference in Potsdam, Germany[*] proposed to use the MA as the foundation to build 'a framework … for articulating the ecological and economic aspects of the analysis necessary for the valuation of biodiversity loss and ecosystem degradation' (TEEB 2010, p. 8). The resulting program called The Economics of Ecosystems and Biodiversity (TEEB) was also coordinated by UNEP. TEEB (2010) was primarily funded by the European Commission and governments from Germany, UK, Norway, the Netherlands and Sweden; with governments from Japan and South Africa also funding later TEEB initiatives. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES 2012) describes the TEEB framework as:

> *... based on the total economic value framework that is widely used in the economic literature, but also draws on the Millennium Ecosystem Assessment*
> *... however, TEEB goes beyond economic valuation and explicitly acknowledges and advocates the use of non-monetary valuation which is in many cases more appropriate to make nature's values ... visible.*

[*] The group of G8 + 5 includes the eight leading industrialised nations and the five emerging economies.

The development of the TEEB (2010, 2014) methodology (process, information and tools) consisted of two Phases.[*] Phase 1 was the framework's information scoping stage involving a call for scientific and economic knowledge held within the global expert community. The global expert community (i.e. natural and social scientists) was asked to contribute resources, publications, studies or expertise relevant to the 'biomes' chosen as the assessment unit for applying TEEB at the global scale; and the value of different ecosystem services derived from these biomes. Benefit transfer was the primary valuation approach applied to determine the value of goods and services in monetary terms across these biomes (TEEB 2010).

The 12 biomes included in TEEB (2010) are a cross-fit with many of the MA's 10 Reporting Categories (discussed in Box 2.1). TEEB biomes include: Marine/Open Ocean; Coastal System; Wetlands, Lakes and Rivers; Forests; Woodland and Shrubland; Grass and Rangelands; Desert; Tundra; Ice/Rock/Polar; Cultivated Areas; and Urban Areas. In contrast to the MA Reporting Categories, TEEB does not include Mountains and Islands; and TEEB has further subdivided Dryland to include Woodland and Shrubland, Grass and Rangelands, and Desert. Tundra has also been included in TEEB. Similar to the MA Reporting Categories each biome was further 'sub-divided into a much larger number of ecosystem types' for smaller scale applications. Biomes are defined in TEEB (2010, p. xxxi) as:

> *… the largest ecological classification that is convenient to recognise below the entire globe. Terrestrial biomes are typically based on dominant vegetation structure … Ecosystems within a biome function in a broadly similar way, although they may have different species composition. Marine biomes are typically based on geochemical properties.*

Phase 2 involved further developing and applying the framework and providing tools for potential users. Tools included reports developed for specific stakeholders (i.e. for local, regional, national and international decision makers, and business and enterprises) and developing a website to house these reports and provide information to individual citizens (TEEB 2010). One of the tools developed under TEEB is a conceptual framework which is shown as Figure 2.3. The figure states the 'four bold-lined boxes

[*] A third phase is currently in process and involves the application of the framework, including facilitating and supporting countries to use the TEEB framework (i.e. in Bhutan, Ecuador, Liberia, Philippines and Tanzania) (TEEB 2010).

coincide with the overall MA [conceptual] framework' (shown as Figure 2.2), these include 'ecosystems and biodiversity', 'human well-being', and 'direct' and 'indirect drivers' of change. This leaves only 'services', 'governance and decision making' and 'external drivers' as new additions to the conceptual framework.

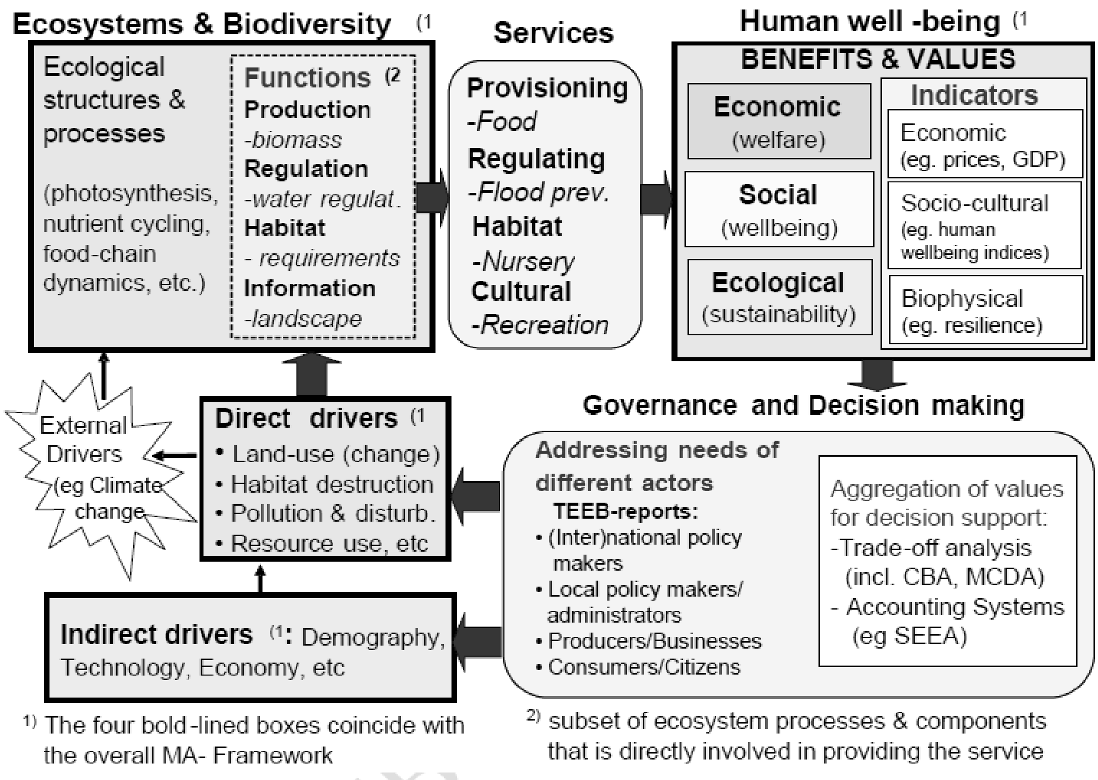

Figure 2.3: The TEEB conceptual framework linking ecosystems and human well-being (TEEB 2010, p. 21)

Consistent with Principle 5 of the CBD's Ecosystem Approach the TEEB conceptual framework shows 'Ecosystems and Biodiversity' to be comprised of 'Ecological Structures and Processes' and 'Ecosystem Functions'. Ecosystem functions, 'a subset of the interactions between ecosystem structure and processes that underpin the capacity of an ecosystem to provide goods and services' are categorised into Production, Regulation, Habitat and Information (TEEB 2010, p. 25). In the corresponding conceptual framework supporting the MA ecosystem functions are not shown. Although in the MA ecosystem services are categorised along functional lines, there is little discussion on functions in their overall framework.

The TEEB function categories are based on the function analysis developed by de Groot (2006). However, TEEB excludes de Groot's (2006, p. 180) category of 'Carrier Functions' which are said to provide 'a suitable substrate or medium for human activities and infrastructure'. Carrier Functions in de Groot's (2006) analysis include land-use types such as those used for energy-conversion, cultivation, mining, and waste disposal to name a few. De Groot (2006, p. 178) says ecosystem services derived from Carrier Functions (e.g. minerals, oil, gold) are not ecologically sustainable as they usually 'involve the conversion of the original ecosystem into another type of land use'. De Groot (2006, p. 178) define ecological sustainability as 'the natural limits set by the carrying capacity of the natural environment (physically, chemically and biologically), so that human use does not irreversibly impair the integrity and proper functioning of its natural processes and components'. Whether to class non-renewable and unsustainable goods and services derived from the environment as ecosystem services and include them in frameworks continues to be a contentious issue in ecosystem services research (Haines-Young and Potschin 2013).

TEEB (2010) analyses 22 ecosystem services in total, two of which are categorised under the 'Habitat' category. This Habitat category is said to replace the Supporting Services incorporated in the MA framework, which are said to underpin the provision of all other goods and services (TEEB 2010). The two Habitat Services included are: the maintenance of life cycles of migratory species (including nursery service) and the maintenance of genetic diversity (especially gene pool protection) (TEEB 2010). Further analysis of the TEEB methodology identifies other changes to the MA methodology, such as, the partitioning of human well-being into economic, social or ecological factors rather than the five categories of COWB.

A noteworthy technical difference between the MA (2005a) and TEEB (2010) frameworks is the definition of ecosystem services applied. How you categorise and define ecosystem services has direct implications on what will be assessed and valued using the framework; and the type of information and tools developed and used in the assessment (Nahlik et al. 2012). The MA definition of ecosystem services, *the benefits people obtain from ecosystems*, has become more controversial since 2007 with many researchers claiming it would lead to double counting within economic valuations (Boyd and Banzhaf 2007; Wallace 2007; EPA 2008; Fisher and Turner 2008; Morrison and Hatton-MacDonald 2010; TEEB 2010; Johnston and Russell 2011; Staub et al.

2011; UK NEA 2011b; Landers and Nahlik 2013). It was for this reason TEEB (2010, p. xxxiv) adopted the following definition of ecosystem services: *the direct and indirect contributions of ecosystems to human well-being.*

The TEEB definition of ecosystem services was derived from previously developed definitions by Boyd and Banzhaf (2007) and Fisher and Turner (2008). Boyd and Banzhaf (2007, p. 616) say the MA definition 'gained currency because it conveys an important idea that ecosystems are socially valuable and in ways that may not be immediately intuited ... beyond that, ecology and economics have failed to standardise the definition and measurement of ecosystem services'. Fisher et al. (2008, p. 2051) say although the MA definition provides 'a context for discussion … it falls short as an operational definition for accounting, landscape management or valuation'.

To advance 'the development of environmental accounting and performance systems' Boyd and Banzhaf (2007, p. 616) say a more precise articulation of 'ecosystem service units' is required. Boyd and Banzhaf (2007, p. 619) therefore coined the term 'final ecosystem services' (FES) defining them as: *components of nature directly enjoyed, consumed or used to yield human well-being*. There are three important characteristics of Boyd and Banzhaf's (2007, p. 619) definition: 1/ 'FES are directly enjoyed or consumed'; 2/ 'they are components of ecosystems'; and 3/ 'they are a quantity to be compared to a price'.

The purpose of Fisher and Turner's (2008) research was much broader than Boyd and Banzhaf's (2007). It aimed to identify 'how ecosystem services deliver human welfare benefits; where the benefits are realised; by whom; and how their value changes across the landscape in regards to different future scenarios' (Fisher and Turner 2008, p. 1168). To suit this purpose Fisher and Turner (2008, p. 1168) defined ecosystem services as: *the aspects of ecosystems utilised (actively or passively) to produce human well-being*. Fisher and Turner (2008, p. 1168) say there are also three important characteristics to their definition: 1/ 'ecosystem services are not benefits'; 2/ 'ecosystem services are ecological in nature'; and 3/ 'ecosystem services do not have to be utilised directly'. Under the third characteristic, ecosystem services can be both 'final' and 'intermediate', with intermediate ecosystem services being those that support FES (similar to the MA's Supporting Services).

Common to both Boyd and Banzhaf's (2007) and Fisher and Turner's (2008) definitions, but dissimilar to the MA (2005a) definition, is recognition that ecosystem services are 'ecological in nature' (i.e. natural capital); and therefore are not 'benefits' because to receive a benefit usually requires the use of other forms of capital as well (e.g. human, manufactured, social). By nature, the concept of 'final' ecosystem services poses the question to what or to whom are these goods and services final to? Under these definitions FES relate 'to a defined benefit that people draw from the FES' (Ott and Staub 2009, p. 5). The third characteristic of Fisher and Turner's (2008) definition is what differs most from Boyd and Banzhaf's (2007) who see ecosystem services as only items you can 'count' (i.e. forests, fish populations); and Fisher and Turner (2008) say ecosystem functions and processes can also be an (intermediate or final) ecosystem service as long as there is a human beneficiary.

Ott and Staub (2009, p. 3) and Staub et al. (2011) provide the first feasibility study into the implementation of Boyd and Banzhaf's (2007) FES approach in terms of how it can contribute to 'effective and efficient [national] resource policy as well as to a more comprehensive measurement of human welfare'. The Federal Office for the Environment who commissioned the study had the specified goal of analysing various ecosystem service approaches for the purpose of integrating ecosystem services into the Swiss (and Austrian) national economic accounts (Ott and Staub 2009). They describe how the Swiss National Accounts are based on the System of National Accounts (SNA); how the UN's SEEA extends the SNA through environmentally related satellite accounts; and how Eurostat and the European Commission compiled the European Strategy for Environmental Accounts based on the Handbook of National Accounting developed in 2003 through SEEA (Ott and Staub 2009; Staub et al. 2011).

Ott and Staub (2009) and Staub et al. (2011) suggest beyond accounting for ecosystem services the use of Boyd and Banzhaf's FES approach has disadvantages in terms of its ability to assess ecological sustainability. In order to make their inventory more precise yet flexible, Ott and Staub (2009) and Staub et al. (2011) include the additional characteristic of 'intermediate' goods and services. Within this study they develop an inventory of 23 FES and a set of indicators for assessing those (Staub et al. 2011). They say these FES and indicators can be used for similar studies in other countries (Staub et al. 2011).

Biodiversity’s role in ecosystem service provision and its position in the Swiss framework are not mentioned in Ott and Staub’s (2009) and Staub’s (2011) studies. Balmford and Bond (2005, p. 1219) suggest the term biodiversity is not adequate for ecosystem services assessments as under this definition living organisms are usually defined in terms of ‘difference’ rather than ‘amount’ which is also important to ecosystem service provision. Kremen et al. (2005, p. 540) suggest although numerous studies have been conducted on ‘the role of diversity in determining ecosystem function’, often studies have been restricted to a small set of ecological processes or they ‘examine communities whose structures differ markedly from those providing services in real landscapes’. According to Kremen (2005) few assessments actually give adequate attention to the role biodiversity plays in the delivery of ecosystem services.

SEEA 2003 was before the release of the MA. The UNSD (2012) has since reviewed SEEA 2003 and the updated version uses ecosystem services as the framework for experimental ecosystem accounting and to address gaps in previous accounting systems. The definition of ‘ecosystem services’ used in the experimental ecosystem accounting is: *the contributions of ecosystems to benefits used in economic and other human activity* (European Commission et al. 2013, p. 164). As a contributor to the revised version of SEEA though the Australian community of practice for environmental-economic accounting (coordinated by the Australian Bureau of Statistics and Bureau of Meteorology), I have first-hand knowledge that little input from ecosystem services specialists was used in the SEEA revision. The process was dominated by national statisticians from developed countries.

No maps or dynamic models are provided to assist stakeholders in the application of SEEA, and until recently little funding or capacity building was available to assist with its implementation. A website is dedicated, however, to providing stakeholders information on the global process applied to develop it. This website also houses numerous documents providing examples of the ‘internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing comparable statistics on the environment and its relationship with the economy across nations’ (UN 2014a). To support the initiative and provide guidance and consistency of incorporating ecosystem services into accounts across nations, the revised version of SEEA uses the Common International Classification of Ecosystem Services (CICES).

CICES was developed through a program funded by the European Environment Agency in response to the inconsistency of ecosystem services classifications applied by researchers and decision makers globally (Haines-Young and Potschin 2013). It has undergone a number of revisions; Version 4.3 is now well accepted by the European Commission and incorporated in many European programs (European Environment Agency 2009). This version of CICES was not accepted by the UNSD however due to lack of technical agreement and an earlier version of CICES has been included (Obst 2012, pers comm., 27 July).

Figure 2.4 presents the CICES 'cascade' conceptual framework that was adapted from Haines-Young and Potschin (2008) and de Groot et al. (2002) (Haines-Young and Potschin 2010a). Unlike the MA (2005a) and TEEB (2010) conceptual frameworks the CICES conceptual framework does not explicitly acknowledge the role of biodiversity in ecosystem service provision. Presented linearly is how biophysical structures and processes become valued by people; how driving change is a change in pressures applied to biophysical structures and processes; and the intervention area for potential policy action to limit these pressures.

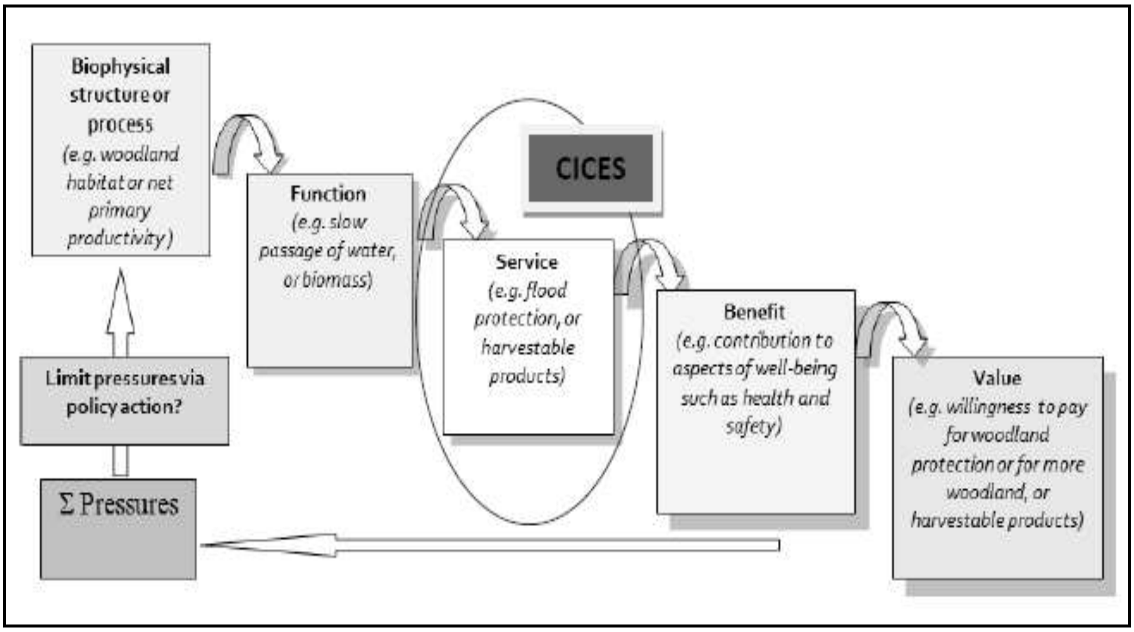

Figure 2.4: The conceptual framework underpinning CICES (extracted from Haines-Young and Potschin 2010a, p. 7).

CICES categorises ecosystem services using the Provisioning, Regulating (and Maintenance) and Cultural categories of the MA but excludes Supporting Services as they distinguish them as ecosystem functions (Haines-Young and Potschin 2013). In a function analysis of particular concern is functional redundancy in species within ecosystems, and the impact of this on ecosystem functioning necessary to ensure service provision (de Groot et al. 2002; MA 2005a). It is well recognised that degraded ecosystems have a reduced capacity to perform functions essential to providing ecosystem services (Kremen 2005; MA 2005a; UK NEA 2011b). As well, it takes more than one function to provide any ecosystem service and one function can contribute to the provision of many ecosystem services (de Groot et al. 2002; MA 2005a; Maynard et al. 2010; Petter et al. 2012). Haines-Young and Potschin (2010a, p. 7) state the key features of the 'production chain' shown in Figure 2.4 are:

> *…that it is important to distinguish between ecosystem structure, process, and function; that it is important to distinguish between ecosystem functions and services; that it is useful to distinguish between services and benefits.*

Similar to Boyd and Banzhaf (2007), Fisher and Turner (2008) and TEEB (2010), Haines-Young and Potschin (2013) who coordinated the CICES program say valuing Supporting Services would lead to double counting. Although the MA service categories are closely followed CICES uses the FES approach to classify ecosystem services under these categories. The FES definition in CICES is most closely related to Fisher and Turner's (2008) and TEEB's (2010) definitions which recognise intermediate services; and to Fisher and Turner's (2008), Boyd and Banzhaf's (2007) and TEEB's definitions that relate FES to human well-being rather than to economic activity such as in SEEA. 'FES' is defined under CICES (Haines-Young and Potschin 2013, p. 9) as: *the contributions that ecosystems make to human well-being*.

Haines-Young and Potschin (2010a, 2010b) say although the MA definition has the advantage of being simple, this simplicity leads to confusion and different interpretations. A five tiered hierarchical and nested ecosystem service classification was developed for CICES to overcome 'some of the challenges that arise in relation to the different spatial and thematic scales used in different applications' (Haines-Young and Potschin 2013, p. 3). At the second broadest tier, CICES lists eight ecosystem services adapted from the MA (2005a) and TEEB (2010) partitioned under the three categories described above (Haines-Young and Potschin 2010a).

Turning our attention towards nations more specifically, there have been many pioneering ecosystem services programs conducted at multi-state or the national scale in Australia. For example, Maher and Thackway (2007) summarise approaches to measuring, accounting and valuing ecosystem services provided by Australian vegetation. Determining the value of Australia's tropical river systems is the primary focus of an Australian Government funded program that brings together some of Australia's leading researchers and institutions (Australian Government 2009). Aimed at integrating ecosystem services assessments into water resource planning, the National Water Commission coordinated the development of a Handbook specifically for water resource planners (Plant et al. 2012).

Steve Cork and I contributed an Issue Paper to the review of SEEA providing a comparison between TEEB, CICES and five ecosystem services frameworks developed and applied in major local to regional scale programs in Australia within the last decade (Maynard and Cork 2011). All frameworks except Wallace (2007) were developed with input from local stakeholders. The purpose of these local to regional scale frameworks varied. The transferability and scalability of these frameworks is yet to be tested, as well their potential use for purposes other than those defined in the research. In these frameworks, the number of ecosystem services included ranged from 11 to 28 and three distinctly different definitions for ecosystem services were applied. The frameworks reviewed included:

- **An inventory of ecosystem goods and services in the Goulburn Broken Catchment:** this highly participatory program coordinated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) assessed 14 ecosystem services provided in a catchment dominated by agricultural land-use and an analysis of change through a series of scenarios (Binning et al. 2001).

- **Ecosystem services and biodiversity indicators:** at the request of the Organising Committee for the 13th Australian Cotton Conference, academic researchers identified 12 important ecosystem services to a community in terms of their input to cotton growing; the vulnerability of these ecosystem services and their management potential; and they developed analytical approaches and tools to assess ecosystem services and the ecological, economic and social impact of changes in delivery of priority ecosystem services (Reid et al. 2006b).

- **Classification of ecosystem services - problems and solutions:** this research conducted by an employee from a state government environment agency presents a theoretical framework for classifying ecosystem services useful to NRM decision making. The MA (2005a) definition was applied; 17 ecosystem services were classified; and examples were provided of ecological processes and assets important to the delivery of those services. The classification explicitly links 'values describing important aspects of human well-being' with ecosystem services (Wallace 2007, p. 242). Wallace (2007) says previous classifications do not do this.

- **Examining links between soil management, soil health, and public benefits in agricultural landscapes - an Australian perspective:** this research conducted by a group of researchers from academia and state government agricultural and environment agencies examines links between soil health, land management changes, ecosystem services and the benefits they provide (Bennett et al. 2010). This framework identifies not only 11 soil-based ecosystem services, but five disservices derived from agricultural landscapes.

- **The South East Queensland (SEQ) Ecosystem Services Project:** SEQ is the fastest growing metropolitan region in Australia (Maynard et al. 2010). This project coordinated by a non-government catchment management organisation aimed to develop an agreed framework across stakeholders for identifying, measuring and valuing 28 ecosystem services in the SEQ region; and to incorporate ecosystem services into NRM and land-use policy and planning (Maynard et al. 2010). This framework and the participatory process of developing it are analysed in-depth in this research as Chapter 4: the SEQ Experience.

Since 2005 there was a strong tendency in Australia to use the MA framework as the standard but more recent studies used the framework developed by TEEB or the UK NEA (Maynard and Cork 2011). Two major outcomes of this Issue Paper were, firstly, that even though the conceptual framework developed by Haines-Young and Potschin (2010a) and presented as Figure 2.4 had not been adopted by any Australian framework, it was consistent with the understanding in most Australian local to regional scale frameworks. Secondly, Maynard and Cork (2011, p. 4) conclude that although the capacity of an ecosystem (ecosystem function) to provide an ecosystem service only becomes a good or service once a benefit and beneficiary can be clearly identified there is still:

> *… merit in estimating the relative potential of different ecosystems to provide ecosystem services when dealing with stakeholder groups and social-environmental planning. A national or international accounting system* [i.e. such as SEEA] *is constrained by having to work with demand for ecosystem services as it is expressed by public opinion, markets and need, but projects that work interactively with stakeholders can often turn capacity into actual services by creating awareness and new land management that generates a "market" for the services.*

The Wallace (2007) and Maynard et al. (2010) research purposely developed 'information' for use by stakeholders other than themselves. Maynard et al. (2010) was the only framework which contained 'tools' specifically for multiple stakeholders and sectors to conduct their own ecosystem services assessments. All programs except Wallace (2007) used maps as assessment tools. No large technical reports were developed describing the methodologies but peer reviewed journal articles were developed on all. At the time of publishing Maynard and Cork (2011), only Binning et al. (2001) provided free open access to information in the form of a website. However, a website providing stakeholders with open access to the SEQ framework was under development (SEQ Catchments 2012).

Although there is now a large range of dynamic models available to assess ecosystem services, changes in their provision, and environmental, social and economic implications of these changes (Chan et al. 2006; Segan et al. 2011; Sherrouse et al. 2011; Bagstad et al. 2013; Vogl et al. 2013; Sharp et al. 2014; Villa et al. 2014), the reviewed local to regional scale programs in Australia did not include dynamic modeling as a component of their framework or in their assessment. The reason for this is unstated except in Maynard et al. (2010) who say the lack of resources available to develop or train in model development and application was prohibitive. Bagstad et al. (2013) and Crossman et al. (2013) say the inconsistent use of maps and models to assess ecosystem services is a global issue. Crossman et al. (2013) suggests that for researchers unfamiliar with modelling approaches determining an appropriate model for use may be a deterrent and hence they provide a checklist of information required for modelling and mapping ecosystem services.

In global scale programs maps and spatially dynamic models are increasingly being used to explore what the future might hold under different policy relevant scenarios (IPCC 2000; MA 2005a). Scenarios applied in the MA were discussed in Section 2.1.2, another global example is the IPCC Special Report on Emissions Scenarios who developed four narrative storylines to describe consistently the relationships between the forces driving emissions and their evolution. The resulting set of 40 scenarios cover a wide range of demographic, economic and technological driving forces of future greenhouse gas and sulphur emissions (IPCC 2000). Binning et al. (2001) was the only local to regional scale program reviewed by Maynard and Cork (2011) that used scenarios as a tool.

In conclusion, the review of local to global scale programs presented in this chapter reveals how the ‘context’ in which a program was conducted (e.g. who coordinated the program, its purpose, scale, participants involved) has led to different methodologies being developed. The development and application of many and varying ecosystem service frameworks has resulted in information and decision support tools with limited transferability and repeatability to other contexts; and outcomes of assessments with limited ability to feed bottom-up and top-down for effective policy and program development and implementation across scales (Nahlik et al. 2012). The lack of analysis into drivers influencing the choice of methodology developed (i.e. the process, information and tools developed) hinders the potential for researchers and decision makers to make informed decisions on which methodology to adopt or adapt; or determine how to develop a new methodology more relevant to their decision making context.

Different stakeholders with potential to apply an ecosystem services framework are also shown to vary in interests, capacities and management scales; as do different decision makers with potential to use outcomes of assessments (Wainger et al. 2010). Reid et al.

(2006, p. 10) describe numerous 'information benefits' resulting from multi-scale assessments that can improve the 'accuracy', 'validity' and 'applicability' of findings to stakeholders, including: better problem definition by focusing less narrowly on issues; improved analysis of scale-dependent ecological and social processes; improved analysis of cross-scale effects; better understanding of change causality; and improved accuracy and reliability of findings by ground-truthing larger scale findings. Reid et al. (2006, p. 10) also describes 'impact benefits' of multi-scale assessments that 'improve relevance, utility, ownership and legitimacy of the assessment with decision makers', these include: improved relevance of the problem definition and assessment findings; improved scenario development by involving stakeholders in their development; and increased ownership of assessment findings by users.

The literature reveals no agreement across researchers as to the appropriate scale from which to assess ecosystem services and to manage them (Cumming et al. 2006). Outside of the literature just discussed, Brunckhorst et al. (2006) have developed a framework that delineates 'resource governance regions' based on social perceptions and geographic boundaries. Meyerson et al. (2005) discuss the need to manage ecosystem services at the scale of 'service delivery'. Potschin and Haines-Young (2013) argue a 'place-based approach' can help us better understand the issues of multi-functionality, value natural capital and frame debates about sustainability. The development of the MA framework at the global scale and its application in sub-global assessments provides insight into diverse ecosystem service decision making contexts and the importance of conducting nested and integrated assessments of ecosystem services.

To mainstream ecosystem services into decision making the cross scale interactive nature of ecosystem services means information needs to be developed and structured in a way that is transferable, credible, legitimate, relevant, defensible, practical and repeatable; and allows for the understanding of this information to be integrated in different contexts including different scales of decision making (MA 2005a; Reid et al. 2006a; Cowling et al. 2008; Ash et al. 2010; Nahlik et al. 2012; Maes et al. 2013). The scale mismatch at which different ecosystem services are derived and valued; the scales of management and governance of the natural resources underpinning them; and the scale in which frameworks for assessments are being developed, has proved problematic to date in terms of not just identifying, measuring and valuing ecosystem services but designing and applying frameworks for consistent assessments across programs and scales (MA 2005a; Cumming et al. 2006; Tress et al. 2006). Cash et al. (2002, p. 1) state:

> *… such impediments result in the archetypal problems of decision makers not getting information that they need and scientists producing information that is not used.*

De Groot et al. (2002, p. 393) state ‘in order to make comparative ecological-economic analysis possible a standardised framework for the comprehensive assessment of ecosystem functions, goods and services is needed’. The MA (2005a), Cowling et al. (2008), Layke (2009) and Maynard et al. (2012) describe the need to simplify the complexity of information for communication and use by decision makers. Within this research, the combination of the *process* applied to develop a framework and the *information* and *tools* to support it are collectively referred to as a *methodology*. The latter two areas (information and decisions support tools) form the actual framework itself.

Chapter 3 describes the research design; outcomes of its application will build on the current state of knowledge on ecosystem services (as described in these previous chapters) by identifying drivers underpinning choices that lead to differences in processes, information and tools. By identifying drivers underpinning the choice of methodology, the outcomes are: 1/ a deepened understanding of the logic underpinning different ecosystem service frameworks developed to date; and 2/ from these provide a set of Recommendations for researchers and decision makers to consider when determining how to develop an appropriate framework for multi-scale assessments, or for choosing an appropriate methodology to adopt or adapt. The literature reviewed in Chapters 1 and 2 are synthesised in the following chapter to form three Lines of Enquiry into methodologies for ecosystem services assessments. The following chapter also describes the three-pronged research approach applied to delve deep into these methodologies.

Chapter 3

The research design

This chapter describes the design of this research aimed at determining *an appropriate methodology to enable ecosystem services assessments across multiple scales.* The research design was significantly shaped by the need to mainstream ecosystem services into stakeholder (e.g. government, non-government, business, industry, researcher, Traditional Owner and community) decision making if we are to sustainably manage natural resources; and to effectively mainstream ecosystem services into decision making a framework that enables stakeholders to conduct ecosystem services assessments in different contexts is required.

Chapters 1 and 2 introduced a wide range of contexts that ecosystem services approaches have been applied to at local to global scales (e.g. agricultural production, land-use planning conservation programs, cost benefit analysis and accounting, international environmental agreements). From this it can be posited that for multi-scale ecosystem services assessments to occur, information and tools supporting a framework need to be useful and accepted by a wide range of stakeholders working in different context including at geographic and jurisdictional scales (e.g. property, city, catchment, region, state, national, global). As demonstrated in Chapters 1 and 2, currently there is no systematic or agreed process, information or tools (methodology) across stakeholders for identifying, measuring and valuing (assessing) ecosystem services.

The aim of this research is not to develop another assessment methodology, or just to identify and describe existing methodologies. In this research different schools of thought are analysed in terms of the drivers behind the choice of information and tools included in frameworks; and the process of developing the information and tools as well. By determining drivers of choices leading to methodological similarities and differences, researchers will be better informed to make decisions on the appropriateness of an existing framework for use, or what to consider when developing a more appropriate framework to suit their purpose.

Figure 3.1 on page 46 shows the design of this research which is discussed in depth in this chapter. Section 3.1 describes how the three components of a methodology (process, information and tools) have been organised into three ‘Lines of Enquiry’. Each Line of Enquiry is described in detail in Sections 3.1.1, 3.1.2 and 3.1.3. In Figure 3.1 the Lines of Enquiry are highlighted as coloured circles labelled LoE 1 (process = blue), LoE 2 (information = orange) and LoE 3 (tools = green). The black arrows connecting the circles show interconnections between these three elements. The three elements do not operate in isolation, the process applied will influence the type of information and tools identified as necessary to conduct assessments; just as the information and tools identified as necessary to conduct assessments will influence the type of process applied to develop them. The framework (the white oval) is shown encompassing information and tools only.

No single research approach was thought to be able to cover the depth and breadth of analysis required to capture the drivers underpinning methodologies developed in different contexts. As well, it was thought using a mix of different research approaches would strengthen and challenge each other and therefore generate greater rigour and robustness of conclusions. Section 3.2 describes the three pronged research approach that was therefore applied. In Figure 3.1, highlighted in dark grey is the ‘document and literature review’ approach which includes the review of the MA and other methodologies. The ‘applied research’ approach in South East Queensland (SEQ, Australia) is highlighted in light grey; and ‘multiple case study analysis’ was conducted in the United States (US) and the United Kingdom (UK) and these are presented in medium grey. Sections 3.2.1, 3.2.2 and 3.2.3 describe each of these approaches respectively. As shown in Figure 3.1 each Line of Enquiry was investigated in the SEQ, US and UK programs.

Section 3.3 of this chapter focuses on how outcomes are synthesised across methodologies, research approaches and Lines of Enquiry. Where the outcomes of the three Lines of Enquiry for the SEQ, US and UK programs are discussed in separate sub-sections of Chapters 4, 5 and 6, the comparing and contrasting of these methodologies and other schools of thought is conducted in Chapter 7. Chapter 7 provides a synthesis of these outcomes into a set of Recommendations for determining an appropriate methodology to adapt, adopt or develop. The following section describes the three Lines of Enquiry in detail.

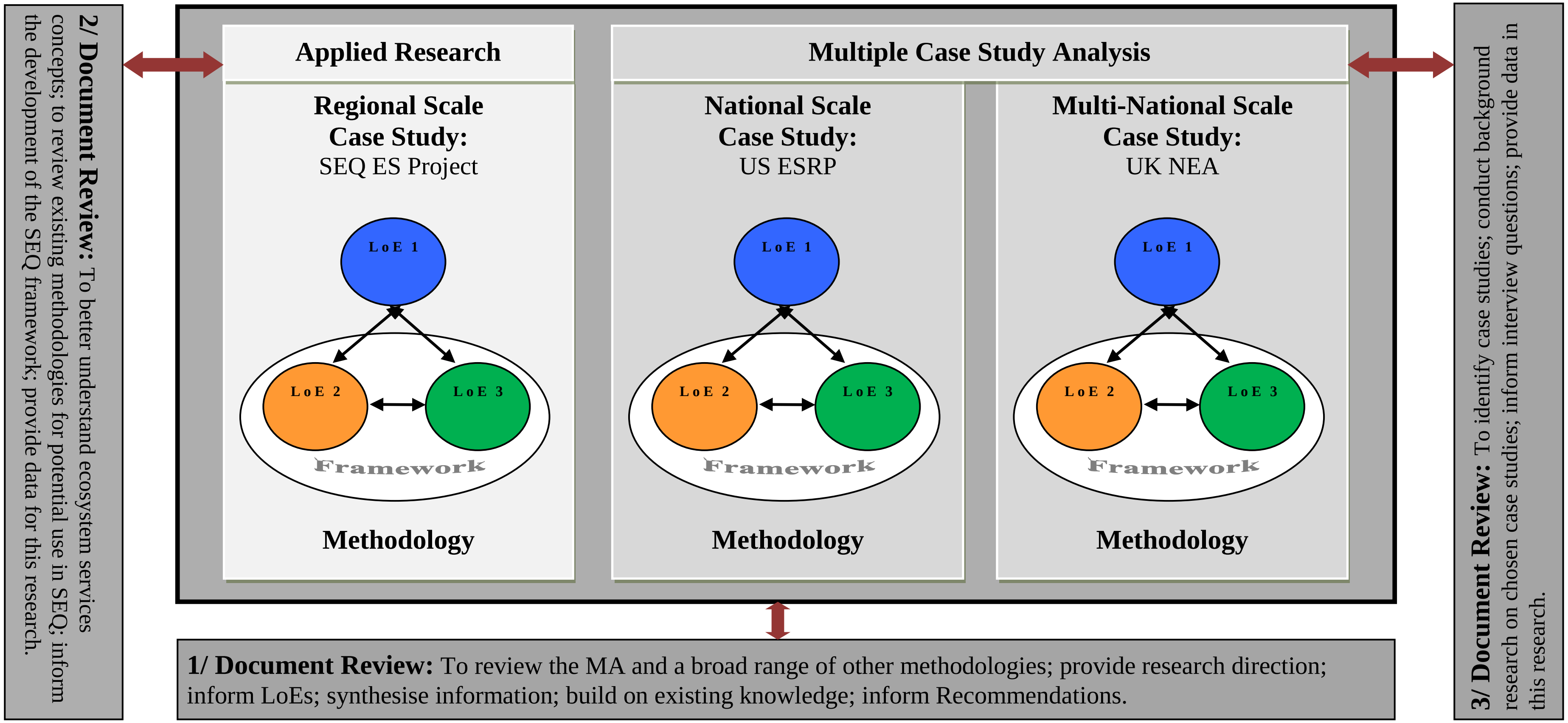

Figure 3.1: The research design. The three Lines of Enquiry (LoE) into methodologies are highlighted as blue, orange and green circles. Black arrows represent interactions across LoE. The three pronged approach is highlighted as follows: the three ways document reviews input to this research are in dark grey (Chapters 1 and 2); the applied research in the SEQ region is in medium grey (Chapter 4); and the multiple case study analysis into the US national and UK multi-national programs is in light grey (Chapters 5 and 6).

3.1 Three Lines of Enquiry

The aim of this research is to provide a set of Recommendations for researchers to consider when determining *an appropriate methodology to enable ecosystem services assessments across multiple scales.* To conduct ecosystem services assessments both information an tools are required to identify, measure and value them. However, information and tools do not materialise so a process (or method) of collecting or developing them is required. For the purpose of this research, a *methodology* is therefore said to consist of *information* and *tools* which together form a framework that when applied ecosystem services assessments can be conducted and communicated; and a *process* (the series of actions required) to develop the framework as well. To break this research into more tractable components these elements of a methodology were developed into three Lines of Enquiry.

As mentioned previously these Lines of Enquiry are shown in Figure 3.1 as coloured circles labelled LoE 1, LoE 2 and LoE 3. A white oval encompasses LoE 2 and LoE 3 as the information and tools together support a framework. To provide a more pointed direction of research for each Line of Enquiry a sub-question to the overarching research question was developed. The three Lines of Enquiry and their research questions are:

- **Line of Enquiry 1: Process (blue circle)**
  What is an appropriate process to develop a framework for ecosystem services assessments across multiple scales?

- **Line of Enquiry 2 - Information (orange circle)**
  What information is required to support a framework for ecosystem services assessments across multiple scales?

- **Line of Enquiry 3 - Decision Support Tools (tools) (green circle)**
  What tools are required to support a framework for ecosystem services assessments across multiple scales?

These Lines of Enquiry are discussed in Sections 3.1.1, 3.1.2 and 3.1.3 respectively. To answer these questions whilst ensuring this research builds on an existing body of knowledge, common threads and gaps in knowledge as determined from the documents reviewed (Chapters 1 and 2) have formed ‘key topics’ for further analysis. Chapters 4, 5 and 6 discuss the outcomes of applying the three Lines of Enquiry and researching the key topics in the SEQ, US and UK methodologies. Section 3.2 describes how the SEQ, US and UK methodologies are analysed through the other two research approaches (applied research and multiple case study analysis); and how methods to extract information and data through the Lines of Enquiry were different for each research approach. The following section is the first of three describing each of the Lines of Enquiry.

3.1.1 Line of Enquiry 1: the process to develop a framework

This Line of Enquiry (LoE 1) extends research beyond just describing *processes* (the series of actions) applied to develop information and tools for ecosystem services assessments (frameworks). It analyses methodologies developed in different contexts (including different scales) to determine the drivers directly influencing and shaping the adoption of different processes; and how these drivers and resulting processes influence and shape the frameworks (information and tools) developed. By identifying these drivers and understanding why certain processes were applied (or not), and using this to reflect on our research and decision making context, we can learn from others experiences and make more objective decisions when determining *an appropriate process to develop a framework for ecosystem services assessments across multiple scales.* The literature revealed four key topics requiring further analysis to answer this question, they include:

- factors underpinning a program’s initiation;
- who coordinated the program;
- resources (e.g. time, money, expertise) invested in developing the framework; and
- the structure of program.

Factors underpinning the initiation of programs can be one or many. The primary factor underpinning the initiation of the MA was realisation by scientists and national governments that current mechanisms for scientific assessments where not halting the loss of biodiversity and reducing land degradation globally; therefore, not meeting the needs of the four major ecosystem-related conventions (MA 2005a; Reid et al. 2006a;

Ash et al. 2010). The need, however, to better include the environment in economic decisions and the MA’s lack of economic analysis encouraged Ministers of the G8 +5 to use the MA as the foundation to build a new framework under TEEB (2010). Similarly, underpinning the initiation of SEEA (UNSD 2012) and Boyd and Banzhaf’s (2007) research was the recognition of traditional economic accounting methods not adequately accounting for ecosystem degradation and environmental inputs to economic goods; a more comprehensive measurement of human welfare to ensure more effective and efficient national natural resource policy making was considered necessary.

Maynard and Cork (2011) showed that at local to regional scales in Australia factors underpinning the initiation of programs were more directly related to communities and on-ground NRM activities. Mostly they had an agricultural focus, focusing on ecosystem services inputting into production processes or other ecosystem services derived from agricultural landscapes that contribute to the broader community’s well-being (Binning et al. 2001; Reid et al. 2006b; Bennett et al. 2010). However, the primary factor leading to the initiation of the SEQ program was the release of the MA and awareness of the potential of ecosystem services approaches to better understand the impact of excessive population growth on the natural resources of the region (Maynard et al. 2010). Due to this variance in factors leading to the initiation of programs, further analysis into the impact they have on framework development is required.

In the methodologies reviewed, the missions and mandates of most *organisations coordinating the development of the framework* have an ‘environmental’ focus, yet the coordinating sectors from which they belong are widely varied. UNEP who is the leading global environmental authority coordinated the collection and development of information supporting the MA (2005a). Maynard and Cork’s (2011) paper describing Australian local to regional scale programs identified frameworks developed by federal scientific organisations (Binning et al. 2001); private environmental consultants (Bennett et al. 2010); individuals from state government environmental departments (Wallace 2007); university researchers from environmental departments (Reid et al. 2006b); and non-government NRM organisations (Maynard et al. 2010). The differences across information and tools supporting these frameworks suggest organisational context as a topic for further analysis.

Although a number of programs openly disclosed the *resources* invested in developing their framework (MA 2005a; Maynard et al. 2010, 2015), in the literature, overall this information is rarely disclosed especially for smaller scale programs. The MA (2005a) global methodology which was built on existing information operated over a four year period and cost approximately US$24 million, but it also required more than US$7 million of in-kind support. The regional scale methodology described in Maynard et al. (2010) said the lack of resources available to develop their framework was prohibitive to developing dynamic models or to train in model development and application. Further research to better understand the influence available resources (e.g. time, money, knowledge, skill (both pro-bono and paid)) have on developing a framework is required as it is important to understanding possible returns on investment, determining the design of a program, and the technical realities of what type of information and tools can be achieved.

In the literature reviewed, authors primarily focused on describing the information and tools developed through their program, or outcomes of applying information and tools to conduct assessments (De Groot 2006; Boyd and Banzhaf 2007; Fisher and Turner 2008; Morrison and Hatton-MacDonald 2010; Johnston and Russell 2011; UNSD 2012; Landers and Nahlik 2013). Few papers provided any information on the *structure of the program* in terms of how the framework or schools of thought were formed and who was involved in its development. From those that did, processes ranged from in-house approaches (Wallace 2007; Ott and Staub 2009; Staub et al. 2011; Plant et al. 2012) to highly participatory and collaborative approaches such as the MA (Binning et al. 2001; MA 2005a; Australian Government 2009; Maynard et al. 2010; TEEB 2010). Only Maynard et al. (2010, 2012) describe the structure of their program in as much depth as the MA (2005a). Further analysis of program structures is necessary to address this gap in the literature and better understand why different structures were chosen and the influence of these on framework development.

The outcomes of the applied research in SEQ (Chapter 4) and case study analysis in the US (Chapter 5) and UK (Chapter 6) will build on knowledge gained from reviewing this literature describing others experiences in developing ecosystem services frameworks. The outcomes from applying this Line of Enquiry to the SEQ, US and UK programs are discussed in Sections 4.1, 5.1 and 6.1 respectively. Each section is broken into four sub-sections providing outcomes of the analysis into each of the identified key topics: the factors underpinning program initiation; the coordinating organisation; resources invested in developing frameworks; and the structure of programs. Section 7.1 presents the lessons learnt from cross-analysing methodologies and research approaches, and from this, provides Recommendations for determining an appropriate process to develop a framework. Lines of Enquiry 2 and 3 are discussed in the following two sections of this chapter.

3.1.2 Line of Enquiry 2: the information to support a framework

Similar to Line of Enquiry 1 described in Section 3.1.1, Line of Enquiry 2 (LoE 2) delves beyond the literature describing the *information* included in frameworks. It analyses methodologies developed in different contexts (including different scales) to determine the drivers directly influencing and shaping the adoption of different types of information; and any interconnections between the information required and the other two elements of a methodology. By identifying these drivers and understanding why certain information was included (or not), we can learn from others experiences and better determine *what information is required to support a framework for ecosystem services assessments across multiple scales?* The literature revealed five key topics requiring further analysis under this Line of Enquiry, they include:

- the position of biodiversity in frameworks;
- assessment units;
- ecological processes;
- ecosystem services; and
- methods for valuing ecosystem services.

The documents reviewed revealed an inconsistency in the priority given to *biodiversity,* its role in providing ecosystem services, and its position within different frameworks; hence the choice of biodiversity becoming another key topic for analysis. These different priorities and positions result in inconsistencies in how biodiversity and ecosystem services are assessed using the frameworks. In both Figure 1.1 showing the MA's schematic of the ecosystem services concept and Figure 2.2 showing the MA's conceptual framework biodiversity (as defined by the CBD) is shown as underpinning all life on Earth and the provision of ecosystem services.

The TEEB (2010a) framework also recognises biodiversity as underpinning the provision of ecosystem services and this position is presented clearly in its conceptual framework (Figure 2.3). In frameworks developed primarily for national accounting systems, however, little if any attention is given to biodiversity's role (Otts and Staub 2009; Haines-Young and Potschin 2010a; Staub et al. 2011; UNSD 2012). Balmford and Bond (2005) suggest the term biodiversity is not adequate for ecosystem services assessments as it does not give attention to the amount of living organisms and only to its diversity. According to Kremen (2005) few assessments give adequate attention to the role biodiversity plays in the delivery of ecosystem services.

The *units* for *assessing* ecosystem services using the MA global scale framework are the 10 Reporting Categories listed in Box 2.1. The MA (2005a, p. 53) states they use overlapping categories 'because this better reflects real-world biological, social and geophysical interactions, particularly at these relatively large scales'. TEEB (2010), another global scale program, uses biomes as their assessment units. The MA Reporting Categories and TEEB biomes were too broad for smaller scale assessments so each Reporting Category and biome contains a number of more defined ecosystems better suited to the scale of sub-global assessments. In the MA (2005a, p. 53) ecosystems were grouped under each Reporting Category by similarities in: 'climatic conditions, geophysical condition, dominant use by humans, surface cover, species composition, resource management systems and institutions'. The size and location of ecosystems are secondary to these criteria in the MA's systems analysis.

Whilst the MA (2005a) recognises the importance of assessing and reporting on the full range of ecosystems in the area under assessment, other researchers dismiss the use of ecosystems as assessment and reporting units opting for alternatives such resource governance regions (Meyerson et al. 2005), the scale of service delivery (Brunckhorst et al. 2006), and place-based units (Potschin and Haines-Young 2013). As noted in Chapter 2, authors say these units better capture the spatial explicitness of ecosystem service provision and value; and their context as a coupled human and nature system (Meyerson et al. 2005; Brunckhorst et al. 2006; Potschin and Haines-Young 2013). The literature revealed no agreement across researchers as to the appropriate spatial unit to assess ecosystem services so this is a key topic for further analysis.

Energy flows, water and nutrient (biogeochemical) cycling, and community dynamics are fundamental *ecological processes* that support life on Earth (TEEB 2010). The most recent literature discussing ecological processes uses the term interchangeably with ecosystem functions, intermediate services and supporting services (MA 2005a; Wallace 2007; Haines-Young and Potschin 2010b; Maynard et al. 2010; UK NEA 2011b). Haines-Young and Potschin (2010a, p. 7) who developed CICES and the underpinning ‘cascade model’ shown as Figure 2.4 say, ‘it is important to distinguish between ecosystem structure, process and function … it is important to distinguish between ecosystem functions and services’. Balmford and Bond (2005) and Nichols et al. (2008) support Haines-Young and Potschin’s (2010a) suggestion that to predict environmental impacts a clear understanding of ecosystem functions is required.

As mentioned previously, the MA framework categorises ecosystem services along functional lines but provides little detail on the links between biodiversity, ecosystem functioning and the provision of ecosystem services (MA 2005a). Since the MA, to better incorporate information on ecological processes in applications of the ecosystem services concept, the function analysis developed by de Groot (2002, 2006) has been widely used (Maynard et al. 2010; TEEB 2010). The attention given to ecological processes in frameworks is highlighted as a key topic for further analysis. The interchangeable use of terms and concepts provides reason to assess ecological processes, ecosystem functions, intermediate services and supporting services together in this research.

The literature revealed the definition, classification and categorisation of *ecosystem services* as an important topic for further research. The MA’s ecosystem services definition has been criticised for its potential to double count if used in economic valuations. In Australia, Maynard and Cork (2011) say that since 2005 there was a strong tendency to use the MA definition but more recent studies use that included in TEEB (2010) or the UK NEA (2011b). The definitions in TEEB (2010), UK NEA (2011b), SEEA (UNSD 2012), CICES (Haines-Young and Potschin 2010a) and others have built on new schools of thought on the classification of ecosystem services, specifically the concept of Final Ecosystem Services (FES) used by Boyd and Banzhaf (2007) and Fisher and Turner (2008).

Inconsistency is not only evident in the definition and classification of ecosystems services but also in the type and number of services being assessed. Using various definitions and categorisations the methodologies reviewed included from 11 to 28 ecosystem services. In the MA framework 24 Provisioning, Regulating and Cultural Services are identified and seven Supporting Services. Cork (2002b), MA (2005a) and Costanza et al. (2011) say the full range of ecosystem services need to be assessed to make ethical and informed decisions and to 'prevent creating dysfunctional incentives and to maximise net benefits to society' (Costanza 2011, p. 2).

The MA (2005a, p. 37) continues, 'just as it is not enough to examine a single ecosystem service in isolation from its interaction with other services, so too it is insufficient to focus on only a single attribute of human well-being'. *Determining the value of ecosystems services* and to whom they provide value presents significant challenges to researchers. Often this value is determined by people's perceptions and people often have limited knowledge on how underlining ecological processes are providing them benefits (MA 2005a). Further challenges exist due to the intrinsic value that some people ascribe to ecosystems and the challenge of measuring values associated with non-marketed ecosystem services (Heal 2000; MA 2005a; Costanza et al. 2007). The MA purposely did not focus on the economics of ecosystem change, but on the human well-being dimensions of service provision (MA 2005a; TEEB 2010). In Figure 1.1 arrows between categories of ecosystem services and COWB show the intensity of linkages between the two and the potential for mediation by socio-economic factors (e.g. markets, access and transportation to areas providing services, education).

The proposed need to conduct economic analysis and the inability of the MA framework to do this robustly were major factors underpinning many other schools of thought such as Boyd and Banzhaf (2007), Wallace (2007), EPA (2008), Fisher and Turner (2008), Morrison and Hatton-MacDonald (2010), Johnston and Russell (2011), Staub et al. (2011), UK NEA (2011b) and Landers and Nahlik (2013). Although the literature discussing the need for economic analysis is extensive many local to regional scale frameworks (such as those in Australia) still preferred valuation through well-being and non-monetary approaches (Wallace 2007; Maynard et al. 2010). The inconsistency of approaches to valuing ecosystem services and the gap between paradigms of thinking on well-being and monetary valuations warrants this topic as an area for further analysis.

The applied research in SEQ and multiple-case study analysis in the US and UK are designed to learn from others experience in developing information to support ecosystem services frameworks. Outcomes of applying this Line of Enquiry to the SEQ, US and UK programs are discussed in Sections 4.2, 5.2 and 6.2 respectively. Relevant sub-sections describe the role of biodiversity in assessments and its position in the frameworks; the assessment units; ecological processes; ecosystem services; and the valuation approaches applied under these programs. Section 7.2 presents the lessons learnt from cross-analysing methodologies and research approaches, and from this, provides Recommendations for determining appropriate information to develop a framework. The Line of Enquiry into decision support tools is discussed next.

3.1.3 Line of Enquiry 3: the tools to support a framework

The US National Research Council (2009, p. 34) says at the core of effective decision support is ‘making scientific knowledge useful for practical decision making’. Nowadays there is limited distinction between what a tool is to ‘communicate’ ecosystem services and what a tool is to ‘assess’ ecosystem services due to advance digital technology and social media. In this research the term *decision support tools* (tools) is therefore used very broadly to include any significantly tangible product developed through a program to coordinate, document and distribute knowledge; assess, monitor and evaluate changes in ecosystems and ecosystem services; peer review information and tools produced; describe the program; report on how objectives and obligations of the program have been met; and to provide users access to the information and tools (the framework) developed.

Similar to the Lines of Enquiry into processes and information Line of Enquiry 3 (LoE 3) looks beyond what is documented in the literature on tools and analyses drivers influencing and shaping their adoption; and any interconnections between the process of developing frameworks and the information included in them. Through this deepened understanding of the choices made to adopt or develop certain tools (or not), we can better determine without supposition *the tools required to support a framework for ecosystem services assessments across multiple scales*. From the literature reviewed in Chapters 1 and 2 four key topics relating to tools were identified for further analysis:

- conceptual frameworks;
- maps and dynamic models;
- scenarios; and
- websites and technical reports.

The MA (2005a, p. 34) states ‘given the complex interactions between ecosystems and human well-being, a prerequisite for both analysis and action is agreement on a basic *conceptual framework*’. The MA’s conceptual framework shown as Figure 2.2 builds on the commonly used DPSIR framework by including feedback loops and assessments across multiple temporal and spatial scales (Ash et al. 2010). No reference is made to temporal and spatial scales in Figure 2.3 and Figure 2.4 presenting the conceptual frameworks of TEEB (2010) and CICES (Haines-Young and Potschin 2010a). Biodiversity, a key feature of the MA (2005a) and TEEB (2010) conceptual frameworks, is also not explicitly incorporated in CICES. Many other schools of thought did not make use of a conceptual framework at all. Requiring further research is the varied importance given to conceptual frameworks across programs and the lack of agreement on what the conceptualisation should represent.

The use of *scenarios* as a tool ‘to explore possibilities for the future that cannot be predicted by extrapolation of past and current trends’ is becoming more common in ecosystem services assessments (IPCC 2000; MA 2005c, p. 225). From the documents reviewed scenario use was most prominent at the global scale. The MA (2005c) ran four scenarios focusing on global cooperation, the breakdown of global cooperation, balancing different forms of capital, and working with nature. The IPCC used scenarios to describe consistently the relationships between demographic, economic and technological forces driving future greenhouse gas and sulphur emissions and their evolution (IPCC 2000). In Maynard and Cork‘s (2011) review of local to regional scale ecosystem services programs in Australia, Binning et al. (2001) was the only program that used scenarios. As the benefits of scenario use at different scales is not well demonstrated, the use of scenarios is identified for further research.

The literature shows both *maps* and *dynamic models* have been used to: identify, measure and value ecosystems and ecosystem services in terms of human well-being (Troy and Wilson 2006; Maynard et al. 2010; Petter et al. 2012; Crossman et al. 2013; European Union 2013; Vila et al. 2014); the changes in ecosystems and trends in ecosystem service provision (MA 2005a; UK NEA 2011b); and the environmental, social and economic implications of trade-offs in terms of the distribution of the costs and benefits derived from ecosystem service use (Binning et al. 2001; Troy and Wilson 2006; Raymond et al. 2009; Segan et al. 2011; Sherrouse et al. 2011; Vogl et al. 2013; Sharp et al. 2014). Maps aim to improve knowledge and assist decision making by constructing and coordinating information into a simplified visual form. The primary data used in the MA for identifying the extent and condition of ecosystems were maps derived from remote sensing and GIS, primarily satellite imagery ranging from 10m – 8km resolution (MA 2005a).

In the Australian studies reviewed, maps were used by all local to regional scale programs except Wallace (2007) whose primary focus was on the development of a classification for ecosystem services (Maynard and Cork 2011). In contrast, although there is now a large range of spatially dynamic models available for use none of the local to regional scale programs in Australia used these as a tool. The MA (2005e, p. 48) states 'dynamic models are required to describe interactions among components of the system' (i.e. biodiversity, ecosystem services and human well-being)' and 'examine assumptions and responses to driving forces'. Bagstad et al. (2013) and Crossman et al. (2013) confirm there is an inconsistent use of maps and models to assess ecosystem services globally. The inclusion of maps and dynamic models in ecosystem services frameworks is further researched under this Line of Enquiry.

Stages of the MA's framework development, details of the program, and outcomes of assessments were primarily recorded on w*ebsites* and in *reports*. Five technical reports (book volumes) each ranging from 399 pages to 918 pages were developed. TEEB also produced a large technical book describing their methodology (TEEB 2010). Synthesis and summary publications were produced for both programs (MA 2005f; TEEB 2009). The MA and TEEB and most other large scale programs (e.g. CICES and SEEA) made high use of a website to house information and tools. In contrast, at local to regional scales in Australia documentation of the framework and the program was primarily through fact sheets, conference proceedings, project reports and journal articles. Only one program had a dedicated website at the time of writing Maynard and Cork (2011); and no programs produced large technical reports or books. The variance in stakeholder access to information on programs through websites and reports requires further research.

This completes the document review into processes, information and tools underpinning methodologies for ecosystem services assessments. The three Lines of Enquiry, sub-questions and key topics are used to maintain focus and structure in the rest of this research whilst addressing the central research question; and ensure this research builds on an existing body of knowledge on ecosystem services assessment methodologies. For a more in-depth analysis of methodologies beyond that reported in literature three programs developing frameworks (i.e. SEQ, US and the UK) are analysed in the following chapters. The approach to analysing these methodologies beyond the use of document reviews is the topic of the following section.

3.2 Three pronged research approach

Chapters 1 and 2 showed the many methodologies developed to date have been designed for different users and applications at different scales. This suggests methodologies pertaining to one context may not be relevant to others. To determine *an appropriate methodology for ecosystem services assessments across multiple scales* it was evident an analysis of multiple methodologies would be required. No single research approach was thought to be able to provide the required breadth and depth of methodological analysis however, so a three pronged research approach was applied. The overall research design was presented as Figure 3.1. Along with the three Lines of Enquiry shown as coloured circles (and discussed in Section 3.1), the three pronged research approach is presented in this figure as:

1. **Document reviews (dark grey box)**
   - focusing on the MA methodology and other schools of thought since its release.

2. **Applied research (light grey boxes)**
   - at the regional scale in SEQ, Australia.

3. **Multiple case study analysis (medium grey box)**
   - at the national in the US and multi-national scales in the UK

This triangulated approach to research aims to address the limitations of individual approaches and strengthen the overall outcomes. For example, the applied research has a unique ability to provide insight into potential problems that might arise in developing a framework in a ‘real world’ policy and planning environment (Denscombe 2003). However, due to time and resources only one methodology could be analysed under this approach; and by playing dual roles of Project Manager and researcher I inevitably played an influencing role under this approach. Multiple case study analysis was therefore applied to explore in-depth contextual nuances underpinning other methodologies developed without my influence (Sarantakos 2005). Document reviews provide a far less obtrusive and reactive approach to data extraction and collection than applied research and case study analysis therefore reduces researcher bias. Document reviews also enabled a wider range and scope of methodologies to be analysed and provided the opportunity to study past programs (Sarantakos 2005).

The three Lines of Enquiry analysed through the three approaches produced large volumes of information in a non-standardised format that required synthesising. Sections 3.2.1, 3.2.2 and 3.2.3 describe the different research approaches used to analyse methodologies using the Lines of Enquiry. As described in Section 3.1 the three Lines of Enquiry, sub-questions and key topics helped break the research effort into tractable components. In Section 3.3 details are provided on how the research is brought together and synthesised across Lines of Enquiry and approaches. Beginning with the first of the three approaches, the role of the document reviews in this research is discussed next.

3.2.1 Document review

The *documents and literature reviewed* in this research (here on termed ‘documents’) were primarily developed by writers and researchers other than myself. Thus the information and data collected, produced and reported on in these documents was not influenced by my research approach; and my review of documents and collecting of information had no effect on the final findings of that research. As stated previously these qualities have added advantages of reducing potential researcher bias that may be evident in other approaches and methods of collecting data (such as applied research and interviews conducted during case study analysis) (Sarantakos 2005).

Information obtained from the review of documents was used as data and input into this research in three primary ways and these are described in more detail in this section. As highlighted in dark grey in Figure 3.1, these three ways are correlated with the major case studies analysed in this research. Table 3.1 lists the primary documents developed as products of these programs that have been used as data for this PhD research; the MA documents are listed first then those developed by the SEQ, US and UK programs. As Chapter 1 stated, the documents listed for SEQ are those that I (co-) authored whilst working as Project Manager for the SEQ project. Full references for all these articles are provided in the References section at the end of this thesis. It is important to note that in this research where information is directly quoted from documents single quotation marks are used, rather than double quotation marks which are used when quotes are obtained from US and UK Leads through interviews.

Table 3.1: Key documents developed under the MA, SEQ, US and UK programs that provided data for this research.

Program	Primary Documents
Millennium Ecosystem Assessment	- Millennium Ecosystem Assessment: Ecosystems and Human Well-being – A Framework for Assessment (MA 2005a). - Millennium Ecosystem Assessment official website: Overview of the Milliennium Ecosystem Assessment (MA 2005b). - Millennium Ecosystem Assessment: Ecosystems and Human Well-being - Scenarios; Findings of the Scenarios Working Group (MA 2005c). - Millennium Ecosystem Assessment: Ecosystems and Human Well-being - Multi-scale Assessments; Findings of the Sub-global Assessments Working Group (MA 2005d).
SEQ Ecosystem Services Project	- The development of an ecosystem services framework for South East Queensland (Australia) (Maynard et al. 2010). - An adaptive participatory approach for developing an ecosystem services framework for South East Queensland, Australia (Maynard et al. 2012). - A methodology to map ecosystem functions to support ecosystem services assessments (Petter et al. 2012). - Determining the value of multiple ecosystem services in terms of community wellbeing: Who should be the valuing agent? (Maynard et al. 2015). - SEQ Ecosystem Services Framework official website (SEQ Catchments 2012).
US Ecosystem Services Research Program	- Ecological Research Program Multi-Year Plan 2008-2014 (EPA 2008). - ESRP Lexicon (EPA 2010b). - ESRP Modelling Plan (EPA 2011e). - US EPA - ESRP intranet (unreferenced).
UK National Ecosystem Assessment	- UK National Ecosystem Assessment: Synthesis Report (UK NEA 2011a). - UK National Ecosystem Assessment: Technical Report (UK NEA 2011b).

The first way documents input into this research was to ensure it drew on, and built on, an existing body of knowledge (Sarantakos 2005). Chapters 1 and 2 discussed (some of) the literature this research drew on. It entailed an in-depth review of the MA methodology and a broad review of a wide range of other methodologies and schools of thought developed since the MA’s release in 2005. The previous section describing the three lines of Enquiry synthesised this literature and highlighted similarities, differences and inconsistencies in methodologies. Yin (2009, p. 14) describes document reviews as a 'means to an end’; the purpose being to develop 'sharper and more insightful questions about the topic' rather than to specifically determine answers. Similarities, inconsistencies and gaps in knowledge were used to identify sub-questions and key topics requiring further analysis in this research.

The second way documents were used is specifically related to the SEQ methodology and the applied research (Section 3.2.2). Documents provided the background information and a broader frame of reference for this research and the SEQ program (which is introduced in Section 3.2.3.1). For example, it was important to familiarise myself with the context (e.g. geography, biodiversity, policies, social structures) under which the SEQ program, methodology and therefore this research was to be developed. The review of NRM, policy and planning documents relevant to the SEQ region was fundamental to both my roles as researcher and Project Manager.

As Project Manager I was required to review documents and interpret and translate best practice ecosystem services science to stakeholders. The schools of thought most widely accepted by SEQ stakeholders and that influenced the technical elements of the SEQ program were those written by the MA and de Groot. I recognise my understanding of concepts and any biases could influence stakeholder decisions to adopt certain elements of other research in the SEQ methodology. As well, a level of bias may have occurred during the interpreting, translating and recording of stakeholder input and outcomes into documents. Care was taken to minimise these biases and accurately record outcomes of the program by engaging stakeholders in (co)authoring documents or reviewing documents I produced. Beyond the documents I (co-)authored and listed in Table 3.1 on the SEQ project I also developed user manuals, planning documents and stakeholder reports. The primary documents I co-developed and used as data in this research are referenced extensively in Chapter 4 describing the SEQ Experience.

The third way as shown in Figure 3.1 that documents contributed to this research is to the multiple case study analysis (Section 3.2.3). Documents were used to identify appropriate case studies, of which one national scale program was chosen in the US and one multi-national scale program was chosen in the UK. Documents provided background information on the chosen programs and helped familiarise myself with the context under which these programs operated before conducting interviews with program Leads. Relevant questions for each Line of Enquiry (Appendix 2) were developed where information gaps were identified in the literature or where further clarification was required. The US and UK programs are introduced in Sections 3.2.3.1 and 3.2.3.2. The primary documents developed under these programs and used as data in this research are referenced extensively in Chapters 5 and 6 analysing the US and UK methodologies.

As can be seen published and peer reviewed documents such as journal articles and books played an important role in this research. But numerous forms of unpublished documentation containing no form of peer review, grey literature, was also reviewed. Grey literature included factsheets, websites, government reports, conference proceedings, internal organisational reports and presentations. Although the reliability and credibility of some documents can be questionable, grey literature was important for accessing the most up-to-date information on programs. Historical material pertaining to the process applied and the context under which methodologies were developed are also more likely to be found in grey literature. For many organisations academic publishing is not a priority and therefore much information on ecosystem services remains unrecorded in peer reviewed papers.

The sub-questions and key topics derived from the literature for each line of Enquiry were used to break down the analysis of the SEQ, US and UK methodologies. The aim is to understand why different aspects of the methodologies were applied over others. Insufficient information in the literature on these key topics provided rationale for pursuing this research through additional approaches, such as applied research and the multiple case study analysis. Outcomes from the wide range of literature reviewed were compared and contrasted to outcomes obtained through the applied research and document review. The second approach, applied research, to collecting data and information is discussed next.

3.2.2 Applied research

According to Sarantakos (2005, p. 10) *applied research* places strong emphasis on 'application' and 'problem solving' in real world situations. Applied research was therefore chosen to capture and create an understanding of the constraints and opportunities that might arise in developing methodologies in everyday practice. To employ this approach, Figure 3.1 shows the applied research (light grey box) conducted through the South East Queensland (SEQ) Ecosystem Services Project as part of the NRM, policy and planning procedures in the SEQ region (Australia).

From 2009 to 2013 I played dual roles of PhD researcher and Project Manager. I designed and facilitated workshops, meetings and expert panels; interacting with stakeholders to develop a regional scale ecosystem services framework. Participants involved in the SEQ project were at all stages, in meetings, workshops and expert panels, informed of the relationship between the project and my personal research. Confidentiality was ensured and care was taken to manage discourse across knowledge types, disciplines, and social and professional structures. At all stages participants were able to end their participation in the research and project without question and for whatever reason they thought necessary.

The research was conducted and the methodology was developed as part of everyday practice in a work place setting (Denscombe 2003). During the process of this research and managing the project I recorded information pertaining to the three Lines of Enquiry (Section 3.1). This approach to research meant I often had to make sense of and interpret information in terms of the meanings stakeholders brought to them. Developing, extracting, collecting or recording information to support this research was often in the form of reflections, observation field notes, conversations, maps, internal organisational documents and memos to self. A goal of this thesis is to relay the most accurate and comprehensive account of activities on which understanding and research constraints permit.

Some might suggest the dual roles of researcher and Project Manager provided an opportunity to shape the outcomes of the research towards my personal preferences. Traditional positivism however assumes there is an objective reality independent of the observer or researcher, and that given the right research methods and design one can accurately capture that reality in the outcomes (Sarantakos 2005). Triangulating outcomes of the applied research with those from document reviews and multiple case study analysis addressed limitations of this approach. Researching with stakeholders in a ‘real world’ NRM, planning and policy environment limited the potential also for my influence or bias. In an attempt to further minimise bias I tried to distance myself from everyday beliefs, to listen and remain objective or neutral.

This 'hands-on' approach to collecting information is particularly suited to small scale research (Denscombe 2003). This approach was applied at the regional scale in Australia (what defines a region in Australia is discussed in the following section). SEQ being my home region and the willingness of SEQ Catchments to support and resource this research is also an important justification for selecting SEQ for this approach. SEQ Catchments being a community-based, not-for-profit organisation, provided flexibility of research design and opportunity to adaptively manage the research. Chapter 4 describes the SEQ experience in developing a methodology. The following section provides background information on the SEQ region and the coordinating organisation.

3.2.2.1 Australia, SEQ Ecosystem Services Project

As a UN Member State Australia is signatory to many international treaties focused on the environment, peace, security and human rights, such as the four major ecosystem-related conventions: the CBD, Ramsar Convention, Convention on the Conservation of Migratory Species of Wild Animals, and the UN Convention to Combat Desertification (CBD 2013; Ramsar undated; UNEP-CMS 2013; UNCCD 2012; UN 2014b). The Environmental Protection and Biodiversity Conservation Act 1999 (the EPBC Act) is the Australian Government’s central piece of environmental legislation; it’s ‘legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places’ (Australian Government 2013c).

Law and policy development and governance occurs at the national, state and territory, and local government scales. Along with managing the EPBC Act, the national government has legislative power over taxation, defense, foreign affairs, postal and telecommunications services (Australian Government 2013b). The six states, two mainland territories and the number of island territories forming Australia[*] hold

[*] Territories are areas within Australia’s borders that are not claimed by one of the six states.

legislative power over matters that occur within their borders including the environment, police, hospitals, education, land-use planning and public transport (Australian Government 2013b). Whilst having responsibility for matters of state and local significance, states and territories must ensure they protect and manage for those of national significance as defined in the EPBC Act (Australian Government 2013b). Local governments are established by state and territory governments to take responsibility for community services such as waste collection, public recreation facilities and town planning (Australian Government 2013b).

The Queensland Government (2012), one of the six state governments, says ‘regional planning plays a key role in helping … plan for and improve the quality of life for all communities’. Within Queensland there are 14 ‘land-use planning regions’ and according to state government planning policy each region requires a statutory regional planning document ‘to foster diverse and strong economic growth; plan and prioritise infrastructure; manage impacts on the environment; and where necessary, plan for urban growth and resolve land use conflicts’ (Queensland Government 2012). The development of each of these regional plans is coordinated by the state government with various levels of stakeholder engagement. Currently, in these regions there are no regional scale institutions or agencies responsible for the development of the regional plan; or with authority to enforce, incentivise or provide penalty for stakeholder’s meeting obligations under these policies.

To better manage Australia’s natural resources in 2004 the Australian Government in conjunction with state and territory governments defined 56 ‘NRM regions’ (Australian Government 2013d). Catchments or bioregions delineate boundaries for these regions (Australian Government 2013d). Each region has an established Regional Body or Catchment Management Agency to assist with coordinating NRM activities across stakeholders in that region; and a plan to aid strategic investment in the region’s natural resources (Queensland Government 2011a; Australian Government 2013d; SEQ Catchments 2015a). The Australian Government’s 14 NRM boundaries and the Queensland Government’s 14 regional land-use planning boundaries do not consistently align in Queensland (this is common in other states of Australia too) (Queensland Government 2009; SEQ Catchments 2015a). However, the two SEQ boundaries are close enough aligned to be collectively referred to as the ‘SEQ region’ across the public domain, and therefore this research.

Figure 3.2 shows where the SEQ region is in relation to the main states and territories in Australia. The SEQ boundary encompasses 11 local governments over approximately 22 420 km^2 (Queensland Government 2012; SEQ Catchments 2013). It consists of 14 major catchments which support a wide range of ecosystems including: wetlands, grasslands, shrublands, dunes and beaches, rainforests, eucalypt forests, rivers, islands and various kinds of cultivated (e.g. tree crops and small crops) and urban ecosystems (e.g. cities and peri-urban areas) (Maynard et al. 2010; SEQ Catchments 2012, 2013; Healthy Waterways 2013). As the fastest growing metropolitan region in Australia, population growth is increasingly placing demands on its natural resources particularly in the coastal areas (Queensland Government 2009).

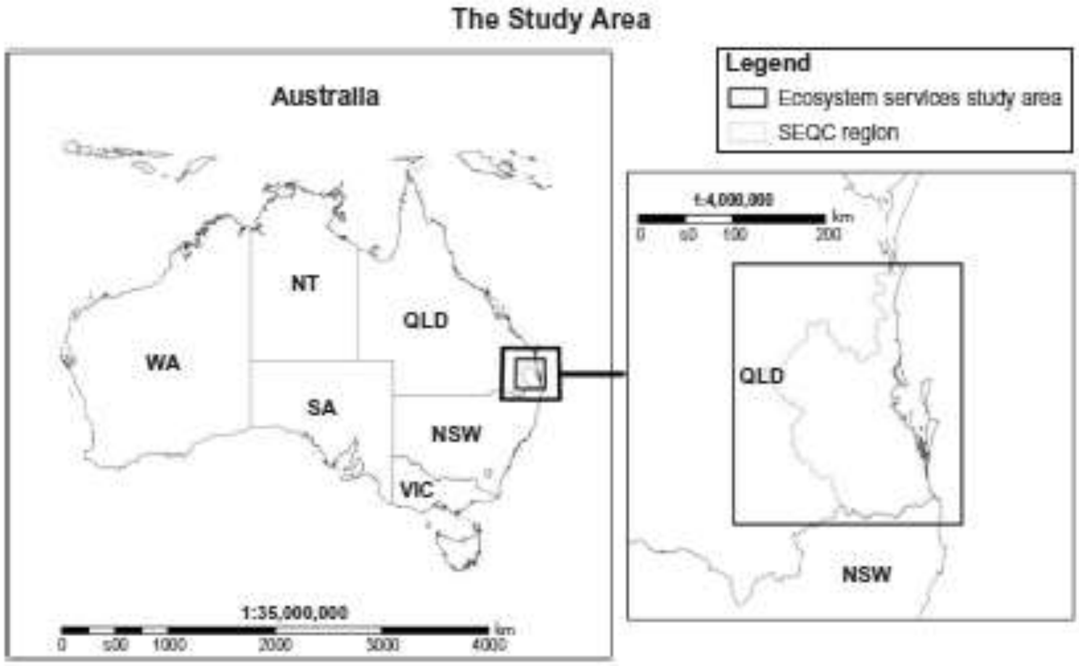

Figure 3.2: The SEQ region in relation to the main states and territories in Australia (extracted from Maynard et al. 2012, p. 2).

At the time of this research SEQ was beginning a new policy cycle with a review of the statutory regional planning document, the SEQ Regional Plan 2005–2026 (updated to the SEQ NRM Plan 2009–2031) (Maynard 2007; Queensland Government 2009). In line with the Regional Plan review, local and state governments and other stakeholders are required to review and amend accordingly their associated plans and policies ensuring their activities continue to reflect regional interests as defined in the new Plan. Consequently, the SEQ NRM Plan 2009–2031 was also in development at the time of this research (updated to the SEQ NRM Plan 2009–2031) (SEQ Catchments 2015a). Integrating ecosystem services into NRM, planning and policy was on SEQ stakeholders’ agenda at the time this research was proposed.

SEQ Catchments, one of the 56 organisations established by the Australian Government to manage the natural resources in each of the NRM regions, coordinated the project to which this research is aligned (Maynard et al. 2010; Queensland Government 2011a; Australian Government 2013d). SEQ Catchments is a non-government organisation with no regulatory or legislative mandates or powers. It is a member organisation governed by a Board of representative SEQ stakeholders (e.g. from local and state governments, business, industry, research, non-government organisations and community) (SEQ Catchments 2015a). It has large networks and working relationships with an extensive range of stakeholders across multiple geographic and jurisdictional scales (SEQ Catchments 2015a, 2015b); and from all fields of research and on-ground NRM (SEQ Catchments 2015a). SEQ Catchments’ unique position provides a basis for aligning on-ground NRM with spatial land-use planning objectives.

SEQ Catchments’ on-ground and extension programs address a broad spectrum of NRM issues. Programs include (but are not limited to): pest and weed management, water quality monitoring, biodiversity and nature conservation, coastal management, property management planning, soil science, farm forestry and community and social capacity building (SEQ Catchments 2015b). However, SEQ Catchments also plays a significant role in: local government programs for example, developing maps to support planning schemes; state government programs for example, the coordination of the SEQ NRM Plan 2009–2031, contributing to State of Region Reports and the statutory SEQ Regional Plan 2009–2031; and national scale programs such as participating in the Wentworth Group of Concerned Scientists experimental ecosystem accounts (SEQ Catchments 2015b).

Chapter 4 provides the outcomes of the applied research conducted through the SEQ Ecosystem Services Project. The outcome from Line of Enquiry 1, the process applied to develop the framework, is recorded in Section 4.1. Line of Enquiry 2 discussing the information supporting the framework and Line of Enquiry 3 on the tools developed, are discussed in Sections 4.2 and 4.3. Section 4.4 synthesises information within and across Lines of Enquiry distilling key features of the SEQ methodology. The following section describes the final approach this research applied, the multiple case study analysis conducted in the US and UK.

3.2.3 Multiple case study analysis

Situations regarding ecosystem service protection, conservation and management differ markedly across scales and purposes for many reasons including geographic, ecological, social and political. Much can be learned from previous attempts to develop frameworks and conduct ecosystem services assessments. According to Stake (2006, p. 40) the application of *multiple case study analysis* supposes the 'complex meanings of a problem are understood differently and better because of the particular activity and context of each case study'.

According to Yin (2009), case study research is an empirical enquiry best applied when the researcher has little control over actual behavioural events. As I inevitably played an integral part in the SEQ methodology analysed through applied research (Section 3.2.2), studying other methodologies outside my influence with an approach other than applied research increases breadth and depth of knowledge and reduces bias in the overall outcomes (Sarantakos 2005; Yin 2009). The documents reviewed in Chapters 1 and 2 helped inform criteria used to identify appropriate case studies for this research, which were then sourced from the World Wide Web and academic journals. The criteria include:

- The methodology must be developed in an English speaking country and recorded in English (as English is the only language I speak);
- The primary focus of the program must be national or multi-national scale (as the national scale is a pivot point between international and local scales) (WRI 2007);
- The framework should attempt to assess a large range of assessment units (e.g. ecosystems) within its boundaries (so to make ethical and informed decisions) (MA 2005a);
- The framework should attempt to assess a large range of ecosystem services derived from within its boundaries (to avoid creating dysfunctional incentives and to maximise benefits to society) (MA 2005a; Cork 2002b; Bennett et al. 2009; Costanza 2011); and

- The program must be advanced enough to be able to analyse a close to complete framework.

The search revealed a number of national and multi-national scale programs had been initiated. For example, Townsend and Thrush (2012) reported on a framework developed and outcomes of its application to coastal environments in New Zealand. Haines-Young and Potschin (2008) discussed their framework and its application to terrestrial ecosystems in England. The US Environmental Protection Agency was developing a multi-scale tool for assessments across numerous environments (EPA 2008). A 1466 page technical report describes the multi-scale assessment across all governed areas of the UK (UK NEA 2011b).

Based on the criteria dot pointed above and because they are also intrinsically interesting (i.e. they are influential nations globally), the US Ecosystem Services Research Program (ESRP) and the UK National Ecosystem Assessment (UK NEA) were selected as case studies (medium grey boxes in Figure 3.1). Two programs were chosen rather than one to provide greater diversity in contexts and methodologies; analysing three programs through this approach was beyond the resources available to this research. A comparison of two cases, however, does not provide enough information to make rigorous conclusions (Stake 2006). By capturing other's experiences in developing methodologies the multiple case study analysis aimed to build on, expand, critique and generalise on outcomes from the review of the MA methodology and other schools of thought; and the in-depth analysis of the SEQ (Australia) methodology through applied research. Howes (2005, p. xix) provides a political perspective supporting the cross-analysing of programs in Australia, the US and the UK:

> *... these countries are where many of the government responses to environmental risk were originally developed. The US has the largest environment agency in the world, led the development of environmental impact assessments and was the first to develop an online environmental pollution inventory. The UK has the oldest pollution inspectorates in the world ... and is the cradle of industrial revolution. Australia created the world's first environmental political party ... and was one of the first states to develop a NSESD. ... all have similar institutional contexts: national*

political systems based on liberal-democratic principles, legal systems built on individual rights, mixed-market economies, advanced industrial production, high standards of living, public welfare support and highly urbanised populations.

Hay (2010) says interviews are a tool for collecting a diversity of meanings, opinions and experiences; and describes how they provide a means to investigate complex behaviours and to check, verify and scrutinise a researchers own opinions and tentative conclusions. Interviews with Leads from the ESRP and the UK NEA were therefore the choice of method to extract information using this approach. Research methods such as experiments, surveys and histories were considered inappropriate for this research as in application they either divorce the methodology from its context; they are limited in their ability to investigate the context under which the methodology was developed; or they are limited in their ability to deal with contemporary issues (Denscombe 2005; Stake 2006; Yin 2009). Yin (2009, p. 4) says the methods to extract information under case study analysis 'allow investigators to retain the holistic and meaningful characteristics of real-life events'.

Interviewing (rather than surveys or mailed questionnaires) enabled depth of discussion into ‘how’, ‘what’ and ‘why’ certain types of processes, information and tools were applied or developed. A semi-formal, semi-structured technique of interviewing was preferred over a structured or unstructured approach. This technique provided direction, but still allowed a free flow of communication between myself and the Lead. This moderately formal and structured approach allowed me to direct rather than control the conversation, probing Leads for responses and allowing and encouraging further elaboration on points of interest (Denscombe 2003; Yin 2009; Hay 2010).

In the first instance, I contacted the ESRP Program Director and UK NEA Chairs requesting access to their programs for the purpose of this research. To inform their decision background information was provided on: myself, the researcher; the proposed research (including the Lines of Enquiry under which the questions would be based); the supporting university; SEQ Catchments; the SEQ program; ethics protocols including confidentiality of outcomes; a list of preferred Leads for interviewing; the dates proposed for interviews; details on how information extracted would be recorded;

and the resources required to conduct interviews (i.e. office space, telephones, internet access).

Potential interviewees were selected from the list of Leads provided on the programs' website. To ensure credibility of responses and to remain focused on extracting information to answer the central research question, the only criterion for selecting Leads was their position in the program. Only people 'leading' research in the three identified elements of a methodology (i.e. the process, information and decision support tools) were invited to participate. As each Lead interviewed was responsible for a specific area of the program no consensus across individuals was required.

The one-to-one interview approach was chosen over group interviews or focus groups so to learn from and record individual experiences. As well, in group interviews and focus groups there is potential for strong personalities to dominate discussions drowning out certain views that might be pertinent to the research. One-to-one interviewing was also considered easier to arrange than group interviews or focus groups (e.g. only two diaries required coinciding rather than many) (Denscombe 2003). Interviews were conducted face-to-face in either the home premises of the Lead; the Lead’s private office space; or in an office space provided to me by organisations who supported the programs. Organisations who supported this research included: the US Environmental Protection Agency (EPA); the Department for Environment, Food and Rural Affairs (DEFRA); the UNEP-World Conservation Monitoring Centre (UNEP-WCMC); and the James Hutton Institute. One or two interviews were conducted with each Lead depending on their availability and preference; each interview went for one to three hours.

All Leads consented to audio recording as a means of capturing their contributions. Following the interview I either transcribed the interviews personally, or where time did not permit the recordings were professionally transcribed. I cross-checked the audio recordings professionally transcribed for accuracy of words and meaningful punctuation. Transcribed interviews were emailed to Leads with an invitation to conduct a final review and provide consent for use. Responses were then input into an Excel spreadsheet and manually colour coded for similarities, differences and anomalies within and across methodologies and Lines of Enquiry.

The questions asked during the interviews were content-focused (Hay 2010). They were designed to address the sub-questions under each Line of Enquiry that together would address the central research question: *what is an appropriate methodology to enable ecosystem services assessments across multiple scales?* Appendix 2 provides the list of questions asked of Leads. A range of question types from open, closed, descriptive, storytelling, opinion based, structural and contrasting were used (Hay 2010). These questions aimed to extract details of events and the experiences of Leads in developing methodologies; and better understand any constraints, opportunities, ideologies, assumptions or experiences underpinning their choice in methodology.

From this list of questions, a sub-set of questions was adapted and compiled for each Lead prior to the interview and used as a guide during the event. Some questions were specifically related to the Lead's expertise or position in the program; some questions were specifically related to a case study; whilst others were more general and had relevance to many Leads, disciplines or both programs. An order of questioning considered important to establishing rapport with the Lead was applied. Interviews began with easy to answer questions to build confidence (e.g. on roles within the program); to those more intellectually challenging and requiring deeper consideration (e.g. determining the position of biodiversity in ecosystem service frameworks); and finalising with more general questions allowing for a comfortable closure (e.g. providing reflections on the program) (Sarantakos 2005; Hay 2010).

Unlike more structured approaches to interviewing the questions developed for each Lead were indicative only. The advantage of the semi-structured approach is the ability to be flexible in the order of questioning allowing the Lead to develop ideas and speak more widely on issues they considered important. As particularly interesting issues or topics were raised the questions were further developed or adapted. It was important to allow the Leads 'to state their answers in the way they saw appropriate, in their own way and in their own words' (Sarantakos 2005, p. 245). Probing was applied to encourage respondents to complete, amplify or expand on answers and to stimulate and guide discussions (Sarantakos 2005). As mentioned in Section 3.2.1, double quotation marks are used throughout this thesis when responses by Leads are directly quoted, as opposed to single quotation marks used for directly quoting from documents.

The main limitation to this research approach was resources in terms of time and money. In large programs such as the ESRP and the UK NEA there are many suitable and desirable people to interview. Within the realms of time and other resources it was only possible to interview a limited number of people. To retain the confidentiality of Leads no names or positions of Leads have been included in this thesis unless otherwise agreed to by the Leads. This anonymity also creates limitations on detailing case study findings and their sources. It is recognised that researcher bias can enter in the design of research questions as well as in the interpretation of Lead responses. All attempts have been made when developing and asking questions to not direct Leads responses; and in the interpretation of their responses.

Outcomes of the analysis of the US and UK methodologies are reported in Chapters 5 and 6 respectively. Responses to questions relating to Line of Enquiry 1 (the processes applied to develop the US and UK frameworks) are recorded in Sections 5.1 and 6.1. Responses to questions relating to Lines of Enquiry 2 and 3 (the information and tools developed to support the US and UK frameworks) are recorded in Sections 5.2 and 6.2, and 5.3 and 6.3. Sections 5.4 and 6.4 provide reflections on the ESRP and UK NEA by program Leads. The programs are synthesised in Sections 5.5 and 6.5. To better understand the context under which these methodologies were developed, similar to Section 3.2.2.1 on SEQ, the following sections provide background information on the chosen case studies.

3.2.3.1 US, Ecosystem Services Research Program

Like Australia, the US is a Member State to the UN and signatory to many international treaties focused on peace, security and human rights (UN 2014b). However, the US is Party to only two of the four global ecosystem-related conventions: the Ramsar Convention and the UN Convention to Combat Desertification (Ramsar undated; UNCCD 2012). The US has no legal framework specifically aimed at the protection and management of internationally important flora, fauna, ecological communities or heritage places.

There are four main levels of administrative divisions in the US: national, state, county and local government (Howes 2005). Fifty states (48 are contiguous, there is a capitol district and a number of territories), over 3000 counties and 89 000 local governments currently exist (US Census Bureau 2014). Figure 3.3 is a political map showing the states and counties of the US (local government areas are not shown due to the large number of these jurisdictions and the scale and size of the map).

The contiguous US is bounded by the Pacific and Atlantic Oceans and the Gulf of Mexico, and shares land borders with Canada and Mexico. It is one of the largest countries by area in the world. Its sheer size allows for tropical, temperate, arctic and semi-arid zones to form. The country is ecologically characterised by and most famous for its wilderness areas such as its wetlands (e.g. the Everglades), mountains (e.g. the Appalachian Mountains), grasslands (e.g. the Great Plains), plateaus and gorges (e.g. the Grand Canyon), large rivers (e.g. the Mississippi) and the largest group of freshwater lakes on Earth (e.g. the Great Lakes).

Figure 3.3: Political map of the US showing states and counties (Maps of World 2012a).

The Department of Interior (a Cabinet department) is responsible for the management and conservation of most federal land and natural resources, and the administration of programs relating to Native Americans (US Department of the Interior 2014a). It contains a number of operating units such as the Fish and Wildlife Service who is responsible for migratory birds, anadromous fish, and endangered species (US Fish and Wildlife Service 2013). Other responsibilities of the Department of the Interior include: historic preservation; surface-mined lands protection and restoration; mapping; geological, hydrological, and biological science; and financial and technical assistance for the insular areas (US Department of the Interior 2014b). Another Cabinet department, the Department of Agriculture, retains the agriculture and forestry portfolios facilitating the marketing of agricultural products; voluntary conservation agreements on private land; rural development; animal and plant health inspection services; foreign market access; and nutritional guidelines for Americans (US Department of Agriculture 2013).

In this research, the US program under analysis is the Ecosystem Services Research Program (ESRP) coordinated by the Environmental Protection Agency (EPA) (a non-Cabinet Department). The EPA has 10 regional offices across the country, each of which is responsible for several states and in some cases, territories or special environmental programs. The EPA mission is to 'protect human health and the environment' across the US (EPA 2006; EPA 2013a). It was originally established in 1970 to administer the growing body of federal environmental legislation, particularly the National Environmental Policy Act 1969 (Howes 2005). The National Environmental Policy Act contains a clause requiring federal agencies to conduct environmental impact assessments on new government projects (Howes 2005).

The EPA operates in both a regulatory capacity through the Office of Air and Radiation and the Office of Water; and on a scientific capacity through the Office of Research and Development (ORD). The ESRP is coordinated by ORD, which is charged with conducting 'research necessary to ensure the Agency's policies, programs and regulations are based on a scientifically defensible foundation' (EPA 2008, p. 1). The ESRP builds on decades of ecological and toxicological research conducted under ORD's Ecological Monitoring and Assessment Program 1990 - 2006 (EMAP) (EPA 2008).

As the EPA has the charge of interpreting and enforcing the Clean Water Act, the Clean Air Act and many environmental laws and Executive Orders related to other pollutants and aquatic ecosystems, EMAP focused its research on issues such as air quality, toxicology, water quality, human health, microbiology, nanotechnology, pesticides and toxic substances, wetlands, streams/rivers and land protection (EPA 2011a). EMAP aimed to advance the science of ecological monitoring and ecological risk assessment and guide national monitoring (EPA 2010a). Specifically, the ESRP evolved from EMAP's third Long Term Goal (EPA 2008, p. 1): 'Decision-makers understand the importance of ecosystem services and make informed, proactive management decisions that consider a range of alternative outcomes'.

Globally, the ESRP established in 2006 is the largest (by budget and staff) of all national research programs into the development and application of an ecosystem services framework. Fourteen interviews were conducted with 13 ESRP Leads between 24th June 2011 and 7th August 2011. These interviews were conducted in four locations across the US: Western Ecology Division (Corvallis, Oregon), Atlantic Ecology Division (Narragansett, Rhode Island), Gulf Ecology Division (Gulf Breeze, Florida) and the EPA's Head Office in Research Triangle Park (Durham, North Carolina). Leads interviewed included:

- the National Program Director;
- the Lead for the classification and monitoring of ecosystem services;
- the Lead for mapping ecosystem services;
- the Lead for modelling ecosystem services and three Leads working on specific models;
- the Lead for overseeing all place-based studies;
- two Leads working on different place-based studies;
- the two Leads working on well-being assessments;
- the Lead working on human health associations; and
- the Lead charged with assisting the integration of the ESRP into the next research program the Sustainable and Healthy Communities Research Program.

Chapter 5 provides outcomes of the analysis into the methodology developed under the ESRP. The process applied to develop the framework is recorded in Section 5.1. The information and tools developed as an outcome of this process are discussed in Sections 5.2 and 5.3. Reflections by Leads on the program are in Section 5.4 and a synopsis of findings is in Section 5.5. The following section provides background to the second case study analysed under the multiple case study approach, the UK NEA.

3.2.3.2 UK, National Ecosystem Assessment

The UK consists of four nations: England, Wales, North Ireland and Scotland. Similar to Australia and the US, the UK is signatory to the UN and therefore many international treaties focused on peace, security and human rights (UN 2014b). Like Australia, the UK is also Party to the four major global ecosystem-related conventions: the CBD, Ramsar Convention, Convention on the Conservation of Migratory Species of Wild Animals, and the UN Convention to Combat Desertification (UNCCD 2012; CBD 2013; Ramsar undated; UNEP-CMS 2013). As a member of the European Union (EU), another tier of governance is positioned between the global and multi-national (UK) scales.

Figure 3.4 presents a political map of the UK showing the four constituent countries and their respective capitals: London, Cardiff, Belfast and Edinburgh (Maps of World 2012b). As can be seen, the North Atlantic Ocean and the Irish Sea separate Ireland from mainland UK; the English Channel separates mainland UK from continental Europe; and the North Sea is bounded on three sides by the UK, Norway and mainland Europe. North Ireland is the only country that shares a land border with another country outside of the UK (i.e. Republic of Ireland). England being central on the main island and the largest country by size and population in the UK shares a border with Wales and Scotland.

Figure 3.4: Map of the UK and its four constituent countries (England, Wales, North Ireland and Scotland) and national capitals (London, Cardiff, Belfast and Edinburgh) (Maps of World 2012b).

Geographically, most of the UK consists of gently rolling hills; the most mountainous areas are located in Scotland and Wales. Much of the land in England is less than 1000 m above sea level forming meadowlands and pastures (Barrows 2012). Less than 10% of the area is covered by woodlands (Barrows 2012). Some of the lowland fens in the UK are at or below sea level (Barrows 2012). Similar to the US, the UK has a number of large lake systems (e.g. the Lake District in England and Loch Ness in Scotland). In contrast to the US, the UK consists of no large river systems (Barrows 2012). There are few areas in the UK that have not at some time been modified or highly dominated by humans, with agriculture playing a dominant role in the history of the UK (UK NEA 2011a).

The UK operates under a system of devolved governance in which sovereignty is constitutionally divided between a central governing authority (the British Government) and its constituent political units (England, Wales, North Ireland and Scotland. The UK's central government delegates power to these constituent units providing them a degree of autonomy. The UK Government can revoke or reduce the power provided to these countries, however, and they are limited in their ability to challenge certain acts of Parliament (UK Government 2013a).

The devolved administrations within the UK have their own national agencies conducting research, developing policies and regulating natural resources. The Department of Environment, Food and Rural Affairs (DEFRA) is the 'department responsible for policy and regulations on environmental, food and rural issues' across the UK; 'it works closely with the devolved administrations in Wales, Scotland and Northern Ireland and generally leads on negotiations in the EU and internationally' (UK Government 2013b). DEFRA is responsible for: 'the natural environment, biodiversity, plants and animals; sustainable development and the green economy; food, farming and fisheries; animal health and welfare; environmental protection and pollution control; and rural communities and issues' (UK Government 2013b).

The UK National Ecosystem Assessment (UK NEA) is the second program chosen as a case study in this research. The UK NEA is part of the Living with Environmental Change (LWEC 2011, 2014) initiative that involves '22 public sector organisations that fund, carry out and use environmental research and observations' with the aim of 'ensuring decision makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from environmental change'. The LWEC (2014) program has a broad focus such as climate mitigation; ecosystems; health and well-being; environmental observation networks; flood and coastal erosion risk management; and water research and innovation.

One of the 22 partners of the LWEC program is the Natural Environment Research Council (NERC). Established in 1965, NERC (2012) 'is the UK's main agency for funding and managing research, training and knowledge exchange in the environmental sciences'. NERC (2012) is a non-departmental public body receiving approximately £370 million of annual funding from the government's Department for Business, Innovation and Skills. NERC (2012) programs 'cover the full range of atmospheric, Earth, biological, terrestrial and aquatic sciences, from the deep oceans to the upper atmosphere and from the poles to the equator'. NERC (2012) collaborates with the other councils on issues of common concern under the banner of Research Councils UK.

The UK NEA (2011b, p. 15) was the 'first analysis of the UK's natural environment in terms of the benefits it provides to society and continuing economic prosperity'. The UK NEA is coordinated by the UNEP-World Conservation Monitoring Centre (UNEP-WCMC) from their head office in Cambridge, England. In 2000 UNEP-WCMC (2013) was established as 'a collaboration between UNEP, the world's foremost intergovernmental environmental organisation, and WCMC, a UK-based charity'. Prior to 2000, WCMC was an independent organisation jointly supported and managed by UNEP, the International Union for the Conservation of Nature (IUCN) and the World Wildlife Fund (UNEP-WCMC 2013). UNEP-WCMC is UNEP's specialist biodiversity assessment arm (UNEP 2013).

A series of interviews with 17 UK NEA Leads working on areas specifically related to the three Lines of Enquiry were conducted between 10th October 2011 and 13th November 2011. Interviews were conducted in numerous locations across the UK, such as: London, Brighton, Oxford, Norwich and Cambridge (England); Belfast (Ireland); and Aberdeen and Edinburgh (Scotland). Three leads unavailable at the time of visitation were interviewed by telephone or Skype under the same format as face-to-face interviews. Leads interviewed included:

- the two Co-Chairs;
- four government representatives from each constituent nation: England, Wales, North Ireland and Scotland;

- the three Leads working on Provisioning, Regulating and Cultural Services respectively (the Lead for Supporting Services passed away three weeks before the proposed interview);
- the Lead on biodiversity;
- the Lead for scenario development;
- the Lead economist; and
- five Leads from the coordinating organisation of UNEP-WCMC (including one Lead developing maps to support assessments).

For ease of analysis across all case studies Chapter 6 provides the outcomes of analysing the UK NEA under the same format as Chapters 4 and 5 analysing the SEQ and US case studies. The process applied to develop the framework is recorded in Section 6.1. The information and tools developed as an outcome of this process are discussed in Sections 6.2 and 6.3 respectively. Reflections by Leads on the program are in Section 6.4 and a synopsis of findings is in Section 6.5.

The following section completes this chapter on research design by describing how the Lines of Enquiry (process, information and tools) used to analyse different methodologies under the different research approaches (document reviews, applied research and multi case study analysis) are brought together and synthesised.

3.3 Synthesis across Lines of Enquiry, case studies and research approaches

Chapter 1 describes how all people on Earth are beneficiaries of ecosystem services and stakeholders to their provision; and how we all receive goods and services and impact on their provision in different ways, at different rates, in different magnitudes and at different (temporal and spatial) scales. To support this claim, it also listed a wide variety of institutional contexts across a nation in which policy and management decisions are made involving natural resources. As Chapter 1 discussed, underpinning this research is the premise that to manage natural resources sustainably we need to mainstream ecosystem services into decision making; and to do this a framework providing information and tools to assist stakeholders in assessing ecosystem services and solving or addressing complex socio-ecological issues is required (MA 2005a; Reid et al. 2006a; WRI 2007; Nahlik et al. 2012).

As Chapter 2 showed through the review of the MA methodology, to mainstream ecosystem services into natural resource decision making it is not sufficient to develop a framework for single scale applications (e.g. an ecosystem, a catchment or region) or for a specific sector or organisation to apply (e.g. catchment management organisation, utility agency, government). A finding of the review of local to global scale programs revealed the development and application of many and varying ecosystem service frameworks has resulted in information and decision support tools with limited transferability and repeatability to other contexts (e.g. scales). As issues pertaining to one context may not be relevant to others, this research aims to determine: *what is an appropriate methodology* [process, information and tools] *to enable ecosystem services assessments* [to be conducted] *across multiple scales?*

As 'national institutions are often the pivot between local or regional institutions and international ones' (WRI 2007, p. 35), this research responds to the research question from the position of developing a multi-scale framework at the national scale (e.g. for Australia). It analyses existing methodologies developed at the regional scale in Australia, at the national scale in the US, at the multi-national scale in the UK, and to a lesser extent a global scale methodology through the MA.

Section 3.1 described the Lines of Enquiry corresponding to the three main elements of a methodology: process, information and tools. The sub-questions for each Line of Enquiry and key topics identified for further analysis are products of the documents reviewed (Chapters 1 and 2). Figure 3.1 showed the three Lines of Enquiry as coloured circles (see dot points below). The three Lines of Enquiry are summarised as:

- **Line of Enquiry 1: the process to develop a framework (blue circle)**
  Sub-question: What is an appropriate process to develop a framework for ecosystem services assessments across multiple scales?
  Key Topics for analysis: factors underpinning a program's initiation; the coordinating organisation for the program; the resources (i.e. time, money, expertise) invested in developing frameworks; and the structure of programs.

- **Line of Enquiry 2: the information to support a framework (orange circle)**
  Sub-question: What information is required to support a framework for ecosystem services assessments across multiple scales?

Key Topics for analysis: the role of biodiversity; assessment units; ecological processes; ecosystem services; and a method for valuing ecosystem services.

- **Line of Enquiry 3: the tools to support a framework (green circle)**
  Sub-question: What tools are required to support a framework for ecosystem services assessments across multiple scales?
  Key Topics for analysis: conceptual frameworks; maps and dynamic models; scenarios; and websites and technical reports.

The previous section (Section 3.2) described the three pronged approach (i.e. document reviews, applied research and multiple case study analysis) used to analyse methodologies and answer the above questions (and therefore the overarching research question). Documents were reviewed (Section 3.2.1) to draw insight from a wide range of recent experiences in developing frameworks. The documents reviewed primarily consisted of recorded knowledge on the MA (Section 2.1) and diverse schools of thought developed since the MA's 2005 release (Section 2.2). The MA makes a good benchmark from which to compare other methodologies due to: the increase in ecosystem services research since its release (Fisher et al. 2011; Costanza et al. 2012); its influence globally and credibility as shown through its adoption in programs (Fischlin et al. 2007; WRI 2007; Secretariat Ramsar 2008; WBCSD 2011, 2012; CBD 2013); and it's multi-stakeholder and multi-scale technical design (MA 2005d; Reid et al. 2006a; Ash et al. 2010).

The need for multi-scale assessments so to mainstream ecosystem services into decision making significantly influenced the choice of programs chosen for in-depth analysis. Applied research (Section 3.2.2) was used to analyse the development of a methodology in a real world policy and planning environment at the regional scale in SEQ, Australia. Reinforcing the choice of case studies to compare against the SEQ methodology, is the UN Development Program who suggests that 'for small scale programs to be effective they should be situated in the wider political context' (UNDP 2006, p. 11). Multiple case study analysis (Section 3.2.3) was used to learn from experiences in the US and the UK in developing methodologies at (multi-)national scales. The three Lines of Enquiry were used to analyse the SEQ, US and UK methodologies, as well as the MA methodology. Depending on which of the three approaches was applied, different methods (e.g. World Wide Web searches; focus groups, semi-formal semi-structured interviews) were used to extract and collect data and information on the methodologies.

Figure 3.5 conceptualises the approach to synthesising data and information across methodologies. It shows the methodologies developed under the SEQ, US, UK and MA (and other) programs analysed using their respective research approach (document reviews, applied research, multiple case study analysis). Each Line of Enquiry (LoE 1: Process; LoE 2: Information; and LoE 3: Tools) and associated key topics for further analysis are shown in columns and colour coded corresponding to coloured circles in Figure 3.1. This means each Line of Enquiry and key topic was analysed using each research approach. As discussed in Section 3.2, this triangulated approach to analysing Lines of Enquiry addresses the limitations of individual approaches and strengthens the overall outcomes.

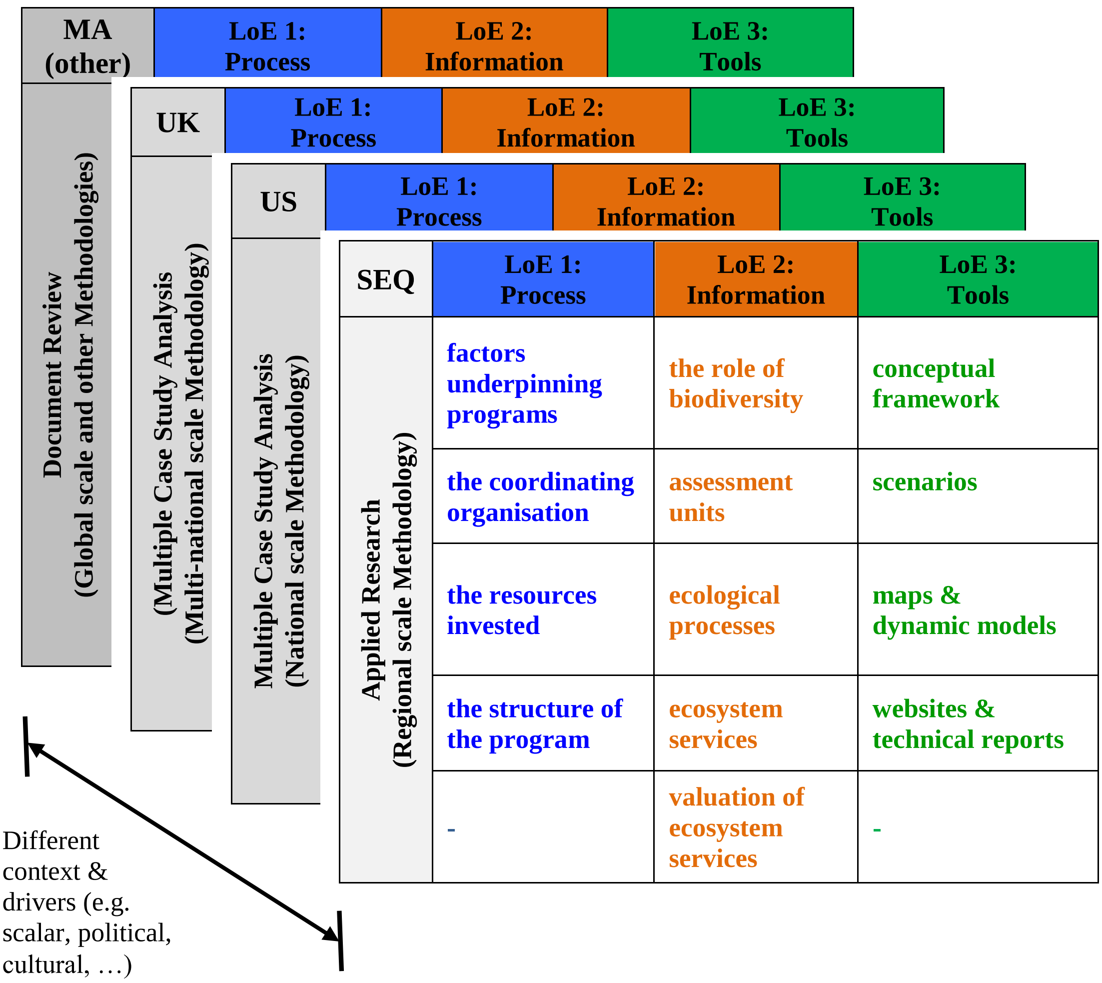

Figure 3.5: The cross-analysis of methodologies through the three Lines of Enquiry.

Large volumes of data and information were collected and developed in a non-standardised format through this research design. The three Lines of Enquiry including sub-questions (to the main research question) and key topics were fundamental to breaking the research into tractable components. The Lines of Enquiry provided the focus for consistent reviewing and analysis of different methodologies under different research approaches; the focal points for cross-analysing different methodologies and synthesising outcomes; and the direction and structure for reporting research outcomes through this thesis.

As shown by the MA's multi-scale design (Figure 2.1), a multi-scale framework (rather than single-scale framework) should allow for nested, interlinked, but semi-independent assessments to be conducted by stakeholders at various scales and levels of organisation (MA 2005d; Reid et al. 2006a; Ash et al. 2010). Appendix 1 presents the key features of the process applied to develop the MA, SEQ, US and UK frameworks including the geographic and jurisdictional scale the methodologies were developed at. Although these scales vary widely across programs there are similarities within program boundaries that provide opportunity for good cross-scale comparisons to be made; and to determine the potential for information and tools to nest and interlink yet be semi-independent. For example:

- There is similarity in geographic and jurisdictional scales between the SEQ region, place-based studies within the national scale US program (Section 5.1.4), and countries in the multi-national UK program. The MA sub-global assessments conducted at watershed, regional and national scales are also of comparative geographic size to the SEQ, US and UK case studies.

- All four program boundaries (i.e. regional, national, multi-national and global) encompass areas composed of smaller scale jurisdictional areas. Each smaller scale jurisdictional area acts as an autonomous unit nested under an overarching government structure. For example, the SEQ region consists of 11 local government authorities each with their own unique policies, planning schemes and programs to manage people and natural resources, however, all local governments must meet obligations defined within state and national government policies, plans and programs. The US and UK have similar nested jurisdictional structures to Australia even if termed differently (e.g. shires or counties). Some place-based studies in the US and sub-global assessments in the MA encompass multiple states, similar to the UK program encompassing multiple nations.

- All programs analysed (except the MA) are also part of larger scale jurisdictional areas. For example, the SEQ region is one of 14 planning regions in the state of Queensland and 56 NRM regions within Australia. Australia, the US and UK have obligations under global policies and programs as defined by their signatory to the UN and international conventions. The UK is also a member of the EU which creates another level of nestedness within the broader political system.

Chapters 4, 5 and 6 report on the methodologies developed in the SEQ, US and the UK; and the drivers behind the choice of methodology for each program. For ease of comparing and contrasting methodologies chapters are structured similarly, each Line of Enquiry forming sub-sections, and key topics further sub-dividing these. Data and information was sort under key topic headings which allowed for a systematic approach to comparing and contrasting methodologies; it constrained focus and provided a clear direction for the analysis. At the end of each chapter a synopsis of the relevant methodology based around a similarly designed set of figures (Figure 4.5, Figure 5.2 and Figure 6.3) is provided.

Outcomes from the analysis into the SEQ, US and UK methodologies are brought together in Chapter 7. Chapter 7 again follows a similar structure to Chapters 4, 5 and 6 describing these methodologies, but now compares and contrasts the processes applied (Section 7.1) and the information (Section 7.2) and tools (Section 7.3) developed in each program. Where relevant these methodologies are also compared and contrasted to the MA and other schools of thought revealing if they are consistent with current theories on methodologies or if they provide new insights.

A set of Recommendations based on lessons learnt from the analysis are provided at the end of each sub-section describing the outcomes of each key topic (Boxes 7.1 to Box 7.13). Numbers next to each Recommendation identify interrelated Recommendations within and across Lines of Enquiry. Appendix 9 builds on Figure 3.5 by providing a complete list of Recommendations and interrelations. These Recommendations will assist researchers and decision makers to make more informed decisions as to an appropriate process to develop a multi-scale framework and the information and tools required to support it.

Chapter 8 concludes this research with a critical analysis of the research design and outcomes; and key messages for taking this research and outcomes forward. The following chapter is the first step to building on the knowledge already gained through the documents reviewed. It begins the in-depth analysis into methodologies by describing the outcomes of the applied research in SEQ, Australia.

Chapter 4

The SEQ Experience

Section 3.2.2 introduced the *applied research* approach in South East Queensland (SEQ), Australia. Much can be learned beyond theoretical and experimental methodology (process, information and tools) development recorded in literature from the practical experience of developing a framework in real-world settings. Applied research was therefore chosen to gain a better understanding of drivers and issues that might arise in everyday practice and influence how frameworks are developed. The SEQ methodology described in this chapter is the first of three major methodologies analysed in this research by using approaches other than just through document reviews; and it's the only methodology analysed under the applied research approach and at the regional scale.

Section 3.2.2.1 provided background information on the SEQ region; SEQ Catchments, the organisation who coordinated the development of the framework; and the SEQ Ecosystem Services Project (the SEQ program) which this research was conducted in concurrence with. It also discussed how a regional scale approach to NRM is endorsed by the Australian state and federal governments providing support for applied research to be conducted at this scale. Other reasons for choosing the SEQ region as a case study included: SEQ is my home region; SEQ has high biodiversity values; SEQ is the fasted growing metropolitan region in Australia and experiencing significant pressures from population growth (Queensland Government 2009); and the Regional Body (SEQ Catchments) agreeing to support this research initiative. The SEQ region was not only a topical area for study but easily accessible.

The aim of the SEQ program was to develop a framework, an 'agreed' framework across SEQ stakeholders (the SEQ Ecosystem Services Framework), to conduct ecosystem services assessments consistently across the region; and to incorporate this framework into NRM, policy and planning (Maynard et al. 2010). During this time I played a dual role as researcher and Project Manager. Much of the information supporting this chapter was developed through notes recorded in the field. Therefore, information in the following sections is a collation of observations, recollections, the development and review of internal and external project documents and reports, conversations, field notes, websites and journal articles. The primary literature I co-authored that provided data for this analysis was listed in Table 3.1.

Section 4.1 applies the first Line of Enquiry to the SEQ methodology. It builds on the background provided in the previous chapter by describing the process applied to develop the SEQ framework and identifying drivers underpinning the type of process applied. Sections 4.2 and 4.3 document the information (Line of Enquiry 2) and tools (Line of Enquiry 3) developed to support the framework. Section 4.4 synthesises these outcomes.

4.1 The process to develop the SEQ framework

This section identifies drivers influencing and shaping the SEQ process and describes the resulting process applied. Sections 4.1.1, 4.1.2, 4.1.3 and 4.1.4 provide outcomes of analysing the key topics under this Line of Enquiry, they include: the key factors underpinning the programs initiation; the coordinating organisation for the program; the resources (e.g. time, money, expertise) invested in developing the framework; and the structure of the program. The key features of the processes applied in the MA, SEQ, the US and UK methodologies are presented in Appendix 1. Column 3 presents the key features of the SEQ program. Although the key topics further analysed are described in isolation from each other in this section of the thesis, it is recognised in reality they are interrelated with other features in Column 3 and other Lines of Enquiry. Below, the factors underpinning the initiation of the SEQ program are discussed.

4.1.1 Factors underpinning the programs initiation

The release of the MA in 2005 was a major factor underpinning the initiation of the SEQ program. The MA identified the significance of ecosystem services to sustainable development and the well-being of individuals and communities. Local stakeholders (i.e. from state and local governments, business, industry, researchers, non-government organisations and communities) aware of the MA considered an ecosystem services approach had potential to address the pressures associated with high population growth in the region (Section 3.2.2.1) (Maynard et al. 2010, 2012). The fundamental question underpinning the initiation of the SEQ program was: how do we accommodate

population growth whilst still maintaining the capacity of the region to provide ecosystem services important to the community’s well-being?
RLOSAC the ‘forum for key stakeholders to discuss policy development and implementation of the statutory regional plan as it impacts on the regional landscape and rural production areas of SEQ developed an interest in ecosystem services’ (see Section 3.2.2.1) (Maynard et al. 2012, p. 3). Stakeholders speculated a framework that enabled them to conduct consistent ecosystem services assessments would assist them to anticipate and monitor losses in services resulting from development activities, and where relevant, would enable decision-makers to maintain or enhance ecosystem services across the region (Maynard et al. 2010).

As also discussed in Section 3.2.1, in line with the SEQ policy and planning cycle and in consultation with SEQ stakeholders every five years the SEQ NRM Plan is reviewed. The community consultation process coordinated by SEQ Catchments (who was previously called NRM SEQ) brought to the Regional Body’s attention the potential of an ecosystem services approach to add value to current NRM approaches. SEQ Catchments saw ecosystem services as a possible approach to addressing internal and external organisational objectives and responsibilities under their Strategic Investment and NRM Plans (Maynard et al. 2012).

Stakeholders working across these organisations and initiatives recognised the need for only a single approach to assessing ecosystem services across the SEQ region. It was considered a single yet flexible framework that provided the language, information and tools to consistently assess the magnitude and value of ecosystem services would allow for better planning, managing and monitoring of ecosystem service provision over time. In 2005 it was agreed by stakeholders that SEQ Catchments should coordinate the SEQ program on their behalf and introduce procedures and management arrangements that would achieve its general aims (Maynard et al. 2010; 2012). Reasons underpinning this decision are discussed in the following section.

4.1.2 The coordinating organisation

Section 3.2.2.1 provided background information on SEQ Catchments the organisation who coordinated the program and development of the SEQ framework. SEQ Catchments was considered an appropriate organisation to coordinate the program for a number of reasons. Firstly, SEQ Catchments is a member organisation governed by a Board of representative stakeholders to the natural resources of the SEQ region (i.e. representatives of local and state governments, business, industry, research, non-government organisations and community). This provided an existing network with representation from potential users of an ecosystem services framework; and SEQ Catchments well positioned to provide an opportunity for stakeholder input and outreach on ecosystem services. With no legislative mandates or missions, SEQ Catchments coordinating the program would allow for a less 'policy influenced' program agenda.

Secondly, inherent in the multi-disciplinary nature of ecosystem services is the need to collect or develop multi-disciplinary information to support the framework. SEQ Catchments has a large existing network and working relationship with a broad range of stakeholders; as did I (the researcher and Project Manager) and the Manager Planning and Innovation of whom I directly reported to at SEQ Catchments (see Section 4.1.3). These networks and relationships exist across many geographic, institutional and jurisdictional scales, fields of research and NRM activities in SEQ. SEQ Catchments was well suited for the collaborative and qualitative approach necessary to collect information to support the framework (Maynard et al. 2010, 2012).

Thirdly, unlike many government and academic programs which often have more siloed missions and mandates, SEQ Catchments' on-ground and extension programs address a broad spectrum of NRM issues pertinent to the provision of ecosystem services. The broad range of NRM issues within the scope of SEQ Catchments activities were listed in Section 3.2.2.1. Through collaborating with stakeholders to develop the SEQ NRM Plan and fund, design and implement on-ground activities aimed at achieving targets within this plan, SEQ Catchments is well placed to take the regional scale framework and implement it through measurable site-based activities. The resources invested to develop the framework for SEQ are described below.

4.1.3 The resources invested

From 2005 to 2007 the SEQ program was funded through the Australian Government's Natural Heritage Trust. Federal elections in 2007 saw a new government introduce changes to federal funding; the Natural Heritage Trust was replaced with Caring for our

Country. As funding under Caring for our Country is generally delivered to Regional Bodies on an asset basis (e.g. investment is on highly valued parts of the landscape, rather than in large areas against broad-scale threats), the SEQ program could not meet the Caring for our Country targets and therefore was no longer eligible for funding. From 2007 the Queensland Government became the single funder of the program.

One full-time employee was dedicated to the SEQ program, the Project Manager. Approximately AU$ 80 000 was designated to employ the Project Manager and support the program each year over a four year period. The role of the Project Manager was to coordinate SEQ stakeholders to develop the SEQ framework; and to assist stakeholders in its implementation. Column 2 in Appendix 3 shows the tertiary qualifications held by the Project Manager and all Leads interviewed in the US and UK programs. The Project Manager for the SEQ program holds qualifications in environmental science and community NRM.

Others highly involved in the program include the Project Manager's direct reporting manager (Manager, Planning and Innovation) whose role was to oversee the frameworks development and its application for both SEQ Catchments and wider stakeholder purposes. Two cartographers from SEQ Catchments provided mapping support as required. An economics Professor from a local university acted as consultant to the program. Although the expertise and input from these professionals has been vital to the success of the program and the development of the framework, their skills are not included in Appendix 3 as they were not directly funded or employed by this program. Occasionally, university students contributed to the program as a work experience component of their degree.

Reflecting on the program, the resources provided to develop the SEQ framework were extremely restrictive. Although the time allocated to actually develop the framework was achievable (four years), the (time and knowledge) of one full time employee provided limitations. The budget allocated also provided limitations, especially to developing new information and tools and formally employing a wider range of expertise on the program. More information on the expertise and skills of who worked on the development of the framework are described under the structure of the program in the following section.

4.1.4 The structure of the program

The purpose of the SEQ program was to develop the information and tools (a framework) for stakeholders to consistently identify, measure and value the ecosystem services derived from the SEQ region; and to use this framework to operationalise ecosystem services in NRM, planning and policy (Maynard et al. 2010). The potential users (target audience) of the framework were therefore wide ranging (e.g. community members, local and state governments, researchers, business and industry, non-government organisations); and the information developed needed to be suitable for activities as diverse as community education, local government planning schemes, community plans, nature conservation strategies, state government regional plans, policy and offsetting, property management planning, and business management strategies. Application of the framework would most likely occur at local government or regional scales.

The structure of the program was extremely organic, adaptive, multi-sectoral and multi-disciplinary (Maynard et al. 2010, 2012). Outside of those directly involved in the development of the framework, over 190 professionals from groups identified as potential users have also contributed pro bono to its development either as an expert or as a representative of their organisation (SEQ Catchments 2012). The decision to adopt this type of approach was an outcome from the first scoping workshop held in May 2006 (Think Tank 1). Maynard et al. (2012) provide reasons for engaging potential users in the development of the framework, they include:

- the multi-disciplinary nature of ecosystem services would require a multi-disciplinary approach to information collection;
- the coordinating organisation being a non-government organisation would require wider input from stakeholders to increase the credibility of information (authoritative, believable and trusted) for policy and planning applications;
- expert local opinion was recognised as an important resource, particularly when information and data is limited;
- involving a wide range of stakeholders would improve the saliency (relevance) to decision making in different applications; and
- resources (including time, number of staff, expertise and funds) limited alternative approaches to developing the methodology.

Furthermore, underpinning the chosen process was the concept that those most likely to apply an ecosystem services framework in their policy, planning and management, are those that should develop the framework (Maynard et al. 2010, 2012). It was thought stakeholders were more likely to have ago applying the framework if they had ownership in developing it (Maynard et al. 2010, 2012). Table 4.1 identifies the types of stakeholders involved in the development of the framework, the role they played, tasks performed and the rationale behind their involvement. More detail on the structure of the program is provided in Column 3 in Appendix 4 which also includes detail on the structure of the MA program (Section 2.1.1), the US program (Section 5.1.4) and the UK program (Section 6.1.4).

The Ecosystem Services Steering Group (ESSG) provided overall guidance and management of the program. Representatives of key agencies, generally the technical advisors of state planning and environmental agencies, local governments and research institutions participated on the ESSG. The disciplines supporting this working group were multiple and varied ranging, for example, from planning, economics, natural and social sciences, and policy making. The primary role of the ESSG was to coordinate technical inputs to the framework and to ensure the outcomes of the project were practical and complied with current planning and policy requirements and agency goals (Maynard et al. 2010).

To oversee more detailed technical aspects of the framework, an Ecosystem Services Working Group (ESWG) was established. This working group was continuously evolving as it consisted of an open forum of SEQ stakeholders. At each stage in the development of the framework, an open invitation was provided to all stakeholders to participate in a workshop aimed at peer reviewing outcomes and developing next steps forward. This activity was conducted as a series of ‘Think Tanks’ focused on theoretical issues and the practical application of the ecosystem services concept (Maynard et al. 2010). This ensured development of the framework aligned with the current plans, policies and practices of the broader range of stakeholders (Maynard et al. 2010).

Table 4.1: Major activities undertaken to develop the SEQ framework including the rationale for including different assemblages of participants, their roles, tasks and the rationale for their engagement (amended from Maynard et al. 2010, p. 12).*

Group	Who	Role	Tasks	Rationale
Ecosystem Services Steering Group	Potential key users of the framework e.g. policy makers & technical experts from government, the Regional Body, CSIRO & universities.	Coordinate the overall development of the framework.	Coordinate technical inputs for the assessment of ES.	Ensure outcomes are practical & comply with current planning & policy requirements & agency goals.
Ecosystem Services Working Group	Open forum of stakeholders.	• Oversee more detailed technical aspects. • Develop & review each step of the program as it evolves.	Activities have been conducted as a series of facilitated Think Tank exercises focusing on theoretical issues & practical application of the ES concept.	Ensure development of the framework aligns with current plans, policies & practices of the broader range of stakeholders.
Expert Panels	Biophysical Working Group: Peer referred technical experts, ecologists, botanists & environmental scientists familiar with ecosystems & their characteristics in SEQ.	• Develop definitions & descriptions of framework components. • Identify relationships between components. • Assist with designing & developing the appropriate tools for ES assessment.	• Develop lists & descriptions of ecosystems, ecosystem functions & ES. • Provide expert knowledge in identifying & quantifying interrelationships between ecosystems, ecosystem functions & ES. • Review & provide feedback on tools developed.	Expert knowledge was recognised as an essential input to the development of the framework, especially to address areas of limited data availability & to provide detailed local knowledge.
	Benefits Working Group: Peer referred economists, social scientists, health experts & other professionals whose expertise lies in defining & assessing indicators of community well-being.		• Develop lists & descriptions of ecosystem functions, ES & constituents of well-being. • Apply their expert knowledge in identifying & quantifying inter-relationships between ecosystem functions & ES; as well, identify different kinds of benefits that can be attributed to different ES (constituents of well-being). • Review & provide feedback on tools developed.	
Community Participants	Local communities & Traditional Owners.	Determine the value of ES.	Score the ES incorporated in the framework in terms of their individual well-being.	Value the ES provided by SEQ in terms of the well-being of its residents.

[*] See Acronym list (page xvii) for translation of acronyms

Expert Panels were held to develop information to support the framework especially where information did not exist or project resources provided limitations to the acquisition of information. These invitation only workshops were composed of two working groups. A Biophysical Working Group managed the work on ecosystems, ecosystem functions and ecosystem services; while a Benefits Working Group managed the work on ecosystem functions, ecosystem services and human well-being. The interface of the socio-ecological system, where ecosystem functions provide services to people, was assessed in multi-disciplinary workshops consisting of members from Biophysical and Benefits Working Groups.

Two approaches have been applied to determine the value of ecosystem services. The first approach is through Expert Panels as detailed above; the second approach is based on the premise that those most likely to be affected by the application of the framework (the SEQ community) should determine the relative value of ecosystem services. Both these approaches are discussed further in Section 4.2.5 on determining values for ecosystem services and Section 4.3.3.3 on matrix models. In recognition of possible value differences demographically and spatially across the region, the program proposed to work with local governments to run community workshops to determine these values. One trial workshop has been held with participants sourced through existing local government networks. Although a representative sample of community members is not expected at workshops, a representative sample for each local government area has been identified and can be used as a benchmark for engagement and to better understand the context of the final result. Further details and the outcomes of this workshop are beyond the scope of this thesis.

Of the stakeholders that participated in the frameworks development there was limited representation from agricultural organisations, the business sector (including fisheries and tourism), and health industries from both the government and private sectors. Attempts by the researcher/Project Manager to engage with these sectors through conferences, meetings, phone calls and emails proved unsuccessful. One reason underpinning this lack of engagement is thought to be limited or no existing networks between these organisations and SEQ Catchments resulting in ineffective targeting of appropriate representatives. Other reasons include: limited interest by organisations (e.g. not a direct mandate of the organisation); no staff or programs within these organisations specifically dedicated to ecosystem services; the organisations could not make the connection between ecosystem services and their missions; and organisations were unsure of who in the organisation would be the appropriate person for dealing with ecosystem services. There was consistently high representation from universities, state and local governments, water resource agencies and organic farmers. Also, there was higher participation by those working in the natural sciences than those in the social sciences.

The SEQ framework (information and tools) was developed through the *process* described in this section. The following section describes the outcomes of applying Line of Enquiry 2 to the SEQ program. It describes the type of information adopted or developed to support the framework and the drivers underpinning this choice of information.

4.2 Information supporting the SEQ framework

Participants at the first Think Tank for the SEQ program determined the information supporting the MA framework should provide the foundation of the SEQ framework. The process of developing the MA framework (i.e. coordinated by UNEP with involvement by more than 1300 natural and social scientists from around the world) was said to have produced the most credible and comprehensive ecosystem services framework developed to date. Two other features of the MA framework important to its adoption in SEQ were its aim to meet the needs of diverse stakeholders; and the target audience for assessment outcomes being wide ranging also.

SEQ stakeholders were clear on the need to develop a flexible framework that recognised the different capacities of stakeholders to apply information on ecosystem services. The information and tools developed to support the framework should allow for ease of integration with current policies, practices and programs. As discussed in Section 4.1 the SEQ program relied heavily on existing information particularly that held in expert local knowledge and Geographic Information Systems (GIS) (Section 4.3). The document review identified limited existing social science information on the links between ecosystem services and human well-being, not just in SEQ but globally. Where required and possible (i.e. within resources), however, new information was developed to support the framework.

A recurring discussion in previous chapters is the need to collect and collate multi-disciplinary information to support ecosystem services assessments. This section of the chapter discusses the drivers influencing and shaping the information supporting the SEQ framework. Sections 4.2.1, 4.2.2, 4.2.3, 4.2.4 and 4.2.5 analyse the SEQ methodology through the following key topics: the role and position of biodiversity in the framework; the assessment units applied; information on ecological processes; ecosystem services; and the method of valuation.

4.2.1 The role of biodiversity

The CBD's definition of biodiversity was adopted for use in the SEQ framework. The position of biodiversity in the SEQ framework, however, was a contentious issue from the very start. Many (natural scientists) thought in our attempts to assess and manage ecosystems for the benefits they provide to people that the value of biodiversity and its existence for its own sake would be lost. This contention between biodiversity and ecosystem service approaches led to a workshop approximately six months into the initiation of the program. The workshop provided an opportunity for stakeholders to voice concerns, discuss the role of biodiversity in ecosystem service provision, and establish the position of biodiversity in the framework.

During the workshop it was determined biodiversity would not be listed as an ecosystem service in the SEQ framework. Stakeholders believed that if it was incorporated in the list of ecosystem services then it would be traded off against other services. This was considered unacceptable to stakeholders who recognised biodiversity as (SEQ Catchments 2012):

> *… an important feature of healthy ecosystems because it increases their flexibility and resilience in the face of change. Some species can perform the same process within an ecosystem (generalist species); however many other specific species (keystone) make unique contributions to the functioning of the system (e.g. fix nitrogen). The possibility of reducing ecosystem function increases as more species are lost to reductions in substitutability. Biodiversity and ecosystem functions are co-dependent and therefore biodiversity is vital to maintaining functioning ecosystems, just as ecosystem functionality is vital to the persistence of biodiversity.*

To support biodiversity's position in the framework participants in the workshop developed four principles. The following points briefly describe these principles (a detailed explanation is beyond the scope of this thesis). Information supporting these points have been directly extracted or amended from the SEQ Ecosystem Services Framework website (SEQ Catchments 2012):

- **The bulk of ecosystem services come from natural ecosystems:** Natural systems provide the primary inputs into our economy and are on average more biodiverse than highly modified ecosystems. Natural systems therefore have greater potential to provide a wider range and suite of ecosystem services.

- **An ecosystem services approach is only one tool for nature conservation:** No individual species, group of species or individual ecosystem can provide the full suite of ecosystem services on which the community depends. An ecosystem services-based approach is not the panacea for the conservation of rare, endangered or threatened species or ecosystems.

- **Ecosystem services for landscape scale conservation rather than for species conservation:** Ecosystem services are derived from complex interactions between biotic and abiotic components of an ecosystem (ecosystem functions) and the size, distribution and diversity of ecosystems occurring across the landscape.

- **Due to the lack of certainty, caution should be used with application:** With the emergence of increasingly unpredictable, uncertain, and unquantifiable but possibly catastrophic risks (e.g. those associated with genetically modified organisms, climate change and loss of keystone species) society is confronted with the need to protect humans and the environment against uncertain risks of human action. The lack of full scientific certainty should not be used as a reason for postponing cost effective measures to prevent environmental damage (Precautionary Principle).

The following section describes the units to assess ecosystem service provision using the SEQ framework.

4.2.2 Assessment units

Box 2.1 presented the 10 Reporting Categories applied in the MA to assess the status and trends of ecosystem services globally. The SEQ program, which used the global scale MA framework as the base for its regional scale framework, considered the Reporting Categories too broad for local or regional purposes. All Reporting Categories (except Polar as there are no polar areas in SEQ) were sub-classified into 32 Ecosystem Reporting Categories (ERCs) specific to the SEQ region. For example, the MA 'Forest' Reporting Category was sub-classified into five ERCs: Rainforests, Sclerophyll Forests, Native Plantations, Exotic Plantations and Regrowth. The 32 ERCs are listed in Column 2 in Appendix 6 along with the assessment units developed to support the MA, US and UK frameworks.

Although ERCs are appropriate for regional scale assessments, they again are too course for property or site scale assessments. Similar to the categorisation of ecosystems in the MA Reporting Categories each ERC contains a number of natural or human modified ecosystems representing all ecosystems across SEQ (Maynard et al. 2010; SEQ Catchments 2012). The Regional Ecosystem Framework already developed by the Queensland Government (Herbarium) was incorporated into the SEQ framework (Queensland Government 2011b). Using the MA (2005a, p. 53) approach, botanists and ecologists from the Herbarium assisted with grouping Regional Ecosystems under each ERC by similarities in: ‘climatic conditions, geophysical condition, dominant use by humans, surface cover, species composition and resource management systems and institutions’ (MA 2005a, p. 53).

The Regional Ecosystem Framework was chosen due to its common use across 10 of the 11 local governments in SEQ and its application in the Vegetation Management Act 1999 (Queensland Government 1999). The three part coding system defining ecosystems consists of the biogeographic region (e.g. SEQ), the land zone (a simplified geology/substrate-landform classification) and an ecosystem number denoting different vegetation communities (Queensland Government 2011b). Where no Regional Ecosystems existed for an ERC (i.e. ERCs in the Marine and Coastal categories with no vegetation; and ERCs highly modified and managed by humans such as the Cultivated and Urban and some of the Forest ERCs), sub-categories were developed by applying

Land Cover or Land-Use categories. These were identified through management plans, advice by experts and managing agencies (Maynard et al. 2010; SEQ Catchments 2012).

Consistent with the assessment of Reporting Categories in the MA, ERCs and the corresponding Regional Ecosystems are recognised as having ‘strong interactions among components of the system and weak interactions across their boundaries; discontinuities of strong interactions become boundaries’ (MA 2005a, p. 51). The ecological interactions (processes) occurring within and across these ecosystems are termed ‘ecosystem functions’ in the SEQ framework. Ecosystem functions are the focus of the next section of this thesis.

4.2.3 Ecological processes

As can be seen by the position of biodiversity and the type of assessment units supporting the SEQ framework (Sections 4.2.1 and 4.2.2), the information included so far closely follows that of the MA. As discussed in previous chapters the MA framework does not specifically define the ecosystem functions contributing to the provision of ecosystem services, rather they categorised ecosystem services along functional lines - Provisioning, Regulating, Supporting and Cultural (MA 2005a). According to SEQ stakeholders, fundamental to assessing the capacity of ecosystems to sustainably provide goods and services is an understanding of the ecological processes that contribute to their provision. It is at the ‘functional’ level the information supporting the SEQ framework diverges most from the MA framework.

‘Ecosystem functions’ is the technical term used in the SEQ framework to define: *the biological, geochemical and physical processes and components that take place or occur within an ecosystem* (Maynard et al. 2010, p. 6; Petter et al. 2012, p. 3; SEQ Catchments 2012). Each ecosystem function can contribute to one or more ecosystem services and it takes more than one ecosystem function to provide any ecosystem service (de Groot et al. 2002; Petter et al. 2012; SEQ Catchments 2012). People may or may not value ecosystem functions because they may or may not provide contributions to human benefits (SEQ Catchments 2012). Ecosystem functions exist, however, regardless of the presence of humans or the value humans place on them.

Included in the SEQ framework is a detailed inventory of the ecosystem functions occurring in SEQ; 19 ecosystem functions are listed, described and categorised under the MA's four categories of ecosystem services. Column 3 in Appendix 7 lists these 19 functions alongside the Supporting Services listed in the MA framework (Colum 2) and the intermediate services included in the UK framework (Column 4). Ecological processes are not included in the US framework (see Section 5.2.3), hence they are not included in this table.

De Groot et al. (2002) present a conceptual framework and typology for describing, classifying and valuing ecosystem functions, goods and services. This was the dominant school of thought influencing ecosystem function discussions (along with the MA) and the final list developed (Petter et al. 2012). The following section describes how many ecosystem services incorporated in the MA (2005a) framework were considered ecosystem functions by SEQ experts, especially the Supporting Services. Many MA services were therefore incorporated in the SEQ list of functions. Research by a local PhD student into the ecosystem functions and services of value to landholders in the Lockyer Valley (the 'food bowl' of SEQ) also informed the development of this list (I. Beitz, per comm., 3 April 2006).

An important recognition in the SEQ framework is that ecosystem functions are important for maintaining ERCs and biodiversity for their own sake, regardless of any human value (SEQ Catchments 2012). In the SEQ framework, establishing 'Supporting Habitats' as a Supporting Function places the maintenance of healthy ecosystems for the provision of other species as an underpinning element in the conceptual and practical application of the framework. The ecosystem services potentially provided by these functions are discussed below.

4.2.4 Ecosystem services

'Ecosystem services' are defined in the SEQ framework as: *the goods and services provided by ecosystems that benefit, sustain and support the well-being of people* (SEQ Catchments 2012). When the SEQ program began in 2005, stakeholders agreed to adopt the definition of ecosystem services developed to support the MA (2005a) framework. However, as research advanced on the classification of ecosystem services and particularly in terms of the meaning of 'benefits' (see schools of thought by Boyd and

Banzhaf 2007; Fisher and Turner 2008; Fisher et al. 2009; and others in Chapter 2), by 2011 the SEQ program adapted the MA's definition to the one described above.

Ecosystem services are recognised as being derived from the structural components of ecosystems (e.g. vegetation; animals; fungi; water; soil; atmosphere) and the complex interactions between these components (e.g. ecosystem functions) (SEQ Catchments 2012). The fundamental difference between ecosystem functions and ecosystem services is people are the valuing agent. Without human value there are no actual ecosystem services, only the potential to provide them. In the SEQ framework 28 broadly defined ecosystem services are identified under the Provisioning, Regulating and Cultural ecosystem service categories in the MA. Supporting claims in Section 4.2.3 that Supporting Services in the MA were considered ecosystem functions in SEQ and therefore consumed in the list of functions supporting the framework are Appendix 7 and 8 listing the functions and services in these frameworks.

Column 3 in Appendix 8 lists the ecosystem services incorporated in SEQ framework alongside those incorporated in the MA, the US and the UK frameworks. The MA's (2005a) list of ecosystem services was adapted to fit definitions and classifications developed to support the SEQ framework. Similar schools of thought used to develop the SEQ list of ecosystem functions were used to develop the list of ecosystem services (de Groot et al. 2002; I. Beitz, per comm., 3 April 2006). The final topic analysed under this Line of Enquiry is how the value of ecosystem services to people is being incorporated in frameworks. The following section describes the approach to valuing SEQ's ecosystem services through use of the SEQ framework.

4.2.5 Determining the value of ecosystem services

People value ecosystem services because they contribute positively to different aspects (or constituent parts) of their lives. Rather than attempt to value these contributions through monetary values SEQ stakeholders unequivocally agreed to use scoring systems to represent the relative values of ecosystem services in terms of their contributions to the well-being of the SEQ community. 'Constituents of Well-being' (COWB) in the context of this framework is the term given to: *the different aspects of human well-being that people experience through the use or knowledge of ecosystem services* (SEQ Catchments 2012). The decision to adopt this approach does not rule out or prohibit the application of monetary valuations in the future, although no monetary valuations have been conducted to date.

The COWB approach rather than monetary valuations was adopted in the MA, on which the SEQ framework is based. SEQ stakeholders stated many ecosystem services are not easily valued in monetary terms. Monetary values for ecosystem services are typically assumed by economists to depend on people's willingness to pay for their provision or prevention of loss (SEQ Catchments 2012; Maynard et al. 2015). Such expressions of value depend at the same time on people's ability to pay. SEQ stakeholders therefore considered the values and priorities of households with limited incomes would not count as meaningfully as those of wealthy households if a monetary approach was taken (Maynard et al. 2010, 2015). Other reasons why monetary valuations were considered inappropriate under project circumstances included (Maynard et al. 2015, p. 4):

> *… the extent and diversity of valuations required; limited budget to conduct valuations; concern about what a monetary value really meant and how people would make tradeoffs using this 'number'; and a tight timeline for completion of the framework in order to incorporate it into statutory plans within the current policy cycle.*

The ecosystem services conceptual diagram developed by the MA (Figure 1.1) shows five categories of well-being: Basic Materials for a Good Life, Freedom of Choice and Action, Health, Social Relations and Security (MA 2005a). Although category titles remained the same, 'what' defines each category was adapted for the purpose of the SEQ framework. Stakeholders redefined each category to better reflect how changes in ecosystems and ecosystem services would impact on the resilience and sustainability of the SEQ community. Definitions for each category were punctuated with terms such as 'ability', 'capacity', 'change', 'variable rates' and 'acceptable costs' (SEQ Catchments 2012).

The individual COWB under these categories were also adapted to better reflect the affluent nature of SEQ rather than the 'Voices of the Poor' on which the MA (2005a) was based (see Section 2.1.2). For SEQ, 15 COWB were identified, defined and grouped under the well-being categories. Leading schools of thought contributing to the development of this list include: the COWB in the MA (2005a); the list of 'human needs' recognised as underpinning quality of life in Costanza et al. (2007); the 'matrix of needs and satisfiers' developed by Max-Neef (1991); and the 'hierarchy of needs' in the seminal paper by Abraham Maslow (1943). Section 4.3.3.3 describing modelling tools provides further details on how these COWBs were developed and the SEQ method for determining the value of ecosystem services derived from the region.

This section of the thesis described the outcomes of applying Line of Enquiry 2 to the SEQ methodology. It identified the drivers underpinning the type of *information* developed to support the SEQ framework, and described the type of information developed as well. Section 4.3 completes the analysis of the SEQ methodology by applying Line of Enquiry 3 into tools.

4.3 Tools supporting the SEQ framework

As discussed under Line of Enquiry 2 (Section 4.2), SEQ stakeholders requested a flexible framework that recognised the different capacities of stakeholders to understand and apply information and decision support tools (tools) for ecosystem services assessments. The information and tools developed to support a framework should also allow for ease of integration with current policies, practices and programs. This section of the thesis begins by describing the conceptual framework underpinning the SEQ framework which highlights the four Components for Assessment (Section 4.3.1). Ecosystem services research is also increasingly employing the use of scenarios and maps and models. These are discussed in relation to the SEQ program in Sections 4.3.2 and 4.3.3. Any websites and major documentation developed to communicate the SEQ program or support decision making through the application of the framework are discussed in Section 4.3.4.

4.3.1 Conceptual framework

The second Line of Enquiry applied to the SEQ methodology identified four key pieces of information supporting the SEQ framework (i.e. Components for Assessment): ERCs, ecosystem functions, ecosystem services and COWB. To communicate the concept of ecosystem services to stakeholders and to coordinate research across the region, the four Components for Assessment were developed into a simple conceptual framework. The SEQ conceptual framework presented in Figure 4.1 shows flows of energy, materials and values across the four Components (in the form of arrows).

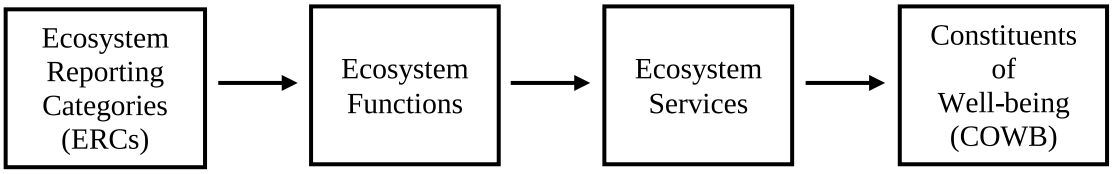

Figure 4.1: The four Components for Assessment developed into a conceptual framework to support the SEQ framework (amended from Maynard et al. 2010; SEQ Catchments 2012).

Although not depicted in this diagram, it is also recognised than in people's attempt to receive well-being (which is also derived through social and economic factors) people impact on the use and condition of ecosystems (SEQ Catchments 2012). Stakeholders thought it impossible to describe all the complex and non-linear interactions between ecosystems, social and economic factors and humans. Therefore, Figure 4.1 shows a linear one-way simplification of how ecosystems contribute to human well-being capable of being understood by a wide range of stakeholders.

Sections 4.2.2, 4.2.3, 4.2.4 and 4.2.5 introduced the lists and descriptions of items under each Component for Assessment; this provided a common language thought fundamental to stakeholder understanding of ecosystem services. The conceptual framework (and associated lists) built bridges across disciplines and sectors improving communication across stakeholders; and providing opportunities for consistent and integrated assessments across purposes (e.g. property management planning, Local Government Planning Schemes) and scales (e.g. regional, site). By placing an item classified under a Component into the relevant box, and by using expert scores identifying relative relationships across Components (Section 4.3.3.3), the conceptual framework provided the story as to the potential of SEQ ecosystems to contribute to the community's well-being.

This conceptual framework informed much of the process applied to develop the information and other tools that comprise the framework. For example, it highlighted the need for multi-disciplinary information and provided structure for the Expert Panel workshops in which the outcomes fed into the maps and matrix models which are discussed further in the following sections.

4.3.2 Scenarios

Where the aim of the MA was to develop a framework and conduct an actual ecosystem services assessment and assess the consequences of ecosystem change for human well-being, this differs to that of the SEQ program which aimed to develop a framework (the information and tools) from which multiple stakeholders could conduct their own assessments. For this reason, and due to limited resources available to develop the framework, scenarios have not been included in the SEQ framework. However, at the time of writing this thesis conducting a regional scale ecosystem services assessment and applying scenario analysis was on the program agenda. The maps and models developed for stakeholders to conduct assessments are discussed in the following section.

4.3.3 Maps and dynamic models

As mentioned previously, the fundamental question underpinning the initiation of the SEQ program and therefore the development of the SEQ framework was: how do we accommodate population growth whilst still maintaining the capacity of the region to provide the ecosystem services important to community well-being? To respond to this question, providing spatial information on where ecosystem services are being derived was recognised by stakeholders as important to understanding the biophysical parameters from which to design plans and management strategies to protect, restore and enhance ecosystem service provision.

The SEQ program relied heavily on existing GIS data sets for spatialising ecological information. To date, two series of maps have been developed to support the framework. The ERC maps are first discussed below (Section 4.3.3.1); the following section describes the ecosystem function maps (Section 4.3.3.2). Developing spatially dynamic simulation models were beyond the scope of available resources in SEQ. Matrix models were therefore developed to describe the interconnections between the four Components for Assessment. These matrix models described in Section 4.3.3.3 are important because relationships between people and ecosystems are dynamic, complex and interdependent.

4.3.3.1 Ecosystem Reporting Category maps

In the SEQ framework ecosystem services are recognised as being derived from ecosystem structure, and interactions within and across ecosystems (ecosystem functions). The first step in the mapping process was therefore to spatially identify where different ecosystems are located across the SEQ region. Section 4.2.2 discussed how for the purpose of the SEQ regional scale framework the MA's 10 Reporting Categories were sub-categorised into 32 ERCs. Each ERC also contains a number of smaller units for finer scale assessments. This three tiered hierarchy of assessment units allows for the SEQ framework to be applied and outcomes of assessments to be reported on, at different scales.

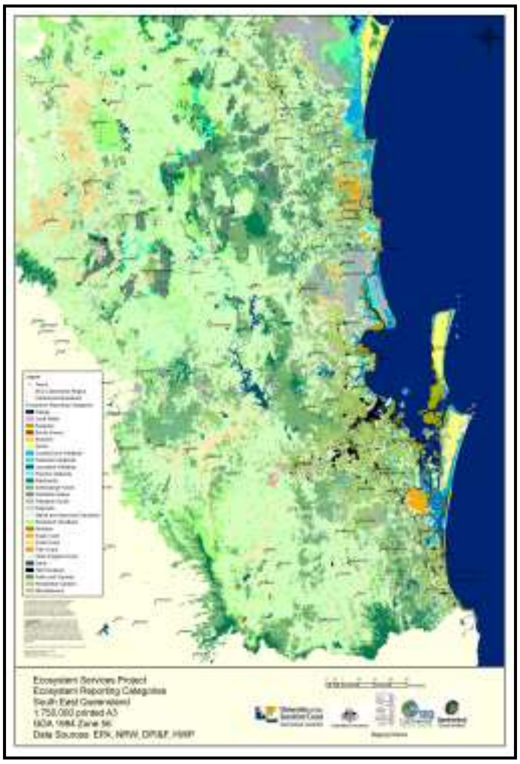

Figure 4.2: Map of the SEQ region showing the location of all 32 ERCs in the SEQ framework.

One map for each of the 32 ERCs was developed to support the framework. Each map provides a visual representation of the location and spatial distribution of one ERC within SEQ. Figure 4.2 is the 33rd map, the outcome of overlaying all 32 ERC maps. Primary datasets applied to map 'natural' ecosystems (e.g. Rainforests, Coastal Zone Wetlands, Grasslands) were data sets underpinning the Regional Ecosystem Framework developed by the Queensland Herbarium (Queensland Government 2011b). The State-wide Land Cover and Trees Study (Queensland Government 2005) and Land-Use (Queensland Government 1999b) data sets that support environmental legislation in SEQ were predominantly used for highly modified ERCs (e.g. Small Crops, Exotic plantations) or those ERCs containing no vegetation (e.g. Beaches).

The Lead cartographer for the SEQ program was asked about the scale and use of these datasets. He responded, ‘Regional Ecosystem and Land-Use datasets have a nominal scale of 1:50 000, the data is applied at the property scale by the State Government’ (S. Mooney, per comm., 11 May 2012). He continued, ‘some secondary datasets (e.g. those used to map coral reefs) were of finer scale and of more accuracy … but all data sets had to provide full coverage of the SEQ region’. As Section 4.2.3 described, ecosystem functions represent the flow of ecological processes within and across these ecosystems. Maps providing spatial representations of ecosystem functions are described in the next section.

4.3.3.2 Ecosystem function maps

An article I co-authored with colleagues (see Petter et al. 2012) describes the methodology applied to develop ecosystem function maps to support the SEQ framework, including the rationale and references for data sets which are beyond the scope of this thesis. One map for each of the 19 ecosystem functions was developed. To develop the maps 59 unique data sets were applied that together and in different combinations represent pathways in which different ecosystem functions take place in the landscape (Petter et al. 2012). For example, due to our knowledge of the role vegetation plays (particularly on slopes or stream banks) in retaining soil through both its root system and organic cover, the map representing the ecosystem function ‘Soil Retention’ contains data sets such as ‘vegetation on slopes’, ‘vegetation on streams’ and ‘good ground cover’ (to name a few) (Petter et al. 2012).

Primary data sets, those data sets used to map at least five of the 19 ecosystem functions, included: Good Grass Cover; Woody Vegetation; Wetlands; Mangroves; Samphire and Salt Marsh; Floodplains; Coastal Deposits; Woody Vegetation on Streams; Sea Surface; Tidal Zone; SEQ Biodiversity Planning Assessment V3.4; Good Agricultural Land (Classes A and B); SEQ Water Bodies; SEQ Streams; and Vegetation Corridors. To develop the individual function maps each of the data sets was standardised to produce a common currency to facilitate the overlaying process within the GIS environment (Petter et al. 2012). Petter et al. (2012) say the aim of this standardisation process was to reduce each data set to a ‘presence’ or ‘absence’ (0 or 1) and to ensure all data sets were at a consistent scale (25 m x 25 m grid).

Figure 4.3 shows all 19 ecosystem function maps overlaid. This 20th map shows areas where low (0) to high (19) ecosystem functions are occurring across SEQ. Areas of high ecosystem function (with 14 – 19 functions occurring) shown in dark green are considered to have high potential to contribute to a greater number of the ecosystem services listed in the framework. These maps now provide an important tool for regional planning. For example, the 2008 State of Region Report coordinated by the Queensland Government commissioned SEQ Catchments to apply the mapping methodology with data sets from two different years (Queensland Government 2008). The resulting map showed change (decrease or increase) in ecosystem function from the period 1991 and 2004; and therefore a decrease or increase in the potential to supply ecosystem services valued by the SEQ community.

Now the baseline ecological information to support the framework is developed (i.e. ERC and ecosystem function maps), at the time of writing this thesis stakeholders were discussing a methodology to develop ecosystem service maps. Although the methodology is yet to be determined, discussions were evolving around overlaying maps depicting ecosystem functions that Experts recognised as contributing to different ecosystem services, then overlaying socio-economic data sets indicative of benefit contributions. Section 4.3.3.3 describes the matrix models describing interconnections between ecosystems and human well-being.

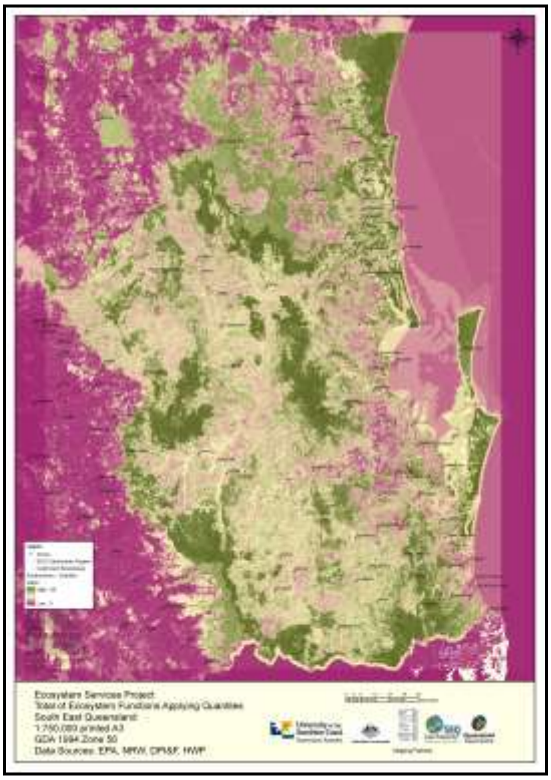

Figure 4.3: Map of the SEQ region showing areas of low to high ecosystem function.

4.3.3.3 Matrix models

Another paper I co-authored (see Maynard et al. 2015) describes the information needed to support a tool to comprehensively assess the multiple ecosystem services derived from the full range of ecosystems across SEQ as ‘enormous’. Tough decisions made on how to construct an appropriate (i.e. relevant, salient and legitimate) and achievable model (i.e. within limited time, money and expertise available) that offered an acceptable representation of ecosystems and their inter-connections with human well-being (Maynard et al. 2012, 2015); and that could assist the community, planners, natural resource managers, business, industry and government bodies in formulating strategies, plans and policies relating to ecosystem services (Maynard et al. 2015).

A method was required to determine the strength of interconnections between the four Components for Assessment (ERCs, ecosystem functions, ecosystem services and COWB), and therefore the magnitude flow of different ecosystem services to the community. Over the course of the program three Expert Panels and one comparison workshop (Section 4.1.4) were held. The conceptual framework (Figure 4.1) provided a basis for exploring the interconnections between Components with relative magnitude scores structured into a series of matrices. Figure 4.4 presents a simplification of the matrix model supporting the SEQ framework.

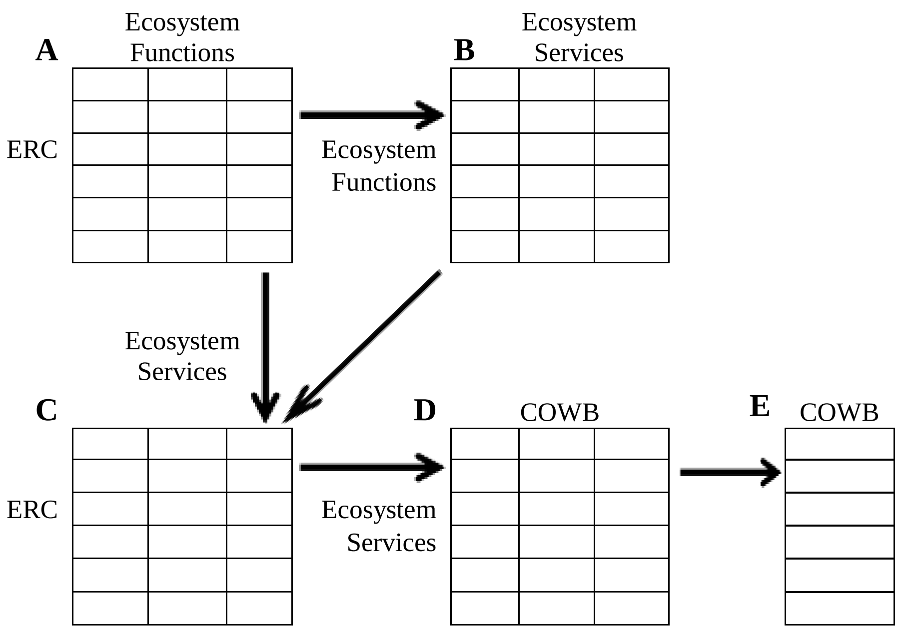

Figure 4.4: The matrix model underpinning the SEQ framework.

Expert opinion was an essential input due to limited data and the vast amount of information and local knowledge required. Experts were asked to score on a scale of 1-5 the relative magnitude:

- each of the 19 ecosystem functions is performed by each of the 32 ERCs (Matrix A – 19 columns x 32 rows);
- each of the 28 ecosystem services is produced by each of the 19 ecosystem functions (Matrix B – 28 columns x 19 rows); and
- each of the 28 ecosystem services contributes to each of the 15 COWB; or the extent to which each of the 15 COWB depends on each of the 28 ecosystem services (Matrix D – 15 columns x 28 rows).

When matrices A and B are multiplied it forms matrix C with scores representing the relative magnitude each ERC has the potential to produce all the ecosystem services (row totals); and the relative magnitude each ecosystem service is being produced by all ERCs across the SEQ region (column totals). For many stakeholders, this level and type of information is all that is required to support their decision making. But for others further information is required on the actual value of ecosystem services (SEQ Catchments 2012). Therefore, matrix D presenting the relative magnitude different ecosystem services contribute to the COWB would be applied.

Ethical questions underpinning the conducting of ecosystem services assessments are ‘whose values should count?’ and therefore ‘who should be the agent valuing ecosystem services?’ (Maynard et al. 2015). The SEQ framework remained deliberately flexible in their modelling and valuation approach. The vector matrix E is applied to weight the matrices and scores based on aspects of well-being most important to the SEQ community. Two agents were trialled in the SEQ program, however, the flexibility of the framework allows for different valuing agents to be determined depending on the application of the framework. The first was experts determining the importance (on a scale of 1 - 10) of each COWB relative to other COWB in terms of the SEQ community’s well-being. The second was community individuals determining the importance (on a scale of 1 - 10) of each COWB relative to other COWB in terms of their own well-being. The aggregated values of individuals could provide results for the SEQ region.

This qualitative approach to model development relied highly on local expert knowledge of SEQ ecosystems, the economy and community. The matrix algebra, the outcomes of these Expert Panels and the resulting scores propagating the matrices are beyond the scope of this thesis. Section 4.3.4 describes the website developed to house the framework and any documentation communicating aspects of the framework or program.

4.3.4 Reports and websites

The SEQ program did not have a formalised process for communicating or documenting the development of the framework to either internal or external stakeholders. Time was a limiting factor to the development of reports and publications. With only one full time employee (playing dual roles of Project Manager and researcher), prioritisation of time was directed towards working with stakeholders to develop aspects of the framework or to assist with incorporating ecosystem services and the framework into their practices. The following sections describe any major reports, journal articles or websites produced under the SEQ program.

4.3.4.1 Journal articles and reports

Two reports were developed throughout the term of the program and distributed to stakeholders to update them on the development of the framework. As well, a one page fact sheet aimed at communicating the program to 'busy people' was produced. Both these types of documents were written in non-technical language so to communicate the program to a wide range of audiences.

As a result of the framework, in 2009 ecosystem services was incorporated into State Planning Policy through provisions in the SEQ Regional Pan 2009 – 2031 (see Section 3.2.2.1). To assist with the frameworks implementation SEQ Catchments ran a workshop with local government (community, environmental and strategic) planners to discuss and document the position of ecosystem services in this statutory document and any resulting changes required through local government obligations and responsibilities (SEQ Catchments 2010a). Another workshop was held with planners to develop a set of guidelines detailing potential opportunities for integrating ecosystem services and the framework into local government management and planning practices

(SEQ Catchments 2010b). These two reports were developed with the assistance of university students.

Table 3.1 listed the primary publications I developed on the SEQ program that were used as data to inform this PhD research. To gain further peer review and credibility of the SEQ program and framework four articles have been published in academic journals, these included: Maynard et al. (2010) provided a broad overview of the methodology; Maynard et al. (2012) specifically focused on the process applied (Section 4.1); Petter et al. (2012) discussed the ecosystem function mapping methodology (Section 4.3.3.2); and Maynard et al. (2015) focused on the matrix models and its flexible application particularly in terms of who should be the valuing agent of ecosystem services.

4.3.4.2 Website

Think Tank 5 for the SEQ program was held in November 2012. The aim of this Think Tank was to launch the new website developed to house the SEQ framework; and to test the practical application of the framework and website in addressing a number of key issues affecting SEQ. The development of the website was a monumental moment in the SEQ program. The website provides the platform from which all data and information developed (i.e. definitions, maps, photos, narratives and Expert Panel scores) come together in the one tool. Although still a work in progress, the website provides free and open access to the technical information and tools developed to date.

This concludes the analysis of the SEQ methodology. In the previous chapter Section 3.2.2 described the applied research approach; and Section 3.2.2.1 provided background information to the SEQ region and the SEQ program. Outcomes of the three Lines of Enquiry into the SEQ methodology were described in this chapter in Sections 4.1 (the process), 4.2 (the information) and 4.3 (the tools). Based on the outcomes described in these previous sections, Section 4.4 provides a synopsis identifying key drivers that shaped the regional scale methodology; and key features of its process, information and tools.

4.4 Synopsis of the SEQ methodology

This chapter shared the experience of developing an ecosystem services framework at the regional scale in SEQ, Australia. Section 3.2.2 described how the applied research was chosen (over other research approaches) due to an added advantage of being able to capture and create an understanding of the constraints and opportunities that might arise when developing a framework in everyday practice. To employ the applied approach, this research was conducted in concurrence with the SEQ Ecosystem Services Project as part of the policy and planning process in the region. Here I played dual roles of PhD researcher and Project Manager; designing and facilitating workshops, meetings and expert panels and interacting with stakeholders. At the time of this research integrating ecosystem services into NRM, planning and policy was on the SEQ agenda and the region was beginning a new policy cycle (i.e. the statutory Regional Plan and non-statutory NRM Plan where under review).

Figure 3.2 showed the SEQ region in relation to states and territories within Australia. Law and policy development and enforcement in Australia occurs at the national, state and territory, and local government scales. To assist with coordinating national NRM activities the Australian Government (2013c) defined 56 NRM regions delineated by catchments or bioregions. Each NRM region has an established Regional Body to coordinate activities and manage natural resources (Australian Government 2013c). The Queensland state government has also determined 14 land-use planning regions of which SEQ is one. Within the SEQ planning region 11 local governments exist each with their own planning criteria. In SEQ the land-use and NRM boundaries are closely aligned so under the SEQ program the framework developed encompassed both.

The type of process applied in SEQ and the information and tools developed are conceptualised in Figure 4.5. For ease of comparing and contrasting the SEQ, US and UK methodologies this figure applies a similar format to Figure 5.2 synthesising the US methodology and Figure 6.3 synthesising the UK methodology. These figures place the three Lines on Enquiry in order, resulting in the information adopted or developed to support the framework at the centre. The process applied to develop different types of information, and which tools used what types of information, are shown in these figures as vertical lines under Line of Enquiry 1 and 3. These vertical lines run parallel to corresponding boxes showing the information under Line of Enquiry 2.

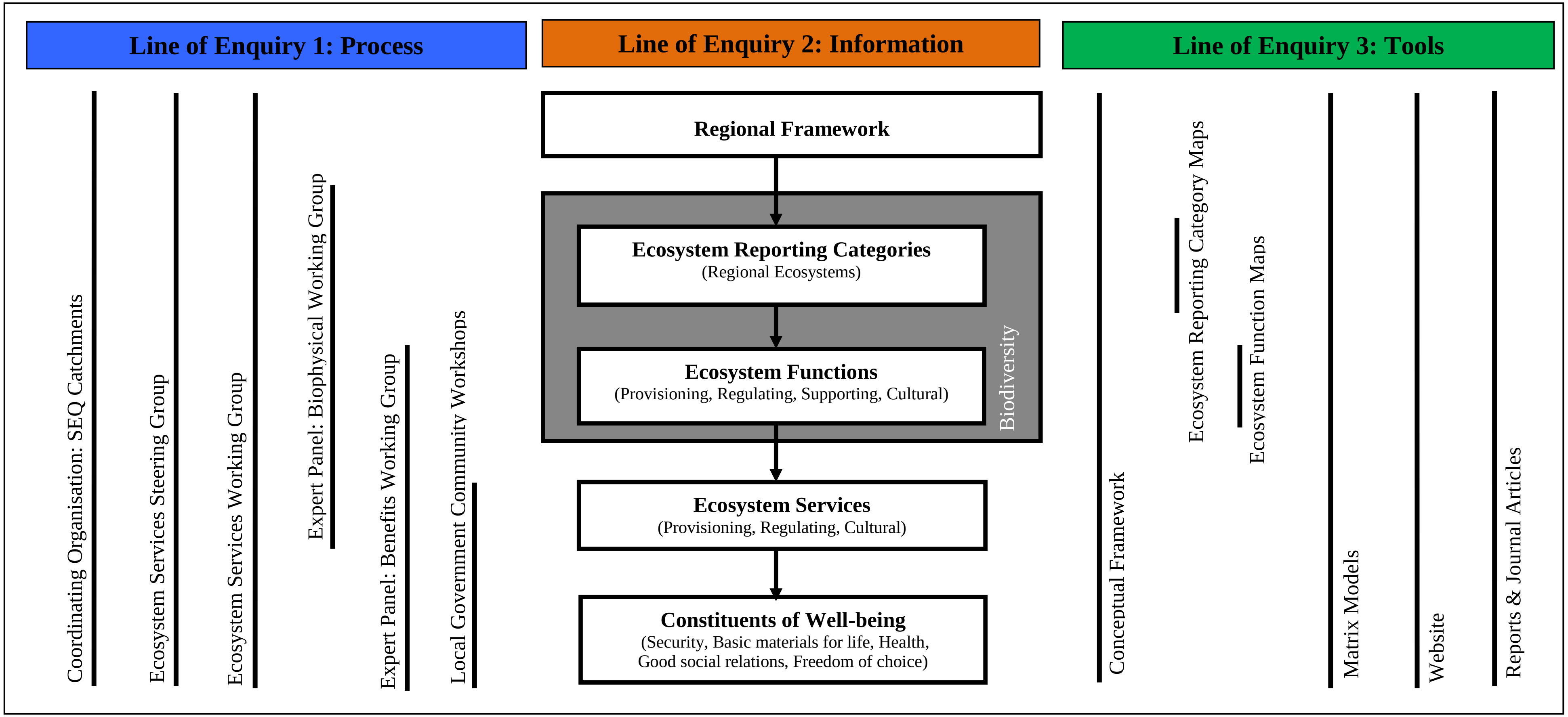

Figure 4.5: Key features of the SEQ regional scale methodology. From left to right the figure shows - Line of Enquiry 1: the process to develop the framework; Line of Enquiry 2: the information to support the framework; and Line of Enquiry 3: the tools to support the framework. Biodiversity is highlighted in dark grey (adapted from Maynard et al. 2010, p. 12).

Column 3, Appendix 1 highlights key features of the process to develop the SEQ framework. The primary *factor underpinning the initiation of the SEQ program* was the release of the MA in 2005. Section 4.1.1 discussed how the MA raised awareness amongst SEQ stakeholders of the potential for ecosystem services approaches to better manage the natural resources of the region in light of the high population growth and associated pressures. The MA was thought a credible tool by SEQ stakeholders due to UNEP developing the framework; the simplicity of the framework; and the large number of stakeholders and multi-disciplinary expertise involved.

Starting from the left hand side of Figure 4.5, the vertical line stretching from Regional Framework to Constituents of Well-being shows SEQ Catchments as the *coordinator* of all elements of the framework. Section 4.1.2 described how the operationalisation of SEQ Catchments relies heavily on a Board consisting of representatives from organisations stakeholder to the natural resources in the SEQ region. SEQ Catchment's position as a non-government, not-for profit organisation with no legislative or regulatory mandates relies heavily on its relationships with individuals, organisations and agencies to input into NRM, planning and policy in SEQ. SEQ Catchment's on-ground and extension programs address a broad spectrum of NRM issues. Their unique position provides a basis for aligning on-ground NRM with land-use planning objectives.

The *resources* to develop the framework were discussed in Section 4.1.3. Originally funds were provided by the Australian Government but new governance and changed NRM funding arrangements meant the program no longer aligned to funding targets - the Queensland Government then funded the program. The AU$80 000 per year invested in the SEQ program provided support for only one employee (the Project Manager), and limited the hiring of new skills or extramural support and the development of new information and tools to support the framework. The available resources significantly determined the dependence of the program on qualitative information and pro bono inputs.

Both Table 4.1 and Appendix 4 show the *structure of the SEQ program* and the major activities undertaken to develop the SEQ framework. Section 4.1.4 expands on these tables and describes who participated in the frameworks development, their roles, tasks and the rationale for their engagement. The MA process of engaging a broad range of expertise from a wide range of stakeholders was adopted in SEQ. Driving this approach was the objective of mainstreaming ecosystem services into decision making; SEQ Catchments having no legislative or regulatory mandates; and SEQ Catchments governance arrangements with individuals, organisations and agencies. A highly organic, open and adaptive process was applied to capture the expert multi-disciplinary knowledge populating the framework (Maynard et al. 2012).

Engaging local experts and stakeholders rather than those from outside the region was recognised as paramount to creating ownership of the framework; and capturing information, data and knowledge specific to the ecosystems in SEQ, their functioning and how these contribute to the community's well-being. This approach was also thought to potentially improve the uptake of the framework and understanding of ecosystem services concepts by stakeholders (Maynard et al. 2012). The multi-disciplinary nature of ecosystem services requiring multi-disciplinary information, and the Project Manager and organisation with dominant skills in natural sciences, also underpinned the need for a collaborative process.

As shown in Figure 4.5 stakeholders participating through the Steering Group and Working Groups (Think Tanks) were involved in developing all areas of information, including the peer review process. Through Expert Panel workshops, natural science experts (Biophysical Working Group) were invited to work on biophysical elements of the framework (ecosystems and functions); and social science experts (Benefits Working Group) were invited to work on the benefit elements of the framework (ecosystem services and COWB). Multi-disciplinary workshops linking the two groups (as shown by overlapping lines) examined the link between functions and services (Maynard et al. 2010, 2012; SEQ Catchments 2013). The Expert Panels were the most structured part of the process as participants were peer-referred and workshops were strongly facilitation (Maynard et al. 2012). To ensure context dependency on ecosystem services was captured, Community Workshops were held in local government areas to assess the value of ecosystem services in terms of community well-being.

As well as the MA process influencing the process applied in SEQ, it was decided by SEQ stakeholders that the information supporting the MA framework should form the foundations of the SEQ framework. Section 4.2 described how the information incorporated in the SEQ framework primarily relied on existing natural science information particularly that held in existing planning and management documents, expert local knowledge and GIS. Social science information was much more limited and little information was available on links between ecosystem services and the SEQ community's well-being. Where required and possible (e.g. within the time, money and expertise available) new information was developed to support the framework.

Section 4.2.1 describing *biodiversity*'s position in the SEQ framework says the CBD's definition of biodiversity was adopted in the SEQ framework. Biodiversity is shown in Figure 4.5 as a dark grey box underpinning ERCs and ecosystem functions. In SEQ, biodiversity and ecosystem functions are recognised as co-dependent and therefore biodiversity is vital to maintaining functioning ecosystems, just as ecosystem functionality is vital to the persistence of biodiversity. Stakeholders concerned about valuing nature based on the benefits it provides to people (rather than for nature's own sake) were provided the opportunity to define the position of biodiversity in the SEQ framework and develop this into a set of principles. Biodiversity is not listed as an ecosystem service as stakeholders believed that if it was incorporated in the list of ecosystem services then it would be traded off against other services.

Line of Enquiry 2 in Figure 4.5 shows the four Components for Assessment: ERCs, Ecosystem Functions, Ecosystem Services and COWB. Section 4.2.2 described the ERCs and the tiers of *assessment units* developed to allow integrated assessments of ecosystem services across multiple scales. Column 2 in Appendix 6 lists the 32 ERCs developed to conduct assessments at the regional scale. Due to stakeholder requests for limiting the amount of new information and the preference for information that would integrate with their current management, planning and policy practices, expert knowledge and existing management plans widely used by SEQ stakeholders were used to group ecosystems under each ERC (e.g. the Queensland Government's Regional Ecosystem Framework). Boundaries of ecosystems were defined by the same socio-ecological criteria applied in the MA (Box 2.1).

Where the information incorporated in the SEQ framework significantly differed from the MA was the inclusion of a comprehensive list of 19 *ecosystem functions* (shown in Column 3, Appendix 7). Ecosystem functions are defined in Section 4.2.3 as: *the biological, geochemical and physical processes and components that take place or occur within an ecosystem* (Maynard et al. 2010, p. 6; Petter et al. 2012, p. 3; SEQ

Catchments 2012). Ecosystem functions are positioned in the SEQ framework similar to Supporting Services in the MA framework. The SEQ framework clearly distinguishes between ecosystem functions and ecosystem services. The fundamental difference being that people are the valuing agent that transforms a function into a service; without human value there are no actual ecosystem services only the potential to provide them.

Column 3 in Appendix 8 lists the 28 broadly defined *ecosystem services* in the SEQ framework that are categorised under the Provisioning, Regulating and Cultural categories developed for the MA. Section 4.2.4 says the SEQ list was built from the services incorporated in the MA, de Groot et al. (2002) and with inputs of local knowledge. At the beginning of the SEQ program the MA definition of ecosystem services was used. However, as research advanced on the classification of ecosystem services and particularly in terms of the meaning of ‘benefits’ (see Chapter 2) the SEQ program adapted the MA’s definition to: *the goods and services provided by ecosystems that benefit, sustain and support the well-being of people* (SEQ Catchments 2012).

The COWB approach rather than monetary *valuations* was adopted in the MA, on which the SEQ framework is based. COWB in the context of the SEQ framework is described in Section 4.2.5 and defined as: *the different aspects of human well-being that people experience through the use or knowledge of ecosystem services* (SEQ Catchments 2012). The SEQ framework adopted the MA’s five categories of well-being (Basic Materials for a Good Life, Freedom of Choice and Action, Health, Social Relations and Security) but SEQ stakeholders redefined each category to better reflect the affluent nature of SEQ and how changes in ecosystems and ecosystem services could impact on the resilience and sustainability of the SEQ community. The 15 COWB identified, defined and grouped under the well-being categories were based on leading schools of thought by Costanza et al. (2007), Max-Neef (1991) and Maslow (1943).

SEQ stakeholders said many ecosystem services are not easily valued in monetary terms. Rather than attempt to value their contribution to the well-being of people through dollar values stakeholders unequivocally agreed to use a scoring system to represent relative values (this is discussed further below). Monetary valuations were considered inappropriate under project circumstances because stakeholders thought values held by households with limited incomes would not count as meaningfully as those of wealthy households due to their ability to pay (Maynard et al. 2015). Other reasons included (Maynard et al. 2015, p. 4):

> *… the extent and diversity of valuations required; limited budget to conduct valuations; concern about what a monetary value really meant and how people would make tradeoffs using this 'number'; and a tight timeline for completion of the framework in order to incorporate it into statutory plans within the current policy cycle.*

To the right of Line of Enquiry 2 in Figure 4.5 are vertical lines showing the different tools adopted or developed to support the framework (Line of Enquiry 3), and what information was captured or used in the different tools. Section 4.3.1 described the *conceptual framework* which is shown as Figure 4.1. The conceptual framework highlights the chain of production from ecosystems performing functions that deliver ecosystem services important to human well-being (Components for Assessments). This conceptual framework helped build bridges across disciplines and sectors improving communication across stakeholders, which provides opportunities for consistent and integrated assessments and decision making across purposes and scales. This conceptual framework informed much of the process applied to develop the information and tools in the SEQ framework. It highlighted the need for multi-disciplinary information and provided structure for workshops in which the outcomes fed into the maps and matrix models. *Scenarios* are not shown in this Figure 4.5 as this tool was not developed or deployed to support the SEQ framework.

Section 4.3.3 described the two sets of *maps* developed to assist in assessing the potential supply of ecosystem services from the SEQ region. Figure 4.2 shows the location and spatial distribution of all ERCs in SEQ based on overlaying each of the 32 individual ERC maps. Figure 4.3 shows where low to high ecosystem functions occur in SEQ based on overlaying all 19 individual ecosystem function maps. Although the methodology is yet to be determined, at the time of finalising this research discussions were evolving around developing ecosystem services maps. Driving the choice of data sets for the ERC and function maps was stakeholder (e.g. governments, communities, private sector) requests to develop tools that could be integrated with their current management, planning and policies. As well, data sets used had to cover all areas of the SEQ region.

Section 4.3.3.3 discussed how developing spatially *dynamic models* was beyond the scope of the project's resources. Due to low resources, data limitations and the large information requirements to comprehensively assess multiple ecosystem services derived from the full range of ecosystems across SEQ, a qualitative approach to model development was applied that relied highly on local expert knowledge of SEQ ecosystems, the economy and community. Expert Panels were held to determine relative magnitude (strength of interaction) scores between ERCs, ecosystem functions, ecosystem services and COWB. Figure 4.4 showed a simplification of the matrix model in which scores were recorded. The model remained deliberately flexible as to who could conduct the valuation of ecosystem services, recognising the appropriate valuing agent is dependent on the issue being addressed. Two agents were trialled in the development of the framework: experts and a local community.

The final tools discussed in this chapter were *websites and reports* (Section 4.3.4). Figure 4.5 shows the journal articles and reports (Section 4.3.4.1), and the website (Section 4.3.4.2), covered all elements of the information developed. The SEQ program did not have a formalised process for communicating or documenting the development or details of the framework to either internal or external stakeholders. Time was a limiting factor to the development of reports and publications. Two reports were developed, however, and distributed to stakeholders to update them on the development of the framework. As well, a one page fact sheet aimed at communicating the program to 'busy people' was produced. These reports and the fact sheet were written in non-technical language so to communicate the program to a wide range of audiences.

More technical forms of documentation were also produced to assist specific stakeholders in understanding and applying ecosystem services concepts and the framework. Two reports were developed providing a set of guidelines detailing potential opportunities for integrating ecosystem services and the framework into local government management and planning practices (SEQ Catchments 2010a, 2010b). To gain further peer review and credibility of the SEQ program and framework four articles have been published in peer reviewed journals (Maynard et al. 2010, 2012, 2015 and Petter et al. 2012). The website providing free and open access to stakeholders is the platform from which all data and information developed (i.e. definitions, maps, photos, narratives and expert panel scores) comes together in one tool (SEQ Catchments 2012).

This concludes the analysis of the SEQ methodology using the three Lines of Enquiry through the applied research approach. Chapters 5 and 6 provide the outcomes of the multiple case study analysis applying the three Lines of Enquiry to the US and UK methodologies. To compare and contrast these methodologies with that developed in SEQ these chapters are structured similar to the SEQ Experience. Chapter 7 cross analyses these three methodologies, and where relevant, also cross analyses them with the MA and other schools of thought discussed in the literature. The US methodology is discussed next.

Chapter 5

The US Ecosystem Services Research Program

Where Chapters 1 and 2 described the MA global scale methodology and other schools of thought developed since its 2005 release, and Chapter 4 introduced the first case study by describing a methodology developed at the regional scale in SEQ, this chapter describes a methodology developed at the national scale in the United States (US). As Figure 3.1 shows, this case study, the methodology developed under the Ecosystem Services Research Program (ESRP), is the second of the three major case studies analysed in this research. It is the first of two case studies analysed using the *multiple case study* approach and by applying semi-formal interviewing (see the UK NEA, Chapter 6).

As discussed in Sections 3.2.3 and 3.2.3.1 the outcomes of this case study analysis are primarily based on the responses to questions asked of 13 Program Leads in 14 interviews conducted from June 28th – August 7th 2011. The same approach was applied to the UK NEA, and the baseline questions from which the US and UK interviews were conducted are listed in Appendix 2. Relevant questions were chosen and adapted to suit the program and the Lead being interviewed at the time.

Figure 3.1 shows documents were also used as data to support this analysis; primary documents used as data are listed in Table 3.1. To begin this analysis the Vision, Mission and Goal as described in the Ecological Research Program Multi-Year Plan 2008-2014 (MYP 2008-2014) that underpins the ESRP are listed below (EPA 2008, p. 8):

> ***Vision:*** *Contribute to a comprehensive theory and practice for characterizing, quantifying, and valuing ecosystem services, to ensure that their relationship to human well-being is consistently incorporated into environmental decision making.*

__Mission:__ Provide the information and methods needed by decision makers to assess the benefits of ecosystem goods and services to human well-being for inclusion in management alternatives.
__Goal:__ To transform the way decision makers understand and respond to environmental issues by making clear the ways in which our policy and management choices affect the type, quality and magnitude of the goods and services we receive from ecosystems.

For ease of analysis across methodologies and research approaches this chapter follows the same format as Chapter 4 on the SEQ program and Chapter 6 on the UK NEA. Section 5.1 begins the enquiry into the US methodology by analysing the process to develop the framework (Line of Enquiry 1). The sections following (Section 5.2 and 5.3) provide the outcomes of Line of Enquiry 2 analysing the information supporting the framework and Line of Enquiry 3 into the tools. Differing from Chapter 4, however, Section 5.4 provides reflections on the program (hindsight) from Leads identifying features of the methodology thought to have worked well and areas that did not work as well. Section 5.5 summarises the previous sections into a synopsis of the US methodology.

5.1 The process to develop the US framework

Line of Enquiry 1 aims to identify the type of process (the series of actions) applied under the ESRP to develop the information and tools to support the framework; and to better understand the rationale (drivers) for adopting that type of process. Sections 5.1.1, 5.1.2, 5.1.3 and 5.1.4 provide outcomes of analysing the key topics under this Line of Enquiry which include: the key factors underpinning the ESRP's initiation; the coordinating organisation for the ESRP; the resources (e.g. time, money and expertise) invested in developing the framework; and the structure of the ESRP. Column 4 in Appendix 1 provides a synthesis of key features underpinning the US process (as well as the MA, SEQ and UK processes). The factors underpinning the initiation of the US program are first discussed.

5.1.1 The programs initiation

The MYP 2008–2014 identified three factors underpinning the initiation of the ESRP. The first was the release of the MA in 2005 (EPA 2008). The ESRP adopted the MA's conceptual model linking ecosystem services and human well-being (Figure 1.1). The MYP 2008-2014 (EPA 2008, p. 4) states, 'the one finding in the MA that may be the single most important concept that the [program] has been designed to address' is:

> *…even today's technology and knowledge can reduce considerably the human impact on ecosystems. They are unlikely to be deployed fully, however, until ecosystem services cease to be perceived as free and limitless, and their full value is taken into account.*

The second factor influencing the initiation of the ESRP was a 1997 report by the National Academy of Sciences (EPA 2008). This report highlighted the importance of ecosystem services and provided suggestions for EPA (2008, p. 2) research to include issues of: 'resource utilisation; diffusion of science into policy; individual and collective decision making; economic, social, political, and legal structures; human settlement and land use; ethics and equity; technological innovation and diffusion; and interactions of social processes with physical/chemical and biological processes'. The third factor was a number of statutory and regulatory mandates such as the Executive Order 12866 which requires an examination of the environmental costs and benefits of EPA's regulatory actions such as the Clean Water Act, the National Environmental Policy Act and the Comprehensive Environmental Response, Compensation and Liability Act (EPA 2008).

To determine if other factors outside of those documented in the literature influenced the establishment of the ESRP and to better understand the motivations behind the program, one Lead was asked: *what were the significant factors underpinning the establishment of the ESRP?* The influence of the MA was confirmed, but more influential was a budget cut experienced by the Office of Research and Development (ORD). ORD, who as mentioned in Section 3.2.3.1 coordinated the development of the framework, is the US federal government's scientific arm of the EPA. ORD received a $30 million decline in budget from $104 million in 1996 to $74 million in 2006 (BOSC 2005). Due to the budget cut the program running prior to the ESRP, the Ecological Monitoring Assessment Program 1990 - 2006 (EMAP), was no longer feasible to run as “the previous program had more money to buy extramural support” (BOSC 2005). The loss in budget and resources provided ORD “an opportunity to look at what had already been achieved, look ahead for things that were going to happen and for what ORD might need moving forward into a new program". Section 5.1.2 describes the rationale behind the EPA and ORD coordinating the development of the framework.

5.1.2 The coordinating organisation

To ascertain the extent to which being a government agency (i.e. ORD in the EPA) provided benefits and dis-benefits to conducting ecosystem services research and developing a framework, six Leads working from national to ‘place-based’ scales (see Section 5.1.4) were asked: w*hat do you think are the benefits and dis-benefits of being a government agency coordinating this research (as opposed to a non-government organisation, private or academic institution)?* On the benefits side, one respondent stated it was a “scale issue - the EPA is responsible for national environmental protection so naturally they are thinking about developing information at the national scale”. This was not supported by another respondent who mentioned that many large non-government organisations are quite use to working at large scales (e.g. the Nature Conservancy, International Union for the Conservation of Nature). The first respondent also thought "the EPA should provide the leadership and much of the funding for developing ecosystem services approaches, but understand that it [the approach] needs to be applicable both at the community and larger scales, so collaborative approaches are required”.

A third respondent stated that other federal agencies deal with a single issue and "all [the agencies] have a contribution to make but it is only the EPA that has at its mission to bring all the pieces together in one place". Two respondents mentioned the ability of government agencies to better leverage other agencies and how it was more natural and easy for government agencies to work together than mixing across sectors. The EPA was also considered to be in a unique position with “potential to propose a nationally standardised accounting and classification system”. The establishment of accounting units could support the creation of markets so the EPA (as a regulatory agency) could potentially cap and trade "things". A consistent stream of funding within government agencies, rather than short term funding arrangements often provided to non-government or academic organisations, was also considered a benefit.

On the dis-benefit side, three respondents felt the EPA was recognised by others "as coming in over the top" with regulatory solutions. That as a researcher, being a regulatory agency can hinder your position because "no-one wants to interact with someone who might turn around and regulate them". Gaining access to properties for research purposes is often difficult as "some are afraid you might sue or fine them or tell them what to do with their property". One respondent said "you can really disrupt a local process with, 'we're from the federal government - we're here to help you!'". "While the other agencies are independent, they are not regulatory organisations, so they can do research and not have the implications".

The inflexibility of government organisations was discussed by the majority of respondents as a dis-benefit. The number and magnitude of (ethics) "rules" and "regulations" was considered a hindrance to conducting certain research activities (e.g. community surveys, workshops) and releasing information. Often released material was considered "old" by the time it had been through the peer review process. Also, "sometimes regulations can provide a hindrance to achieving [research goals] because they often focus on one problem at a time rather than taking a systems approach – also they can be short sighted".

It was mentioned that "ORD tries to provide the scientific basis for regulation and policy but it never draws the line as to the criteria and standards that need to be used". It was recognised that not all problems can be solved by regulation – the law is required "to get close enough to managing the public good but then you need to use other non-regulatory methods to achieve the goals ... the solutions we [ORD] are trying to achieve are more design solutions" - so the information and tools developed must also inform non-regulatory decisions. This comment was supported by another Lead who said "if we can make these services of value we can begin trading those services and economically using them, then ultimately we will end up protecting ecosystems without regulation". The resources invested (e.g. expertise, money and time) in terms of developing the framework is discussed next in Section 5.1.3.

5.1.3 The resources invested

The ESRP has a single Lead, the National Program Director (Director). The Director was asked to confirm his role in the program, the timeframe for the program, the program budget and the number of staff employed in the frameworks development. The role of the Director is "to coordinate the group (including the exchange of information across the ESRP, ORD and with external stakeholders); to ensure research stays within the boundaries of the program; and to assist the scientists in procuring the resources they require". The program had a five year timeframe. In 2011, 182 in-house scientists and other staff were employed on the program in either a full-time or part-time capacity under an approximate budget of US$70 million per year. Employees are located in various EPA Laboratories across the country.

Of the 182 in-house scientists employed, 13 program Leads working in key areas relating to the three Lines of Enquiry were interviewed. To determine the resources invested in the framework's development in terms of the skill base (qualifications and disciplines), all 13 Leads interviewed were asked: *what are your professional qualifications and training?* Column 3 in Appendix 3 shows the tertiary level qualifications held by the 13 ESRP Interviewees. Overall 38 qualifications were held, each Lead held at least two qualifications and a maximum of four. Although a diverse group of qualifications the most common were biology and ecology. There is little representation from the social sciences including economics. "The domination of natural scientists was inherent from the transfer of EMAP employees to the ESRP. Social scientists working on the ESRP have mostly been brought in from outside the program".

With the aim of better understanding the implications of resources on the types of processes that can be applied to develop methodologies, the Director was also asked: *to what extent do you think the resources available to work on the program have influenced the process applied and the information and decision support tools produced?* The respondent stated that because "resources are in people it limits you quite a bit. It is what people can do and are able to do and learn ... so, I would say it is a little restrictive". In terms of the budget cut experienced, opportunities for innovation that you get with using grant programs, "where people with great ideas can submit them", have been missed. The amount of money was not considered restrictive but the way it had to be used was. In interviews with other Leads it was mentioned the loss of post-doctorate researchers in complimentary but different skill sets to their own (e.g. in economics) was disappointing and if they had the opportunity they would definitely request access to these skills sets again. Section 5.1.4 describes the structure of the ESRP, completing this first Line of Enquiry into the process applied to develop the US framework.

5.1.4 The structure of the program

Appendix 4 shows the structure of the US program (and the MA, SEQ and UK programs) in terms of who was engaged in the framework's development and the roles they played. To better understand the choice of a "mostly in-house" approach at ORD* , one Lead was asked: *were there discussions with other federal departments/offices/ agencies about working on the program together in some form of collaborative approach?* Although "a more collaborative approach to the program across federal agencies" was recognised as "preferable" and there were "relationships across employees that could make it work", past experiences and the agencies' objectives and missions were considered different enough to deter a more collaborative approach. "Collaboration" in the ESRP predominantly occurs "within the sections of the program rather than at the national scale". For example, in the course of these interviews the National Atlas of Ecosystem Services and the Tampa Bay place-based projects were described by most Leads as highly collaborative.

A recommendation in a Board of Scientific Counsellors (BOSC 2005) report was that more collaboration between EPA scientists and external stakeholders was required. In light of this recommendation and the in-house approach of the ESRP the same Lead was also asked: *from your own position, what do you see as the importance of stakeholder engagement in the development of frameworks?* From an EPA perspective stakeholder engagement was considered "high priority". From an ORD position it was not considered "something that was done very well". With the transition of the ESRP into the new Sustainable and Healthy Communities Research Program at the time of this interviewing, this was said to be already changing. Scale was not considered an issue to engaging stakeholders "because all local governments and stakeholders have groups that aggregate up and we certainly could have gone to them as representatives of these stakeholders".

Three other Leads were also asked about their experience with collaborative research to assess the pervading impression across the program towards participatory approaches. They were asked: *from your professional experience, what have been the benefits and dis-benefits of working collaboratively with other agencies and trans/inter-disciplinary*

* "Federal agencies do get together four times a year to share information and discuss any organisational ecosystem service related activities" but this is not a process under the ESRP.

with other sectors and professionals? The slow pace of collaborative research was said to be “frustrating for most researchers and stakeholders alike”; and “keeping them excited and engaged over a long period was challenging”. Yet, another respondent said their current inter-disciplinary research was progressing quicker due to the diverse skill sets available and that everyone educated each other. "Some people [project managers] do it well and others do it terribly".

One Lead from a place-based project identified three tiers of stakeholders "we want to engage with: 1/ the public; 2/ their representatives, managers, neighbourhood associations, city mayors, natural resource managers; and 3/ the science, technical people". They said the tools they were developing to support ecosystem services assessments would look “a lot different” (much “more complex”) if they had not worked collaboratively and received stakeholder feedback. Identifying groups of stakeholders was considered the easy part of collaboration, identifying who should be in these groups was considered the challenge.

Figure 5.1 is the organisational matrix providing the structure for the program, an important part of the ESRP’s Strategic Plan. This matrix structure is designed to facilitate cross-functional collaborations and cost-effectiveness within the program (EPA 2008). To achieve this, five Long Term Goals (LTGs) were developed to guide the research. A Project or Theme Lead was established to take responsibility for each LTG and sub-section of the program. The Leads’ positions are shown in the final row and column in the matrix. As interviews were conducted with Leads of the program the people selected for interviewing were generally located in this final row or column. The interior block of white cells contains scientists working on cross-cutting themes (i.e. participating in both row and column research) (EPA 2008).

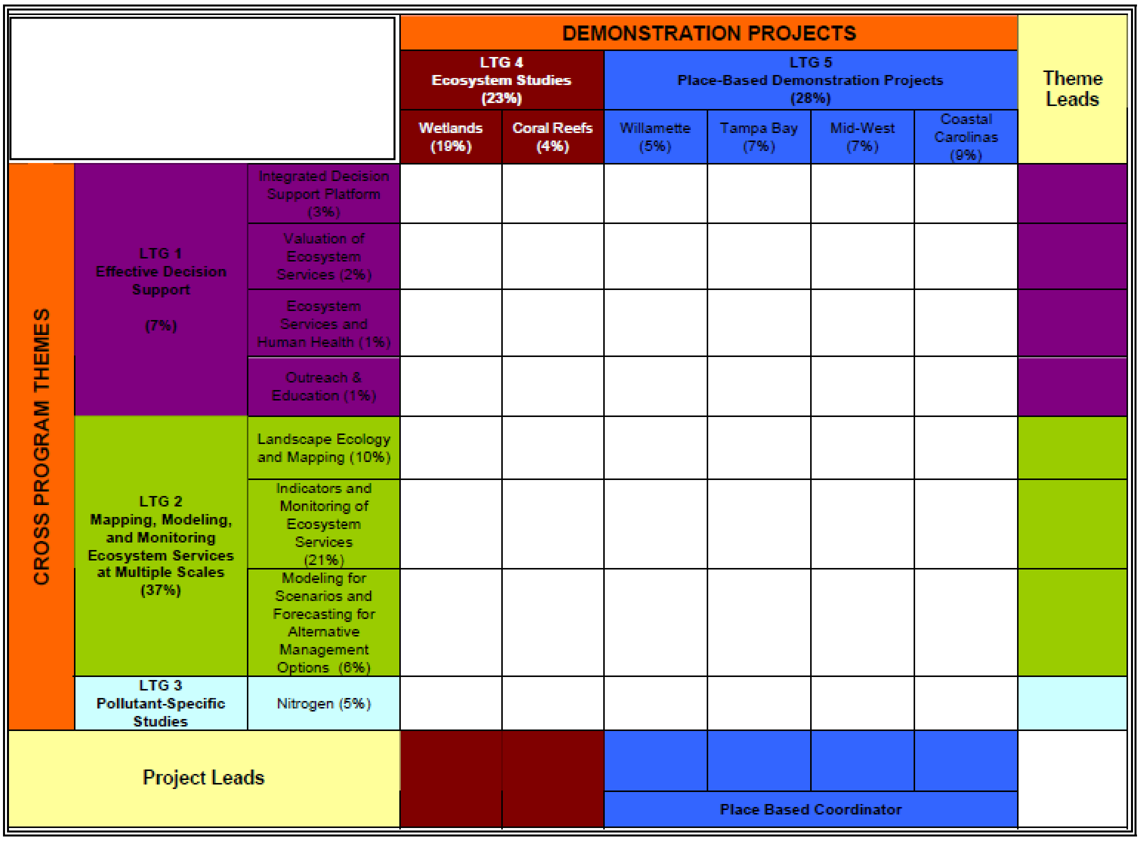

Figure 5.1: The ESRP organisational matrix showing the five Long Term Goals (LTGs) (extracted from EPA 2008, p. 16).

Cross Program Themes were developed to achieve LTG 1 (Decision Support), LTG 2 (Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales) and LTG 3 (Pollutant Specific Studies). Demonstration Projects were developed to achieve LTG 4 (Ecosystem Studies) and LTG 5 (Place-Based Demonstration Studies). The percent of total ESRP effort dedicated to each LTG is presented in brackets in the matrix. As can be seen, the largest amount of resources (37%) was dedicated to developing tools, specifically the 'Mapping, Modelling and Monitoring Ecosystem Services across Multiple Scales'. The following dot points break down the organisational matrix presenting the five LTGs.

Cross Program Themes:

Outcomes from projects focused on these cross cutting themes provided data and information to support demonstration projects, or supported demonstration projects by developing relevant tools (EPA 2008). Three themes were selected:

LTG 1 – Effective Decision Support: The MYP 2008-2014 suggests the aim of effective decision support is to reduce impediments to decision making by developing the understanding and tools for quantification and comparative analysis of ecosystem services and the impacts decisions make on HHWB (EPA 2008). With the "loss of LTG1's Lead" early in the program and a "reduced ESRP budget", the decision was made to redistribute the remaining resources to other areas of the program. At the time of this research the ESRP no longer consisted of a section addressing this LTG (which included a section on the valuation of ecosystem services). The only area of LTG 1 continuing at the time of this research was 'Ecosystem Services and Human Health'. The human health component of this research is discussed in Line of Enquiry 2 (Section 5.2.5).

LTG 2 – Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales: No specific monitoring section of the ESRP was ever established. However, areas of the program (i.e. the development of a rigorous and repeatable classification system) were considered to contribute to the monitoring design and process. In this thesis the outcomes of the mapping and modelling section of the program are discussed under Line of Enquiry 3 (Section 5.3.3).

LTG 3 - Pollutant–Specific Studies – Nitrogen: As a cross cutting theme research into the role of nitrogen in the landscape is being conducted at multiple scales, through ecosystem, place-based and national scale studies; as well, incorporated into the National Atlas of Ecosystem Services. Reactive nitrogen is recognised as both a stressor and enhancer of ecosystem services (EPA 2008, 2011c). The EPA (2011b, 2011c) describes the dis-benefits of nitrogen release as: causing oxygen-depriving conditions such as hypoxia in waterways that can result in algal blooms killing fish and other aquatic life; contributes to impaired human health through reduced air quality and the formation of ozone and particulates; the threat to Earth's climate systems and protective ozone layer. Although nitrogen studies are an important component of the ESRP, not being a key topic identified for further analysis the nitrogen studies are beyond the scope of this thesis.

Demonstration Projects:

Demonstration projects can be described as 'applied research' or "living laboratories", research operating in the 'real world' within communities, ecosystems, economies and socio-political systems. Two types of demonstration projects were conducted:

LTG 4 - Ecosystems Studies: The MYP 2008-2014 states two priority ecosystems have been the focus of ESRP research: wetlands and coral reefs (EPA 2008). Why these ecosystems were chosen and details of these assessment units are discussed under Line of Enquiry 2 (Section 5.2.2).

LTG 5 - Place-Based Studies: Although the following sections provide some detail on the place-based studies, this research is focused on the overall national program (the ESRP) so the specific details of individual studies is also beyond the scope of this thesis. 'The concept of place is central to the development of the science of ecology and is critical to the investigation of ecosystem services' (EPA 2008, p. 92). The MYP 2008-2014 describes the 'nature, structure, value and the aggregation of ecosystem services as all place-dependent' (EPA 2008, p. 92). As ecosystem functions are associated with the biogeographic characteristics of a place, place is also considered important to better understanding ecosystem functions from which the services are derived, (EPA 2008). In the ESRP place structures the research in two primary ways (EPA 2008, p. 92):

1. *through the consideration of a stressor (e.g. nitrogen) or a resource (e.g. a wetland) and the policies that affect them; and/or*

2. *through the ways in which a full suite of ecosystem services are derived from the characteristics of a place and change in response to alterations in that place.*

Expressions of interest were sort from EPA laboratories to conduct place-based projects. Originally four demonstration areas were chosen. To determine why those particular places were chosen two Leads were asked: *what factors underpinned the choice of place-based projects?* Primary reasons included: areas where the EPA had laboratories; where the EPA already had a lot of data; where the laboratory had existing activities that could be capitalised on; where the laboratory had a partner willing to work with them; and those places that showed the greatest interest. "Three of the four place-based projects were put in place more in order to learn about ecosystem services than for the purposes of actually solving a particular problem for a location”. The Future Mid-West Landscape that crosses 12 states was chosen however "due to the biofuel issues, so the EPA was already charged to do this". Other criteria for selection were: sites being in different areas of the country with both similar and dissimilar issues to address; and the desire to study a particular driver (e.g. Tampa Bay being coastal / estuarine) (EPA 2008). In short, different places were chosen for different purposes.

A report developed by the Science Advisory Board (SAB 2009) criticised the selection of place-based studies identifying no demonstration projects in the South West - “the concern was for misrepresentation of a whole section of the country i.e. there was not enough diversity in the place-based portfolio”. A fifth study was therefore added in the highly diverse areas of California, Nevada and Arizona. When asked: *are the place-based studies equally funded?* the response was “no” because the place-based studies vary widely by scale and research questions.

To determine comparability of the place-based projects for future synthesis of information and potential to integrate, aggregate and up-scale information to state or national scales, two Leads were asked: *what is comparable or different across the place-based projects?* One Lead said initially the places were not chosen for future comparison although that became more of an objective later in the program - "[ideally] you would do things in a similar way in different places so that you could end up with comparability across the places" – there was now "an attempt to retrofit". Given the lessons learnt from developing and applying ecosystem services information and tools across the five place-based projects, it was agreed some form of conceptual framework would be provided if someone was to take up another (sixth) place. To do comparable work across projects, a budget was required and this was not available to the ESRP.

One Lead was asked about the peer review process for the information and tools developed. The program is reviewed by subject matter experts within SAB, the Board established by the US Congress to provide scientific advice to the EPA Administrator. At the program and the project level, peer review is conducted by BOSC, another Board established to provide advice but specifically on technical and management issues of ORD programs. ORD also have a policy to have all potential publications peer reviewed prior to submission to a journal or for internal EPA publication as a report.

This section completes the enquiry into the process applied to develop the US framework, including the drivers determining why that type of process was chosen. The following section applies the second Line of Enquiry to the ESRP and analyses the information developed to support the framework.

5.2 Information supporting the US framework

This second Line of Enquiry aims not only to identify the type of information identified as necessary to support the US framework, but to better understand why that information was chosen by identifying the determining drivers. The review of the MA methodology and other schools of thought revealed the type of information developed to support the frameworks has been dependent on the purpose of application and proposed users (Section 3.1.2). To determine the users of the US framework one Lead was asked: *who are the end users of the information and tools produced through the national program?*

The users of the framework developed under the ESRP included the EPA itself, particularly the Program Offices (e.g. Office of Water and Office of Air and Radiation), "who would incorporate information on ecosystem services into their decision making on how to evaluate water regulations and air regulations etc.". “Being a national scale agency the primary scale of application is the national scale with the regional scale (14 regions) being the smallest scale decisions are made, but the EPA does not regulate anything at the regional scale”. Although even finer scales are used to enforce certain regulations the EPA "basically regulates what comes out of the national picture".

Another group of users are the "investors" (e.g. business, industry, developers). It is thought "to show them [the investors] the value of ecosystem services and how it can help them achieve their goals (make more money) they are less likely to degrade those areas and resources". At the community level "application of the information and tools has not been given a lot of thought across the national program". However, the focus on an internal audience "has changed a bit over time - recognising that everybody can use it [the tools], just at different scales".

"Different sections of the ESRP are being tailored for different audiences and scales". To identify these different audiences and scales Leads working on mapping products, in place-based projects, and health and well-being assessments were asked: *who are the end users of the information and tools that you have developed?* The responses varied across projects ranging from "any level of decision making" - Regional Offices, managers, planning councils or academics. For example, for the National Atlas of Ecosystem Services (Section 5.3.3) the audience was identified as federal agencies, counties as well as communities - "general public that would read a National Geographic". In the Tampa Bay place-based project the tools (i.e. the website) are being developed for use by the community or general public - "anyone from grade school up".

To determine the actual type of information recognised as necessary to conduct an ecosystem services assessment and therefore to support a framework, one Lead working at the national scale and one Lead working at the place-based scale were asked: *what type of information is required by users to conduct an ecosystem services assessment?* Both the respondents stated "biophysical information". This included, but was not limited to, information on "biodiversity, soil types, water types and the type, structure and function of ecosystems". The second type of information identified was that on "beneficiaries". Ecosystem services being anthropocentric by nature require beneficiaries to turn ecological attributes into goods and services. Some idea of the "value" (both monetary and non-monetary) of those individual services was also considered necessary by both respondents, as well, information on "how each one of those ecosystem services is going to change under a decision scenario".

The key topics as they relate to the information included in the US framework are discussed in the following sections. Section 5.2.1 describes the role of biodiversity in ecosystem services assessments and its position within the US framework. Section 5.2.2 describes the units applied to assess ecosystem services. Section 5.2.3 describes ecological processes, which are sometimes referred to as ecosystem functions, intermediate services or supporting services depending on the framework. Section 5.2.4 defines ecosystem services under the ESRP. Information on the valuation process is provided in Section 5.2.5.

5.2.1 The role of biodiversity

According to one US Lead the role of biodiversity in ecosystem services assessments was discussed very early on in the ESRP. No resolution was made in these discussions but this did not become a hindrance to moving forward with the program. There is no reference to biodiversity in the MYP 2008-2014. However, in the Lexicon developed with the aim to provide consistent terminology and understanding across researchers in the program (described further in Section 5.3.1), 'biodiversity' is defined under the list of General Terms as (EPA 2010b, p. 11):

> *… in general, the variety and variation among plants, animals and microorganisms, and among their ecosystems … considered at three levels: ecosystem diversity, species diversity and genetic diversity.*

To identify where biodiversity was positioned within the framework and gain understanding of the role of biodiversity in ecosystem services assessments in general, nine Leads were asked: *what is the role of biodiversity in ecosystem services assessments? Is biodiversity an ecosystem service or not?* Only Leads involved in modelling or well-being assessments were excluded from the questioning due to the indirect relevance of the role and position of biodiversity to their section of the program. Appendix 5 presents a condensed version of the responses provided.

Six of the nine Leads stated biodiversity is not an ecosystem service; however, providing habitat to maintain biodiversity was considered a service by one respondent. The majority of Leads noted biodiversity was something people cared about, but this still did not make biodiversity an ecosystem service. Two respondents stated it was "more of a structural thing" than an ecosystem service. Therefore, "what and how ecosystems produce components or attributes people care about [final ecosystem goods and services] are dependent upon biodiversity". This dependence of ecosystem services on biodiversity was echoed by four other respondents. The subjective nature of biodiversity and our inability to actually measure and value it was another reason for respondents claiming biodiversity is not a service.

Two respondents said the extrinsic value of biodiversity made it an ecosystem service. One respondent was undecided. It was noted as a nation "the US is not quite oriented towards biodiversity and that biodiversity is not an EPA mandate" - it tended to be more regulatory towards pollutants and "the EPA does not have the authority to legislate land-use key to protecting biodiversity". Across both responses (yes and no) to the question, a system that has higher biodiversity was considered to be stronger, more robust, resilient and sustaining in its delivery of ecosystem services than one with less biodiversity. Biodiversity was described as an "insurance policy for ecosystem services". The units applied to assess ecosystem services using the US framework are discussed next in Section 5.2.2.

5.2.2 Assessment units

Two types of ecosystem service assessment units support the US framework: ecosystems and environmental classes. Column 3 in Appendix 6 lists these assessment units. The following sections briefly describe these units and why they were adopted.

5.2.2.1 Ecosystems

In the table describing General Terms in the ESRP Lexicon an ‘ecosystem’ is defined as: *the biotic community (including humans) and abiotic environment within a specified location in space and time* (EPA 2010b, p. 20). As shown in the organisational matrix presented as Figure 5.1 wetlands and coral reef ecosystems were selected for demonstration projects. These projects are addressing specific research questions by developing information, or building on information developed through the EMAP, on the current state (area, extent, condition and function) of the ecosystems; and the effects of drivers of change (e.g. climate change, land use, invasive species and wetland modifications) on the ecosystems, ecosystem functions and the provision of services.

Wetlands were chosen due to their decline in the US, and this decline is expected to increase with population growth and associated pressures (EPA 2008). Wetlands in the US were also reported to be experiencing loss in specific wetland types (EPA 2008, 2011c). One Lead noted that “wetlands were a good example of something ORD had to look at from a Program Office perspective” because it is “one of the ecosystems ORD has a lot of responsibility for”. Coral reefs were chosen, however, “as this group of researchers … were inherited from EMAP, and as their research program had been changed a number of times over the past 10 years there was little willingness to make them change again into another line of research so coral reefs were adopted in the program”.

The wetland and coral reef projects both aim to provide the tools needed to evaluate policy and management actions that protect, enhance, and restore the ecosystem goods and services provided by these ecosystems at multiple spatial scales (EPA 2008, 2011c, 2011d). It is thought information and tools developed through the wetland program "will assist regulatory offices". Also, it will enable EPA Regional Offices to conduct prioritisation activities for better watershed management (e.g. wetland restoration, enhancement of critical ecosystems or ecological resources) (Engle and Kentula 2007*)*. The users of information and tools developed under the coral reef program "are those in-charge of managing natural resources in the jurisdictional areas in the US". More specifically, users of the wetland and coral reef information and tools include resource managers, planners, government decision makers and others (EPA 2008).

Some more theoretical studies in the ESRP have focused on streams, wetlands and estuary ecosystems. Two workshops (in 2009 and 2010) were held to identify the indicators of final ecosystem goods and services (FEGS) from these ecosystems (Ringold et al. 2010, 2013). One Lead noted these ecosystems were selected due to the large amount of existing data and expertise held by the EPA; and because the EPA also has responsibility for the US Clean Water Act. According to this Lead, "the plan is to eventually apply the successful elements of the workshop to a wide range of ecosystems across the US in similar categories to the Reporting Categories identified in the MA". The second form of assessment units, environmental classes, is discussed in the following section.

5.2.2.2 Environmental classes

Environmental classes are "a broader classification of ecological components aimed at better encompassing abiotic elements (such as atmosphere and groundwater) contributing to ecosystem service provision and that are not captured by other categories of units (such as ecosystems and those in the MA's Reporting Categories)". Environmental classes are "generally mappable from satellite remote sensing and are easily derived from national Land Cover or other existing datasets". Although neither groundwater nor atmosphere 'is mappable from satellite platforms, other mapped resources are available to characterise them at broad spatial scales' (Landers and Nahlik 2013, p. 3). Three environmental classes (aquatic, terrestrial and atmosphere) are further refined into 15 environmental sub-classes (Landers and Nahlik 2013). Landers and Nahlik (2013, p. 5) state:

The scale at which the Environmental Sub-Classes is developed is intended to present a comprehensive but manageable organisation of environmental boundaries. Nevertheless, the scale at which Environmental Sub-Classes are presented … can easily be increased or decreased depending on the specific objectives of the user.

Outside of the wetland and coral reef demonstration projects there is "no standard approach to the ecological units assessed across the ESRP". The type of ecological unit applied or assessed (e.g. in place-based studies) is "dependent on the particular problem or issue being addressed". As the environmental classes were in the final stages of development at the time of conducting this research they were not formally incorporated in the US framework and little explanation of these was provided in any EPA literature. Section 5.2.3 describes ecological processes, ecosystem functions and intermediate services as applied in the framework.

5.2.3 Ecological processes

Under the list of General Terms in the Lexicon, 'ecological processes' are defined as *a characteristic physical, chemical and/or biological activity that influences the flow, storage and/or transformation of materials and energy within and through ecosystems* (EPA 2010b, p. 17). The term 'ecosystem function' is not defined within the Lexicon or used in the program. However, again under General Terms 'intermediate services' is defined as *components of nature that are not directly enjoyed, consumed or used to yield human well-being, but which are important for the production of final ecosystem services* (EPA 2010b, p. 24).

As can be seen by the definition of ecological processes and intermediate services these terms are not interchangeable. In the US framework intermediate services are anthropocentric and only exist if underpinning the provision of a FEGS (see Section 5.2.4). Although the ESRP defines intermediate services there is no further information, examples or lists of intermediate services in the program. The reason for this is:

… the focus is on the FEGS and the specific ecological processes and intermediate services may be unknown or poorly known. The intermediate services reside, therefore, in the domain of the ecological process modellers

who have the task of understanding the workings of the ecosystems that produce the FEGS through the complex interactions of the intermediate services. By focusing on the FEGS, we can then efficiently identify and understand those intermediate services that are essential to FEGS production. This is certainly a more efficient way of addressing ecological understanding as opposed to attempting to understand all intermediate services and processes.

The following section describes more of the FEGS concept.

5.2.4 Ecosystem services

The Lexicon developed to encourage a consistent use of terms across the ESRP says ecosystem services are derived from the structural components of ecosystems and the complex interactions between these components. However, it expands on this concept by specifying indirect and direct ecosystem services and recognising the needs of future generations. In both the Core Terms and the General Terms, the Lexicon defines 'ecosystem services' as (EPA 2010b, p. 4, 20):

> ... *outputs of ecological functions or processes that directly (final ecosystem services) or indirectly (intermediate ecosystem services) contribute to social welfare or have the potential to do so in the future - often abbreviated as ecosystem services*.

The General Terms in the Lexicon also defines 'FEGS'. This definition was based on the FES concept developed by Boyd and Banzhaf (2007) aimed at advancing the development of environmental accounting and performance systems. Four Leads working in mapping, modelling, well-being and place-based studies were asked: *are FEGS and the Lexicon definition consistently used across the program?* All four respondents said "there was variability, but all were on the same path".

To confirm which definition(s) were applied across the ESRP and any consistency, nine Leads were asked: *what is the definition of ecosystem services you use in your research?* Four respondents provided definitions that described benefits or values similar to that of the MA (2005a). Another said there are two definitions of ecosystem services they relate to. The first is the definition developed by the MA, the second definition relates to FEGS. Three Leads provided modified FEGS definitions. One respondent stated FEGS are "an indicator of something people care about and ... the ecosystem structures and functions that support these different services”. Based on the Lexicon definition and the responses by Leads, FEGS are interpreted as:

- FEGS are "biophysical components or attributes" of ecosystems "that people care about";
- a biophysical component or attribute can be an intermediate service or FEGS depending on what people care about;
- FEGS are the "final" biophysical components or attributes of ecosystems that people (beneficiaries) interact with;
- a "specific beneficiary" is required for a FEGS to be recognised - "individuals can be made up of one or more beneficiary".

To further identify comparable information and attributes for possible synthesis, integration, aggregation and up/down-scaling across the program, Leads working on the ecosystem services classification system, mapping and modelling, and well-being components of the framework were asked: *is there a list of ecosystem services you all use across the ESRP (i.e. in the ecosystem and place-based studies and to develop decision support tools)?*. “No, there was never any consistency across the program”. “We spent a lot of time talking about developing that consistent list that everyone would subscribe to but that never happened”. This however contradicts the MYP 2008-2014 (EPA 2008, p. 6) which provides a ‘list of ecosystem services the ESRP will focus’ on.

Column 4 in Appendix 8 lists the ecosystem services/FEGS assessed across the ESRP (and the MA, SEQ and UK programs). As no definitive list of services was used across the overall program, for the purpose of this research documents, websites, presentations and comments from interviews were compiled to develop this list. Twenty-three ecosystem services were being assessed across the major projects within the ESRP. One Lead said those in the place-based studies were provided the option to “assess whichever services they felt feasible as long as it fitted the ESRP definition of ecosystem services”.

Although all respondents agreed there was variation in the ecosystem services assessed across the program, all projects assessed the supply or provision of water for people. Habitat, clean air and food production were the next most commonly assessed. The variation in services assessed across place-based studies was driven by their different contexts (which also drove the choice of scenarios). Developing a definitive list of ecosystem services (i.e. a common classification) is now a focus within the ESRP. This new focus was raised and strongly supported by many Leads interviewed. Discussed below is how the value of ecosystem services was incorporated in the US framework.

5.2.5 Determining the value of ecosystem services

A report prepared by SAB recommended to the EPA Administrator that the EPA should improve ecological valuation at the agency; the focus being on "all ecological effects that people believe are important, not simply those effects that are easiest to value" (EPA 2006, p. i). To determine the method of valuation incorporated in the framework one Lead was asked: *is the ESRP valuing ecosystem services in both economic and well-being terms?* The response was "yes, although the human health and well-being component would not be a prominent part of the program the ESRP maintained a small research effort in this area".

Previously discussed in Section 5.1.3 were the qualifications held by ESRP Leads. Appendix 3 listing these qualifications shows limited social science and economic training held in the program, hence I asked: *who is doing the dollar valuation of ecosystem services for the ESRP?* Because money was limited for this area of the program it was said to be difficult to engage with other areas of the agency (e.g. the National Centre for Economics, the Office of Air and Radiation and the Office of Water) where most the economists are positioned. All areas of the program, however, have "tried to have an economist" on board either internally or externally to assist with valuations. As the focus of this analysis is on the development of the national scale methodology and "dollar valuations are being conducted within the place-based projects rather than at the national scale", it is beyond the scope of this research to discuss all the valuations conducted within the five place studies.

Although the MYP 2008-2014 introduces the term 'human health and well-being endpoints' it does not define or provide a list of these, only examples such as 'physical fitness, mental health and neighbourhood stability' (EPA 2008, p. 24). The Lexicon does, however, provide the following definition of ‘human well-being’ under Core Terms (EPA 2010b, p. 5):

> *… broadly, the condition of humans and society, defined in terms of the basic material needs for a good life, freedom and choice, health, wealth, social relations and personal security. In economics, the term is often used interchangeably with social welfare [although the definition provided here is broader than the standard economic definition].*

The condition of humans and society as defined in the Lexicon are similar to the COWB developed for the MA (Figure 1.1). The MYP 2008-2014 states ecosystem services need to be characterised by human health and well-being (HHWB) across the whole program. The ESRP recognises assigning values to ecosystem services (i.e. classifying and quantifying HHWB endpoints) is required in order to compare these values to the costs and benefits of environmental protection activities (EPA 2008). The MYP 2008-2014 states the proposed research on HHWB will build on EMAP research into the condition of ecosystems and how this relates to ecosystem functioning and the delivery of services (EPA 2008). It will take the findings of this condition research and characterise the societal implications on HHWB (EPA 2008).

In the US framework 'human health' and 'well-being' are separated into two research projects. Recognising this was a variation from most other programs four Leads were asked: *human health and well-being are separated in the title of your program, why is this so and what are your thoughts on this separation?* All respondents agreed that HHWB were "one" sitting under the "well-being umbrella" (i.e. health is a component of experiencing well-being). The separation in the program was attributed to:

- the structure of the EPA - for many years ORD had people working on ecology and another group on human health; “the health group does not do well-being - they do human health (toxicology, cancer studies and exposure studies)”;
- the separation of the topics provided acknowledgement of previous research;
- teasing out the health component had advantages; "people are going to respond to mortality and morbidity issues (e.g. obesity, asthma, premature mortality)";
- for “greater acceptance and buy-in of the ESRP across the EPA”; and

- “the ESRP wanted to get to well-being in the end, of which human health is a piece”.

According to the MYP 2008-2014 the heath section will focus on the potential dis-benefits of ecosystems (e.g. Lyme disease) (EPA 2008). It will also focus on the disruption to ecosystem services by stressors (e.g. nitrogen) and human vulnerability from these disruptions (EPA 2008). “Information from the health section will feed into research nationally through the National Atlas and also in the place-based projects”. One Lead working on the health section of the program was asked: *what type of information is required to conduct a health assessment?* They responded:

> *… cancers, deaths, birth outcomes are always at the county scale … the county is just not fine scale enough when you’re looking at ecosystem things that may be happening in watersheds that may have to do with biogeographic features like mountains or coastlines, counties just don’t nest that way. You can do area weighting but it’s just not as good as if you had … an address identified or even to our census. We have a census that takes data down to neighbourhood scale and if we could have better health data released at finer spatial scales that would really help this research go forward ... and ... more issues ... not just deaths and ... big problems like cancer, but, chronic illnesses that everybody is living with and that really reduce quality of life like depression and other mental health issues. Obesity … that’s another good one. There’s more to living than … there’s more to health than not dying. I don’t think we have enough attention paid to other aspects of poor health that we could relate to the environment. The big goal behind all of that is to really increase environmental intelligence in the ordinary person as well as health scientists … their acknowledgement or appreciation for the importance of a well-managed natural environment for our health.*

One Lead working on the well-being section of the ESRP said their aim is to develop a human well-being index that will “become a predicted endpoint for a decision support tool that bundles relevant service flow measures from capital-based modules’" (e.g. social capital, economic capital and natural capital). More specifically, it focuses on “those things that contribute positively to well-being as opposed to ill-being” (also

Smith et al. 2012). “This does not mean the program is necessarily trying to maximise well-being – but if considered on a continuum it tries to minimise ill-being as a goal, or keep it from reaching its tipping point”.

Two Leads working on the well-being component were asked: *what type of information is required to conduct a well-being assessment?* The “elements” of well-being were identified as “environmental, economic and societal” (also Smith et al. 2012). The "Canada Index of Wellbeing was the key piece of literature applied in this research, other important pieces included the General Social Survey, the Gallop Survey, National Education Statistics, American Time Use Surveys, Labour Statistics and the Census Bureau". A set of “criteria” was developed “to evaluate what a perfect set of indicators would look like”. In areas where there were large gaps in information it was recognised indicators would need to be developed “which may include new questions in existing surveys”. The next stage was “applying professional opinion assigned as relative importance values and to rank data in conjunction with public perception to evaluate well-being in terms of the relationships among ecosystem services, domains and their constituent elements” (also Smith et al. 2012).

So, *how often should information on HHWB be updated or reviewed?* This was considered “dependent on what you are trying to track as to how frequently and long it needs to be measured for, but generally speaking every five to 10 years”. Section 5.3 provides the outcomes of the third and final Line of Enquiry into the US methodology. It discusses the tools developed to conduct ecosystem services assessments, communicate the outcomes, and the program.

5.3 Tools supporting the US framework

This section identifies the type of decision support tools (the tools) developed to conduct and communicate ecosystem services assessments using the US framework, and the drivers underpinning this choice of tools developed. Section 5.3.1 provides detail on the conceptual framework and Lexicon developed for consistent terminology across ESRP researchers and proposed users of the overall framework. Section 5.3.2 describes the use of scenarios to assess alternative futures and Section 5.3.3 the modelling and mapping approaches developed. Key websites and documents developed to conduct assessments or communicate aspects of the framework or the program are discussed in Section 5.3.4.

5.3.1 Conceptual framework

No conceptual framework was developed to support the national scale US framework. However, “the different place-based projects have developed different conceptual models [frameworks]”. Sometime into the ESRP “it was suggested the place-based studies adopt a consistent conceptual framework, something similar to that developed for the Long Term Ecological Research Network”. One Lead said “those involved with the place-based studies were more comfortable staying with their current models [conceptual frameworks], which are mostly biophysical rather than ecological-social-economic because they are natural scientists”. The Long Term Ecological Research Network conceptual framework:

> *... was developed by over 100 scientists and deals with drivers of change affecting disturbance regimes, that would affect ecosystem structure and function that support ecosystem services, that would affect human outcomes and behaviour, that would in turn affect the drivers and stressors.*

With the aim of providing a consistent use of terms across projects, disciplines, employees and consultants working on the program a Lexicon was developed to support the framework (EPA 2010b). One Lead said “fundamental to identifying, measuring and valuing ecosystem services is a clear and concise definition of what ecosystem services are”. A clear definition is required "to understand ecosystem services, describe ecosystem services, monitor ecosystem service provision over time and to "doing co-ordinated research on ecosystem services". “With hundreds of potential biophysical metrics you could measure in an ecosystem, a clear definition is important to sorting out what you really need”. The Lexicon consists of three tables with an additional references and sources section. The three tables in the Lexicon are (EPA 2010b):

- **Table 1: Core ESRP Terms and Their Preferred Definitions** – these terms are ‘specifically used’ in the framework and an understanding of these is required by ESRP researchers and proposed users;

- **Table 2: General Ecological and Economic Terms –** this table provides a much broader listing of terms ‘useful’ to ESRP researchers and proposed users. It also includes some of the Core terms in Table 1; and

- **Table 3: Modelling Supplement** - is a set of ‘modelling terminology for use’ and understanding by ESRP researchers and proposed users.

The following section introduces the use of scenarios in the US framework.

5.3.2 Scenarios

No national scale scenarios have been developed to support the US framework. “Five years down the track the goal of the ESRP has seen only a little change”. One change, is that now there is “greater acceptance that trade-offs are inevitable”, and so greater focus and a more "pro-active approach" is being placed nationally on identifying "how ecosystem functions and services change under alternative management strategies".

Details of the scenarios developed at the place-based scale are beyond the scope of this thesis, which is focused on analysing methodologies at the scale they were developed (e.g. national). As Section 5.1.4 discussed, the specific context and scale of the place-based studies varied influencing the choice of relevant scenario and therefore the type of information and tools developed. Four of the five place-based studies are conducting scenarios of climate change; another four of the five are studying the costs and benefits of introduced nitrogen (EPA 2011b). According to the MYP 2008-2014 (EPA 2008, p. 15) all demonstration studies aim to:

> *... illustrate how decision makers can proactively use alternative future scenarios to conserve and enhance ecosystem goods and services in order to benefit human well-being and to secure the integrity and productivity of ecological systems.*

One Lead described the benefits of scenario use as:

> *... we're not really expecting people to even know what ecosystem services are or care and then you've got to really try to educate and sell ... the*

scenarios can be useful …because if they're not even thinking about this kind of planning ... then you can say, "Well, look, you can see how this would change your drinking water supply or your risk of flooding"

Just as the scenarios vary across place-based studies, so do the types of maps and models required to conduct these assessments and run scenarios. The following section provides an overview of the maps and dynamic models developed to extract and provide information to support decisions on ecosystem services through use of the framework.

5.3.3 Maps and dynamic models

Figure 5.1 showed the organisational matrix providing the structure of the ESRP including the allocation of 37% of ESRP resources to achieve LTG2: Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales. This section first describes the maps and then the models developed to achieve this goal.

5.3.3.1 National Atlas of Ecosystem Services

"A major component of the ESRP, especially since the dissolution of the decision support section of the program (LTG1), is the National Atlas of Ecosystem Services". The importance of the Atlas to the overall assessment framework was highlighted by all Leads in the ESRP. The mission of the Atlas is to 'develop a publicly accessible, scalable, digital National Atlas of Ecosystem Services to inform decision-making at multiple levels' (EPA 2008; Neale 2011).

When one Lead was asked about the data sets underpinning the Atlas they said "over 60 data layers have been included in the Atlas". Foundational data sets include "Land Cover, crop type, soils and species habitat". "The Atlas relies heavily on existing national datasets; however, some data sets have been developed specifically for application in the Atlas (e.g. soils)". "One of the prerequisites for inclusion is that it has a peer reviewed journal article published supporting its development".

In the Atlas interface there are "three spatial scales: 1/ the national scale; 2/ the community scale; and 3/ the special study area where the place-based projects can reside - although not all place-based projects have opted for inclusion at this stage". The

Atlas is the “only place that will be serving up data on ecosystem services on the national scale”. At the national scale “the reporting units in the Atlas are 12 digit HUCS (or catchments)”. HUCS are unique hydrologic unit codes developed by the US Geological Survey (2015) and used widely by US national government agencies. “There are approximately 83 000 HUCS across the nation mapped in 30 m grids”. For place-based studies these are too course, however, and “these studies must use the National Hydrology Data scale … that divides the whole nation into about two million catchments. “National Hydrology Data nest within HUCS”.

To develop the Atlas a highly collaborative approach was adopted working predominantly with other federal agencies allowing them "to work within their specialist areas of expertise". Both intermediate services and FEGS are mapped within the Atlas. Proposed users of the Atlas are “national agencies, counties and the general public - general public that would read a National Geographic".

5.3.3.2 Dynamic models

To determine the types of dynamic simulation models developed to support the framework one Lead was asked: *what dynamic models are being used in the national framework developed by the ESRP?* The response was “there is no consistency in model type being applied”. There is no "one size fits all" model. The most common models being applied are listed and described in the Final Draft Modelling Plan for the program (EPA 2011e). Some models were "stand alone" and "built to fit" for specific purposes (e.g. specifically for a place-based study), whilst other models provide the infrastructure to support the integration of many models and often rely on inputs from existing internally and externally built models to the ESRP (i.e. "plug and play models like ENVISION”).

A modelling plan was developed for the ESRP in 2008 in recognition of one highly desirable output of the ESRP, a “whole of system” model (EPA 2011e). Workshops were held in 2009 and 2010 to refine the goal and build on this proposal. This whole of system model would provide an ”interface to integrate and run models in parallel to enable cross-communication and provide representations of dynamic systems that include feedbacks, feed forwards, non-linear relationships and time-lagged responses”. One workshop outcome was two sets of requirements that a system satisfying this goal would need to meet: 1/ user requirements; and 2/ software engineering requirements (EPA 2011e). These requirements were used to rate a series of models for their potential application into this system. “The ENVISION model rated the highest” (EPA 2011e).

“An area of much contention within the ESRP”, as identified by majority of Leads, was “a strong reluctance to adopt a common modelling approach across the place-based projects”. The Final Draft Modelling Plan suggests it is now best to wait until the Sustainable and Healthy Communities Research Program is fully planned before embarking on this research. There has been no mention of a “national scale” model to date. "Given a national scale question however a national model could be developed – eco-regions could be the spatial unit for a national model".

To better understand the benefits and dis-benefits of maps and dynamic models as tools to conduct and communicate ecosystem services assessments nine Leads were asked: *what do you think are the benefits and dis-benefits of using maps versus dynamic simulation models as tools to extract and communicate information on ecosystem services (and their use in isolation)?* One respondent stated that “models assist us with better understanding other peoples’ mental visions”. Another said maps are models because they provide a "representation of reality". However, comparing static maps and temporally and spatially dynamic models, “the primary benefit of simulation models is their ability to provide future projections”. Two respondents stated that maps were great for looking at what you had now and trying to make some assessment of current conditions - but they did not cover the dynamics required to understand the context of ecosystem services decision making and assessing alternative futures.

For ecosystem service assessments “point' models” were considered insufficient; "an ecological point at the top of a mountain – this data cannot be used to address issues at the bottom of a mountain – one point is not equal to another point - one point is not necessarily representative of other points in the landscape - more sampling units (points) are required". Another Lead supported this comment, "because it is not just where we have databases it has got to be where we don't have data bases, it has got to be where we don't have data period, and then you have to calculate something new and point models just can't do that”.

Some of the words used to describe the development and use of dynamic models included "complicated", "complex", "time consuming", "back-boxish" and "having to have technical expertise and time – because you can't just give someone a model and say ‘trust me all this stuff works’”. Experience in "participatory modelling" was found to be positive and a learning experience; "if you have people working with the model and developing the model they can learn more about the outputs". Maps on the other hand were described as "simple", "straight forward" and "easy to understand" whilst "not requiring a whole lot of complicated software development or machinery". Maps were also recognised as cheaper to develop and apply than simulation models.

People were considered to "trust" and "relate" to maps - it was more difficult to get people to have "faith" in dynamic models. Maps "spoke easy to people" and were "able to reach many more people than technical model output". It was thought this was because maps were "visual" - "if people can see where these things are coming from then there is a huge difference in how they become interested in them". One of the problems with all maps is identifying uncertainty that underlies the images - this is not easily represented. Additionally, “maps often have very discrete boundaries and this is rarely the case in nature”.

Although it was thought that some decision makers might be happy with only maps, and regardless of the benefits or dis-benefits of dynamic models and maps, both maps and models were considered necessary for ecosystem services assessments. "Maps and simulation models are not isolated and juxtaposed ... they often are used in concert". One Lead was asked: *how do you see FEGS interacting with the modelling and mapping components of the ESRP?* They responded:

> *…if we are modelling and mapping FEGS then our work would be foundational ... the FEGS work would allow those making models and maps to make sure they are presenting output that resonates with people and their well-being and is non-duplicative.*

The following section discusses any websites and technical reports developed to conduct ecosystem services assessments or to communicate aspects of this national program.

5.3.4 Reports and websites

A number of documents and forms of media were released by the EPA for internal and external stakeholder use and communication. These documents can be found on the EPA's extranet and intranet and are introduced in the following sections.

5.3.4.1 Journal articles and reports

Numerous academic journal articles have been developed communicating aspects of the ESRP, the framework, and how this research builds on the current state of knowledge of ecosystem services. Articles on this program used to guide this PhD research, provide data, and develop outcomes are listed in Table 3.1 and referenced at the end of this thesis. No technical or communication reports have been developed for external stakeholders beyond a one page fact sheet on ecosystem services located on their website. The development of such materials was the mission of LTG1 on Effective Decision Support which and as described in Section 5.1.4 dissolved early in the program.

5.3.4.2 Websites

The EPA contains an intranet for compulsory use by internal ESRP stakeholders (i.e. employees). This intranet provides access to information developed in different ESRP projects other than their own (e.g. nitrogen studies, wetland and stream workshop outcomes, place-based studies). External stakeholders can be 'sponsored' by internal stakeholders and granted secured access to the intranet allowing them to view internal program documentation.

The general website for the EPA is primarily for use by external stakeholders (EPA 2013b). It is not a program requirement to release project information on the website. The website contains brief information on ecosystem services concepts and links to some specific projects of the ESRP. For example, it provides links to the Tampa Bay place-based study, research conducted in the Chesapeake Bay, information on ecosystem services and human health and a link to the National Atlas of Ecosystem Services (EPA 2013b). The following section provides reflections on the program by ESRP Leads.

5.4 Reflections on the program

To provide hindsight on the process applied and the information and tools developed under the ESRP, eight of the 13 Leads were asked: *looking back at what you have done to date, is there anything you would do differently if doing it again – what has worked well and what hasn't?* The Leads asked this question included the Director, the coordinator of all place-based studies, as well, Leads developing information and tools relating to the classification of ecosystem services, mapping, modelling, health, well-being and one Lead working on a place-based study.

A few respondents commented on the process they had applied to extract and synthesis information and develop tools. One respondent leading a highly collaborative area of the ESRP said "what I would do exactly the same ... engaging other agencies. I think that's really, really, really important". Another respondent expressed "getting Memorandums of Understanding in place" was difficult and a deterrent to engaging more stakeholders up front and conducting a more collaborative approach, so this is something they would want addressed. Other Leads mentioned the need for more community and (other) stakeholder outreach. Another discussed the need for centralising some of the program design so to ensure scalability and transferability of outcomes:

> *... you would try and guide it more rather than everyone going off and doing their own thing – to some degree you would try and centralise some of the problems and issues so that everybody was working on common problems and issues – because, what are the most important communities, ecosystems, problems so we can be focused on those and get answers to those - we broke it up to teach and learn to the point where there is some overlap but we are not getting an answer to the questions we need (i.e. what is the value of ecosystem services), so we can plug them in and to all these different places – it depends on where you are, and we should have accounted for that, what kind of design do you develop up front to account for that – it is an issue of representativeness, ... the scalability and extrapolation potential is something we should have thought more about.*

Regarding the structure of the program, Nitrogen as a Cross Program Theme was considered an appropriate stressor to assess and “this would be chosen again”. Conducting Demonstration Projects and assessing other ecosystems other than just wetlands and coral reefs was mentioned. One respondent felt the wetlands project was an area that could have been done better – researchers “getting bogged down in the finer details was presenting a problem”.

In regards to the place-based projects, “as the places have been busy doing their own internal program they have been limited in their time/resources/capacity to do the ‘cross place’ types of stuff ... so I would want to change that". The Tampa Bay Project was referred to a number of times in interviews as a well-designed and run place-based study. Supporting a previous Lead’s comments on the need for centralising some of the program design so to ensure scalability and transferability of outcomes, one respondent stated:

> *… [what] we could have done better would be to design more specific parallel design components in our place-based efforts. That is, we should have had very similar and specific objectives but allowed different tools and approaches to be used ... this should have been done explicitly and performed as an experiment ... ideally, the FEGS approach would have been completed before we moved ahead with the place-based studies.*

One respondent specifically referring to, but not directly involved in the development of the National Atlas of Ecosystem Services, said there was nothing they would do differently in the mapping section of ESRP. One approach that worked well with the maps and dynamic models was the ability for stakeholders to be involved in the development of data layers up front (where possible) due to the frustration of trying to standardise data later.

One respondent said "the modelling was wrong – we needed a modelling plan up front ... because if you don’t you are never going to pull it back together and if you do it is going to be a very painful and expensive process". “Criteria for appropriate models should be developed early on and the best models to meet this criterion should be used”. The lack of consistency in models used across the ESRP was said to bring innovation however. “Some of the new models the program has come up with (such as temporally dynamic water quality models) were considered "one of the best products we [ESRP] have ... because it is performing so much better than any existing model right now".

Eight of the 13 Leads were asked: *do you have a 'wish list' for future resources for your research?* The most common response was more ESRP internal, inter-divisional, face-to-face collaborations "so as to better share and coordinate information and learn across the program". Also having the capacity (time, money, ability) for stakeholder outreach was mentioned many times during interviews. At the time of these interviews the ESRP was morphing into the Sustainable and Health Communities Research Program - still having the time and money to deliver the tools they set out to under the ESRP was important to one respondent. Two others mentioned the need for more scalable health data.

Further thinking about synthesising, integrating and scaling information across the ESRP, led me to ask one of the Leads: *how are you planning to synthesise information across the program?* "There was no upfront synthesis plan - originally it was considered the National Centre for Environmental Assessment would become involved in the ESRP and track the program through periodic summaries and assessments". Much of the information developed will transition also into the new Sustainable and Healthy Communities Research Program. But as far as synthesising information developed in the ESRP, the resources (time and funding) are not available for such research. "So I am thinking like in many of our big programs that we will walk away without ever really having put the big picture together and leaving behind all we learned and all the value associated with the research other than what has been gathered in the literature".

To complete the analysis of the ESRP methodology and determine how Leads would determine the success of their program, six Leads were asked: *how will you measure the success of your research section of the ESRP?* All respondents stated a determinant of success is the use of the information and tools by stakeholders (at all scales and levels) of decision making. Increased awareness of ecosystem services and publication in scientific literature was also mentioned. Similar to Chapter 4 on the SEQ program the final and following section concludes this chapter; it provides a synopsis of the outcomes of the analysis into the US methodology as discussed in previous sections.

5.5 Synopsis of the US methodology

This chapter analysed the experience of developing an ecosystem services framework at the national scale in the US. Section 3.2.3 described the multiple case study approach used to analyse the US (and the UK) methodology. According to Yin (2009, p. 4), methods to extract information under case study analysis (i.e. interviewing) ‘allow investigators to retain the holistic and meaningful characteristics of real-life events'. Case study research is an empirical enquiry best applied when the researcher has little control over actual behavioural events (Yin 2009). Studying other methodologies outside my influence (unlike the SEQ methodology) increases breadth of knowledge and reduces bias in the overall outcomes (Sarantakos 2005; Yin 2009).

Section 3.2.3.1 provided background information on the US, the US program and the coordinating organisation. As a Member State to the UN the US is a signatory to many international treaties (UN 2014b). The US is also Party to two of the four major global ecosystem-related conventions: the Ramsar Convention and the Convention to Combat Desertification (Ramsar undated; UNCCD 2012). The four main levels of administrative divisions within the US include: national, 50 states, 3000 counties and 89 000 local governments (Howes 2005; US Census Bureau 2014). Figure 3.3 is a political map showing US states and counties.

The US is one of the largest countries by area in the world. Its sheer size allows for tropical, temperate, arctic and semi-arid zones to form. The country is ecologically characterised by its wilderness areas such as its wetlands, mountains, grasslands, plateaus, gorges, large rivers and the largest group of freshwater lakes on Earth. The Department of Interior contains a number of operating units responsible for programs relating to the management and conservation of most federal land and natural resources (US Department of the Interior 2014a; US Department of the Interior 2014b). The Department of Agriculture retains the agriculture and forestry portfolios (US Department of Agriculture 2013).

The ESRP analysed in this chapter was coordinated by the EPA which operates on a regulatory capacity through the Office of Air and Radiation and the Office of Water, as well, in a non-regulatory capacity through the ORD. The EPA has the charge of interpreting and enforcing the Clean Water Act, the Clean Air Act and many other environmental laws related to pollutants and aquatic ecosystems. ORD is charged with conducting 'research necessary to ensure the Agency's policies, programs and regulations are based on a scientifically defensible foundation' (EPA 2008, p. 1). With 10 regional offices, the EPA mission is to 'protect human health and the environment' across the US (EPA 2006; EPA 2013a).

Based on the outcomes of the three Lines of Enquiry (Sections 5.1, 5.2 and 5.3) and reflections by ESRP Leads (Section 5.4), the *process, information* and *tools* are conceptualised in Figure 5.2. For ease of comparison across methodologies and research approaches this figure's format is similar to Figure 4.5 conceptualising the methodology developed at the regional scale in SEQ and Figure 6.3 conceptualising the methodology developed at the multi-national scale in the UK. The process applied to develop different types of information, and what tools used which types of information, are shown in these figures as vertical lines parallel to corresponding boxes showing the information. This figure does not show the process, information and tools developed for specific sections of the ESRP (e.g. nitrogen, place-based studies or ecosystem studies), as this research is focused on the scale of framework development (e.g. national).

Starting from the left of Figure 5.2, the vertical line stretching from National Framework to Health and Well-being shows the EPA coordinated all elements of the information supporting the framework. Column 4 in Appendix 1 highlights key features of the process applied to develop the US framework including four key *factors underpinning the initiation of the ESRP.* Section 5.1.1 discussed these factors which included*:* the MA release in 2005; a report by the National Academy of Sciences; a number of statutory and regulatory mandates; and a budget cut resulting in EMAP no longer feasible to run because less money was available to buy extramural support. The ESRP builds on decades of research conducted under EMAP which focused its research on issues such as air quality, toxicology, water quality, human health, microbiology, nanotechnology, pesticides and toxic substances, wetlands, streams/rivers and land protection (EPA 2008, 2011a).

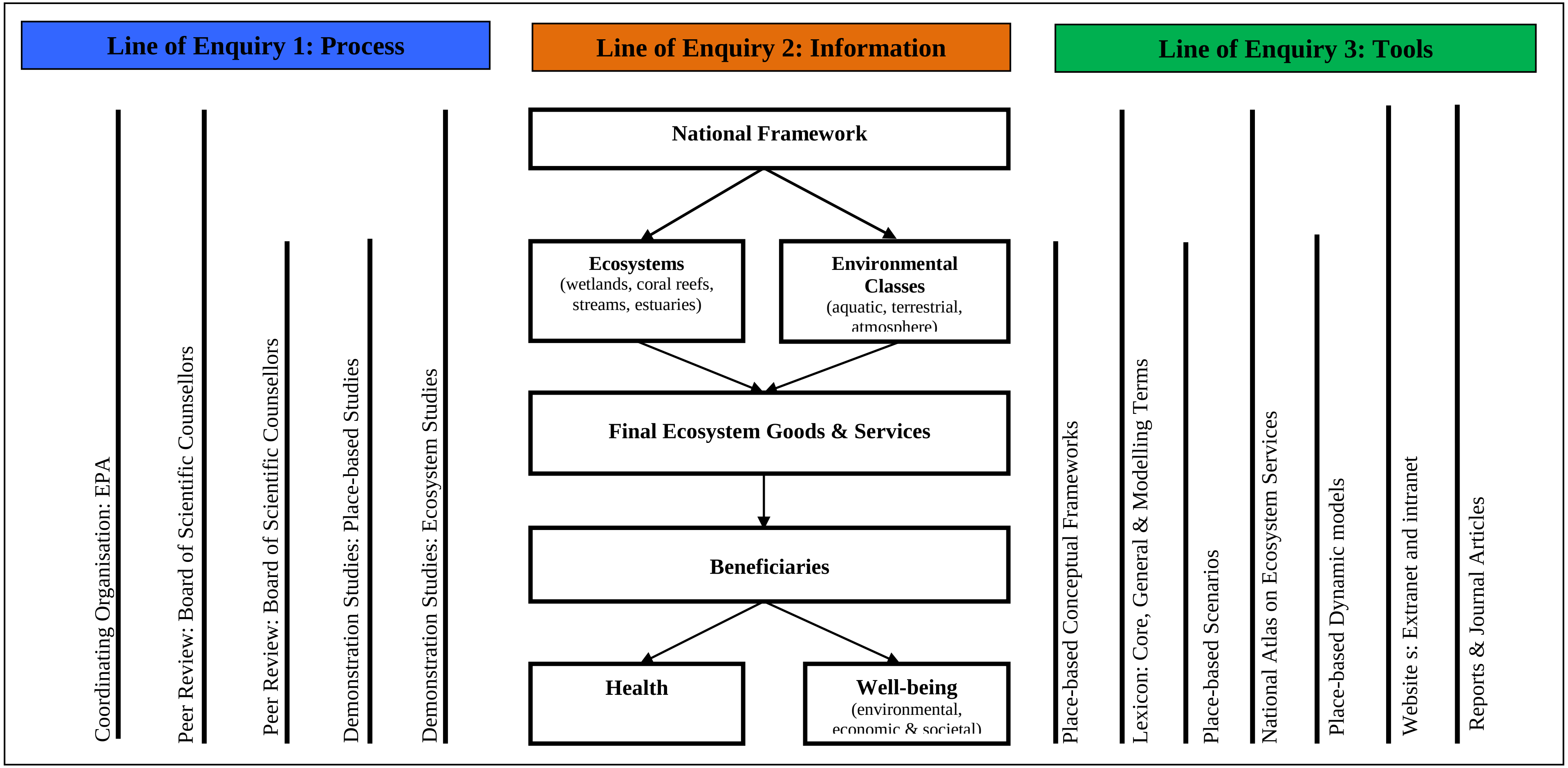

Figure 5.2: Key features of the US national scale methodology. From left to right the figure shows - Line of Enquiry 1: the process to develop the framework; Line of Enquiry 2: the information to support the framework; and Line of Enquiry 3: the tools to support the framework.

The rationale behind the EPA *coordinating the program* was discussed in Section 5.1.2. Leads working in the national and place-based studies said there were benefits and dis-benefits to being a government agency coordinating the development of the framework. The benefits included: the EPA being responsible for national environmental protection and already working on national scale information; the EPA managing a large range of environmental issues; the ability of government agencies to better leverage other government agencies; a consistent stream of funding; and the “potential [for EPA] to propose a nationally standardised accounting and classification system” and to cap and trade "things".

Dis-benefits of being a government agency coordinating the development of the framework included: the EPA being recognised by others "as coming in over the top" with regulatory solutions; gaining access to properties for research was difficult; the inflexibility of governments due to their rules and regulations; released material are "old" by the time it had been peer reviewed; "regulations can provide a hindrance … because they often focus on one problem at a time rather than taking a systems approach – also they can be short sighted"; and that other agencies are independent and not regulatory so they can do research and not have the same implications.

Section 5.1.3 detailed the *resources* (e.g. time, budget and employees) invested in the ESRP. The ESRP operated over a five year period. The National Program Director coordinated the activities of 185 in-house scientists and support staff located in various EPA Laboratories. Column 3 in Appendix 3 shows the tertiary qualifications of the Leads interviewed was mostly in biology and ecology. Those employed in EMAP generally transitioned to the ESRP hence "the domination of natural scientists”. Social scientists (including economists) have mostly been “brought in from outside the program". The budget supporting the ESRP (approximately US$70 million per year) was not considered restrictive but the way it had to be used was, it limited new innovations and the hiring of extramural support.

Supporting Section 5.1.4 which described the *structure of the ESRP* is the table presented in Appendix 4 showing the major activities undertaken to develop the US framework. From an EPA perspective stakeholder engagement was considered “high priority” but from an ORD position it was not considered “something that was done very well”. The process to develop information and tools at the national scale was mostly conducted “in-house” (at ORD). Although “a more collaborative approach to the program across federal agencies” was recognised as “preferable” past experiences and the agencies' objectives and missions were different enough to deter a more collaborative approach. Scale was not considered an issue to engaging stakeholders "because all local governments and stakeholders have groups that aggregate up". BOSC peer reviewed information and tools at the program and project level. All potential journal or EPA publications required peer review prior to public release.

Figure 5.1 shows the matrix structure of the ESRP. Five LTGs guided the program through Cross Program Themes and Demonstration Projects aimed at ‘maximising coordination, integration, consistency, and team effectiveness dynamics’ (EPA 2008, p. 15). Cross Program Themes included: LTG 1: Effective Decision Support; LTG 2: Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales; and LTG 3: Pollutant–Specific Studies (i.e. nitrogen). Demonstration Projects included: LTG 4: Ecosystems Studies; LTG 5: Place-Based Studies. As can be seen in Figure 5.1 the highest amount of resources (37%) was dedicated to ‘Mapping, Modelling and Monitoring Ecosystem Services across Multiple Scales’.

Relevant Cross Program Themes and Ecosystem Studies are discussed further below when describing the information and tools incorporated in the framework. Of importance to describing the ESRP’s structure are the place-based studies; research operating in the real world within communities, ecosystems, economies and socio-political systems. The ESRP states 'the concept of place is central to the development of the science of ecology and is critical to the investigation of ecosystem services' (EPA 2008, p. 92). The 'nature, structure, value and the aggregation of ecosystem services are all place-dependent' (EPA 2008, p. 92). Place is considered important to understanding ecosystem functions from which the services are derived, as ecosystem functions are associated with the biogeographic characteristics of a place (EPA 2008).

Four place-based studies were chosen based on: where the EPA had laboratories; where the EPA already had a lot of data; where the laboratory had existing activities that could be capitalised on; where the laboratory had a partner willing to work with them; those places that showed the greatest interest; sites being in different areas of the country with both similar and dissimilar issues to address; and the desire of laboratories and organisations to study a particular driver or policy. Criticism from the SAB concerned with “misrepresentation of a whole section of the country” saw a fifth place added. It was agreed a conceptual framework would be provided if someone was to take up a sixth place.

Initially places were not chosen for future comparison, synthesis of information across projects, or to up-scale information to state or national scales. This became more of an objective later in the program. One respondent said a more “guided” approach and “centralising” of “problems and issues” across projects would have improved outcomes in terms of “scalability” and “extrapolation” potential. They said, what “we could have been done better would be to design more specific parallel design components in our place-based efforts …we should have had very similar and specific objectives but allowed different tools and approaches to be used”. As well, “ideally, the FEGS approach would have been completed before we moved ahead with the place based studies”. “As the places have been busy doing their own internal program they have been limited in their time/resources/capacity to do the cross-place types of stuff ".

“Collaboration” in the ESRP predominantly occurs “within the sections of the program, rather than at the national scale”. The National Atlas of Ecosystem Services and the Tampa Bay place-based project were described as highly collaborative. Responses from Leads sharing their experience with collaborative research were mixed. Some said the slow pace of collaborative research was frustrating for most researchers and stakeholders and keeping them excited and engaged over a long period was challenging; whilst others said current inter-disciplinary research was progressing quicker due to the diverse skill sets available and that everyone educated each other. Three tiers of stakeholders "we want to engage with” were identified as: “1/ the public; 2/ their representatives, managers, neighbourhood associations, city mayors, natural resource managers; and 3/ the science, technical people”. They said the tools they were developing to support ecosystem services assessments would look a lot different (more complex) if they had not worked collaboratively and received stakeholder feedback.

Proposed users of the information and tools produced through the ESRP are the EPA itself, particularly the Office of Water and Office of Air and Radiation. The primary scale of application is the national scale with the 10 regions being the smallest scale decisions are made. At the community level "application of the information and tools has not been given a lot of thought across the national program". However the focus on an internal audience "has changed a bit over time - recognising that everybody can use it [the framework] just at different scales". "Another group of users are the "investors" (e.g. business, industry, developers).”Different sections of the ESRP are tailored for different audiences and scales" (e.g. the Regional Offices, managers, planning councils, communities or academics).

The analysis of information developed to support the US framework began in Section 5.2.1 with a discussion on *biodiversity*. Although the ESRP’s Lexicon provides a paraphrased version of the CBD’s definition there is no reference to biodiversity in the US framework (hence why it is not presented in Figure 5.2. Early on in the program discussions were held on biodiversity’s role and no resolution was made but this did not become a hindrance to moving forward with the program.

Appendix 5 provides a condensed version of the responses from Leads when asked about biodiversity’s role in assessments and its position in a framework. The majority of Leads said biodiversity is not an ecosystem service (even though it was something people cared about) and that it was "more of a structural thing". The subjective nature of biodiversity and our inability to actually measure and value it was another reason for respondents claiming biodiversity is not a service. It was noted as a nation “the US is not quite oriented towards biodiversity and that biodiversity is not an EPA mandate” - it tended to be more regulatory towards pollutants and “the EPA does not have the authority to legislate land-use key to protecting biodiversity”. Across both yes and no answers to the question, a system that has higher biodiversity was considered to be stronger, more robust, resilient and sustaining in its delivery of ecosystem services than one with less biodiversity. Biodiversity was described as an "insurance policy for ecosystem services".

Supporting the discussion on ecosystem services *assessment units* in Section 5.2.2 is Appendix 6 which lists the two types of units in the US framework: Ecosystems and Environmental Classes. Wetland and coral reef ecosystems were selected as these ecosystems are in decline in the US and wetlands are “one of the ecosystems ORD has a lot of responsibility for” (EPA 2008). Coral reefs, however, were chosen because researchers were inherited from EMAP and their research program had been changed a number of times so there was “little willingness to make them change again”. Outside of these demonstration projects there is “no standard approach to the ecological units assessed across the ESRP". The type of ecological unit applied or assessed within projects is "dependent on the particular problem or issue being addressed".

More theoretical studies on streams, wetlands and estuary ecosystems were also conducted. In these studies expert multi-disciplinary workshops were applied to identify the indicators of FEGS from these ecosystems. These ecosystems were selected due to the large amount of existing data and expertise held by the EPA; and because the EPA also has responsibility for the US Clean Water Act. "The plan is to eventually apply the successful elements of the workshop to a wide range of ecosystems across the US in similar categories to the Reporting Categories identified in the MA". These workshops became a precursor to developing the second type of assessment units, environmental classes.

Environmental classes "are a broader classification of ecological components aimed at better encompassing abiotic elements (e.g. atmosphere and groundwater) contributing to ecosystem service provision and that are not captured by other categories of units (such as ecosystems)". Three environmental classes (aquatic, terrestrial and atmosphere) are further refined into 15 environmental sub-classes (Landers and Nahlik 2013). As the environmental classes were in the final stages of development at the time of conducting this research they were not formally incorporated in the US framework and little explanation of these was provided in any EPA literature.

Ecological processes are discussed in Section 5.1.3. Ecological processes and intermediate services are defined in the Lexicon but ecosystem functions are not. As discussed, the terms ecological processes and intermediate services are not interchangeable in the US framework as unlike ecological processes, intermediate services are anthropocentric and only exist if underpinning the provision of a FEGS. Neither ecological processes nor intermediate services are presented in Figure 5.2 as although they are defined they are not included in the framework. The reason for this is:

> *… the focus is on the FEGS and the specific ecological processes and intermediate services may be unknown or poorly known. The intermediate services reside in the domain of the ecological process modellers who have the task of understanding the workings of the ecosystems … this is certainly*

a more efficient way of addressing ecological understanding as opposed to attempting to understand all intermediate services and processes.

The Lexicon defines both *ecosystem services* and FEGS (Section 5.2.4). FEGS as defined in the Lexicon is based on the FES concept developed by Boyd and Banzhaf (2007) which, as Chapter 2 described, aimed to advance the development of environmental accounting and performance systems. “There was variability” in the definition applied across the program regardless of the Lexicon definitions. The definitions varied between the MA’s benefits definition and the FEGS. Based on responses by Leads the key components of the FEGS approach are:

- FEGS are "biophysical components or attributes" of ecosystems "that people care about";
- a biophysical component or attribute can be an intermediate service or FEG depending on what people care about;
- FEGS are the "final" biophysical components or attributes of ecosystems that people (beneficiaries) interact with;
- a "specific beneficiary" is required for a FEG to be recognised - "individuals can be made up of one or more beneficiary".

Appendix 8 provides a list of the ecosystem services/FEGS assessed under the ESRP. There was variation in which ecosystem services were the focus of assessments in each place-based study due to their different context. Those in the place-based studies were provided the option to “assess whichever services they felt feasible as long as it fitted the definition of ecosystem services for the ESRP”. Although the MYP 2008-2014 provided a list of ecosystem services that were to be the focus of the ESRP, no definitive list was used across projects. Therefore, for the purpose of this research documents, websites, presentations and comments from interviewees were compiled to develop the list in Appendix 8. Developing a common classification and list of ecosystem services for all researchers to use is now a focus of the ESRP. Twenty-three ecosystem services were being assessed across major ESRP projects. All projects assessed the supply or provision of water for people; habitat, clean air and food production were the next most common.

How *ecosystem services* are being *valued* in the US framework was discussed in Section 5.2.5. They deployed both monetary and non-monetary methods to value ecosystem services although monetary methods were only deployed in place-based studies and not at the national scale. Because the budget was limited for this area of the ESRP it was said to be difficult to engage with other areas of the EPA where most the economists are positioned. All areas of the program, however, have tried to have an economist (external to the ESRP) come on board to assist with valuations.

The MYP 2008-2014 introduces the term 'human health and well-being endpoints' (HHWB). HHWB are researched separately in the program because: ORD previously had a group of people who worked on human health and they do "not do well-being, they do human health (toxicology, cancer studies and exposure studies)"; separation of the topics provided acknowledgement of previous research; and because "people are going to respond to mortality and morbidity issues (e.g. childhood obesity, asthma, premature mortality)".

The heath section focused on potential dis-benefits of ecosystems (e.g. Lyme disease) and the disruption to ecosystem services by stressors (e.g. nitrogen) and human vulnerability (EPA 2008). Information from the health section fed into research nationally through the Atlas and also in the place-based projects. When one Lead was asked about the type of information necessary to conduct a health assessment they said current information on cancers, deaths and birth outcomes is good but not fine scale enough (neighbourhood scale would be better); information on chronic illnesses such as depression and other mental health issues would be advantageous; as well, information on obesity.

The ESRP Lexicon provides a paraphrased MA definition of human well-being. The aim of this section is to develop a human well-being index that will "become a predicted endpoint for a decision support tool that bundles relevant service flow measures from capital-based modules". More specifically, it focuses on the positive measurements of well-being (i.e. "those things that contribute positively to well-being as opposed to ill-being". What aspect of human wellbeing you are trying to track will determine how frequently and long data needs to be measured for, but generally every five to 10 years the well-being component of the framework should be reviewed.

The “elements” of well-being were identified as “environmental, economic and societal”. A set of criteria was developed to evaluate (existing and needed) well-being indicators. Key research and literature used to develop the well-being index include: Canada Index of Wellbeing, General Social Survey, Gallop Survey, National Education Statistics, American Time Use Surveys, Labour Statistics and the Census Bureau. The next stage was “applying professional opinion assigned as relative importance values and to rank data in conjunction with public perception to evaluate well-being in terms of the relationships among ecosystem services, domains and their constituent elements”.

To the right of Line of Enquiry 2 in Figure 5.2 are vertical lines showing the different tools developed to support the US framework; and what information was captured or used in the different tools. Section 5.3.1 discussed how no *conceptual framework* was developed to support the national scale framework. “The different place-based projects have developed different research conceptual models”, however. “It was suggested the place-based studies adopt a consistent conceptual framework …” but “those involved with the place-based studies were more comfortable staying with their current models [conceptual frameworks]” which are primarily ecological by nature.

A Lexicon was developed to support the framework with the aim of providing a consistent language across projects, disciplines, employees and consultants working on the program (EPA 2010b). A clear definition is “fundamental to identifying, measuring and valuing ecosystem services”; and required "to understand ecosystem services, describe ecosystem services, monitor ecosystem service provision over time and to doing coordinated research on ecosystem services". “With hundreds of potential biophysical metrics you could measure in an ecosystem, a clear definition is important to sorting out what you really need”. The Lexicon consists of three tables: 1/ Core Terms with Their Preferred Definitions – understanding of these is required by ESRP researchers and proposed users; 2/ General Ecological and Economic Terms – providing a broader listing of terms useful to ESRP researchers and proposed users; and 3/ Modelling Supplement - is a set of modelling terminology for use and understanding by ESRP researchers and proposed users.

Section 5.3.2 discussed how *scenarios* were developed to support place-based studies but no national scale scenarios were developed under the ESRP. The variation in context and scale of the place-based studies created variation in the scenario topics applied and therefore the type of information and tools collected or developed. Details of the scenarios developed at the place-based scale are beyond the scope of this thesis which is focused on analysing methodologies at the scale they were developed (e.g. national). However, nearly all place-based studies conducted scenarios on climate change and nitrogen.

Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales was the topic of LTG2 and this was discussed in Section 5.3.3. The aim was to 'develop a publicly accessible, scalable, digital National Atlas of Ecosystem Services to inform decision-making at multiple levels' (Neale 2011). A highly collaborative approach was adopted working predominantly with other federal agencies allowing them "to work within their specialist areas of expertise". In the Atlas interface there are three spatial scales: 1/ the national scale; 2/ the community scale; and 3/ the special study area where the place-based projects can reside. The Atlas is the “only place that will be serving up data on ecosystem services on the national scale”. Both intermediate services and FEGS are mapped within the Atlas. “The Atlas relies heavily on existing national datasets”, however, “some data sets (e.g. soils) have been developed specifically for application in the Atlas”. To date “over 60 data layers have been included”. "One of the prerequisites for inclusion is that it has a peer reviewed journal article published supporting its development". Proposed users of the Atlas are national agencies, counties and "general public that would read a National Geographic".

“There is no consistency in model type being applied” across the ESRP because there is no "one size fits all" model. Some models are "stand alone" and "built to fit" for specific purposes (e.g. specifically for a place-based study) whilst other models provide the infrastructure to support the integration of many models. There was “a strong reluctance to adopt a common modelling approach across the place-based projects” and this is “an area of much contention within the ESRP”. A modelling plan was developed in recognition of one highly desirable output, a “whole of system” model (EPA 2011e). This whole of system model would provide an ”interface to integrate and run models in parallel to enable cross-communication and provide representations of dynamic systems that include feedbacks, feed forwards, non-linear relationships and time-lagged responses”. There has been no move to develop a “national scale” model to date but "given a national scale question this could be developed – eco-regions could be the spatial unit for a national model".

Leads were asked about the benefits and dis-benefits of maps and dynamic models as tools to conduct and communicate ecosystem services assessments. Some of the words used to describe the development and use of maps were "simple"; "straight forward"; "easy to understand"; "not requiring a whole lot of complicated software development or machinery"; and they were said to be cheaper to develop and apply than simulation models. People were considered to "trust" and "relate" to maps - it was more difficult to get people to have "faith" in dynamic models. Maps "spoke easy to people" and were "able to reach many more people than technical model output" because maps are "visual". One of the problems with all maps is identifying uncertainty that underlies the images - this is not easily represented. Additionally, “maps often have very discrete boundaries and this is rarely the case in nature”.

Dynamic simulation models were described as "complicated", "complex", "time consuming", "back-boxish" and "having to have technical expertise and time". Experiences in "participatory modelling" were positive. “The primary benefit of simulation models was their ability to provide future projections”. Maps were said to be great for looking at what you had now and trying to make some assessment of current conditions - but they did not cover the dynamics required to understand the context of ecosystem services decision making and assessing alternative futures. “Point' models” were considered insufficient for ecosystem services assessments because “one point is not necessarily representative of other points in the landscape - more sampling units (points) are required" and "because it is not just where we have databases, it has got to be where we don't have data bases … and then you have to calculate something new and point models just can't do that”. Although it was thought that some decision makers might be happy with only maps, and regardless of the benefits or dis-benefits of dynamic models and maps, both maps and models were considered necessary for ecosystem services assessments.

As shown in Figure 5.2, all elements of the information developed to support the US framework were described on the website or in some form of report or journal article. Table 3.1 lists the primary ESRP literature used in this research as data in the analysis of this methodology. Numerous journal articles and internal technical reports were produced communicating how this research builds on the current state of knowledge of ecosystem services. The general website for the EPA contains a fact sheet and brief information on ecosystem services including links to projects within the ESRP. An EPA intranet shares information with internal stakeholders (ESRP employees); although external stakeholders can be sponsored by internal stakeholders and granted access to internal documentation. The National Atlas of Ecosystem Services is also online with free open access.

Looking back on the process, information and tools (methodology) developed through the ESRP (and described in this chapter), hindsight on what worked well and not so well was provided by Leads (Section 5.4). These included:

- "What I would do exactly the same ... engaging other agencies. I think that's really, really, really important".
- Nitrogen as a Cross Program Theme was considered an appropriate stressor to assess and “this would be chosen again”.
- “Assessing other ecosystems” (as demonstration projects) other than just wetlands and coral reefs.
- The Tampa Bay place-based study and the development of the National Atlas on Ecosystem Services were “well-designed projects”.
- "Getting Memorandums of Understanding in place" was difficult and a deterrent to engaging more stakeholders up front and conducting a more collaborative approach, “an opportunity for engaging stakeholders was missed”. More community and (other) stakeholder outreach were needed.
- Regarding mapping, the ability to be involved in the development of data layers up front due to the frustration of trying to standardise data later.
- Regarding modelling, "the modelling was wrong – we needed a modelling plan up front ...” Criteria should be developed early on and the best models to meet this criterion should be applied. However, the lack of consistency in modelling also brought innovation.

The most common wish on the list for future research was more ESRP internal, inter-divisional, and face-to-face collaborations “so as to better share and coordinate information and learn across the program”. Also, having the capacity (time, money, ability) for stakeholder outreach (locally to internationally). As at the time of these interviews the ESRP was morphing into the Sustainable and Health Communities Research Program, still having the time and money to deliver the tools they set out to under the ESRP was important to one respondent. More scalable health data was also mentioned. As “there was no upfront synthesis plan” the resources (time and funding) were not available to do comparable work across place-based studies in the ESRP.

This concludes the analysis of the US methodology using the three Lines of Enquiry. Similar to Chapter 4 analysing the SEQ program and this chapter analysing the US program, Chapter 6 provides the outcomes of the three Lines of Enquiry as applied to the UK National Ecosystem Assessment (UK NEA). Chapter 7 cross analyses these three methodologies and where relevant benchmarks these against the MA and other schools of thought discussed in the literature.

Chapter 6

The UK National Ecosystem Assessment

Chapter 4 discussed the outcomes of the applied research used to analyse the SEQ (Australia) regional scale methodology. Chapter 5 discussed the outcomes of the second methodology analysed, the methodology developed through the national scale ESRP. The ESRP was the first methodology analysed using the *multiple case study analysis* and this chapter provides the outcomes of the second. The following sections of this chapter describe the multi-national scale methodology underpinning the United Kingdom's National Ecosystem Assessment (UK NEA).

Similar to the US case study, and as discussed in Sections 3.2.3 and 3.2.3.2, the outcomes of this case study analysis are primarily based on responses to questions asked of 17 Program Leads in 17 interviews conducted from 10th October 2011 – 13th November 2011. The baseline questions from which the US and UK interviews were conducted are listed in Appendix 2. Relevant questions were chosen and adapted to suit the UK program and the Lead being interviewed. The primary documents used as data to support this analysis are listed in Table 3.1. To begin this analysis the objectives of the UK NEA (2011b, p. 3) as described in their Technical Report are listed below:

1. *Produce an independent and peer-reviewed assessment of the state and value of the UK's natural environment* and *ecosystem services.*
2. *Identify and understand what has driven change observed in the natural environment and the services it has provided over the last 60 years, and what may drive change in the future.*
3. *Foster better interdisciplinary cooperation between natural and social scientists to assist in strengthening policy making in order to ensure effective management of the environment and ecosystem services in the future.*
4. *Ensure full stakeholder participation and encourage different stakeholders and communities to interact with each other.*
5. *Use the key messages from the assessment to raise awareness among society of the importance of the natural environment to human well-being and economic prosperity.*

For ease of analysis across methodologies and research approaches this chapter follows the same format as Chapters 4 and 5 on the SEQ and US programs. Section 6.1 begins the enquiry by analysing the process to develop the UK framework (Line of Enquiry 1). The sections following (Section 6.2 and 6.3) provide the outcomes of Line of Enquiry 2 on the information supporting the framework and Line of Enquiry 3 on the tools. Differing from Chapter 4 but similar to Chapter 5, Section 6.4 provides reflections (hindsight) by Leads identifying features of the program considered to have worked well and areas that did not work as well. Section 6.5 summarises the previous sections into a synopsis of the UK methodology.

6.1 The process to develop the UK framework

This section aims not only to describe the process applied to develop a framework in the context of the UK and at the multi-national scale, but to better understand the drivers behind the choice of applying that type of process. Appendix 1 provides a synthesis of key features underpinning the MA and the SEQ, US and UK processes. Specifically, Column 5 presents key features of the process applied in the UK NEA. As mentioned in Chapters 4 and 5, although these features of the process are discussed in isolation in the following sections they are recognised as interrelated with other features in the table. Outcomes of analysing the UK NEA under the key topics identified in Section 3.1.1, are in Sections 6.1.1 (factors underpinning the initiation of the UK NEA), 6.1.2 (the coordinating organisation behind the UK NEA), 6.1.3 (the resources invested in developing the UK NEA framework), and Section 6.1.4 (the structure of the UK NEA program).

6.1.1 Factors underpinning the programs initiation

The UK NEA’s Technical and Synthesis Reports describe factors underpinning the program’s initiation (UK NEA 2011a, 2011b). They describe the impact technological developments, especially agricultural intensification and the industrialisation of fishing, have had on productive ecosystems across the UK (UK NEA 2011a, 2011b). Fertiliser (particularly nitrogen and phosphorous) and pesticide use are identified stressors on aquatic ecosystems, landings of fish and the decline of other seafood. The Farmland Bird Index (a key indicator of the state of biodiversity on agricultural lands used in the UK) showed a 43% decline in biodiversity between 1970 and 1998 (UK NEA 2011a). It is recognised that more recently the UK's responses to managing biodiversity and agricultural production have been driven by EU policy (UK NEA 2011b). Climate change is said to have had only small impacts on the loss of UK's biodiversity and ecosystems (UK NEA 2011a).

To determine if other factors outside of those documented in the literature influenced the UK NEA's initiation, and to better understand motivations underpinning the involvement of England, Wales, Northern Ireland and Scotland in the program, six Leads including those representative to the national governments were asked: *were there any significant factors underpinning the programs initiation?* Climate change and the Stern Report 2006 were identified by two Leads. Two more factors were the inability of governments to meet the CBD's 2010 Biodiversity Targets, as well, the need to apply the CBD's Ecosystem Approach to resource management (which is also endorsed by the Department of Environment, Food and Rural Affairs (DEFRA)). Other factors identified or confirmed as influencing the governments' involvement include:

- existing involvement in the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES);
- recognition of the need for a stronger evidence base on which to base policy decisions;
- the recognition that ecosystems are interconnected across countries;
- the need to look at the environment and scientist's use of the environment in a more integrated and positive way; and
- Britain's involvement with European policy.

Section 6.1.2 discusses the choice of organisation coordinating the development of the UK methodology.

6.1.2 The coordinating organisation

The development of the methodology underpinning the UK NEA was coordinated by the United Nations Environment Program-World Conservation Monitoring Centre (UNEP-WCMC). UNEP-WCMC is the result of collaborations between UNEP the environmental branch of the UN's system and the world's foremost intergovernmental environmental organisation (UNEP 2013); and WCMC which is UNEP's specialist biodiversity branch and a UK-based charity (UNEP-WCMC 2013). The official website for UNEP-WCMC (2013) states:

> *For WCMC ... the collaboration with UNEP allows the charity to increase its access to decision makers and broadens opportunities for collaboration and data access, thereby increasing its ability to achieve its objectives. For UNEP the collaboration with WCMC ... provides access to substantial experience of biodiversity information and its use in providing support to decision making, thereby increasing UNEP's ability to deliver on its international mandates.*

To determine why a non-government agency was chosen to coordinate the UK program rather than a government agency or private organisation, nine Leads were asked: *what do you think is the role of government in developing ecosystem services assessment methodologies?* The respondents were a broad mix of Leads, including the Co-Chairs, representatives from national governments positioned on the Client Group (i.e. funders of the program), and Leads from the Secretariat. All respondents agreed, in country scale programs national governments need to be involved in the development of such methodologies. However, most respondents also stated the process of developing it should be independent of government and that "this was very clear at the beginning of the process". The three points below are a list of the roles the 'majority' of Leads (at least five out of the nine Leads asked) said government should play in the development of a framework:

- government should fund the program, their role was described as: "as funders of the program"; "to have a say where money is being spent"; "to have a mechanism for potentially locating more money or for stopping it if it was all proving to be a waste of time";
- government should participate "as one of the stakeholders, to have ownership of the program";
- government should "ensure the outcomes have policy relevance" and "the outcomes have traction".

Other roles of government mentioned included:

- "to understand and communicate the information to their Ministers and then the Ministers can talk to the other Ministers";
- “overseeing the program”;
- data collection, including providing access and consistency of data and information; and
- they should “contribute to agenda setting and developing the major questions”.

Also provided in response to this question were many reasons why the program should be coordinated independent of government, such as:

- "the need for it [the program] to be an independent review" was discussed by nearly all Leads;
- a number of Leads said "it [the program] requires independent scientific leadership"; that the "leader needs scientific credibility (which usually is not held in government or their position in government taints their credibility)";
- two Leads mentioned that "an individual leading it from one specific agency, isn’t so favourable to the other agencies";
- one Lead said "it [the program] needs to be kept at arm’s length of Politicians";
- another Lead noted "if the government itself did it, its legitimacy is less in the eyes of many other stakeholders";
- one of the Co-Chairs stated that "UNEP was most attractive to them [the British Government] as they are actually one step outside the normal UK institutions", so are less bias to politics and stakeholder agendas;
- two Leads said that collaborating is easier for non-government organisations, "... they have greater flexibility".

One respondent described the effects of diverging interests between governments and other stakeholders involved in developing the UK methodology and the need for “balance” across information:

> *... I think there were sometimes tensions between what the Client Group [government] wanted and maybe what the Expert Panel [independents] thought that they should be doing – nothing you couldn’t resolve - but whereas the Expert Panel was saying “This is our focus and we balance everything up like this” – some of the individual funders specifically looking*

after, for example, the rivers, they would have a particular focus on "We really need to move flooding up the agenda". It's another impact that ecosystem services have, but maybe not the one the Expert Panel wanted to pull out as any different to any of the other ones.

Section 6.1.3 describes the resources provided to UNEP-WCMC to develop the UK methodology in terms of time, money and expertise.

6.1.3 The resources invested

The UK NEA has a pair of Co-Chairs with "complimentary experience, not substitutable". When asked separately about their role in the UK NEA their combined response was, "we have extensive experience on large scale environmental projects"; "were heavily involved in the conceptual framework development"; "we liaised between the coordinating organisation and the scientists"; and "helped the coordinating organisation put the science teams together for the different chapters suggesting Lead Authors and other Co-Authors who could contribute".

As noted in Section 3.2.3.2, the UK NEA is part of the Living with Environmental Change (LWEC) initiative that includes 22 public sector organisations that fund, carry out and use environmental research and observations with the aim of ensuring decision makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from environmental change (UK NEA 2011b). From LWEC, "the UK NEA received approximately £1.3 million [in funding] over the two-year duration". As responsibility for developing components of the methodology were delineated to a wide range of organisations it is difficult to account for all paid individuals involved in the development of the framework. However, "it is estimated over 500 professionals paid and voluntary were involved overall".

To determine the resources in terms of the skill base (qualifications and disciplines) supporting the UK NEA, all 17 Leads interviewed were asked: *what are your professional qualifications and training?* Column 4 in Appendix 3 shows the university level qualifications (degree, graduate diploma, masters or PhD) held by these Leads and the number of Leads holding each qualification. Across all Leads, 31 tertiary qualifications were held, with each Lead holding at least one qualification and a maximum of three. Although Leads held a diverse range of qualifications the most common were zoology and biology, the natural sciences and economics closely followed. Similar to the SEQ and US, the social sciences were the least prevalent. Section 6.1.4 describes the structure of the UK NEA program providing information on the multi-scale process, who was involved in the program, and their role.

6.1.4 The structure of the program

The UK NEA (2011b, p. 2) aimed ‘to provide an analysis of the UK’s natural environment in terms of the benefits it provides to society and the nation’s continuing prosperity’. To do this, the framework developed to conduct the assessment was structured in a way that allowed the status and trends of ecosystems and ecosystem services to be assessed at multiple spatial scales. Terrestrial, freshwater and marine habitats are assessed at the national scale and the outcomes are captured in four separate individual syntheses (UK NEA 2011b). At the local scale, a series of case studies were conducted to better capture the context dependency of communities on ecosystem services. Recognising that not all ecosystem services delivered to the UK people will be derived from within the UK itself, trends in the dependence of the UK population on ecosystem services derived from outside the UK were also assessed (UK NEA 2011b).

Appendix 4 presents the structure of the UK program (and the MA, SEQ and US programs) in terms of who was engaged in the framework’s development (and conducting the assessment) and the roles they played. Section 6.1.2 introduced UNEP-WCMC the organisation who coordinated the development of the UK methodology. Within UNEP-WCMC 11 persons formed the UK NEA Secretariat (2011b, p. v). When four Leads from UNEP-WCMC were individually asked, *what is your specific role in the UK NEA?*, collectively their responses were:

- “budget management”;
- “work plan management”;
- “liaising with the Co-Chairs”;
- “ensuring deadlines are kept”;
- “sorting out any User Group grievances because they felt that they weren’t having a voice”;

- “a lot of talking to the Expert Panel and getting their opinion and then going to the relevant people and getting them to implement that”;
- “coordinating the peer review process”;
- “pulling together everyone’s comments and remarks”; and
- “developing communication products and mapping”.

One Lead from UNEP-WCMC captured well the organisation’s role in the development of the UK framework, they said:

> *… essentially it was to set up the process, the timelines, the programs, talk with the Co-Chairs about who’s going to be on the Expert Panels, contacting everyone who’s going to be responsible for writing the different components of it and tying it altogether. Then we oversaw the running of everything else, arranging the different meetings and the workshops and review processes and then basically stringing it all together.*

Funders of the UK NEA had their own group, the Client Group, through which they could contribute to the program. One UK Lead said the “aim of this was to separate organisational mandates and political agendas from the design of the assessment methodology and type of information produced”. Funders of the UK NEA and therefore the organisations included in the Client Group were: representatives of the Welsh, English, Northern Ireland and Scottish Governments; the Economic and Social Research Council (ESRC 2013) - ‘UK's largest organisation for funding research on economic and social issues’; NERC (2012); and DEFRA (UK Government 2013b). Both ESRC and NERC are non-departmental organisations who receive most of their funding from the Department for Business, Innovation & Skills which is the ministerial department for economic growth in the UK.

Twenty-seven of the UK’s leading natural and social scientists and economists formed the UK NEA’s Expert Group. The primary role of the Expert Group was to design the framework, approve the final chapters of the UK NEA Technical Report (Section 6.3.4.1), define key messages, and to conduct an actual ecosystem services assessment for the UK. This group was comprised mostly of researchers and academics from UK universities, however, representation also included those from other independent organisations and programs particularly in the fields of marine science, forestry, and agriculture and horticulture.

A group of 22 proposed users of the information derived from the UK NEA were invited to form the User Group (UK NEA 2011b). This group involved a broad mix of representatives from UK Treasury, national government environment agencies, national health organisations, energy and mineral agencies, farmer's federations, national water agencies, local government organisations, biodiversity groups, forestry organisations, department of communities, architecture and built environments, and heritage groups (UK NEA 2011b). Their primary role was to ensure the outputs of the applied framework were relevant to different audiences.

Two Leads said the information developed under the UK program was peer reviewed by invited independent reviewers on an as needed basis. As well, in the UK NEA Technical Report each chapter begins with a set of key findings that are rated for its 'level of certainty'. The method to rate for certainty under the UK NEA was adopted from the MA and the IPCC (in which one of the UK NEA Co-Chairs was also the Co-Chair of both these programs).

Over 300 Authors in 26 teams worked across a matrix structure to develop the framework (and conduct assessments). The matrix consisted of the four ecosystem service categories and eight habitat types. Coordinating Lead Authors oversaw the teams collecting and developing the cross-cutting information and knowledge to support the framework (and conduct assessments and write chapters of the UK NEA Technical Report). One of these Authors was positioned to specifically collect and develop the knowledge base underpinning the conceptual framework which aimed to "coordinate research across internal and external stakeholders" (Section 6.3.1). According to the UK NEA Technical Resort (UK NEA 2011b), Lead Author positions and teams were also developed to focus on:

- biodiversity;
- the three types of valuations (Section 6.2.5);
- scenario analysis; and
- policy options.

Through using the UK framework both multi-national and national assessments were conducted. One Lead Author was established to oversee each of the assessments for England, Wales, North Ireland and Scotland. As well, one Lead Author was dedicated to assessing the UK's dependence on ecosystem services derived from outside UK boundaries (UK NEA 2011b).

This completes the analysis into the type of process applied to develop an ecosystem services framework under the UK NEA, and the drivers influencing the choice of process applied. It described the factors underpinning the initiation of the program; the reason for adopting UNEP-WCMC as the coordinating agency (rather than a government agency); the resources invested in the development of the framework; and the structure of the program. The following section describes the output of the process applied in terms of the information included to support the framework (Line of Enquiry 2).

6.2 Information supporting the UK framework

This section provides the outcomes of the second Line of Enquiry aimed at identifying the type of information supporting the framework and better understanding the drivers behind this choice of information. The review of documents revealed the type of information is influenced by the framework's proposed purpose of application and the users (Section 3.1.2). To identify the users of information and tools produced under the UK NEA, 10 Leads consisting of the Co-Chairs, and members of the Secretariat and the representative national governments, were asked: *who are the users of the information and tools produced through your program?*

The UK framework and assessment outcomes were targeted at a wide range of stakeholders including: "students; farmers and the National Farmers Union; industry and tourism; the Royal Society for the Protection of Birds and the Wildlife Trust; foresters; and the general public". One Lead, however, refuted the general communities' use of the framework. "Certain people who are interested in certain habitats" were considered likely to use the framework. The majority of Leads mentioned "the service chapters were more for policy-makers rather than individual sectoral managers". Decision makers, academics, Natural England, and the NERC and the ESRC who fund the universities, were also mentioned as end users.

Now knowing more about the proposed users of the framework, to determine the type of information necessary for multiple stakeholders to conduct assessments, five Leads were asked: *what type of information is required to conduct an ecosystem services assessment?* The respondents stated: "information on habitats”; “a way of representing the biophysical processes that underpin the delivery of goods via ecosystem services from an understanding of the landscape and potential land use types”; the “‘goods’ that influence human wellbeing”; and “some way of measuring their relative importance or values". Two Leads referred to the 'cascade model' developed by Haines-Young (2010a, p. 7) which distinguishes between ecosystem structure and processes, functions, services, benefits and values; and was adapted for the purposes of SEEA and CICES (Figure 2.4). The UK framework was developed almost entirely on the 'evidence base' (UK NEA 2011b).

The following sections build on these insights into user information requirements, by delving into the key topics identified for further research under Line of Enquiry 2 (Section 3.1.2). Section 6.2.1 describes the role of biodiversity in ecosystem services assessments and its position within the UK framework. Section 6.2.2 describes the units applied to assess for ecosystem services. Section 6.2.3 discusses ecological processes, and how ecosystem services are defined and incorporated in the UK framework is discussed in Section 6.2.4. Information on the valuation process is in Section 6.2.5.

6.2.1 The role of biodiversity

The UK framework adopted the definition of biodiversity from the CBD (1992). This definition, however, was said to be ‘less than ideal from the perspective of ecosystem services, because diversity per se may have only a limited effect on specific ecosystem services’ (UK NEA 2011b, p. 68). To gain multi-disciplinary insight into where biodiversity should be positioned in a framework, as well, to compare schools of thought on biodiversity with those held in other methodologies, all 17 Leads were asked: *what is the role of biodiversity in ecosystem services assessments? Is biodiversity an ecosystem service or not?* Appendix 5 provides condensed responses from UK (and US) Leads to this question.

According to one Lead, from the very beginning of the UK program “the role of biodiversity in providing ecosystem services was controversial amongst stakeholders involved in the program". Two respondents from the UK stated the position of biodiversity in an ecosystem services assessment "doesn't really matter". Whilst another disagreed with this statement saying:

> *... it is quite an important question to solve at the very beginning because a lot of people have been working in the biodiversity paradigm for a really long time ... and we've spent all this time convincing governments that's what they should be worried about ... and to suddenly now turn around and say, "Oh, it's about ecosystem services" without making the link is quite dangerous ... and I think you have the potential then also to alienate so many stakeholders.*

One respondent stated that "for too long biodiversity has been treated separately ... by separating biodiversity, you separate out certain species from humans and therefore people don't see the linkages". Another supported this statement, "the whole point of ecosystem services is to consider all of these different things and balance them up, so biodiversity should be in the mix". A third respondent said "that trying to make biodiversity this completely separate thing will not work ... if you set biodiversity up in obvious opposition to everything else, well yeah, long term I want biodiversity but today I want sand or I want wheat and so I'll sort biodiversity out tomorrow ... and you know about tomorrow??". The recent report of the CBD was quoted as proving this "... because everybody met ... and said right we've got to halt the sliding biodiversity and reverse it, and they haven't even reduced the pace of losses. So, it's not working. You have to have a radically different approach".

In the UK NEA Technical Report biodiversity is written into the framework in three ways. One respondent described the three ways as: "What role does it play in processes?; What role does it play in services?; and What role does it play in goods?". Another said "... actually most of conservation is about biodiversity as a 'good' because it's actually the organism itself or the species that has value". Below is one Lead's detailed description of the interrelationship between the definition of biodiversity and its three positions in the framework:

> *... there isn't a single role for biodiversity, it depends what you mean by biodiversity. There are some bits of biodiversity, for example, the amount*

and variability of microorganisms in the soil… that are underpinning final ecosystem services and therefore goods. So there really is an underpinning role of biodiversity. There's also an ecosystem service that is biodiversity which is mainly around aesthetic recreational values. So people like to see lots of wild birds and corals, coral reef fish and some landscape diversity... that biodiversity doesn't particularly correlate with the underpinning role of biodiversity. And then there's actually a third type … which is at the goods level. But sometimes the goods themselves have to be diverse, and the best example there is around the diversity that you might think is there, is novel pharmaceutical products, where it's actually the chances of finding novel drugs or new foodstuffs that is directly correlated with the amount of diversity there is at the goods level. So I think it depends what you mean by biodiversity.

Two other respondents also said it depends on what is meant by biodiversity, as "... how people treat biodiversity depends on where they're coming from and what they see it as". Biodiversity as defined by the CBD was considered a service when "it's actually appreciated as biodiversity", as "some of the delight that people take in nature is the fact that it's hugely complex and diverse". Many Leads thought biodiversity was a service when people "directly visited" or enjoyed biodiversity. A number of respondents said that "biodiversity itself, by the fact it is diverse, is a service to give the system resilience".

Nearly half the respondents stated that biodiversity, in terms of "wild species diversity", is a Cultural Service. A common example provided was bird watching, a long standing popular past time in the UK. Four Leads noted that not all aspects of biodiversity are ecosystem services "its specific wild charismatic species" (e.g. "puffins, eagles, albatross and cranes"). Wild species diversity was also identified as a Provisioning Service, for example it "produces medicines and things we can eat like mushrooms". "Wild species that we don't harvest, we culturally value".

The role of biodiversity in the "delivery of ecosystem services" was discussed by the majority of respondents. The majority of respondents also used the terms ecosystem function, ecosystem processes, supporting services and intermediate services to discuss the role of biodiversity in ecosystem services assessments (note these terms are used interchangeably in the UK program) (UK NEA 2011b). In this context, biodiversity was discussed by many participants in terms of the fundamental role of lower order species such as microorganisms, soil biodiversity and insects. One respondent said they were not sure of biodiversity's role. Another said biodiversity was not an ecosystem service that in a list of ecosystem services they would have "habitat types" rather than biodiversity. Three respondents who stated biodiversity is a service also mentioned the importance of habitats and defined them as a component of biodiversity and an ecosystem service.

Biodiversity is addressed in the Technical Report in its own chapter and in each of the habitat chapters. Although the UK is rich in data on the status and trends of biodiversity, the data collected to date has not been specifically linked to ecosystem services (UK NEA 2011b). Including biodiversity in ecosystem services assessments would require combining data sets across different monitoring programs and employing different assessment methods (UK NEA 2011b). The primary practical constraint on the use of existing data for the purpose of ecosystem services assessments is ‘biodiversity data in the UK tends to relate to taxonomic groups distinguished by specific monitoring programs …biodiversity groups need redefining in terms of their functional role in ecosystem services’ (UK NEA 2011b, p. 68).

As quantitative information is still limited on the relationship between biodiversity and ecosystem services the UK NEA (2011b) applies a qualitative assessment (i.e. expert opinions of low, medium, high) rating the importance different biodiversity groups make to the provision of final ecosystem services. This level of importance is used in the UK NEA (2011b) to assess the sensitivity of each ecosystem service to changes in each biodiversity group. Experts were also asked to identify the level of certainty of this information (UK NEA 2011b).

The biodiversity chapter of the Technical Report says when assessing ecosystem services it is important to determine the functional component of biodiversity, because: a ‘service may be related to a specific aspect of diversity (e.g. species diversity)’ (UK NEA 2011b, p. 67); or a service ‘may depend on a specific functional group’ (UK NEA 2011b, p. 67); or ‘even an individual species that plays a specific functional role’ (UK NEA 2011b, p. 67). The units to assess ecosystem services and support the UK framework are discussed in the following section.

6.2.2 Assessment units

The UK NEA (2011a, p. 16) says ecosystems are usually defined in practice "by the scope of the function, process or issue being studied". 'Habitats' are defined in the UK program as: *an ecological or environmental area that is inhabited by a particular animal or plant species* (UK NEA 2011a, p. 84). "So to better integrate with current programs", 'Broad Habitat' types based on those already developed for European Policy and the Countryside Survey 2000 were applied rather than ecosystems (also UK NEA 2011b). The Countryside Survey 2000 is a major 'audit of the British countryside involving both detailed field observations [in a random sample of 1 km grid squares] and satellite imagery providing a complete Land Cover census for Great Britain and Northern Ireland' (NERC 2012).

The habitat approach allowed for "linking the biodiversity functional groups with specific areas of the landscape". For use at the national or multi-national scale, eight habitats were identified including: Mountains, Moorlands and Heath; Semi-natural Grasslands; Enclosed Farmland; Woodlands; Freshwaters – Open Waters, Wetlands and Floodplains; Urban; Coastal Margins; and Marine. Although not listed, it is mentioned that each broad group contains more refined habitats that would be more appropriate for use at smaller scales (UK NEA 2011b). Section 6.2.3 discusses how information on ecological processes was included in the framework.

6.2.3 Ecological processes

The UK NEA Technical and Synthesis Reports apply the terms ecological processes, ecosystem functions and intermediate services interchangeably. When one Lead with economist training was asked about the interchangeable use of terms describing ecological processes, the response was:

> *… as an economist… what I'm interested in is the contribution of the environment to human wellbeing and I don't need to know about all the very complex interactions between different supporting services and that sort of stuff because… well, to value what's going on I don't need to know it. Now there is obviously a pressing need to have a scientific understanding of that because otherwise we might hack away at things that we don't understand and literally remove the supporting structures of the environment. So,*

somebody has to know about it. Somebody has to be able to say, by the way, if you do that, do you realise that you're tipping a particular environment over the edge and you're going to lose all of it, and that sort of thing.

The UK NEA notes that some intermediate services can be 'final ecosystem services' (Section 6.2.4) depending on the benefit received and who the valuing agent is. It defines intermediate services as: *those whose ecological processes and functions support all life, and, by definition all other services* (UK NEA 2011b, p. 1453). It lists 12 ecosystem processes/ecosystem functions/intermediate services that contribute to FES. Appendix 7 contains this list, as well, the ecosystem functions incorporated in the SEQ framework and the supporting services incorporated in the MA framework (the US did not incorporate ecological processes in their framework). The following section defines and describes ecosystem services in the UK framework.

6.2.4 Ecosystem services

The UK NEA (2011b) adopts the definition of ecosystem services developed for the MA. However, the program also adopts the concept of 'final ecosystem services' (FES) based on that developed by Fisher and Turner (2008). FES are defined in the UK NEA (2011b, p. 1453) as: *the outcomes from ecosystems that directly lead to good(s) that are valued by people*. The UK NEA (2011b, p. 1453) defines 'goods' as: *all the use and non-use, material and non-material outputs from ecosystems that have value to people.* It says that goods derived from FES have a value, only some of which is derived from ecosystems as some are derived from other capital inputs (e.g. labour, machinery) (UK NEA 2011b). One respondent with an economic background said:

… so we deliberately did not use the terms goods and services. We deliberately divorced those two…the service is what you get from this whole chain of very complex lateral interactions. It's like the natural environment's input into the goods you're going to enjoy. Sometimes to get from the service to the good you actually have to have other inputs like manufactured capital, skill, whatever, to get that good. The good is the thing that actually gives you well-being.

To better understand the importance of consistent terminology and to confirm the same concept of ecosystem services was being applied across the UK program, seven Leads were asked: *what is the definition of ecosystem services you use in your research?* One Lead responded "ecosystem services are things that are delivered by ecosystems in the way that they function that are of use to society". Two other respondents described the role of ecosystem processes in providing goods that contribute to human well-being. Another Lead defined them simply as the "contributions that nature makes to human well-being". Three respondents were very clear on how ecosystem services are derived and the need for clarity of terminology along the production chain. The following comments by one respondent capture this thinking well:

> *... one of the really important things we recognised right from the beginning was that we had to get those distinctions sorted out... the distinction between what we would call intermediate services or processes, final services, goods, values and benefits have to be sorted out because people use some of those terms as if they mean the same thing... and some of them use the terms in very different ways.... there are processes going on in ecosystems that underpin services... they're not services themselves, they're processes. Then those processes lead to ecosystem services which are outputs from ecosystems from which all sorts of goods, values and benefits are ultimately derived. But they're not the goods, values and benefits themselves necessarily.... and then we wanted to be quite clear that those services are often transformed in various ways by other inputs from people to produce the good things that are actually then the objects, mainly, that people derive value and benefit from.*

The 14 FES included in the UK framework are listed in Appendix 8 along with the ecosystem services included in the MA and SEQ frameworks and the ecosystem services/ FEGS assessed in the US framework. These FES were categorised under the MA's four categories of ecosystem services (Provisioning, Regulating, Cultural and Supporting). Similar to how Supporting Services are recognised in the MA, in the UK framework Supporting Services differ from the other three categories of services as they are considered primary or intermediate services (their impacts on human well-being are indirect and mostly long-term in nature). Regulating Services can also be intermediate or final depending on the decision making context (UK NEA 2011b). Section 6.2.5

describes the final topic under this second Line of Enquiry, the approach applied to determine the value of ecosystem services.

6.2.5 Determining the value of ecosystem services

The UK NEA Technical Report says economic analysis should focus on FES ‘which is the last link in the chain of natural processes contributing to human well-being by inputting to the production of goods’ (UK NEA 2011b, p. 1071). The report provides discussion on the different types of valuation methods, as well, issues associated with valuing ecosystem processes or intermediate services such as double counting. The valuation conducted for the UK NEA rests predominantly upon the wealth of existing literature with few new analyses prepared partly or wholly (UK NEA 2011b).

Figure 6.1 presents the components of value as identified in the UK framework. It shows the ecosystem processes contributing to ecosystem service provision which provide goods to people. It identifies elements of individual well-being such as health and economic values; and those values shared collectively across society that are measured in relative terms (UK NEA 2011b). The UK approach to valuing ecosystem services includes both monetary and non-monetary values of ecosystem service flows to people. The Technical Report for the UK NEA (2011b, p. 1071) states, 'it is not accepted that the complete absence of economic monetary data in ecosystem management and decision making is an acceptable situation'.

The focus on change in value between feasible policy-relevant scenarios is the approach adopted in the UK NEA. This is done by ‘estimating the value of a single unit change in a good (the marginal willingness to pay) and then multiplying this by the size of the change provided under a given scenario’ (UK NEA 2011b, p. 21). The UK NEA (2011b, p. 1076) says that to conduct a valuation of any good three pieces of information are required:

1. *An understanding of the change in provision of the good given changes in the environment, policies and societal trends;*
2. *A robust and reliable estimate of the marginal value; and*
3. *Knowledge of how 2) might alter as 1/ changes.*

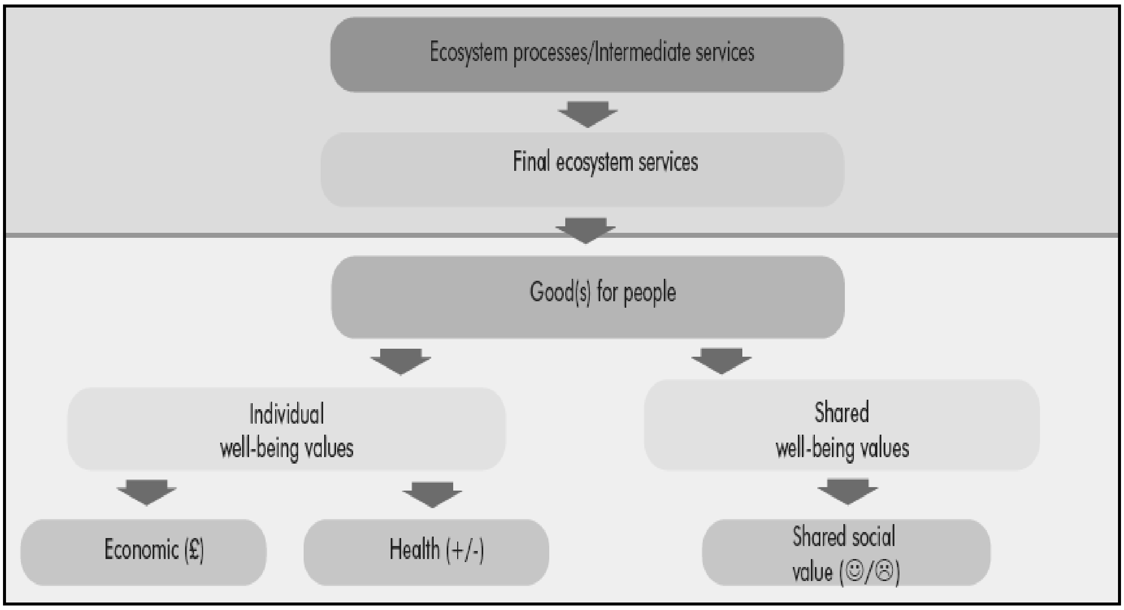

Figure 6.1: Components of value in the UK framework - the ecosystem processes contributing to final ecosystem service provision which provide goods to people. Two kinds of individual well-being values are recognised (economic and health). Also recognised are shared well-being values (social values) (extracted from the UK NEA 2011b, p. 21).

For the 'health' component of the UK NEA (2011b, p. 1156) the definition of health adopted is that of the World Health Organisation: *health is a state of complete physical, mental and social (individual) well-being, and not merely the absence of disease or infirmity*. Positive and negative changes in health values were not recorded in monetary values they were recorded with either plus or minus signs (+/-). This section of the valuation depended on two types of existing research; experimental research and epidemiological research - much of which has depended on pre-existing questionnaires (UK NEA 2011b). Through these reviews three generic health benefits derived from ecosystem services have been identified (UK NEA 2011b):

1. Direct positive effects (e.g. mental health and physical health);
2. Indirect positive effects (e.g. facilitating nature based activity and social engagement, and providing a catalyst for behavioural change); and
3. Reducing the threats and incidence of pollution and disease vectors.

One key finding of the UK NEA (2011b) is recognition that ecosystems can be a direct source of threats to human health including *Lyme borreliosis*, *Cryptosporidium* and *Plasmodium* species; provide physical threats from animals, pollutants or contaminants;

and elemental threats through extreme temperatures and radiation. Another is that 'health benefits are a function of ecosystem type, ease of access to nature and frequency of use of green places' (UK NEA 2011b, p. 1158). One Lead noted the challenge of better incorporating health impacts in ecosystem services assessments through the use of existing information:

> *There are potentially huge volumes of data out there which would be demanding of the best statisticians ... to unravel all the potentially confounding variables that influence a particular distribution of health statistic ... and they will be socio-economic and environmental things compounded.*

‘Shared social values' in the context of the UK NEA (2011a, p. 33) relates 'to ethical concerns and aesthetic judgements as well as the collective benefit derived from ecosystem services'. This approach combined with economic valuations and health assessments aims to provide a ‘more holistic and pluralistic perspective of the value of ecosystem services by recognising the collective assignment of meaning and significance provided to some ecosystem services that cannot be reduced to individual preferences and motivations alone’ (UK NEA 2011b, p. 1188). To determine shared social values expressed through environmental discourses, practices and institutions an important focus of this research has been to analyse 'cultural texts' such as television, magazines, cinema, art, literature and official documentations such as reports on the outcomes of surveys, interviews and focus groups (UK NEA 2011b). Improvements or loss in shared social values were recorded in smiley or sad faces (☺/☹).

'Deliberative valuation', referring to a process by which 'people confer, ponder, exchange views, consider evidence, reflect on matters of mutual interest, negotiate, and attempt to persuade each other', provides for the qualitative expression of shared value (UK NEA 2011b, p. 1188). Results from research applying integrated or hybrid methodologies such as 'deliberative monetary valuations' (combining stated preference methods with deliberative processes to elicit willingness to pay/accept values) and 'deliberative multi-criteria analysis' (scoring and weighting monetary and non-monetary criteria to provide a systematic assessment of priorities for decision making) have played an important role in providing information for this valuation (UK NEA 2011b, p. 1188).

Although the framework developed and actual assessments conducted through the use of the framework do not include minerals, fossil fuels or renewable energy, the discussion extends beyond biotic ecosystem services to include a brief overview of a few specific abiotic services such as renewable energy and wider issues such as raw materials and ecosystem-related employment (UK NEA 2011b). The aim was to argue for a wider application of the approach beyond purely biotic resources and better harmonisation of methods across all related fields of decision-making (UK NEA 2011b). Overall, the UK NEA (2011b, p. 1070) makes the case that 'ecosystems and their services are economically very significant at the national scale'.

This section finalises the outcomes of the second Line of Enquiry into the type of information developed to support the framework underpinning the UK NEA. It described the position of biodiversity in the framework and the role it plays in the provision of ecosystem services. It continued to describe ecological processes, FES and how the value of these FES is determined within the framework. Section 6.3 provides the outcomes of the third Line of Enquiry analysing the tools developed to support the UK framework and communicate ecosystem services and the program.

6.3 Tools supporting the UK framework

The process applied to develop the UK framework was discussed in Section 6.1. Section 6.2 discussed the information supporting the framework and why that information was included. This section describes the tools developed for proposed users of the UK framework to conduct assessments, and to communicate outcomes of the UK national ecosystem assessment and the program underpinning it. Similar to Chapters 4 and 5, first the conceptual framework is discussed (Section 6.3.1), then the use of scenarios to support the framework (Section 6.3.2) In Section 6.3.3 the modelling and mapping approaches are explained and primary websites and reports are in Section 6.3.4.

6.3.1 Conceptual framework

The UK NEA developed a basic conceptual framework to coordinate research, and to communicate ecosystem services, the framework and program to internal and external stakeholders. “We had our conceptual framework which was tweaked very, very slightly [throughout the program]…. and this was used to raise awareness of the project and to get people excited about the [UK NEA] release". One Lead when describing the development and importance of the conceptual framework said:

> *… of the things that I was very keen on, having been a member of the Millennium Assessment team, was that we got the conceptual framework and methods agreed before everyone set about doing the work. So one of the problems has been methods being developed in parallel with the assessment… and in the Millennium Assessment [that] meant some bits of it diverged through the process. So what I wanted to do… was to get all the terminology, the definition of ecosystem services and even a list of agreed ecosystem services before all the major habitat and service chapter authors really got going with their work. To some extent we succeeded in that.*

Figure 6.2 is a schematic of the UK NEA conceptual framework. It builds on that developed to support the MA by clearly distinguishing between ecosystem services, and the goods derived from them (this is important to reducing potential double counting in valuations). Rather than the MA's 5 categories of COWB, the three types of human well-being values (economic, health and shared social values) discussed in Section 6.2.5 are shown in this conceptual framework. Although not explicitly stated, biodiversity is captured in the nested boxes of 'Ecosystems' and 'Air, land, water and all living things'.

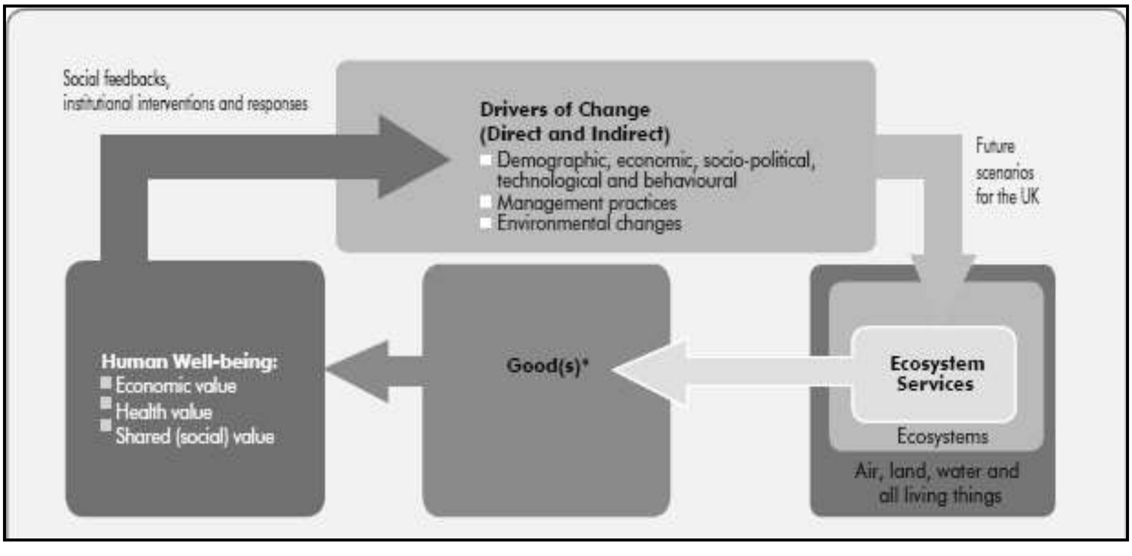

Figure 6.2: The UK NEA conceptual framework showing links between ecosystems, ecosystem services, goods(s), human well-being and social feedbacks leading to drivers of change in ecosystems and their services (extracted from the UK NEA 2011a, p. 15).

Similar to the MA, the UK NEA conceptual framework identifies direct and indirect drivers of change in ecosystem services. Figure 6.2 shows how in our attempts to acquire well-being, social feedbacks and institutional interventions influence the type, rate and magnitude of drivers. The following section provides information on the scenarios supporting the UK framework, in which the drivers and their effects informed their development.

6.3.2 Scenarios

Scenario development was a key feature of the UK framework and its application in assessments. The Technical Report describes scenarios as 'a set of conceptual tools that enable people to collectively deal with a particular type of problem that involves high uncertainty and complexity' (UK NEA 2011b, p. 1191). The UK NEA "followed pretty much the MA model … scenario responses were seen as a natural element of the UK NEA". Below is the response from one Lead when asked: *how was the choice of scenario topics chosen?*:

> *…we did spend a lot of time early on talking to potential users of NEA type data. So we ran workshops with devolved administration - or people from England, Wales, Scotland … we did online surveys of potential users to say well, what questions do you want to ask about the future?*

When asked if the topics chosen were 'UK-centric' the response was, "I think we could have done a better job of grounding them in a more global picture. But they are the sorts of issues that crop up in other countries". "To better understand what the future might hold for the provision of ecosystem services under different management approaches" six plausible scenarios were developed, these included (UK NEA 2011a, p. 14):

- ***Green and pleasant land:*** *A preservationist attitude arises because the UK can afford to look after its own backyard without diminishing the ever-increasing standards of living.*

- ***Nature at work:*** *The belief that the promotion of ecosystem services through the creation of multifunctional landscapes is essential for maintaining the quality of life in the UK is widely accepted.*

- ***Local stewardship:*** *This is a future where society is more concerned with the immediate surroundings and strives to maintain a sustainable focus within that area.*

- ***Go with the flow:*** *This scenario is essentially a projection based on current trends and results in a future UK that is roughly based on today's ideals and targets on life.*

- ***National security:*** *Under this scenario climate change results in increases in global energy prices forcing many countries to attempt greater self-sufficiency (and efficiency) in many of their core industries.*

- ***World markets:*** *High economic growth with a greater focus on removing barriers to trade is the fundamental characteristic of this scenario.*

One Lead commenting on the importance of scenarios said ”with scenarios it’s often in the process of doing it that you learn things, and certainly when you run six scenarios as we did, then it’s the contrast between them that is the most informative”. When another Lead was asked about the scale at which the scenarios were developed, the response was:

> *…the intention was that we would have differentiated country scenarios, but the time available and the audiences that came along to those devolved meetings; there was no great pressure to do that… I mean, there would have been too many political issues… if we tried to come up with an official set of Welsh, Scottish ... scenarios. So the UK was a sort of suitable buffer.*

The following section provides an overview of any maps and dynamic models developed to support ecosystem services assessments using the UK framework. As well, comments by Leads on the benefits and dis-benefits of applying these tools for ecosystem service assessments.

6.3.3 Maps and dynamic models

As mentioned previously, the UK program relied strongly on the use of existing information (i.e. the evidence base) to develop their assessment methodology (UK NEA 2011a). “Resources (time and money) did not permit the development of new data sets”. Maps and dynamic models were not developed for application by external stakeholders to the UK NEA, but rather, existing data sets were applied to conduct national and multi-national assessments (i.e. in scenario analysis and to communicate outcomes of valuations). “The most common data sets applied were Land Cover, Land Use, soil and habitat maps”. “The scale of mapping ranged from 25 m^2 grids to 5 km^2 grids depending on the scale and type of valuation or scenario conducted”.

To better understand the benefits and dis-benefits of maps and spatially dynamic models as tools for ecosystem services assessments three Leads from the four national governments, the Lead for the conceptual framework and one Lead working on valuations were asked: *what do you think are the benefits and dis-benefits of maps and dynamic models as tools to conduct and communicate information on ecosystem services (and their use in isolation)?.* Generally, maps were considered models because they provide a representation of reality. But one UK respondent stated "there is a problem ... what I tend to call the tyranny of GIS ... because you can model and map something, it can develop a sort of integrity and reality that it doesn’t really have".

Decisions about land-use (e.g. "how much of some land-use should be protected, how much should be certified for agriculture, or should it all be multiple use") were said to require dynamic models. One Lead stated "I think that is the biggest problem at the moment, we’re getting better maps and data on the services that regions are providing, but then you get into the difficult decisions about how you should prioritise what the land and water usage should be". “Involving stakeholders in identifying the maps required (and as inputs into models) is important to the acceptance and credibility of the final outputs”. The development and use of models were described as "black-boxish" and requiring technical expertise and time to apply. In terms of using maps and models in scenarios:

> *…the trouble is that if they’re too black box nobody understands what the scenario is. I found the mapping as one of the most accessible ways into*

this… they're both a product … but they can also be an input to the scenario creation. So I think mapping is still an under-used resource in terms of scenarios. I mean, people have tended to use them simply as a way of showing what the model predicts, but I think they can be much more imaginatively used than that.

The majority of Leads stated that "decision makers" would not be happy with only maps, that models were also required. One respondent from a federal government said "from a national policy perspective often maps are quite dangerous … quite misleading because they make everything look simple and decided". Two Leads noted that at the regional scale maps could be "useful for displaying information", for example, for "local parishes and local community groups not having an awful lot of resource or technical capability". One respondent stated, "decision makers, like 99% of people actually understand pictures better than words. … so then maps become useful". Another noted:

... at an operational level you need it [maps]*, but there needs to be some interaction. It can't just be a printed map or even a fixed map – it's got to be one that responds to some sort of system that responds to the type of change that may be happening and what the impact of that would be ... if there is a greater understanding of impacts of change then it would be worth doing.*

Section 6.3.4 discusses the website and technical reports where the information and tools to conduct ecosystem services assessments, or that were used to communicate the UK NEA program, can be found.

6.3.4 Reports and websites

To communicate the program and house information and tools for stakeholders to use, the UK NEA released two major pieces of documentation: the UK NEA Technical Report and the Synthesis of Key Findings. These documents, which can be found on the website supporting the program, are introduced in the following sections.

6.3.4.1 The Technical Report

The primary piece of documentation is titled ‘UK National Ecosystem Assessment Technical Report: Understanding Nature's Value to Society’. This 1466 page hardcover book “weighing 4.5 kilograms” contains 27 chapters that detail the methodology underpinning the UK NEA. A number of Leads questioned the usefulness of such a document beyond academic studies both because of its “awkward’ size and weight and “depth of detail”. It was thought different stakeholders would focus on chapters of most relevance to their issue as not all of the assessment, and therefore information outlined in the Technical Report, would have relevance to everyone. The Technical Report was synthesised into key findings as discussed below.

6.3.4.2 Synthesis of Key Findings

The second major piece of documentation is the ‘UK National Ecosystem Assessment: Understanding Nature's Value to Society, Synthesis of Key Findings’. This glossy and highly pictured document synthesises the Technical Report in 85 pages. Key findings of the UK NEA are discussed in the beginning, followed by a description of the ecosystem services assessed and the building blocks of the framework including the assessment units applied (i.e. UK’s habitats). A summary of outcomes in terms of the questions asked under the UK NEA provides the bulk of the document. The final 10 pages provide an overview of the assessment outcomes as conducted in England, North Ireland, Scotland and Wales.

6.3.4.3 Website

A sophisticated website providing both these documents is publically accessible. The website also houses information on the process applied including names and contact details for those participating on the Secretariat, User Group, Expert Group and the Client Group (UK NEA 2012). The complex framework and assessment procedure (as detailed in the 1466 page Technical Report) is broken down into key aspects of the framework, key concepts and definitions. Detailed information such as underlying data sets, math or methodologies underpinning outcomes of specific research sections of the assessment are not provided on the website. The Coordinating Lead Author is the suggested first point of contact for this information (UK NEA 2012). Details of upcoming meetings and any media reports on the program are also provided (UK NEA 2012).

This concludes the analysis of the UK methodology through the three Lines of Enquiry. Section 6.1 discussed the process applied to develop the framework (Line of Enquiry 1), Section 6.2 discussed the information recognised as necessary to support the framework (Line of Enquiry 2), and Section 6.3 discussed the tools supporting the framework (Line of Enquiry 3). In the following section Leads working on developing the UK framework provide reflections on the process applied and the information and tools developed; providing expert insight into areas of the program considered to have worked well and those that did not.

6.4 Reflections on the program

To provide hindsight on the process applied and information and tools supporting the UK framework, the following question was asked of nine Leads involved in the program: *how do you think, if at all, that the resources (expertise, money, time) invested in this programme have contributed/influenced the process that was applied as well as the information and tools that were developed?* The Leads questioned included three federal government Leads (one was not asked as they joined the UK NEA later in the program), one Co-Chair, four Leads from UNEP-WCMC and the lead coordinating the development of the conceptual framework.

Nearly all Leads said the timeframe to develop the methodology and conduct the assessment was restrictive and it was considered a better product could have been produced should more time have been available. The amount of funding provided to the program was considered adequate to develop the UK NEA by over half of the respondents. One respondent said, however, the amount of money limited the ability to develop new information or data sets that may have improved the framework (and therefore assessment findings). With all respondents discussing the high availability of professionals willing and able to contribute to the UK NEA in paid or unpaid positions, it is evident the collaborative and participatory approach applied was key to developing the framework. Six Leads noted the high pro bono input from stakeholders was fundamental to its success.

Leads were also asked: *looking back at what you have done to date, is there anything you would do differently if doing it again – what has worked well and what hasn't?* Both Co-Chairs stated the resources available did not influence the structure of the program and should it be repeated the structure would remain the same or similar. Although these comments were supported by four other respondents, three respondents noted that 'how' stakeholders were engaged in the process could be improved. This was supported by a number of Leads who said those in the User Group were not heard well enough. It was said “often [the User Group] meetings were held separately … some information didn’t always filter in … so you’d learn from the stakeholder engagement … I think the big challenge is to make sure that you’re getting a more balanced weighting of all the different groups in society”. One Lead from the Secretariat said:

> *… we couldn’t get the voices of the User Group heard enough with the Client Group, with the funders and with the people running the UK NEA ... and also we weren’t effective at some way of getting it under their noses to be able to have it taken into account. I think what we’d really want to do is to continue to engage that User Group – finding out what they want.*

A number of other Leads supported the previous comments specifically the need to better engage the private sector. One Lead stated "the UK NEA ... has not scored the goal in the end, because it hasn’t gone back to the users of this data and asked how has it changed your understanding, how has it moved things, what do we need to do next?". Two respondents stated:

> *... the technical process probably needs to be devolved down to local and regional levels before you can answer those bigger questions.*

> *... I think the bottom up approach is important, but if you have bottom up approaches that all involve different solutions to that problem of doing the assessments then you’ve got nothing to scale up with, because the bits don’t talk to each other. So you do need a broader agreement that there are these frameworks that everyone will use. You’ll call ecosystem services by the same labels in different places and that kind of thing.*

In terms of the information produced there was little comment except that "all was adequate". However, when reflecting on the role and position of biodiversity in the framework one Lead stated:

> *... we were pragmatic in the way we recognised biodiversity groups ... because what we did was just take groups that were monitored. Well, that makes no biological sense really ... that means we have all these terrestrial invertebrates, but we recognise each vertebrate order. Well, that is just barmy, isn't it, given the range of diversity in each of those groups? ... so one of the things to have done better ... is to actually try to map service linkages onto the tree of life properly ... trying to map rather than using expert opinion, actually using literature reviews of the links between particular biodiversity groups and services ... so we can start to say things about status and trend information in a way that we haven't been able to before ... and then from that there's a huge amount of research needed particularly in understanding the really fundamental role in ecosystems that these more poorly described biodiversity groups play ... but not the charismatic stuff, you know, things in soil, things in ocean sediments and all that kind of thing.*

As the aim of the UK NEA was not just to develop a framework but also to use this to conduct an assessment of the status and trends of ecosystems and ecosystem services at multiple spatial scales (i.e. local, national, and multi-national and also to identify those services derived from outside of the UK), one Lead was asked: *how do you synthesise information across disciplines, sectors and geo-jurisdictional scales using the UK framework?; and what are the issues for consideration when crossing scales?*. They responded:

> … w*ell aggregating data in the UK did prove more difficult than I think we thought it would … a lot of it was collected in different ways so it's making sure that you are comparing apples with apples and apples to oranges … that's always going to be your biggest problem really. Maybe there's that site scale stuff that's not such an issue because you haven't got as many sources coming from different places, but as soon as you start up-scaling to either regions or states or nationwide then it may come down to the point*

that you can't compare everything and you might have to say "this is what's happening in New South Wales, this is what's happening in Queensland – things are collected in slightly different ways but these are the stories that are being told" – and let people make their own decisions on how comparable they are. If you're looking for different types of data … look for sources that can be either aggregated or disaggregated simply, as well, you've got various places you can get the same information but … you'd want to have a look to see how far you can break it down or how much you can combine it with something else, particularly if you're going to have to pay for it … that might be a deciding factor in whether you go for one type of data or another.

When reflecting on decision support tools, two Leads discussed the need "to develop a conceptual framework which is agreed and cast in stone at the beginning ... that then everyone writes to ... because then we all call the services the same things and we don't make them up as we go along". Leads noted the holistic nature of ecosystem services providing an opportunity to "draw a huge range of experts together and they talked to each other". One Lead stated "the process itself produces a result more than the numbers and maps in the end I think". "Getting all society to talk from a multi-disciplinary perspective … the different natural scientists, economists and social sciences actually all coming together, I think that's been a really positive thing and something that we need to do more of. That comes back to that whole language thing ... finding that common language between everyone – that's a real challenge".

Regarding scenarios, one Lead stated "nobody really sat down and tried to say okay, can we produce some production functions for these services ... related to current conditions and the assumptions that control the operation of these processes? We needed those to actually make the scenarios work better". When further discussing the scenarios in general one respondent stated:

… one of the … things that is wrong with our scenarios is they're simply the description of an end point and there's no discussion of the path that you went along to get there. I think scenarios should also be about the process of change rather than speculation about some distant destination.

> *… the other thing that was a bit of a tension is that because we've got climate change scenarios - and there's a big lobby and industry around those - is that climate change scenarios are the ones that sort of dominate your work … the impact of land-use change due to other drivers has changed. It's probably much bigger than the impact of climate change in the UK. But if you talk to most people, its climate change at the top of their agenda and not the land-use changes that we're likely to see through social and demographic technological and other sorts of environmental change over the same period.*

Another Lead noted "you need to look at status and trends". This was supported by a response from a Co-Chair:

> *... the one big thing ... and I think this is quite important actually ... ecosystem services and goods are all about flows, and what we didn't evaluate was the status or trends in our stocks, and that's a major issue. Maybe it's an oversight that we should have considered? ... you know, what is the natural asset, the natural capital of the stocks of that, and how are they changing? You understand that by trying to measure the flows from them, but it's not just the flows, its well, are those flows sustainable? ... are you in danger of that stock being reduced to a stage where it might hit some catastrophic tipping point or something? So I think that's a major oversight if you like, but that's because we took and we evolved the MA. The MA doesn't look at stocks ... and clearly if you're really moving into the sustainability arena, and that is what this is actually all really connected to. For some people in these different communities, it comes back to language ... the ecosystem assessors, they seem to like the sustainability framework ... then you've got to look at stocks. This is all part of a process of learning, and while in an ideal world you might have done it all in one, I think in the time available and skill sets and so on, that because you're not sitting down and starting with a clean sheet, you tend to start with things ... well, 'how can you improve this?' and perhaps not always ask the question, 'well what's missing?' And I think if we'd asked the question well what's missing, we would have realised that there was the things that underpin all of this ... and then certainly people who work on natural resources, they're quite*

interested in this, but they are obviously really worried about natural capital stocks.

The two Co-Chairs, the four national governments representatives from the Client Group and the Leads involved with scenarios and the development of the conceptual framework, were asked: *how will you measure the success of (your research section of) the UK NEA?* One Lead stated the program was already successful based on the following four determinants: 1/ the "good scientific quality of the document"; 2/ "it stimulated some really inter and multi-disciplinary work"; 3/ "it had a profound effect immediately on two policy documents"; and 4/ both the "OECD and European Commission are asking us to go over there and actually how would we do one in Europe, or OECD wide". The profound effect on two policy documents was mentioned by all other respondents. "Seeing it implemented into all levels of decision-making" was a measure of success by half of the respondents. Other determinants of success included "the enthusiasm and the number of people that have been engaged with it"; "the willingness of funders to put more money on the table for a second phase"; and "if people come back and say that they found it useful".

At the time of interviewing Leads, Phase 2 of the UK NEA was confirmed for 2012-2014. Five Leads were therefore asked: *do you have a wish list for Phase 2?* On the process to be applied in Phase 2 one respondent stated "we need better engagement for the next stage with industry and the private sector". Another said "there needs to be a lot of emphasis on tools (maps and models) on making it real for people". Another Lead’s response supported this statement, "we need to engage the stakeholders ... to have people who want to attempt to operationalise it ... it may not be a huge amount more than a conceptual structure to use information and to undergo a deliberative participatory process using quantitative and qualitative data ... and running a few case studies rather than generating software".

One Lead said "we're going to focus on the economics, the plausible futures, the policy and a really solid piece of work on the social issues (cultural services and its concept of shared social value)". The need for more economics work was a wish from two respondents specifically "valuing non-economic goods, not just valuing traditional sorts of public goods". More scenario interpretation was a wish of another, and the social political aspects were thought to require more work also. More marine information (particularly where there are current gaps in the evidence) was also considered important.

This section of the report provided reflections on the UK methodology by Leads involved in the development of the framework. Similar to Chapters 4 and 5 the final section of this chapter provides a synthesis of information across the three Lines of Enquiry into a synopsis of the methodology developed under the UK NEA.

6.5 Synopsis of the UK methodology

Section 3.2.3 described the multiple case study approach used to analyse the UK (and the US) methodology. Section 3.2.3.2 provided background information on the UK, the UK program and the coordinating organisation. It discussed how the UK is a Member State to the UN and signatory to many international treaties including the four major global ecosystem-related conventions (CBD 2013; Ramsar undated; UNCCD 2012; UN 2014b).

As shown in Figure 3.4 the UK is a multi-national state consisting of four nations: England, Wales, North Ireland and Scotland. The UK operates under a system of devolved governance in which sovereignty is constitutionally divided between a central governing authority (the British Government) and England, Wales, North Ireland and Scotland. The UK’s central government delegates power to these constituent units providing them a degree of autonomy, however, these constituent units are limited in their ability to challenge certain acts of Parliament and the UK Government can revoke or reduce the power provided to these countries (UK Government 2013a).

Geographically, most of the UK consists of gently rolling hills although Scotland and Wales have high mountainous areas. Much of England is less than 1000 m above sea level forming meadowlands and pastures. Less than 10% of the UK area is covered by woodlands (Barrows 2012). Similar to the US the UK has a number of large lake systems, but in contrast, the UK consists of no large river systems (Barrows 2012). There are few areas in the UK that are not modified or highly dominated by humans. Agriculture has played a dominant role in the history of the UK (UK NEA 2011a).

The UK NEA is part of the LWEC initiative involving ‘22 public sector organisations that fund, carry out and use environmental research and observations’ across the UK (UK Government 2013b). The aim of LWEC is to ensure ‘decision makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from environmental change’ (UK NEA 2011b, p. 13). One of the 22 partners is the NERC (2012), a non-departmental public body and ‘the UK's main agency for funding and managing research, training and knowledge exchange in the environmental sciences’. NERC’s activities ‘cover the full range of atmospheric, Earth, biological, terrestrial and aquatic sciences, from the deep oceans to the upper atmosphere and from the poles to the equator’.

Based on the outcomes of the three Lines of Enquiry (Sections 6.1, 6.2 and 6.3) and reflections on the program by Leads (Section 6.4), the UK methodology is conceptualised in Figure 6.3. For ease of comparison this figure applies a similar format to Figure 4.5 conceptualising the methodology developed at the regional scale in SEQ; and Figure 5.2 conceptualising the methodology applied at the national scale in the US. As stated previously, placing the three Lines on Enquiry in this order resulted in information supporting the framework at the centre. The process (series of actions) applied to develop different types of information, and which tools applied different elements of the information, are shown by vertical lines paralleling boxes representing the information in these figures.

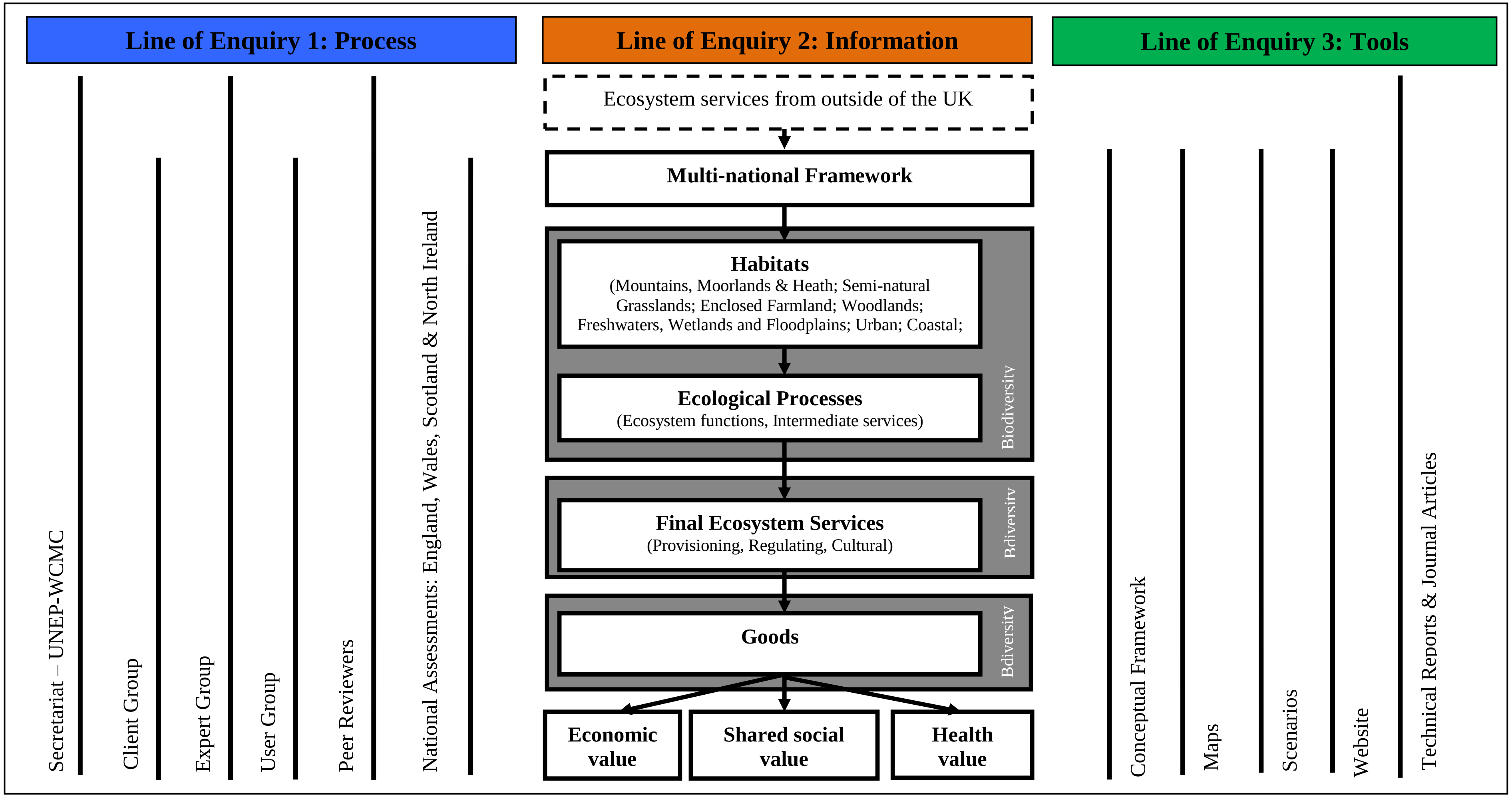

Figure 6.3: Key features of the UK multi-national scale methodology. From left to right the figure shows - Line of Enquiry 1: the process to develop the framework; Line of Enquiry 2: the information to support the framework; and Line of Enquiry 3: the tools to support the framework. Biodiversity is highlighted in dark grey.

Column 5 in Appendix 1 highlights key features of the process applied to develop the UK framework, including *factors underpinning the initiation of the program*. As discussed in Section 6.1.1 the following factors were identified by Leads or described in the Technical and Synthesis Reports (UK NEA 2011a, 2011b):

- technological developments impacting on productive ecosystems, especially agricultural intensification (e.g. nitrogen inputs) and industrialisation of fishing;
- biodiversity decline as shown by the Farmland Bird Index (UK NEA 2011a);
- the inability of governments to meet the CBD's 2010 Targets;
- the need to apply the CBD's Ecosystem Approach to resource management;
- European Union policy driving the management of UK's biodiversity and agricultural production (and not prioritising national issues);
- the Stern Report 2006;
- UK's involvement in the IPBES;
- recognition of the need for stronger evidence on which to base policy decisions; recognition that ecosystems across the countries are interconnected; the need to look at the environment and scientist's use of the environment in a more integrated and positive way.

UNEP-WCMC, the *coordinating organisation* or Secretariat, is the result of collaborations between UNEP the voice for the environment within the UN's system and the world's foremost intergovernmental environmental organisation (UNEP 2013); and WCMC which is UNEP's specialist biodiversity assessment arm and a UK-based charity (UNEP-WCMC 2013). UNEP-WCMC coordinated all elements of the information supporting the framework; this is represented by the vertical line stretching from Multi-national Framework to Economic value/Shared social value/Health value in Figure 6.3. The role of the 11 person team was: "budget management"; "work plan management"; "liaising with the Co-Chairs"; "ensuring deadlines are kept"; "sorting out any User Group grievances"; "talking to the Expert Panel and getting their opinion and then going to the relevant people and getting them to implement that"; "coordinating the peer review process"; "pulling together everyone's comments and remarks"; and developing communication products and mapping".

The rationale behind UNEP-WCMC coordinating the program was discussed in Section 6.1.2. A non-government agency (rather than a government agency or private organisation such as DEFRA) was chosen for the following reasons: because of the need for the program to be an “independent review"; the program “requires independent scientific leadership"; that the "leader needs scientific credibility”; "an individual leading it from one specific agency isn’t so favourable to the other agencies"; the program “needs to be kept at arm’s length of Politicians"; "if the government itself did it, its legitimacy is less in the eyes of many other stakeholders"; because collaborating is easier for non-government organisations; and that "UNEP were attractive to them [the British Government] as they are actually one step outside the normal UK institutions" so are less bias to politics and stakeholder agendas.

Although preference was for an agency outside of the UK’s governance to coordinate the UK NEA, national governments were said to play a very important role in the framework’s development. It was said by Leads that a national government should play these key roles: “as funders of the program”; “as one of the stakeholders, to have ownership of the program”; “ensuring the outcomes have policy relevance”; that “the outcomes have traction"; "to understand and communicate the information to their Ministers and then the Ministers can talk to the other Ministers"; “overseeing the program”; in “data collection” including providing access and consistency of data and information; and to “contribute to agenda setting and developing the major questions”.

Section 6.1.3 detailed the *resources* invested in the UK NEA. A pair of Co-Chairs with "complimentary experience, not substitutable” and with “extensive experience on large scale environmental projects” oversaw the program. They “were heavily involved in the conceptual framework development”; “they liaised between the coordinating organisation and the scientists”; and “helped the coordinating organisation put the science teams together for the different chapters (suggesting Authors)”. “The UK NEA received approximately £1.3 million over the two-year duration”. Responsibility for developing components of the methodology were delineated to a wide range of organisations and coordinated by Leads. “It is estimated over 500 professionals paid and voluntary were involved overall”. Appendix 3 lists the tertiary qualifications held by the Leads interviewed and the number of people holding each qualification. Although a diverse group of qualifications, the most common were zoology, biology, the natural sciences and economics.

Figure 6.3 shows the Secretariat (discussed above) and three main working groups that formed *the structure of the UK program*: the Client Group, Expert Group and User Group. The structure of the UK program (and the MA, SEQ and US programs) in terms of who was engaged in the framework's development and the roles they played are presented in Appendix 4, and were discussed in detail in Section 6.1.4. The Client Group was a special working group for funders of the UK NEA. The "aim of this group was to separate organisational mandates and political agendas from the design of the assessment methodology and type of information produced". Represented on the Client Group were those from the English, Welsh, Northern Ireland and Scottish Governments; ESRC; NERC; and DEFRA.

Twenty-seven of the UK's leading natural, economic and social scientists from universities and independent organisations formed the Expert Group. The primary role of the Expert Group was to design the framework and to conduct an actual ecosystem services assessment for the UK. A group of 22 proposed users of the information were invited to form the User Group (UK NEA 2011b). This group involved a broad mix of representatives from UK Treasury, national government environment agencies, national health organisations, energy and mineral agencies, farmer's federations, national water agencies, local government organisations, biodiversity groups, forestry organisations, department of communities, architecture and built environments, and heritage groups (UK NEA 2011b).

Independent experts were invited to peer review the information and tools on an as needed basis. As well, in the UK NEA Technical Report each chapter begins with a set of key findings that were rated for its level of certainty. The methodology applied to rate for certainty was adopted from the MA and the IPCC (in which one UK NEA Co-Chair was also the Chair of these other programs).

Section 6.2 provided the outcomes of the second Line of Enquiry into the UK methodology, the *information* developed to support the framework. The framework, that when used to conduct an assessment would provide a comprehensive picture of past, present and possible future trends in ecosystem services at multiple scales, was dependent almost entirely on the existing evidence base (UK NEA 2011b). As discussed, nested units for assessing ecosystem services at national and local scales were developed. Recognising that not all ecosystem services delivered to the UK people will be derived from within the UK's boundaries, a method to assess the trends in the dependence of the UK population on ecosystem services derived from outside the UK was also developed (UK NEA 2011b).

To better identify the target audience for the information (and tools) produced under the UK NEA Leads were asked who the intended users of the information and tools were. A wide range of stakeholders were identified including: "students; farmers and the National Farmers Union"; "industry and tourism"; "the Royal Society for the Protection of Birds and the Wildlife Trust"; "foresters"; and the "general public" (although one Lead refuted the general communities' use of the framework). "Certain people who are interested in certain habitats" were also considered likely to use the framework. The majority of Leads mentioned "the service chapters were more for policy-makers rather than individual sectoral managers". Decision makers, academics, and Natural England, the NERC and the ESRC who fund the universities were also mentioned as users.

When Leads were asked about the type of information required to support an ecosystem services framework (i.e. information that users would require to conduct assessments) the responses included: "information on habitats"; "a way of representing the biophysical processes that underpin the delivery of goods via ecosystem services from an understanding of the landscape and potential land use types"; "the goods that influence human wellbeing; and some way of measuring their relative importance or values". Two Leads referred to the 'cascade model' developed by Haines-Young (2010a, p. 7) which identifies ecosystem structure and processes, functions, services, benefits and values; and was adapted for application in the SEEA and CICES (Figure 2.4).

Section 6.2.1 described the role of *biodiversity* in the provision of ecosystem services and its position in the UK framework. Biodiversity's role in providing ecosystem services "was controversial amongst stakeholders" from the initiation of the program. One Lead said biodiversity's role is an important issue to solve at the beginning "because a lot of people have been working in the biodiversity paradigm ... and we've spent all this time convincing governments that's what they should be worried about". So not resolving this issue up front was said to be "dangerous" and have "potential" to "alienate so many stakeholders". A number of Leads discussed the importance of assessing biodiversity in conjunction with ecosystem services or "people don't see the linkages". Overall, it was said “there isn’t a single role for biodiversity, it depends what you mean by biodiversity”.

The UK framework adopted the definition of biodiversity from the CBD. This definition, however, was said to be ‘less than ideal from the perspective of ecosystem services, because diversity per se may have only a limited effect on specific ecosystem services’ (UK NEA 2011b, p. 68). Because biodiversity is incorporated in the UK framework in three ways, the role of biodiversity and its position in the framework is shown in Figure 6.3 as three dark grey boxes. One respondent described the three ways as: "What role does it play in processes (e.g. soil biodiversity and insects)?; What role does it play in services (e.g. wild species diversity)?; and What role does it play in goods (e.g. pharmaceuticals)?".

Appendix 5 provides condensed comments from Leads describing biodiversity’s role and position. Fifteen out of 17 Leads claimed biodiversity is an ecosystem services. Biodiversity was considered a service when "it’s actually appreciated as biodiversity"; when people "directly visit" or enjoyed biodiversity; and that "biodiversity itself, by the fact it is diverse, is a service to give the system resilience". Nearly half the respondents stated that "wild species diversity" is a Cultural Service (e.g. bird watching). Many Leads noted that not all aspects of biodiversity are ecosystem services that "its specific wild charismatic species". One respondent said they were not sure of biodiversity's role. Another said biodiversity was not an ecosystem service that in a list of ecosystem services they would have "habitat types" rather than biodiversity.

The primary practical constraint on the use of existing biodiversity data for the purpose of ecosystem services assessments is that ‘the UK tends to relate to taxonomic groups distinguished by specific monitoring programs’ (UK NEA 2011b, p. 68). Two key findings in the biodiversity chapter of the Technical Report include: the need to determine the functional component of biodiversity because a ‘service may be related to a specific aspect of diversity (e.g. species diversity)’ (UK NEA 2011b, p. 67). Alternatively, a service ‘may depend on a specific functional group or even an individual species that plays a specific functional role’ (UK NEA 2011b, p. 67).

Section 6.2.2 described the *assessment unit* incorporated in the UK framework. For the purpose of national and multi-national scale assessments, eight Broad Habitat types based on those already developed for European Policy and the Countryside Survey 2000 were used as the assessment unit (UK NEA 2011b). The Countryside Survey 2000 is a major ‘audit of the British countryside involving both detailed field observations [in a random sample of 1 km grid squares] and satellite imagery providing a complete Land Cover census for Great Britain and Northern Ireland’ (NERC 2012). The habitat approach allowed for linking the biodiversity functional groups with specific areas of the landscape. Although not listed, it is mentioned that each broad group contains more refined habitats that would be more appropriate for use at smaller scales (UK NEA 2011b).

Section 6.2.3 described the interchangeable use of the terms *ecological processes*, ecosystem functions and intermediate services in the UK framework. The UK NEA predominantly uses the term intermediate services however. Column 4 in Appendix 7 contains the list of 12 intermediate services that contribute to FES. The UK NEA notes that some intermediate services can be FES depending on the benefit received and who the valuing agent is.

Ecosystem services as they are incorporated in the UK framework were discussed in Section 6.2.4. The UK NEA adopted the definition of ecosystem services from the MA and recognises the MA’s four categories of services, including the role of Supporting Services in the delivery of the other three categories. However, the framework also adopts the concept of FES based on that developed by Fisher and Turner (2008). Goods derived from FES are said to have a value but only some of this value is derived from ecosystems and the rest is derived from other capital inputs (e.g. labour, machinery) (UK NEA 2011b). The terms services and goods were deliberately “divorced” because “the service is … the natural environment’s input into the goods you’re going to enjoy …to get from the service to the good you have to have other inputs like manufactured capital, skill, …. the good is the thing that actually gives you well-being”.

Although the framework does not include minerals, fossil fuels or renewable energy as ecosystem services, the discussion extends beyond biotic ecosystem services to include a brief overview of a few specific abiotic services such as renewable energy and wider issues such as raw materials and ecosystem-related employment (UK NEA 2011b). The aim was to argue for a wider application of the approach beyond purely biotic resources and better harmonisation of methods across all related fields of decision-making (UK NEA 2011b).

Appendix 8 lists the 14 FES included in the UK framework. To better understand the importance of consistent terminology and to confirm the definition and concept of ecosystem services was being applied across the program Leads were asked what definition of ecosystem services they use. Overall there is consistency in terms used across the UK NEA. One Lead explained the importance of developing clear terms at the beginning of the program, they said "the distinction between what we would call intermediate services or processes, final services, goods, values and benefits have to be sorted out because people use some of those terms as if they mean the same thing ... and some of them use the terms in very different ways"

The approach to *determining the value of ecosystem services* using the UK framework was discussed in Section 6.2.5. Figure 6.1 shows the components of value as identified in the UK framework. It shows ecosystem processes contributing to FES which provide goods to people. These goods are valued by individuals because they contribute to their well-being. As well, some of these values are shared collectively across society. The Technical Report says economic analysis should focus on FES 'which is the last link in the chain of natural processes contributing to human well-being by inputting to the production of goods' (UK NEA 2011b, p. 1071).

Both monetary and non-monetary values of ecosystem service flows to people are determined. The focus on change in value between feasible policy-relevant scenarios is the approach adopted in the UK NEA. This is done by 'estimating the value of a single unit change in a good (the marginal willingness to pay) and then multiplying this by the size of the change provided under a given scenario' (UK NEA 2011b, p. 21). Three pieces of information are said to be required to conduct a valuation (UK NEA 2011b, p. 21):

1. *An understanding of the change in provision of the good under consideration given changes in the environment, policies and societal trends;*
2. *A robust and reliable estimate of the marginal value; and*
3. *Knowledge of how 2/ might alter as 1/ changes.*

Positive and negative changes in health values, an element of individual well-being, were recorded with either plus or minus signs (+/-) rather than monetary values. Three generic health benefits derived from ecosystem services were identified (UK NEA 2011b): 1/ direct positive effects; 2/ indirect positive effects; and 3/ reducing the threats and incidence of pollution and disease vectors. The UK NEA (2011b) also recognises that ecosystems can be a direct source of threats to human health. A key finding of the health research is that 'health benefits are a function of the ecosystem type, ease of access to nature and frequency of use of green places' (UK NEA 2011b, p. 1158). The major challenge to incorporating health impacts in ecosystem services assessments was described as: “there are potentially huge volumes of data out there which would be demanding of the best statisticians ... to unravel all the potentially confounding variables that influence a particular distribution of health statistic”.

Shared social values relate 'to ethical concerns and aesthetic judgements as well as the collective benefit derived from ecosystem services' (UK NEA 2011a, p. 33). This approach, along with economic valuations and health assessments, aims to provide a more holistic and pluralistic perspective of the value of ecosystem services (UK NEA 2011b). 'Deliberative valuation' referring to a process by which 'people confer, ponder, exchange views, consider evidence, reflect on matters of mutual interest, negotiate, and attempt to persuade each other' provides for the qualitative expression of shared values (UK NEA 2011b, p. 1188). To determine shared social values cultural texts such as television, magazines, cinema, art, literature and reports on the outcomes of surveys, interviews and focus groups were analysed (UK NEA 2011b). Again, rather than using monetary values improvements or loss in shared social values were recorded in smiley or sad faces (☺/☹).

Line of Enquiry 3 into the *tools* developed to support the UK framework was discussed in Section 6.3. Section 6.3.1 discussed the first tool analysed, the *conceptual framework* developed to coordinate research and to communicate ecosystem services, the framework and program across internal and external stakeholders. One Lead said “of the things that I was very keen on … was that we got the conceptual framework and methods agreed before everyone set about doing the work”.

Section 6.3.2 discussed how *scenario* development was a key feature of the UK framework and its application in assessments. Scenarios are defined as 'a set of conceptual tools that enable people to collectively deal with a particular type of problem that involves high uncertainty and complexity' (UK NEA 2011b, p. 1191). Underpinning the choice of topic for the six plausible scenarios was outcomes of "talking to potential users", "workshops with devolved administrations" and "online surveys of potential users" asking them "what questions do you want to ask about the future?". "With scenarios it's often in the process of doing it that you learn things and … then it's the contrast between them that is the most informative". Scenarios were developed for the whole of UK rather than for individual nations because of "the time available and the audiences" and that "there would have been too many political issues".

Section 6.3.3 discussed how *maps and dynamic models* were not developed for application by external stakeholders, but rather, existing data sets were applied to conduct national and multi-national assessments using the UK framework (i.e. in scenario analysis and to communicate outcomes of valuations). "Resources (time and money) did not permit the development of new data sets". "The most common data sets applied were Land Cover, Land Use, soil and habitat maps". "The scale of mapping ranged from 25 m^2 grids to 5 km^2 grids depending on the scale and type of valuation or scenario conducted". "Involving stakeholders in identifying the maps required (and as inputs into models) is important to the acceptance and credibility of the final outputs".

Decisions about land use were said to require dynamic models. But, "the trouble is that if they're too black-box nobody understands" and "they require technical expertise and time to apply". The majority of Leads stated that "decision makers" would not be "happy with only maps". "From a national policy perspective often maps are quite dangerous … quite misleading because they make everything look simple and decided". However, at the regional scale maps could be "useful for displaying information" particularly for groups "not having an awful lot of resource or technical capability". "At an operational level you need it [maps], but there needs to be some interaction. It can't just be a printed map or even a fixed map – it's got to be one that responds to some sort of system that responds to … change". "Decision makers, like 99% of people actually understand pictures better than words. … so then maps become useful".

Section 6.3.4 described the *website and reports* developed for use by internal and external stakeholders. The 'UK National Ecosystem Assessment Technical Report: Understanding Nature's Value to Society' is a 1466 page hardcover book with 27 chapters that weighs 4.5 kilograms. A number of Leads questioned the usefulness of such a document because of its “awkward’ size and weight and “depth of detail”. The Technical Report was synthesised into a glossy and highly pictured 85 page document titled, the ‘UK National Ecosystem Assessment: Understanding Nature's Value to Society, Synthesis of Key Findings’. Both these documents can be found on the website supporting the program which also contains information on the process applied, details of upcoming meetings and any media reports on the program (UK NEA 2012).

Looking back on the process, information and tools (methodology) developed under the UK NEA (and described in this chapter), hindsight on what worked well and not so well was provided by Leads (Section 6.4). These included:

- The timeframe was restrictive and it was considered a better product could have been produced should more time have been available.
- The amount of funding was considered adequate although one Lead said it limited the ability to develop new information or data sets.
- The collaborative and participatory process, especially the high pro bono input, was vital to the program’s success.
- "Getting all society to talk from a multi-disciplinary perspective … I think that’s been a really positive thing and something that we need to do more of … the process itself produces a result more than the numbers and maps in the end ".
- The structure of the program was well done - although 'how' stakeholders were engaged in the process could be improved. As meetings for the User Group were held separately to others the User Group was “not heard well enough”. Better engagement with the private sector was also required.
- “The technical process probably needs to be devolved down to local and regional levels before you can answer those bigger questions.... the bottom up approach is important, but … you do need … agreement that there are these frameworks that everyone will use … you’ll call ecosystem services by the same labels in different places …otherwise you have nothing to scale up with”.
- The use of biodiversity already being monitored was said to be inadequate. It was said “ there’s a huge amount of research needed particularly in understanding the really fundamental role in ecosystems that these more poorly described biodiversity groups play ... but not the charismatic stuff, you know, things in soil, things in ocean sediments and all that kind of thing”.

- “Aggregating data in the UK did prove more difficult than … we thought it would … it was collected in different ways so … if you’re looking for different types of data … look for sources that can be either aggregated or disaggregated simply”.
- The need "to develop a conceptual framework which is agreed and cast in stone at the beginning” was very important.
- Regarding scenarios, "nobody … tried to … produce some production functions for these services ... We needed those to actually make the scenarios work better".
- “One of the… things that is wrong with our scenarios is they’re simply the description of an end point and there’s no discussion of the path that you went along to get there …scenarios should also be about the process of change rather than speculation about some distant destination”.

When Leads were asked how they would determine program success one respondent stated “the program was already successful” because of its scientific quality; because “it stimulated some really inter and multi-disciplinary work"; because "it had a profound effect immediately on two policy documents"; and because the "OECD and European Commission are asking …how would we do one in Europe, or OECD wide". Others Leads said “seeing it implemented into all levels of decision-making"; "the enthusiasm and the number of people that have been engaged with it"; "the willingness of funders to put more money on the table for a second phase"; and "if people come back and say that they found it useful". For the second phase of the UK NEA Leads said there needs to be more emphasis on: maps and models for stakeholder use; valuing non-economic goods; engaging stakeholders who will use the framework; and more marine information.

This completes the analysis of methodologies through document reviews (i.e. the MA and other schools of thought), applied research (i.e. in SEQ), and multiple case study analysis (i.e. in the US and UK). The following chapter, Chapter 7, compares and contrasts the three methodologies highlighting similarities and differences in processes, information and tools, and where relevant uses the MA and other schools of thought as a benchmark. These outcomes are synthesised into a set of Recommendations for researchers and decision makers to consider when adopting or adapting an existing methodology or developing a new ecosystem services framework from the start.

Chapter 7

Findings and Recommendations for developing a methodology

A synthesis of findings and Recommendations into *an appropriate methodology to enable ecosystem services assessments across multiple scales* are provided in this chapter. In the context of this research, a methodology was defined as a framework that includes information and decision support tools (tools) to assess ecosystem services; and the process of developing the framework as well. This chapter brings together outcomes from previous chapters that:

- described the concept of ecosystem services and how world leaders endorse an ecosystem services approach to NRM; and how ecosystem services are managed and received by different stakeholders at different scales hence the need to mainstream ecosystem services into decision making through the development of a multi-scale framework (Chapter 1);
- provided a review of documents describing existing methodologies and schools of thought on ecosystem services, with a primary focus on the MA the most well-known methodology developed to date (Chapter 2);
- transformed the three components of a methodology (process, information and tools) into Lines of Enquiry and topics for further analysis based on consistencies, inconsistencies and gaps in knowledge in the documents reviewed (Chapter 3);
- described the outcomes of the applied research analysing the development of a methodology at the regional scale in SEQ (Australia) (Chapter 4);
- described the outcomes of the multiple case study analysis and interviews with Leads developing a methodology at the national scale in the US (i.e. the ESRP) (Chapter 5); and
- described the outcomes of the multiple case study analysis and interviews with Leads developing a methodology at the multi-national scale in the UK (i.e. the UK NEA) (Chapter 6).

Fundamental to breaking the research into tractable components and delivering the outcomes coherently through the structure of this thesis was the three Lines of Enquiry. Figure 3.1 showed the overall research design and the Lines of Enquiry applied to the

SEQ, US and UK case studies as coloured circles labelled LoE 1, 2 and 3. A more pointed direction of research was achieved by developing the following sub-question to the main research question for each of the Lines of Enquiry:

- **Line of Enquiry 1 (LoE 1): Process (blue circle)**
  What is an appropriate process to develop a framework for ecosystem services assessments across multiple scales?

- **Line of Enquiry 2 (LoE 2): Information (orange circle)**
  What information is required to support a framework for ecosystem services assessments across multiple scales?

- **Line of Enquiry 3 (LoE 3): Decision Support Tools (green circle)**
  What tools are required to support a framework for ecosystem services assessments across multiple scales?

To answer these questions, this chapter compares and contrasts the drivers behind the choice of process, information and tools that define the SEQ, US and UK methodologies; and the type of processes, information and tools that have resulted because of the constraints and opportunities provided by these drivers (Chapters 4, 5 and 6). Where relevant, it also compares and contrasts these methodologies to the MA methodology and other schools of thought discussed in the literature (Chapters 1 & 2 which were synthesised in Section 3.1). A range of tables in the Appendices support outcomes and highlight key features or findings.

For ease of analysis this chapter is structured along the three Lines of Enquiry similar to Chapters 4, 5 and 6; the outcomes of each Line of Enquiry are discussed in Sections 7.1, 7.2 and 7.3 respectively. Each section is broken into sub-sections describing the findings into the key topics analysed under each Line of Enquiry. Interconnections across topics are discussed, recognising the topics do not operate in isolation. By learning from other's experiences in developing methodologies, Recommendations for determining an appropriate process to develop a multi-scale framework and the information and tools to include in a framework have been developed. The Recommendations are presented in boxes under the findings for each key topic.

Appendix 9 follows the format of Figure 3.5 showing the approach to cross-analysing methodologies. In Appendix 9 the detail is trimmed off the Recommendations described in Boxes 7.1 to 7.13. Interconnections between Recommendations are highlighted in coloured text corresponding to the coloured circles in Figure 3.1 the research design. Section 7.4 discusses important features of a multi-scale framework based on the findings and Recommendations presented in Sections 7.1, 7.2 and 7.3, and the interconnections identified in Appendix 9. The following section presents the findings and Recommendations for Line of Enquiry 1 into processes.

7.1 Process: Findings and Recommendations

Section 3.1.1 described the first Line of Enquiry aimed at answering the research question: *what is an appropriate process to develop a framework for ecosystem services assessments across multiple scales?* This section of the thesis compares and contrasts the processes applied to develop frameworks in SEQ, the US and UK; and better understand the influence of different drivers on the choice of process applied. Therefore, this section primarily draws from Sections 4.1, 5.1 and 6.1 describing the SEQ, US and UK processes, but it also draws on relevant outcomes from other sections. The SEQ, US and the UK processes are also compared and contrasted to the MA and other schools of thought revealing if they are consistent with current theories on processes or if they provide new insights.

The factors influencing the initiation of programs; the organisations coordinating programs; the resources invested in developing frameworks; and the structure of the programs were key topics analysed under this Line of Enquiry. Key features of the MA, SEQ, US and UK processes are presented in Appendix 1. Appendix 3 shows the tertiary qualifications of those leading the program and Appendix 4 shows the broader groups of stakeholders engaged in the framework's development. Based on findings from this analysis, 'Recommendations' for determining an appropriate process to develop a multi-scale framework are presented after the discussion on each key topic in Boxes 7.1 to 7.4. After each Recommendation, other interconnected Recommendations are presented in brackets. The first key topic is discussed below.

7.1.1 Factors underpinning the initiation of programs

Chapter 2's document review revealed that underpinning the initiation of the MA was realisation by scientists and governments representing the Parties signatory to the four major ecosystem-related conventions (i.e. the CBD, Ramsar Convention, Convention on the Conservation of Migratory Species of Wild Animals, and the UN Convention to Combat Desertification) that current mechanisms for scientific assessments where not halting global biodiversity loss and reducing land degradation (important to reducing poverty) (MA 2005a; Reid et al. 2006a; Ash et al. 2010). Although not explicitly stated in the documents supporting the three programs analysed, it can be presumed the MA's influence is directly related to the associated nations (i.e. Australia, US, England, North Ireland, Scotland and Wales) all being UN Member States; and signatory to a number, or all, of the four ecosystem-related conventions (see Sections 3.2.2.1, 3.2.3.1 and 3.2.3.2). The US is not a Signatory to the CBD or Convention on the Conservation of Migratory Species of Wild Animals (CBD 2013; UNEP-CMS 2013).

Chapter 1 discussed how since the MA's release in 2005 there was exponential growth in ecosystem services research and the MA framework has been adopted inter alia by the WRI (2007), the WBCSD (2011, 2012), the Ramsar Convention (Secretariat Ramsar 2008), the CBD (2013), and the IPCC (Fischlin et al. 2007). The need to better include the environment in economic decisions and the MA's lack of economic analysis however encouraged Ministers of the G8 +5 countries to build a new global scale framework using the MA as the foundation. Section 2.2 described this new framework, TEEB (2010), aimed to better understand the costs of this biodiversity loss, and benefits of taking protective measures and conserving biodiversity. Similarly, the recognition of national accounting methods not adequately including the costs of ecosystem degradation and environmental inputs into economic production underpinned the initiation of SEEA (UNSD 2012) and research conducted by Boyd and Banzhaf (2007), Ott and Staub (2009) and Staub et al. (2011).

Further driving the development of frameworks are contextual factors, such as those specific to: SEQ (e.g. high population growth); the US (e.g. National Academy of Sciences recommendations, government requirements for cost benefit analysis of regulatory actions, and budget cuts); and the UK (e.g. not meeting 2010 Biodiversity Targets, the impact of European policy on Britain's biodiversity and agricultural production, and climate change). Chapter 2 identified at local to regional scales in Australia the need to better understand ecosystem services inputs to agricultural production, and other ecosystem services derived from agricultural landscapes that contribute to the broader community's well-being, drove the research by Binning et al. (2001), Reid et al. (2006b) and Bennett et al. (2010). The wide range of factors shown to drive the development of frameworks globally suggests the list of Australian institutional contexts requiring decisions on ecosystem services (p. 9) has relevance to other nations.

The analysis of this key topic supports statements by Fisher et al. (2011) and Costanza et al. (2012) that the 2005 release of the MA methodology and assessments has driven ecosystem services research and framework development. Testament to the breadth and depth of the MA's influence is the initiation of many global scale programs (e.g. TEEB, CICES, SEEA). As well, local to regional scale programs in Australia had a strong tendency to use the MA framework early on (but more recent studies used TEEB or the UK NEA frameworks) (Maynard and Cork 2011). Beyond the programs described in the documents, the applied research and case study analysis revealed the MA also influenced the initiation of the SEQ, US and UK programs (Maynard et al 2010; EPA 2008; UK NEA 2011b). The first Recommendation in the Box below recognises the MA as a credible tool to help validate the need for a program to develop a multi-scale framework.

Another key finding is the purpose of the framework and the context under which they were developed strongly influenced differences in methodologies globally (see Recommendation 2). Many potential uses of an ecosystem services approach (e.g. environmental accounting, examining the costs and benefits of environmental regulations and taking protective measures) require information on the value of ecosystem services in terms other than those applied in the MA methodology (leading to Recommendation 3). Primarily, it is the need for knowledge on how ecosystem services contribute to economic production and estimates of their (change in) economic value that drove new programs and methodological variations from the MA (at different scales).

After Box 7.1 with Recommendations based on this topics analyses, the following section provides findings and Recommendations based on the coordinating organisations.

Box 7.1: *Recommendations on the process for developing a multi-scale framework based on factors underpinning programs.*

1) **The MA as program validation:** as is evident from the wide use of the MA at different scales, the MA methodology provides a credible tool to help validate the need for a program to develop a multi-scale framework.

2) **Contextual differences of stakeholders**: as contextual factors are shown to influence methodological differences, when developing a framework for multiple purposes consideration must be given to the wide range of contexts (including scales) under which different stakeholders operate (5,17, 19, 34, 61iii).

3) **Beyond MA valuation methods:** many potential uses of an ecosystem services approach will require information on the value of ecosystem services in terms other than just those applied in the MA methodology (47, 49, 50, 51, 52, 53).

7.1.2 The coordinating organisations

Section 3.1.1 synthesising documents reviewed in Chapters 1 and 2 identified the organisations coordinating programs belonged to a wide variety of sectors (e.g. government, academia, NGO), but all had environmentally related missions and mandates. Examples include at the global scale the UN statistical and environmental divisions coordinating different ecosystem service related programs (i.e. SEEA and the MA); at the multi-national scale CICES was developed through a program funded by the European Environment Agency (Haines-Young and Potschin 2013); and at the national scale Otts and Staub (2009) and Staub et al. (2011) conducted research for the Swiss Federal Office of the Environment. At local to regional scales, frameworks were developed by federal scientific organisations (Binning et al. 2001); private environmental consultants (Bennett et al. 2010); individuals from state government environmental departments (Wallace 2007); university researchers from environmental departments (Reid et al. 2006b); and non-government NRM organisations (Maynard et al. 2010).

Appendix 1 shows the MA, SEQ and UK programs were coordinated by non-government organisations. According to the SEQ experience, responses from UK Leads, and the literature, this ensured the program and the resulting framework was developed independent of politics and policies. UK Leads discussed the importance of “independent scientific leadership” and the need to keep the scientific foundations and the process of conducting assessments at “arm’s length of Politicians” (p. 174 – 175). It was said “legitimacy is less in the eyes of many other stakeholders" if frameworks are developed by governments. UNEP-WCMC coordinating the UK framework was attractive to the British Government as they are “one step outside the normal UK institutions”.

Generally, preference of coordination was given to organisations whose missions and mandates covered a broad range of environmental assets and issues (rather than a single environmental asset or issue). For example, UNEP’s mission is to provide leadership in caring for all aspects of the environment and its mandate is to work with nations to set and implement a global environmental agenda (UNEP 2013). UNEP-WCMC who coordinated the UK NEA is UNEP’s specialist biodiversity branch (UNEP-WCMC 2013). Section 3.2.2.1 described the broad spectrum of NRM issues that SEQ Catchments aims to address and the significant role it plays in other environmental programs at local, state and national scales (SEQ Catchments 2015a, 2015b).

In many programs, organisations with existing networks and working arrangements at the interface of government, non-government, industry, business, academia, Indigenous groups and communities were the preferred coordinating organisation. Section 3.2.2.1 also described how SEQ Catchments is governed by a Board of stakeholders to the natural resources of the SEQ region (Queensland Government 2011a; SEQ Catchments 2015a). Section 3.2.3.2 discussed how the UK NEA was part of the LWEC (2011, 2014) initiative that involved ‘22 public sector organisations that fund, carry out and use environmental research and observations’. Relating to the coordination of the MA, the UN is comprised of nearly 200 Member States (UN 2014b).

As shown in Appendix 1, in contrast to the MA, UK and SEQ programs, the US program was coordinated by a national (federal) government agency. US Leads said a national government agency coordinating the program had benefits of them being in a position to potentially “propose and develop nationally standardised accounting and classification systems”. This is supported by Otts and Staub (2009) and Staub et al. (2011) who conducted research for the Federal Office of the Environment with the specified goal of analysing various ecosystem service approaches for the purpose of integrating ecosystem services into the Swiss and Austrian economic accounts.

Understanding and communicating information to Ministers and ensuring the framework and assessment outcomes have “policy relevance” were identified by UK Leads as one of a national government’s primary roles. They said government should “oversee the program” and “contribute to agenda setting and developing major questions” which the application of the framework will help to answer. As government agencies have “better leverage with other government agencies” they should also play a major role in data identification, access and collection.

In all programs, at all scales, governments played an important role. However, US Leads working on place-based projects under the ESRP (which is comparative to the SEQ regional scale and many sub-global assessments in the MA – see Section 3.3) said “being government” can “disrupt a local process” as “no-one wants to interact with someone who might turn around and regulate them"; and governments are often thought to “come in over the top" with regulatory solutions. From a technical perspective US Leads said governments were “inflexible” and the number of “rules" and "regulations" meant information and tools developed were often "old" by the time they were released. Information and tools developed by government were also generally “more complex” than other stakeholders require or have capacity to use.

This analysis of coordinating organisations highlights a number of important findings. First, the missions and mandates of coordinating organisations have mostly been environmentally related, but the coordinating sectors (e.g. government, academia, non-government) and the main purpose the framework is to be used for varied widely. This suggests the primary purpose for which the framework is expected to be used and the culture of coordinating organisations developing the frameworks are driving differences in methodologies. As methodologies developed for single purposes and scales and by a specific organisation might not have relevance for other purposes, scales or organisations, this finding confirms the need for a collaborative approach to developing a mutli-scale framework (see Recommendations 4 and 5).

Secondly, outside of developing national environmental accounts, at all scales preference for coordinating programs was given to organisations that were independent of government. This preference was primarily due to the need for independent scientific leadership and government's inflexible rules and regulations (Recommendation 6). A coordinating organisation considered legitimate by users of the framework and the audience for assessment outcomes is important; and greater legitimacy to develop a framework was given in most cases to organisations with existing networks and/or who have representation from a range of stakeholders on their Board or as a Party to programs.

Thirdly, drawn from the outcomes of analyses using all three research approaches, government's role in developing a framework can be decoded as: setting agendas; ensuring the framework and assessment outcomes have "policy relevance" and are communicated to Ministers; because governments have "better leverage with other government agencies", governments are also fundamental to data identification, access and collection; and ensuring data and information meet the needs of national environmental accounting practices and regulatory requirements (Recommendation 7).

At place-based and regional scales, however, challenges exist with government accessing and collecting data due to local stakeholder concerns of top down and regulatory enforcements (Recommendation 8). The methods and scale of data collection and analysis usually applied in national assessments (e.g. desktop analysis; no site access required; data is aggregated and the scale of maps rarely show private properties) and local assessments (e.g. where community participatory approaches or site visits are more common; data is less aggregated; use of cadastral maps is common; and the scale of maps often details private properties) are likely factors contributing to the different perceptions of government's role at these scales.

A fourth finding relates to the importance of government as "funders" of programs (Recommendation 9). Testament to their funding importance at national, multi-national and global scales is the US (EPA 2008), UK (UK NEA 2011b), MA (2005a), TEEB (2010), Otts and Staub (2009) and Staub et al. (2011), and Haines-Young and Potschin (2013) all being partially or fully government funded. The importance of government as funders of smaller scale programs is also demonstrated by their contribution to the

MA's sub-global assessments (MA 2005a), the SEQ program (Maynard et al. 2010) and place-based studies in the US program (EPA 2008).

The amount of funding provided to programs is discussed in the following section, along with other resource features such as the time and skills required to develop frameworks and the necessary qualities of successful leadership. Recommendations based on the findings into coordinating organisations described in this section are presented in Box 7.2.

Box 7.2: *Recommendations on the organisation to coordinate the development a multi-scale framework.*

4) **Legitimacy of the coordinating organisation:** the organisation coordinating the development of a framework requires legitimacy in the eyes of proposed framework users and the audience for assessment outcomes. Primary consideration should be given to organisations with existing networks and/or who have representation from different stakeholders as part of their management structure (e.g. on the Board, or as a Signatory) (2, 5, 6, 16, 17, 18, 19).

5) **Consideration of broad missions:** for a framework to have relevance to multiple stakeholders and be useful to different purposes a broad range of organisational missions and mandates require considering. Two ways to address this issue include: applying a collaborative approach to develop the framework; and a coordinating organisation that has at its mission the management of a broad spectrum of NRM issues and environmental programs (2, 4, 17, 19).

6) **Arm's length of politics:** the scientific foundations of the framework and the process of conducting assessments should be developed independent of any politics or policies. Two ways to address this issue include: the coordinating organisation being independent of government; and independent scientific leadership (4, 13, 14, 22).

7) **Government as a stakeholder:** government is a key stakeholder to the development of a framework (especially at the national scale) and their recommended role includes: overseeing the program to ensure outcomes have policy relevance; contributing to agenda setting; developing the policy questions that the framework when applied will answer; to communicate the program and outcomes to Ministers; and to assist with data identification, access, collection and its standards (2, 8, 9, 17, 19, 20).

8) **Government involvement at small scales:** local stakeholder concerns for top-down regulatory enforcement can provide barriers to government developing frameworks and conducting assessments at local to regional scales. Collaborative approaches to developing frameworks and non-government organisations coordinating place-scale projects have the potential to remove barriers (2, 7, 9, 18).

9) **Government as the funder:** financial support from government is fundamental to the development of a multi-scale framework (7, 8, 10, 26, 61ii).

7.1.3 The resources invested

Appendix 1 shows the resources invested in developing the MA, SEQ, US and UK frameworks in terms of the amount of funding allocated to programs, the time allocated to developing the frameworks, and the number of Chairs leading each program. Although some global scale programs (such as the MA) openly disclose in the literature the resources invested in developing a framework (and conducting assessments), overall this is rare especially for smaller scale programs. Regardless of the scale of program coordination, of all the programs reviewed or analysed that disclosed their budgetary information, the largest budget allocated was to the US national scale program. The amount of approximately US$70 million per year did not restrict the type of information and tools developed through the ESRP, however, how the money was required to be spent did (i.e. it limited extramural support). The smallest budget allocated was to the regional scale SEQ program. Although there were no restrictions as to how this money was to be spent the amount of approximately AU$80,000 per year significantly restricted the type of information (i.e. valuation methods) (see Section 7.2.5) and tools developed (i.e. dynamic models) (see Section 7.3.3).

The large budget allocated to the US program is directly related to the ESRP's mission to develop 'the information and methods needed by decision makers to assess the benefits of ecosystem goods and services to human well-being for inclusion in management alternatives' (EPA 2008, p. 8). To achieve this over one-third of resources were dedicated to 'Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales' (see Figure 5.1). Unlike the US program the MA, SEQ and UK programs did not specifically aim to develop new information or tools; they relied mostly on the existing evidence-base and pro-bono inputs from stakeholders. The ESRP made no assumption in its design that the evidence-base or appropriate tools existed to support their framework or that pro-bono inputs were available.

The time allocated to developing the SEQ, US and MA frameworks was relatively consistent, showing scale also was not a driver of the time required to develop the frameworks. Ash et al. (2010, p. 116) say timeframes should be long enough so to collect and 'develop reliable data, but not so long that too much change occurs within it'. The MA program was a four year process, the SEQ program was four years also, and the US program was five years. It was said by UK Leads their two year timeframe to develop the framework was restrictive particularly to the development of decision support tools. Driving the proposed framework review periods are the scale the methodology was developed at and related policy cycles aligned with the main purpose of assessments. For example, in line with the regional planning policy cycle in SEQ the review period is five years; US Leads suggest their national framework should be updated every five to 10 years (with the Census); and at the global scale the MA (2005a) is reviewed on a 10 year basis.

A single Manager or Director led the SEQ and US programs; Co-Chair arrangements were established to coordinate the MA and UK NEA programs. The UK Co-Chairs had "complimentary experience, not substitutable". Extensive experience on large scale environmental projects was a significant factor underpinning the appointment of both UK and US Directors. UK Leads said the most important quality of a leader is “scientific credibility” and this is not usually “held in government or their position in government taints their credibility"; and that “an individual leading it from one specific [government] agency isn’t so favourable to the other [government] agencies". The role of a leader(s) coordinating the development of a framework was described as:

- to coordinate the group including the exchange of information - “liaising between the coordinating organisation and the scientists”;
- assisting the “coordinating organisation to put the science teams together for the different chapters, suggesting Lead Authors and other Co-Authors”;
- to assist the scientists in “procuring the resources they require”;
- to ensure research stays within the boundaries of the program; and
- to assist stakeholders in the implementation of the framework.

Appendix 3 shows the distribution of expertise in the SEQ, US and UK programs measured by the number of times each tertiary qualification was held by a Lead. Across the programs expertise was highest in the fields of biology, ecology, zoology and other natural sciences; showing natural scientists rather than social scientists or a multi-disciplinary mix of expertise strongly led the technical development of the frameworks. The domination of natural scientists leading the development of the US methodology was strongly influenced by the transition of employees from the previous program which the ESRP built on (i.e. EMAP); ORD’s budget cut and funding restrictions limited purchasing extramural support (e.g. from economists). Across programs, only three UK Leads had qualifications in economics. In the SEQ and US programs extramural support for economic expertise was brought in on an as needed basis.

From this analysis of the resources allocated to developing frameworks at different scales the following findings provide insight into the resources required to develop a multi-scale framework. The first is, that it is still unclear as to whether the need to develop information and tools to support a framework is driving the amount of funding allocated to develop frameworks, or, if the amount of funding allocated to developing frameworks is driving the decision to use existing information and tools to support the framework. Similarly, it is still unclear if the level of pro-bono input expected drove the amount of funding available or vice versa. If pro-bono input is not expected, either the expertise required to develop the framework must be available within the coordinating organisation or adequate funding is required for extramural support. Flexibility of funding is necessary as the amount of funding available and restrictions on how the funding must be spent will influence the ability to develop information and tools and acquire necessary expertise (see Recommendation 10).

Secondly, the relative consistency of timeframes to develop a framework at regional to global scales suggests a four to five year time period is sufficient to develop a multi-scale framework at the national scale (Recommendation 11). A review of this multi-scale framework should occur in accordance with relevant policy and planning cycles, which, based on the analysis of different methodologies a five to 10 year time period is most appropriate (Recommendation 12).

Thirdly, a scientifically credible lead with experience working on programs at the scale of framework development is required (Recommendation 13). However, two people leading the development of a framework (rather than one) can share the tasks of “liaising between the coordinating organisation and the scientists”; identifying and coordinating science teams and authors; procuring resources; ensuring research stays within program boundaries; and assisting stakeholders in the implementation of the framework. If co-leads have complimentary rather than substitutable skills a more expansive knowledge base and skill set is also achieved in a science dependent on multi-disciplinary inputs (Recommendation 14).

The fourth finding builds on that determined through the analysis of coordinating organisations (Section 7.1.2). The domination of natural scientists leading programs is a product of the coordinating organisation's environmentally focused missions and mandates; and the transition of scientists from any previous programs that the current program builds on. Therefore, it should not be assumed the expertise required to develop a framework is held solely within the coordinating organisation (Recommendation 15).

Recommendations based on these findings into the resources required to develop a multi-scale framework are presented in Box 7.3. More detail on the individuals and organisations involved are provided in the following section, along with how these individuals and organisations were positioned within the program's structure.

Box 7.3: *Recommendations on the resources required to develop a multi-scale framework.*

10) **Determining funding:** as the available funding and any restrictions on its use will influence the information and tools developed and the purchasing of skills and expertise, when determining funds to develop a multi-scale framework consideration of the following factors is important: whether primary information exists or new information is required; what tools are required and do they exist; whether extramural support is required; and possibilities of pro-bono input (9, 15, 17, 20, 26, 35, 48, 61ii, 64iii, 66).

11) **Time required:** a four to five year timeframe to develop the framework is adequate (66).

12) **Timeframe for review:** policy cycles relevant to the main purpose of assessments should be considered when determining an appropriate period for reviewing the framework (2, 5).

13) **Program leadership:** the most important qualities of a successful program leader are scientific credibility as recognised by stakeholders; experience on projects at the scale of framework development (e.g. national); and people and coordination skills (6, 14, 20, 22).

14) **Program co-leadership:** co-leadership by individuals with complimentary (not substitutable) skills and experience should be considered (13, 15).

15) **Sourcing the expertise:** it should not be assumed the full range of expertise required to develop the framework exists within the coordinating organisation (7, 16, 17, 18, 19, 20, 27, 54i, 54ii, 54iii, 60, 65, 67).

7.1.4 The structure of programs

Cash et al. (2002) say one of the ways audiences judge the legitimacy of a process is by who participated and who did not. The literature revealed the structure of programs developing frameworks ranged from in-house approaches (Wallace 2007; US EPA 2008; Ott and Staub 2009; Staub et al. 2011) to highly participatory approaches and collaborative structures (Binning et al. 2001; MA 2005a; Maynard et al. 2010; TEEB 2010; UK NEA 2011a, 2011b). Appendix 4 shows those engaged in the development of the MA, SEQ, US and UK frameworks and the roles they played. As can be seen, unlike the US national program the MA, SEQ and UK programs applied highly collaborative and participatory arrangements.

The participatory approaches and collaborative structures that developed the MA, SEQ and UK frameworks show that scale was not a constraint to working with stakeholders. In fact one US Lead working at the national scale said “all local governments and stakeholders have groups that aggregate up and we certainly could have gone to them as representatives of these stakeholders". From an EPA perspective collaboration and stakeholder engagement was a “high priority” but from within the agency it is “something that was not done very well”. “A more collaborative approach to the [US] program” was said to be “preferable”. Past experiences between agencies and differences of objectives and missions was what deterred a more collaborative approach. Collaborating with stakeholders was said by UK Leads to be “easier for non-government organisations” than government agencies. Areas of the US program with the highest stakeholder input were the National Atlas of Ecosystem Services and the place-based projects. When US Leads who adopted collaborative approaches reflected on the program they said if coordinating their project again they would take the same approach.

For the MA to achieve its goal of improving global mechanisms for scientific assessments and with many nations signatory to the four ecosystem-related conventions, a process that would ensure the credibility, saliency and legitimacy of the framework to all stakeholders presented a challenge (Ash et al. 2010). Factors requiring consideration included the wide range of intended applications of the framework, as well, the audience for assessment outcomes extending across countries, cultures, sectors, disciplines, scales and users. In response, the MA engaged over 1300 scientists from 95 countries to develop the framework (and conduct assessments) (MA 2005a; Reid et al. 2006a; Ash et al. 2010). Support for collaborative approaches through similar experiences of improved credibility, saliency and legitimacy of the framework, but now developed at the regional scale, was discussed in Section 4.1.4.

Because the multi-disciplinary nature of ecosystem services requires multi-disciplinary knowledge, the MA's 1300 scientists from 95 countries contained a broad mix of natural and social scientists. Different to the US and UK methodologies engagement in the MA extended beyond academic disciplines to also include a gender and geographic balance and Indigenous and local knowledge (at different scales) (MA 2005a). Although in SEQ a similar process to the MA was applied, no geographic or gender balance of experts was considered due to the smaller scale the framework was developed at and the dependence on pro bono expertise and its availability. In SEQ local knowledge (e.g. extracted through Expert Panels, community workshops) was essential to developing the framework and an attempt was made to include Indigenous input.

Section 7.1.3 discussed how Leads involved in the SEQ, US and UK programs were predominantly natural scientists. This was a result of the environmentally focused missions and mandates of coordinating organisations and the transition of scientists from previous programs. For these types of organisations and programs collaborating with other organisations or purchasing extramural support is important to capturing input from a broader range of expertise. Appendix 4 showing who was engaged in the development of the MA, SEQ, US and UK frameworks reveals little collaboration or representation by health organisations, business and industry, and Indigenous groups across the programs. Local government planners were highly involved in the development of the SEQ framework but not in the development of frameworks at national, multi-national or global scales. Land-use planning activities primarily being a local and state government mandate, rather than a national government or an international conventions mandate (see Sections 3.2.2.1, 3.2.3.1 and 3.2.3.2), likely influenced the lack of involvement by planners at these larger scales.

In each of the MA, SEQ, US and UK programs over 180 professionals were involved in the frameworks' development (see Appendix 1). Positions within the MA, SEQ and UK working groups were mostly pro-bono. The EPA being a government agency created challenges to attracting pro-bono input. However, with its larger budget the EPA had greater opportunity to employ experts (also in Appendix 1) and purchase extramural support. Programs working with large groups of people (either paid employees or pro bono) are highly dynamic as those involved are capable of adjusting the objectives and the methodologies to make them fit emerging needs (Maynard et al. 2012). Programs must be carefully structured to allow participants to contribute information in a way they are capable, feel comfortable and that meets the needs of the program (Maynard et al. 2012, 2015).

The US and UK programs adopted a matrix structure to facilitate cross-functional collaborations among researchers and cost-effectiveness of research (EPA 2008; UK NEA 2011b). Figure 5.1 shows the organisational matrix for the ESRP where three cross-program themes (i.e. Effective Decision Support; Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales; and Pollutant–Specific Studies – Nitrogen) were established and applied to two types of Demonstration Projects (i.e. ecosystem and place-based studies) (EPA 2008). In the UK NEA the matrix consisted of the four ecosystem service categories and eight habitat types (similar to matrix C presented in Figure 4.4 for determining interconnections and values in the SEQ framework). Leads were established in the US and UK programs to oversee the collection and development of cross-cutting information and knowledge to support these frameworks (and these were primarily the Leads interviewed for this research). A major difference between the US and UK matrix approaches was that Leads in the ESRP were all paid EPA employees, and those in the UK NEA were from a wide range of organisations.

Referring back to Appendix 4 and the MA, SEQ and UK collaborative processes, although some minor differences are revealed, similarities can be drawn in how those engaged were organised to contribute their expertise. One similarity across programs is the establishment of an overarching working group comprising key users and funders of the framework and outcomes of assessments (e.g. the MA Board, the ESSG in SEQ, and the UK Client Group). These groups oversaw the technical elements of the framework and allocation of funding (MA 2005b; Maynard et al. 2010; UK NEA 2011b). UK Leads said establishing this working group ensured “organisational mandates and political agendas” were “separate” from “the design of the assessment methodology and type of information produced” to support the framework. Maynard et al. (2010) say this group also ensures the assessment methodology is practical and complies with current planning and policy requirements and agency goals.

The US process made strong use of experts within ORD but had little connection with potential users of the framework or those who might be most affected by its application (e.g. communities). In contrast, underpinning the collaborative approach to developing the SEQ framework was the principle that those most likely to apply the framework in their policy, planning and management should be responsible for the framework's development (Maynard et al. 2010, 2012). Although challenges exist of this approach, the establishment of the UK User Group is further support for its adoption. Three UK Leads reflecting on the approach described their lessons learnt: "we couldn't get the voices of the User Group heard enough"; "often [the User Group] meetings were held separately ... some information didn't always filter in"; "the big challenge is to make sure that you're getting a more balanced weighting of all the different groups in society".

All programs included a peer review process. Due to the regulatory nature of the EPA the US process through the Board of Scientific Counsellors (BOSC) is the most formal; the SEQ process had the least formal. As a policy ORD have all potential journal and EPA publications peer reviewed prior to submission. Furthermore, for data inclusion in the National Atlas of Ecosystem Services a pre-requisite is a published peer reviewed article. In SEQ at each stage of the program the outcomes were reviewed through an open-forum of stakeholders in a Think Tank exercise (Maynard et al. 2010; 2012). Levels of uncertainty were not established for information and tools developed in the SEQ or US programs; the MA and UK programs adopted the IPCC method (MA 2005a; UK NEA 2011b). Common to all programs was that reviewers of information and tools were an independent group of professionals from outside the project team who were invited for their expertise and credibility.

The concept of 'place' plays an important role in the development of the MA, SEQ, US and UK methodologies. For example, place scale studies include the sub-global assessments in the MA; local government valuation workshops in SEQ; place-based studies in the US; and national assessments using the UK framework. Place scale studies capture and convey an area's unique context, including environmental, cultural, social, economic and political dimensions - all the things that together make it special to people within that place and different from other places (Tasmanian Government 2012).

The MYP 2008-2014 states the ‘nature… value and the aggregation of ecosystem services is all place-dependent' (EPA 2008, p. 92). Place is important to better understanding ‘ecosystem functions from which the services are derived as ecosystem functions are associated with the biogeographic characteristics of a place’ (EPA 2008, p. 92). Section 3.4 discussed how ‘for small scale programs to be effective they should be situated in the wider political context’ (UNDP 2006, p. 11). This becomes even more relevant when considering a program to develop a framework at the national scale, as Chapter 1 discussed, ‘national institutions are often the pivot between local or regional institutions and international ones’ (WRI 2007, p. 35).

Figure 2.1 presents a simplified version of the multi-scale design of the MA methodology using three different scales. In reality, 34 sub-global assessments were conducted at local, watershed, national and regional scales to better facilitate decision making at these scales (Reid et al. 2006a; Ash et al. 2010). The MA sub-global assessments were not chosen to be representative samples of ecosystems, regions or nations (MA 2005d). Rather, they were chosen based on the interest and available resources of those coordinating them; and they were designed to meet the needs of decision makers in these areas (Reid et al. 2006a; Ash et al. 2010).

The approach to identifying and determining the US place scale programs was similar to that applied to the MA sub-global assessments. According to US Leads they were chosen where the EPA had laboratories; where the EPA already had a lot of data; where the laboratory had existing activities that could be capitalised on; where the laboratory had a partner willing to work with them; and those places that showed the greatest interest. A report developed by the SAB (2009) criticised this selection, one Lead said “the concern was for misrepresentation of a whole section of the country (i.e. there was not enough diversity in the place-based portfolio)”. Comparative to the MA and US, the approach to identifying place scale study areas in the UK and SEQ was very straight forward. They were based on the smaller governance areas within the boundaries of the framework (i.e. the four constituent countries comprising the UK and 11 local governments in SEQ).

Collaboration and participation by stakeholders was high in these place scale projects. One US Lead working at the place scale said identifying groups of stakeholders (e.g. "the public; their representatives, managers, neighbourhood associations, city mayors, natural resource managers; and the science, technical people") was the easy part of developing collaborations, identifying individuals who should be in these groups was the challenge. Section 4.1.4 describing the SEQ process provided the following reasons for adopting this collaborative approach: the coordinating organisation being a non-government organisation required wider input from stakeholders to increase the credibility of information; expert local opinion was a recognised important resource; involving a wide range of stakeholders would improve the saliency to decision making in different applications; the resources limited alternative approaches; and it was thought stakeholders were more likely to use the framework if they had ownership in developing it (Maynard et al. 2010, 2012, 2015).

Section 2.1 described how developing a flexible framework at the global scale yet establishing standards and criteria for others to use in sub-global assessments (i.e. by using the MA conceptual framework, engaging users and following MA policies), allowed information, data and assessment outcomes to integrate bottom-up and top-down to further refine frameworks and inform assessments at different scales (MA 2005d). When questioned on the potential to upscale and synthesise information across place scale studies in the US program, one Lead stated "initially the places were not chosen for future comparison although that became more of an objective later in the program".

One US Lead's reflection on how the approach to upscaling place studies might be improved supports the MA's use of criteria and standards for sub-global assessments: "you would do things in a similar way in different places so that you could end up with comparability across the places" ... "you would try and guide it more rather than everyone going off and doing their own thing"; "[what] we could have done better would be to design more specific parallel design components in our place-based efforts". For example, "ideally, the FEGS approach would have been completed before we moved ahead with the place-based studies". It was agreed some form of conceptual framework would also be provided if someone was to take up another place-based study.

Section 7.1.1 comparing and contrasting the factors underpinning the initiation of programs describes the UK's stronger focus on environmental issues outside its jurisdictional boundaries (i.e. its recognition of not meeting the 2010 Biodiversity Targets; the impact of European policy on Britain's biodiversity and agricultural production; and climate change). These initiating factors drove a unique feature of the UK program; the UK's framework was used to assess ecosystem service provision derived from outside the UK's boundaries. UNEP-WCMC being a global organisation was therefore well placed to ensure the UK framework addressed global issues (e.g. climate change), and aligned with the needs of global conventions (e.g. CBD, IPCC).

From this analysis into the structure of programs coordinated at different scales the following findings into developing a multi-scale framework are revealed. Firstly, the multi-disciplinary nature of ecosystem services is inherent and therefore a wide range of expertise is required to develop a framework (see Recommendation 16). Knowledge in environmental, social and economic processes operating at different scales is required to develop a multi-scale framework. To capture this breadth of expertise a large number of people will need to be engaged (Recommendation 18 and 19). Further research is required into the importance and impact of gender and geographic imbalances at different scales. Indigenous and local knowledge are important resources at all scales.

Secondly, this research showed that scale provides no constraints to collaborative approaches, and collaborative approaches are the preferred approach at all scales (Recommendation 17). Ensuring the framework and assessment outcomes have credibility, saliency and legitimacy to proposed users and target audiences were the main reasons provided for adopting highly collaborative and participatory approaches (MA 2005a; Maynard et al. 2010, 2012; TEEB 2010; UK NEA 2011b). To capture multi-disciplinary and multi-sectoral input in a legitimate, credible and salient way collaboration needs to occur horizontally (i.e. within scales) and vertically (i.e. across scales). Small scale stakeholder groups (e.g. local governments) have representative organisations at larger scales (e.g. the Australian Local Government Association) that should be engaged.

A third finding from this analysis is that working with large groups of people requires a carefully structured program that allows participants to contribute information in a way they are capable, feel comfortable and that meets the needs of the program (Maynard et al. 2012) (Recommendation 20). As an example, the US and UK programs showed how adopting a matrix approach can facilitate cross-functional collaborations and cost-effectiveness of the research required to develop a framework (EPA 2008; UK NEA 2011b) (Recommendation 21). Also, supporting findings in Section 7.1.2 that the scientific foundations of the framework and the process of conducting assessments should be developed independent of any politics, the MA, SEQ and UK programs separated “organisational mandates and political agendas” from “the design of the assessment methodology and type of information produced” by creating a separate working group for these representatives (Recommendation 22).

How programs have nested ‘place’ into the design of their broader scale (e.g. national) frameworks and assessments provides insight into how a multi-scale framework might operate (Recommendation 23). For example, the EPA (2008) says the nature, value and the aggregation of ecosystem services is all place-dependent; and the biogeographic characteristics of a place are important to understanding ecosystem functions from which the services are derived. The choice of place scale studies should extend beyond just where the capacity exists, to also consider the diversity and the representativeness of places across the broadest area of framework coverage, and the potential to compare and aggregate outcomes of small scale assessments to larger scale activities (Recommendation 24).

Another finding that builds on the previous into nesting place scale studies in broader scale frameworks is the importance of developing a robust, repeatable, yet flexible framework (Recommendation 25, 27 and 28). Within the broader scale framework, the development of standards and criteria for consistent use in place scale studies allows information, data and assessment outcomes to integrate bottom-up and top-down to further refine frameworks and inform assessments at different scales (MA 2005d) . To guide the place scale studies it is important to develop specific parallel design components (e.g. conceptual frameworks, definitions and classification systems) so to “do things in a similar way in different places so …you [get] comparability across the places" (Recommendation 26).

The final finding into the structure of programs is derived from the UK program. In contrast to other programs reviewed or analysed in this research, and in recognition that ecosystems and ecological processes are not confined to human boundaries and many ecosystem services are derived from and require management from outside of the UK, the UK program used their framework to assess the ecosystem services derived from outside their jurisdiction. This is an area of further research as little information on this process is provided and this approach was not adopted by other programs. Box 7.4 below provides the Recommendations on an appropriate process to develop a multi-scale framework based on these findings into the structure of programs.

Box 7.4: *Recommendations on the structure of a program to develop a multi-scale framework.*

16) **Multi-disciplinary input:** due to the multi-disciplinary nature of ecosystem services a wide range of expertise is required to develop a framework (e.g. economists, planners, cartographers, and natural and social scientists (15, 17, 18, 19, 20, 29, 47, 51, 54i, 54ii, 54iii, 60, 64).

17) **Collaborative approach:** collaboration with proposed users of the framework, the target audience of assessment outcomes, and those most likely to be impacted by the application of the framework, is the preferred approach to developing a framework as it improves its legitimacy, saliency and credibility (7, 19, 20, 21, 24, 42, 51, 54i, 54ii, 54iii, 60, 65).

18) **Diverse forms of knowledge:** diverse forms of knowledge such as Indigenous and local knowledge are essential to the development of the framework. Within the mix of experts consideration should also be given to gender and geographic balances (15, 16, 17, 19, 20, 29, 51, 60, 65).

19) **Sector participation:** when scoping collaborations and expert inputs to develop the framework consideration of the potential use and users of the framework (i.e. health organisations; business, industry; government; Indigenous groups; agricultural groups; NGOs; and tourism organisations - to name a few) within and across scales is required (2, 5, 7, 15, 16, 17, 18, 20, 24, 35, 42, 54i, 54ii, 54iii, 60, 65, 67, 68).

20) **Carefully structured program:** a carefully structured program is required to ensure contributors (e.g. scientific, government, Indigenous and local) understand their roles and responsibilities; where their information and expertise fits in the development of the framework; and how their input will be used in the application of the framework (7, 16, 17, 18, 19, 21, 23, 27, 29, 42, 51, 54i, 56, 60, 65).

21) **Matrix structure:** applying a matrix structure can facilitate cross-functional collaborations between stakeholders and improve the cost-effectiveness of research required to develop a framework (10, 17, 19, 20).

22) **Independent of political agendas:** within the structure of the program a separate working group should be considered for key framework users or funders to ensure organisational mandates and political agendas do not influence the design of the assessment methodology including information and tools developed (2, 5, 6, 7, 20).

23) **Inclusion of place studies:** as the nature, value and the aggregation of ecosystem services is all place-dependant; and the biogeographic characteristics of a place are important to understanding ecosystem functions from which the services are derived; when developing a multi-scale framework it is important to structure place scale studies in the broader program design (24, 25, 26, 38, 39, 47, 59).

24) **Selecting place study areas:** the following factors should be considered when determining areas for place studies: places where a suitable coordinating organisation exists; where stakeholder organisations are willing to work together; where data is available; where previous or existing initiatives can be capitalised on; and places that are diverse yet representative of the broadest area the framework can assess so future comparisons and comparability can be made (4, 17, 19, 23, 25, 26, 35, 48, 64iii, 64iv).

25) **Place study design:** place studies should apply parallel design components to ensure comparability of assessment outcomes; and that outcomes can be aggregated or up-scaled to provide assessments at larger scales. Parallel design components include: the use of common definitions; a common ecosystem services classification system; the use of an overarching conceptual framework; all place studies should adopt a collaborative and participatory process; and any principles or policies supporting the framework should be adhered to (17, 19, 20, 23, 24, 26, 30, 36, 37, 38, 40, 41, 43, 45, 52, 54i, 54ii, 54iii, 63, 64v).

26) **Place study funds:** when determining the overall program budget, funding for both conducting place studies and conducting comparability analysis across studies, should be included (9, 10, 23, 24).

27) **Peer Review:** a well-structured independent peer review process that meets the needs of regulatory activities is required (20, 62, 64ii, 66, 67).

28) **Uncertainty of data and information:** recording a level of certainty of data and information included in the framework, and any relevant assumptions made and principles used when conducting this rating, is important for transparency and credibility of assessment outcomes using the framework (27, 62, 64ii, 66).

This concludes the analysis of methodologies under Line of Enquiry 1. The 28 Recommendations listed in Boxes 7.1, 7.2, 7.3 and 7.4 were derived from the cross-analysis of processes to develop frameworks at different scales using the three research approaches. These Recommendations will assist researchers with determining *an appropriate process to develop a framework for ecosystem services assessments across multiple scales.* The following section continues the analysis of methodologies through the second Line of Enquiry into information required to support a multi-scale framework.

7.2 Information: Findings and Recommendations

This second Line of Enquiry aimed to answer the following research question: *what information is required to support a framework for ecosystem services assessments across multiple scales?* The key information supporting the MA framework was discussed in detail in Section 2.1.2 and synthesised with other literature in Section 3.1.2. From this synthesis the following key topics were identified for further analysis: the role of biodiversity and its position in an ecosystem services framework; the type of units included to assess ecosystem service provision; how ecological processes and ecosystem services are defined and included; and an approach to determining the value of ecosystem services.

This section of the thesis compares and contrasts outcomes from the analysis of information included in the SEQ, US and UK frameworks using these key topics. It primarily draws from Sections 4.2, 5.2 and 6.2 but it also draws on relevant outcomes from other sections. The SEQ, US and the UK information are also compared and contrasted to the MA and other schools of thought revealing how different drivers have shaped information underpinning a wide range of frameworks; and if the SEQ, US and the UK information is consistent with current theories on information required or if they provide new insights. Recommendations derived from the cross analysis of case studies and schools of thought are presented in Boxes 7.5 – 7.9 below the findings from each key topic.

7.2.1 The role of biodiversity

The importance of defining and establishing the position of biodiversity in an ecosystem services framework early on in a program is evident from the MA and experiences in SEQ, the US and the UK. In the MA biodiversity is clearly defined and recognised as underpinning ecosystem service provision as is shown by the boxes encompassing Supporting, Provisioning, Regulating and Cultural Services in Figures 1.1 and 2.2. Chapter 1 discussed how this ‘human-centric focus on nature’ has been the main criticism of an 'ecosystem services approach' to managing natural resources (Hansen 2011). This is shown true through the SEQ, US and UK experiences as many (natural scientists) thought in an attempt to assess and manage ecosystems for the benefits they provide people that the value of biodiversity’s existence for its own sake would be lost.

In contrast to the SEQ and UK programs which were challenged to proceed before addressing this issue the US program continued to move forward without a resolution.

UK Leads said biodiversity’s role in the provision of ecosystem services “depends on what is meant by biodiversity” as "... how people treat biodiversity depends on where they’re coming from and what they see it as". The MA, SEQ and UK frameworks all adopted the CBD’s (1992) definition of biodiversity, which the MA says enabled them to better integrate with existing global environmental policies and programs and meet the aims of decision makers from the four major ecosystem-related conventions. (MA 2005a). The UK Technical Report states the CBD’s definition is ‘less than ideal from the perspective of ecosystem services because diversity per se may have only a limited effect on specific ecosystem services’ (others may be dependent on quantity) (UK NEA 2011b, p. 68). The US definition included in the Lexicon’s General Terms (providing terms ‘useful’ to ESRP researchers and proposed framework users) is a condensed version of the CBD’s but it was not technically modified.

As shown in Appendix 8 listing the ecosystem services included in the MA, SEQ, US and UK programs biodiversity is not listed as an ecosystem service in the SEQ framework. The most closely related is ‘Iconic Species’ (species revered as emblematic or charismatic). In the SEQ framework biodiversity is recognised as an important feature of healthy ecosystems because it increases their flexibility and resilience (SEQ Catchments 2012). The following four principles that were developed by stakeholders defined biodiversity’s position in the SEQ framework (SEQ Catchments 2012):

- *the recognition that the bulk of ecosystem services come from natural ecosystems;*
- *that ecosystem services is only one tool for nature conservation and there may be better approaches to conserving different aspects of biodiversity;*
- *that ecosystem service approaches are more appropriate for landscape scale conservation rather than for species conservation; and*
- *due to the lack of certainty on the role of biodiversity caution should be used with applying ecosystem service approaches.*

Appendix 5 shows the US and UK Leads' responses when asked: *what is the role of biodiversity in ecosystem services assessments? Is biodiversity an ecosystem service or not?* Fifteen of the 17 UK Leads said biodiversity is an ecosystem service. Biodiversity, as defined by the CBD, was considered a service when "it's actually appreciated as biodiversity" as "some of the delight that people take in nature is the fact that it's hugely complex and diverse". In the UK Technical Report biodiversity is incorporated in the framework in three ways, one respondent described these as "what role does it play in processes?, what role does it play in services?, and what role does it play in goods?". The fundamental role of lower order species such as microorganisms, soil biodiversity and insects in the "delivery of ecosystem services" was discussed by many Leads. Nearly half the respondents said biodiversity in terms of "wild species diversity" is a Cultural Service. Another said "... actually, most conservation is about biodiversity as a 'good' because it's actually the organism itself or the species that has value".

In contrast to UK Leads only two out of the nine US Leads responding to the same question said biodiversity is an ecosystem service (based on its extrinsic values). However, Appendix 8 shows biodiversity, wildlife populations, habitat, refugia and biodiversity related processes listed as ecosystem services. The majority of Leads said biodiversity was something people cared about but this did not make it an ecosystem service. Some said biodiversity was "more of a structural thing" than an ecosystem service. The subjective nature of biodiversity and our inability to actually measure and value it was another reason for respondents claiming biodiversity is not a service. It was noted by Leads that the US is not quite oriented towards biodiversity; that biodiversity is not an EPA mandate it tends to be more regulatory towards pollutants; and the EPA does not have the authority to legislate land-use key to protecting biodiversity.

Only the UK framework specifically linked data on biodiversity with ecosystem service provision. Although the UK is rich in data on the status and trends of biodiversity, a practical constraint on the use of this data for the purpose of ecosystem services assessments is that it 'tends to relate to taxonomic groups distinguished by specific monitoring programs … biodiversity groups need redefining in terms of their functional role in ecosystem services' (UK NEA 2011b, p. 68). Using existing biodiversity data in ecosystem services assessments requires combining data sets across different monitoring programs that employ different assessment methods (UK NEA 2011b). As quantitative data was limited on the relationship between biodiversity and ecosystem services the UK NEA (2011b) applies a qualitative assessment (i.e. low, medium, high) of the importance different biodiversity groups make to the provision of FES.

The SEQ framework says biodiversity and ecosystem functions are co-dependent; biodiversity is vital to maintaining functioning ecosystems, just as ecosystem functionality is vital to the persistence of biodiversity (SEQ Catchments 2012). A system with higher biodiversity is said to be stronger, more robust, resilient and sustaining in its delivery of ecosystem services than one with less biodiversity (SEQ Catchments 2012). This is supported by the MA (2005a) and the UK Technical Report (UK NEA 2011b), and also by US Leads who described biodiversity as an "insurance policy for ecosystem services". The possibility of reducing ecosystem function increases as more species are lost due to reductions in substitutability (SEQ Catchments 2012).

From the analysis of this key topic the following findings can be deduced. First, it shows biodiversity's role in ecosystem service provision is still not well understood, or consistently understood across contexts (e.g. countries, cultures, disciplines, sectors, scales) (Recommendation 29). Although the MA, SEQ, US and UK frameworks all use (a version of) the CBD definition, how and where biodiversity is placed varies across these frameworks. One driver of this variation is the 'less than ideal' biodiversity definition in the CBD being used in ecosystem services assessments (UK NEA 2011b, p. 68). In terms of the inconsistency in biodiversity's role and position across US projects, the difference can partly be contributable to the lack of inclusion of biodiversity as a 'core' ESRP term.

Secondly, it was revealed at the national scale different cultural perceptions on biodiversity influenced the level of consideration given to biodiversity's role in delivering ecosystem services, and its position in a framework. For example, the document review providing background information on the SEQ (Section 3.2.2.1), US (Section 3.2.3.1) and UK (Section 3.2.3.2) programs discussed how unlike Australia and the UK, the US is not a signatory to the CBD (2013) or the Convention on the Conservation of Migratory Species and Wild Animals (UNEP-CMS 2013). US Leads said "the US is not quite oriented towards biodiversity". For signatory nations (such as Australia) to better integrate national policies with existing global environmental initiatives, there are benefits to aligning (where relevant and possible) information included in frameworks and assessments with that of global initiatives.

Thirdly, similar to the finding on cultural perceptions the missions and mandates of organisations coordinating programs influenced the level of consideration given to biodiversity's role in delivering ecosystem services, and its position in a framework (Recommendation 30). Both the background information provided in Section 3.2.3.1 and responses from US Leads confirmed, that unlike SEQ Catchments and UNEP-WCMC the EPA's mandates do not include the management of biodiversity which is primarily a function of the Department of Interior under the Fish and Wildlife Service (UNEP-WCMC 2013; US Fish and Wildlife Service 2013; SEQ Catchments 2015b). This analysis shows frameworks developed in one context (e.g. in one country or by one organisation) may not have relevance to stakeholders' needs in other contexts. Ensuring a multi-scale framework has relevance to the large and diverse range of missions and mandates of proposed users therefore requires input from a large and diverse range of stakeholders.

The strong agreement across researchers developing frameworks that biodiversity plays an 'insurance' role in the provision of ecosystem services is the fourth finding (Recommendation 31). Although 'some species can perform the same process within an ecosystem … other species make unique contributions to the functioning of the system' (SEQ Catchments 2012) (Recommendation 32). This supports the claim that biodiversity and ecosystem functions are co-dependent; and the possibility of reducing ecosystem function will increase as more species are lost due to reductions in substitutability (SEQ Catchments 2012). 'Redefining biodiversity groups' and ensuring research and monitoring programs focus (not just on taxonomic groups but) on the 'functional role' biodiversity plays in providing ecosystem services is important (UK NEA 2011b, p. 68) (Recommendation 33).

Based on these findings, Recommendations into the role of biodiversity in providing ecosystem services and its position in a framework are presented in Box 7.5. The assessment units included in frameworks are the topic of the following section.

Box 7.5: *Recommendations on biodiversity to support a multi-scale framework.*

29) **Managing diverging paradigms of thought:** a proactive approach to managing diverging paradigms of thought held by different disciplines and stakeholders on biodiversity and ecosystem services, is to engage stakeholders early on in the program to develop definitions, guidelines, principles and assumptions that establish biodiversity's position in a framework (16, 17, 18, 19, 20, 30, 31, 32, 33, 39, 43, 54i, 54ii, 54iii, 55).

30) **Defining biodiversity:** an agreed definition of biodiversity representing its shared conceptualisation across stakeholders is required. The foundation from which to base discussions is the CBD definition, as the use of information included in existing global initiatives will improve opportunities for integrating assessment outcomes into them (17, 29, 31, 32, 33, 35, 54i, 54ii, 64iv).

31) **The insurance role of biodiversity:** biodiversity plays an 'insurance' role in the provision of ecosystem services and this should be reflected in a framework. A system that has higher biodiversity is stronger, more robust, resilient and sustaining in its delivery of ecosystem services than one with less biodiversity (29, 30, 32, 33, 39, 54i).

32) **More than one position and role:** stakeholders establishing biodiversity's position in the framework and defining its role may determine there is no one role played or position held by biodiversity (29, 30, 31, 33).

33) **Co-dependence of biodiversity and ecosystem function:** as the possibility of reducing ecosystem function increases as more species are lost due to reductions in substitutability, understanding the link between biodiversity and ecosystem functioning is important to designing management and monitoring programs (29, 30, 31, 32, 39).

7.2.2 Assessment units

In the schools of thought reviewed and the three frameworks analysed four main types of assessment units were included: ecosystems, biomes, environmental classes and habitats. The assessment units included in the MA, SEQ, US and UK frameworks are listed in Appendix 6. The CBD's (1992) definition of an 'ecosystem' was adopted in the MA, SEQ and UK frameworks and a slightly amended version of this definition is provided under General Terms in the ESRP's Lexicon (MA 2005a; EPA 2010b; UK NEA 2011b; SEQ Catchments 2012). Common to the theory underpinning ecosystems in all programs is that humans are an integral and often dominant component of them (MA 2005a; EPA 2010b).

Although they are categorised and classified differently 'ecosystems' are the assessment unit included in the MA, SEQ and US frameworks. Box 2.1 described the MA's 10 Reporting Categories developed to assess the global status and trends of ecosystem services using the framework. All natural and human modified ecosystems across the globe were grouped under each Reporting Category by similarities in: 'climatic conditions, geophysical condition, dominant use by humans, surface cover, species composition and resource management systems and institutions' (MA 2005a, p. 53). The MA (2005a, p. 51) states ecosystems have 'strong interactions among components of the system and weak interactions across their boundaries; discontinuities of strong interactions become boundaries'.

Different to the MA's systems approach to defining the units for assessment, the 12 biomes incorporated in TEEB (2010) were 'based on dominant vegetation structure' and 'marine biomes were based on geochemical properties' (TEEB (2010, p. xxxi). TEEB's boundaries were based on ecological structure and processes and did not include reference to social or economic processes (except for the Cultivated and Urban). The MA (2005a, p. 53) says they used categories with overlapping boundaries 'because this better reflects real-world biological, geophysical, social, and economic interactions, particularly at these relatively large scales'.

Documents supporting the US and SEQ frameworks say that to conduct standardised, repeatable and consistent ecosystem services assessments clear boundaries are required (SEQ Catchments 2012; Landers and Nahlik 2013). Stakeholders involved in developing the SEQ framework said the MA provided a credible framework; therefore, to improve the potential to integrate and upscale information, data and assessment outcomes the MA should provide the foundations for the SEQ framework. The MA categories were too broad for regional or smaller scale assessments; Appendix 6 shows the relevant MA Reporting Categories sub-classified into SEQ's 32 ERCs (Maynard et al. 2010; SEQ Catchments 2012).[*] For use in property or site scale assessments these ERCs were further sub-classified using the MA's criteria described above. Each ERC contains a number of natural or human modified ecosystems representing all ecosystems across the region (Maynard et al. 2010; SEQ Catchments 2012). For natural ecosystems the Queensland Government's Regional Ecosystem Framework commonly used by

[*] No Polar areas exist in SEQ so this Category was excluded (Maynard et al. 2010; SEQ Catchments 2012).

stakeholders in planning and development assessments was used to further refine ERCs (Maynard et al. 2010; SEQ Catchments 2012). Management plans and advice by experts were used to refine ERCs for human modified ecosystems.

Two types of assessment units were developed to support the US framework: ecosystems and environmental classes. Wetlands and coral reefs were selected as ecosystem demonstration projects; and streams, wetlands and estuaries were the focus of more theoretical studies. Driving the choice of these five ecosystems was: the large amount of information already existing within ORD on wetlands and coral reefs; staff from previous wetland and coral reef programs (e.g. EMAP) would be transitioning to the ESRP; and because the area of wetlands and coral reef are in decline in the US (EPA 2008). From a program office perspective, "wetlands, streams and estuaries are ecosystems ORD have a lot of responsibility for under the Clean Water Act".

US Leads said "'environmental classes' are a broader classification of ecological components that better encompass abiotic elements such as atmosphere and groundwater contributing to ecosystem service provision that are not captured by other categories of units" (e.g. the MA's Reporting Categories). The three environmental classes and 15 environmental sub-classes supporting the US framework were in the final stages of development at the time of this research and not formally incorporated in the framework. Outside of the two ecosystem demonstration projects there is "no standard approach to the ecological units assessed across the ESRP". The type of assessment unit developed or used in the program's projects (e.g. in place-based projects) is "dependent on the particular problem or issue being addressed".

In contrast to the ecosystem assessment units included in the MA, SEQ and US frameworks the UK NEA (2011b) included 'habitats'. A main driver behind the use of habitats was the requisite to use the existing evidence-base to develop the framework and conduct assessments; resulting in the Broad Habitats used in European policy and the Countryside Survey 2000 being included. The UK NEA (2011b) says habitats and ecosystems are closely related and in reports they often use the terms interchangeably. However boundaries of habitats are defined by the area inhabited by a particular biotic species (UK NEA 2011b), and ecosystem boundaries are defined by the discontinuity of strong interactions across components of a system (MA 2005a; UK NEA 2011b). Similar to Reporting Categories, ERCs and environmental classes, the eight Broad

Habitats developed for (multi-)national assessments in the UK were further sub-classified into smaller habitats for use in smaller scale assessments.

Five key findings are derived from this analysis of assessment units using the three research approaches. The first is that a number of drivers have influenced the choice of assessment units included in frameworks, they are: 1/ the availability of data; 2/ the potential to integrate the framework and assessment outcomes into current natural resource activities (e.g. Queensland Government planning activities, European policy); 3/ the requisite to use the existing evidence-base to inform frameworks and conduct assessments (e.g. the UK NEA); 4/ the missions and mandates of the coordinating organisation (e.g. wetlands being an EPA mandate); and 5/ the scale the framework was developed at (e.g. the MA's 10 global Reporting Categories were sub-divided into SEQ's 32 regional ERCs) (see Recommendation 34).

The second finding relates to points 1/, 2/ and 3/ above. These existing units of assessment were developed for different purposes. Two implications of using existing units are: outcomes are subject to any inherent contextual biases of those units; and they will be sensitive to the classifications and descriptions developed for previous purposes. Assessment units developed for purposes other than ecosystem services assessments (e.g. biodiversity assessments) may not capture the required understanding of interactions across systems. As an example, the US program recognised the limitations of both ecosystems and habitats in capturing environmental assets such as groundwater and atmosphere important to providing ecosystem services; however environmental classes lack the ability to qualitatively link biodiversity functional groups with specific areas of the landscape such as with habitats. It should not be assumed existing units are appropriate for ecosystem services assessments (Recommendation 35).

Thirdly, at all scales the methodologies analysed using the three research approaches showed information is required on the 'full range' of units within the largest spatial area the framework covers (Recommendation 36). For example, the MA's (2005a) 10 Reporting Categories covered all the ecosystems across the globe; the UK NEA covered all habitats across the nations; and the SEQ's 32 ERCs covered all the ecosystems across the region (Maynard et al. 2010). According to one US Lead, although only a few ecosystems important to meeting the EPA's mandates were included, "the plan" was to eventually include “a wide range of ecosystems across the US in similar categories to the Reporting Categories identified in the MA”.

Finding four under this analysis relates to defining unit boundaries (Recommendation 37). Although the MA uses overlapping boundaries for global scale assessments stating this better reflects real world socio-ecological processes, as discussed by US Leads, clear boundaries are required for the purpose of collecting data and administering and managing ecosystem services through monitoring, environmental accounting and markets. Documents supporting the US and SEQ frameworks say clear boundaries are needed to conduct standardised, repeatable and consistent ecosystem services assessments (SEQ Catchments 2012; Landers and Nahlik 2013).

The final finding into this analysis of assessment units is that the MA, TEEB, SEQ, US and UK frameworks all included a set of ‘nested’ units suitable for ecosystem services assessments at different scales (Recommendation 38). For example, to extend its usefulness in assessments at smaller and larger scales three tiers of units were developed to support the SEQ regional framework (Reporting Categories, ERCs, Queensland Government’s Regional Ecosystem Framework) and two tiers of environmental classes were established to support the US national framework. Nested units allow assessment outcomes to inform and integrate with other assessments and outcomes across scales (MA 2005a; Maynard et al. 2010). Comparing the categorisation of ecosystems/biomes/habitats developed for large scale assessments with those developed for smaller scales (e.g. ERCs), greater ecological differentiation is shown across large scale categories and significant amounts of information are lost when assessment units are aggregated. The type of data sets currently available, the resources available to develop new data (Section 7.1.3), and the potential to aggregate and dis-aggregate any existing or new data and information, can influence the potential to develop nested units. Recommendations into the units required to assess ecosystem services through a multi-scale framework are presented in Box 7.6. The analysis of ecological processes is the topic of the following section.

Box 7.6: *Recommendations on assessment units to support a multi-scale framework.*

34) **Integrate information with other initiatives:** stakeholders should be consulted as to their use of existing information and its usefulness in an ecosystem services framework. Although the potential to integrate the framework with current initiatives is improved through the use of existing information (e.g. assessment units), it should not be assumed these (units) are in the right form for ecosystem services assessments (16, 17, 18, 19, 35, 48, 61iv, 64iv).

35) **Use of existing information:** stakeholders should be engaged in a review of existing information, and determine its fit-for-purpose in ecosystem services assessments. When reviewing existing assessment units specific sensitivities to include are: the recognition of humans as an integral component of the system; the unit's ability to assess ecosystem services derived from groundwater and the atmosphere; how these units reflect the role of biodiversity in ecosystem services provision and its position in the framework; and the scalability of information (17, 19, 20, 29, 31, 32, 33, 34, 36, 37, 38, 61iv, 64v).

36) **The full range of assessment units:** information is required on the 'full range' of possible units within the largest spatial area that can be assessed using the framework (34, 35, 37, 38, 44, 64i).

37) **Defining unit boundaries:** clear unit boundaries are required to conduct standardised, repeatable and consistent ecosystem services assessments (34, 35, 36, 38, 40, 43, 54i, 54ii, 54iii).

38) **Nested assessment units:** so stakeholders can consistently and repeatedly assess ecosystem services for different purposes operating at different scales, a list of nested assessment units is necessary to support the framework. This nestedness allows for assessments and outcomes at one scale to inform and integrate with assessments and outcomes at larger and smaller scales (35, 37, 54iii, 64v).

7.2.3 Ecological processes

This analysis of methodologies revealed that at the ecological processes level the information supporting frameworks differs a lot (de Groot et al. 2002; Boyd and Banzhaf 2007; Fisher and Turner 2008; Haines-Young and Potschin 2010a; UK NEA 2011b; Petter et al. 2012). Across the methodologies and schools of thought reviewed in Chapter 2, the terms ecological processes, ecosystem functions, intermediate services and supporting services were used interchangeably (hence in this research they are analysed under the one key topic). One divergent to this interchangeable use of terms is the US framework, which defines ecological processes and intermediate services differently relative to their usefulness to humans.

Haines-Young and Potschin (2010a, p. 7) say ‘it is important to distinguish between ecosystem structure, process, and function’ and also between ‘ecosystem functions and services’. This distinction is shown in Figure 2.4 presenting the conceptual framework developed for CICES. Appendix 7 lists the 28 ecological processes, ecosystem functions, intermediate services and supporting services included in the MA, SEQ and UK frameworks. The number of ecological processes included in each program ranged from seven to 19. Soil formation and nutrient cycling were the only ecological processes included in all programs. Climate regulation, water cycling, soil retention, pollination and primary production were included in at least two frameworks.

As shown in the MA’s concept of ecosystem services (Figure 1.1) and its conceptual framework (Figure 2.2), the MA framework does not specifically identify ecological processes contributing to the provision of ecosystem services instead they categorised ecosystem services along functional lines - Provisioning, Regulating, Supporting and Cultural (MA 2005a). Where people obtain direct benefits from ecosystems services under the Provisioning, Regulating and Cultural categories, the seven Supporting Services included are said to underpin the provision of the other services. Since the release of the MA, to better incorporate information on ecological processes in ecosystem services assessments, the function analysis developed by de Groot et al. (2002) and de Groot (2006) has been most widely used (Maynard et al. 2010; TEEB 2010; Petter et al. 2012).

Of all the schools of thought reviewed the SEQ framework provides the most comprehensive analysis of ecological processes (however the term ecosystem function is used). SEQ stakeholders said understanding ecosystem functions was fundamental to assessing the capacity of ecosystems to sustainably provide goods and services (Maynard et al. 2010; Petter et al. 2012; SEQ Catchments 2012). Ecosystem functions exist regardless of the presence of humans or the value humans place on them; and people may or may not value ecosystem functions because they may or may not provide contributions to human benefits (SEQ Catchments 2012). Existing data sets, local knowledge (I. Beitz, per comm.) and schools of thought by the MA (2005a) and de Groot (2006) were used to develop the SEQ list of 19 functions (Maynard et al. 2010). Maps of ecosystem functions were a primary tools developed to support ecosystem services assessments using the SEQ framework (Section 7.3.3).

One UK Lead said “there are processes going on in ecosystems that underpin services ... they’re not services themselves, they’re processes” (note, the terms ecological processes, ecosystem functions and intermediate services are used interchangeably in the UK framework). Appendix 7 shows the seven supporting services listed in the MA framework and 12 ecological processes in the UK framework share the most similarities. One UK Lead discussed the importance of including information on ecological processes in ecosystem services frameworks:

> *... there is obviously a pressing need to have a scientific understanding of that [ecological processes] because otherwise we might hack away at things that we don’t understand and literally remove the supporting structures of the environment ... somebody has to be able to say “by the way if you do that do you realise that you’re tipping a particular environment over the edge and you’re going to lose all of it”.*

Section 6.2.4 discussing the valuation of ecosystem services in the UK context noted that some intermediate services (particularly Regulating Services) can be FES depending on the benefit received and who the valuing agent is (see Section 7.2.4). This is consistent with Fisher and Turner’s (2008) definition of FEGS that differs from Boyd and Banzhaf’s (2007) by including ecosystem functions and processes as both intermediate and final ecosystem services as long as there is a human beneficiary. Ott and Staub (2009) and Staub et al. (2011) suggest the use of Boyd and Banzhaf’s FEGS approach beyond accounting has disadvantages in terms of its ability to assess ecological sustainability, hence to make their inventory more precise yet flexible they include the additional characteristic of intermediate goods and services.

Maynard and Cork (2011, p. 4) say ‘a national or international accounting system [i.e. such as SEEA] is constrained by having to work with demand for ecosystem services as it is expressed by public opinion, markets and need, but projects that work interactively with stakeholders can often turn capacity [i.e. ecological processes] into actual services by creating awareness and new land management that generates a market for the services’. Maynard and Cork (2011, p. 4) conclude that although the capacity of an ecosystem (ecosystem function) to provide an ecosystem service only becomes a good or service once a benefit and beneficiary can be clearly identified, there is ‘merit in estimating the relative potential of different ecosystems to provide ecosystem services when dealing with stakeholder groups'.

Neither ecological processes nor intermediate services are listed in Appendix 7 for the US framework because although defined there is no further information or examples for either. One US Lead said this was because the focus of their program is on FEGS and intermediate services "reside in the domain of the ecological process modellers who have the task of understanding the workings of the ecosystems that produce the FEGS". They continued to say that "ecological processes and intermediate services may be unknown or poorly known" so focusing on FEGS is "a more efficient way of addressing ecological understanding as opposed to attempting to understand all intermediate services and processes".

The first finding into this key topic is the pressing need to have a scientific understanding of the ecological processes that underpin the provision of ecosystem services because "otherwise we might hack away at things that we don't understand and literally remove the supporting structures of the environment". There is merit in estimating the relative potential of different ecosystems to provide ecosystem services (supply) rather than being constrained to just the demand for ecosystem services (Ott and Staub 2009; Maynard and Cork 2011; Staub et al. 2011). Defining and including ecological processes and intermediate services in the framework has advantages in terms of our ability to assess ecological sustainability (Ott and Staub 2009; Staub et al. 2011) (Recommendation 39).

The second finding supports statements by Haines-Young and Potschin (2010a, 2013) who coordinated the development of CICES that clear distinctions are required between ecosystem structure, processes, functions and services (Recommendation 40). This clarity of terms is especially important in applying ecosystem services concepts to environmental accounting as shown by the European Environment Agency (2009) and SEEA's (UNSD 2012) adoption of CICES (Haines-Young and Potschin 2010a, 2013). In some programs (e.g. in the MA, SEQ and the UK) these terms are defined similarly enough to be interchangeable but in others they are not (e.g. in the US). As the type of data and information developed or collected on ecological processes is dependent on how they are defined and classified, differences across frameworks limits the ability to use data, information and assessment outcomes from one program to support another.

The third finding relates to how ecological processes are identified and measured in frameworks and the capacity of stakeholders to understand and apply information (and tools) (Recommendation 42). There is a significant difference in how the US program proposes that users of the framework are to engage the use of ecological process modellers to develop the understanding of ecosystems and how they produce FEGS, and the SEQ framework which places high emphasis on ecosystem functions and provides maps for stakeholder use. Section 7.1.3 discussed the largest amount of funds invested in developing any framework reviewed was the US program; and the largest percentage of these funds was dedicated to 'Mapping, Modelling and Monitoring Ecosystem Services at Multiple Scales'. In contrast, the SEQ program operated under the smallest amount of funds and this amount was said to hinder the potential to develop tools such as spatially dynamic models.

Finally, Appendix 7 lists the 28 ecological processes included in the MA, SEQ and UK frameworks. As shown by their inclusion in three different scale frameworks, soil formation and nutrient cycling can be considered the two most important ecological processes to include in a list. Ecological processes included in two of the frameworks listed in Appendix 7 are: climate regulation, water cycling, soil retention, pollination and primary production. Together these seven ecological processes provide the basis for developing a comprehensive list of ecological processes to support a multi-scale framework (Recommendation 41).

Recommendations on how information on ecological processes can support a multi-scale framework are presented in Box 7.7. Section 7.2.4 provides the findings and Recommendations on how ecosystem services are defined and included in frameworks.

Box 7.7: *Recommendations on ecological processes to support a multi-scale framework.*

39) **Contribution to ecological sustainability:** there is a pressing need for a scientific understanding of the ecological processes that underpin the provision of ecosystem services or we might involuntarily remove the supporting structures of the environment. It is important to estimate both the supply and demand of ecosystem services to improve our ability to assess and manage for ecological sustainability (31, 33, 40, 41, 47).

40) **Consistent and clear use of terms:** clear terminology is required to ensure a common language and understanding of ecosystem services concepts across researchers and users of the framework. Terms describing ecological processes should be carefully selected and a clear distinction made between ecosystem structure, ecological processes, ecosystem functions and supporting services. To ensure the definition has relevance to a wide range of disciplines, sectors and decision making contexts these terms should be developed by stakeholders with multi-disciplinary expertise (5, 15, 16, 17, 18, 19, 37, 40, 41, 43, 45, 54ii, 54iii, 55).

41) **A common list:** a list of ecological processes should be developed by stakeholders to ensure the resulting classification system has relevance to a wide range of decision making contexts (including at different scales). Developing this list early in the program will allow for consistency, comparability and scalability across stakeholder assessments. Seven ecological processes provide the basis for developing a comprehensive list to support a multi-scale framework: soil formation, nutrient cycling, climate regulation, water cycling, soil retention, pollination and primary production (39, 40, 54ii, 54iii, 55).

42) **The capacity of stakeholders:** the capacity of stakeholders to understand and apply information and tools so to conduct ecosystem services assessments is important to consider. Consideration of stakeholders with the least capacity (e.g. technical staff, funding) to understand ecosystem services concepts or apply tools is necessary to developing a framework for consistent use by all stakeholders (5, 17, 19, 23, 29, 59, 61iii, 67, 68).

7.2.4 Ecosystem services

The analysis of the SEQ, US and UK frameworks support findings from the synthesis of reviewed documents (Section 3.1.2) that controversy still exists around the definition of ecosystem services. The MA’s (2005a, p. 49) definition of ecosystem services being *the benefits people obtain from ecosystems* has been criticised for its potential to ‘double count’. In economic terminology a ‘benefit’ is derived from combining natural capital and other forms of capital (e.g. human, manufactured) and therefore the MA definition does not clearly define the ‘components of nature’ that are contributing to human well-being (Boyd and Banzhaf 2007; Wallace 2007; Fisher and Turner 2008; TEEB 2010; Johnson and Russell 2011; Landers and Nahlik 2013). The MA definition has been accused of falling ‘short as an operational definition for accounting, landscape management or valuation’ (Fisher et al. 2008, p. 2051).

Originally the SEQ framework adopted the MA definition of ecosystem services but as research on definitions advanced, in 2011 the SEQ program adapted the MA’s definition. The new definition expanded the previous by highlighting the role ecosystem services play in sustaining and supporting human well-being; and the reference to ecosystem services being the actual 'benefit' was changed to being 'goods' and 'services' derived from ecosystems that can provide benefits (Maynard et al. 2010; SEQ Catchments 2012). Due to the repeating of the defined term within the predicate however, this definition itself becomes partly deficient (Section 4.2.4).

An adapted version of the FEGS definition developed by Boyd and Banzhaf (2007) is provided under both Core and General Terms in the ESRP Lexicon (EPA 2010b). Boyd and Banzhaf (2007, p. 619) say the three characteristics to their definition are: 1/ 'that final ecosystem services are directly enjoyed or consumed'; 2/ 'that they are components'; and 3/ 'that they are a quantity to be compared to a price'. According to Boyd and Banzhaf (2007, p. 616) this definition 'advances the development of environmental accounting and performance systems' through precisely articulating 'ecosystem service units'. The EPA's potential (as a federal government agency) to propose and develop "nationally standardised accounting and classification systems" to support the creation of ecosystem services markets (Section 7.1.1) provides impetus for the use of Boyd and Banzhaf's (2007) definition in the US framework.

Two definitions for ecosystem services are included in the UK program; the MA (2005a) definition of benefits and a FES definition closely aligned to Fisher and Turner's (2008). Section 6.2.4 described how and why for the purpose of the UK NEA the term 'goods' was deliberately separated from definitions of FEGS and the more traditional definition of ecosystem services. Figures 6.1, 6.2 and 6.3 show this distinction conceptually. In one UK Lead's explanation of this separation the concept of goods is similarly described to the concept of benefits:

> *… the service is what you get from this whole chain of very complex lateral interactions. It's like the natural environment's input into the goods you're going to enjoy. Sometimes to get from the service to the good you actually have to have other inputs like manufactured capital, skill … The good is the thing that actually gives you well-being.*

The purpose of Fisher and Turner's (2008 p. 1168) research was not specifically environmental accounting like Boyd and Banzhaf's (2007) it was much broader: 'how ecosystem services deliver human welfare benefits; where the benefits are realised and by whom; and how their value changes across the landscape in regards to different future scenarios'. Fisher and Turner (2008, p. 1168) say there are also three important characteristics to their definition. The third differs from Boyd and Banzhaf's (2007) by not only seeing quantities or components of ecosystems you can 'count' (i.e. forests, fish populations) as ecosystem services but also including ecological processes if there is a human beneficiary (Fisher and Turner 2008). As Chapter 2 discussed and a key finding under the analysis of ecological processes, Ott and Staub (2009) and Staub et al. (2011) say that beyond accounting for ecosystem services the use of Boyd and Banzhaf's approach has disadvantages in terms of its ability to assess ecological sustainability; so to make their inventory more precise yet flexible they included intermediate goods and services (or ecological processes).

The need for clarity of definitions early on in a program and a rigorous process of enforcing these definitions is evident in responses by US and UK Leads. When US Leads were asked if FEGS were consistently applied across the programs it was said "there was variability, but all were on the same path". When US Leads were asked the definition of ecosystem services they use in their research however, the results ranged from: "an indicator of something people care about and ... the ecosystem structures and functions that support these different services" (similar to Fisher and Turner 2008); definitions that described benefits or values (similar to that of the MA 2005a); and modified Boyd and Banzhaf (2007) FEGS definitions. When UK Leads were asked the same question their responses were much more consistent. One Lead capturing well the need for clear terms:

> *... one of the really important things we recognised right from the beginning was that we had to get those distinctions sorted out ... the distinction between what we would call intermediate services or processes, final services, goods, values and benefits have to be sorted out because people use some of those terms as if they mean the same thing... and some of them use the terms in very different ways....*

Further to the criticisms of the MA definition are the list of ecosystem services included in the framework and the four categories under which they are placed: Provisioning, Regulating, Supporting and Cultural. Although the MA categories and list of services are said to be useful as a heuristic tool they are also said to lead to 'double-counting' when assigning economic values (Boyd and Banzhaf 2007; Fisher et al. 2007; Johnston and Russell 2011; Landers and Nahlik 2013). The primary criticism is the list contains ecological processes (e.g. the Supporting Services) which contribute to ecosystem services and as the value of these processes is inherent in the FES/FEGS, if assessed and valued it will lead to double counting (Boyd and Banzhaf 2007; Fisher et al. 2007; Johnston and Russell 2011; Landers and Nahlik 2013).

In an attempt to avoid these problems the SEQ framework excluded the Supporting Services category as these were considered ecosystem functions (ecological processes, intermediate services). This is consistent with later developed frameworks such as TEEB (2010) and CICES (Haines-Young and Potschin 2013). The UK NEA (2011b) identified further issues with the MA's list and categories of services and in response removed both Supporting and Regulating Services. They say these differ from the other two categories as they are intermediate services; yet Regulating Services can also be FES depending on the decision making context. Furthermore, the UK NEA (2011b) says many ecosystem services listed in the MA framework are not 'ecological by nature' particularly Cultural Services so they were excluded from the UK list of FES also.

Fisher and Turner (2008, p. 1167) say ecosystem service classifications are 'founded upon the specific context in which they are being used as well as the definition used'. The need to develop early on in a program a list of ecosystem services for consistent use is evident when reviewing Appendix 8. Appendix 8 shows lists the 24 ecosystem services included in the MA framework; the 28 ecosystem services in the SEQ framework; the 23 ecosystem services assessed across the US program; and the 14 ecosystem services included in the UK framework. In CICES (which specifically aimed to develop a classification system for use in different contexts including different scales) a five tiered hierarchical and nested ecosystem service classification was developed to overcome 'some of the challenges that arise in relation to the different spatial and thematic scales used in different applications' (Haines-Young and Potschin 2013, p. 3).

The US list is a collection of those used across the program, as, although they "spent a lot of time talking about developing a consistent list that everyone would subscribe to" no consistent list of FEGS was developed. The different context of place-based studies leading to different scenarios being applied, the lack of a common ecosystem services classification system, and no consistent list of ecosystem services available for researchers to use, clearly influenced the assessment of different ecosystem services across US projects. As an example, Section 7.2.1 revealed how US Leads said biodiversity is not an ecosystem service, yet it is included in Column 3, Appendix 8. Contrary to the FEGS definition used, the list also shows ecological processes and non-ecosystem components included in projects (e.g. sense of place, spiritual value, existence value/ bequest value, recreation and culture and aesthetics).

The MA (2005a), Bennett et al. (2009) and Costanza et al. (2011) say to prevent creating dysfunctional incentives, to maximise net benefits to society, and to make ethical and informed policy, planning and management decisions, the full range of ecosystem services should be assessed. Recognition of this drove the development of lists to support the MA, SEQ and UK frameworks (MA 2005a; Maynard et al 2010; UK NEA 2011b). Further reasons provided for these lists included the need for a consistent language to encourage consistent assessments across stakeholders (MA 2005a; Maynard et al. 2010); and so outcomes from assessments can feed into or integrate with other assessments (MA 2005a).

Identifying the most common ecosystem services included in frameworks developed at different scales can assist in identifying core services for inclusion in a multi-scale framework (although what is specifically defined as an ecosystem services will be dependent on the chosen ecosystem service definition). Appendix 8 shows four ecosystem services included in the MA, SEQ, US and UK frameworks (i.e. regulation of pests and disease, water - regulation and quality, regulating or maintaining of climate, and natural hazard regulation). Nine other ecosystem services were included in three of the programs, they include: food; aesthetic values; fuels; pollination; air quality; sense of place; spiritual value; recreation; and fibre provisioning.

From this analysis the first finding is the fundamental need for a clear definition of ecosystem services to support the framework, as how you define, categorise and classify ecosystem services has direct implications on what will be assessed and valued using the framework (Nahlik et al. 2012); and the type of information and tools collected, developed and used in the assessment (Nahlik et al. 2012) (see Recommendations 43). Popular opinion to not include Supporting Services in more recent frameworks than the MA (e.g. Maynard et al. 2010; TEEB 2010; UK NEA 2011b) support Haines-Young and Potschin (2010a, p. 7) statement on the importance of “distinguish[ing] between ecosystem … process and function … functions and services … and services and benefits”. Findings in Section 7.2.3 into ecological processes also revealed the need for clear definitions that provide these distinctions.

The second finding is the correlation between definitions of ecosystem services (i.e. based on benefits to people, or as components of ecosystems) and assessment units included in frameworks (Section 7.2.2) (Recommendations 44). Frameworks defining ecosystems as ‘benefits’ (i.e. consisting of multiple forms of capital) tended to adopt systems approaches to defining unit boundaries (MA 2005a; Maynard et al. 2010; SEQ Catchments 2012). Those using FES or FEGS which say ecosystem services are ‘components of nature’ (Boyd and Banzhaf 2007; Fisher and Turner 2008; UK NEA 2011b; Haines-Young and Potschin 2013) tended to use ecological structures or processes to define unit boundaries. A fundamental difference between the benefits and components of nature approaches is whether human systems are considered an element within the assessment unit.

The third finding is the importance of developing a list of ecosystem services early on in the program that everyone can consistently use (Recommendations 45). Due to the large range of potential applications of the framework, to ensure relevance to the large range of stakeholders a collaborative and participatory approach is required to develop this list. One US Lead’s comments support findings on the need for a well-structured program that holds some components constant to guide the process of developing information and tools to support the framework (Section 7.1.4), they said; “design[ing] more specific parallel design components” such as lists of FEGS would “guide it [the research] more rather than everyone going off and doing their own thing”.

Following on from the previous finding is the need to include the full range of ecosystem services in the list (Recommendations 46). The MA (2005a) and Costanza et al. (2011) describe the reasons for this; and the large number of ecosystem services listed in the MA, TEEB, CICES (at the fourth and fifth tier of their classification), SEQ, US and UK frameworks support this. The 15 ecosystem services listed above provide a good baseline from which to develop a comprehensive list. A common list of ecosystem services developed early on in the program will improve the potential transferability and repeatability of information and tools and outcomes of assessments. A hierarchical and nested ecosystem service classification system such as in CICES will improve the scalability of assessments and integration potential.

Recommendations on how ecosystem services can be defined and included to support a multi-scale framework are presented in Box 7.8. Section 7.2.5 provides the findings and Recommendations into the final topic under this third Line of Enquiry, the approach applied to valuing ecosystem services in each of the programs.

Box 7.8: *Recommendations on ecosystem services to support a multi-scale framework.*

43) **Consistent and clear use of terms:** to reduce the potential to double count, and ensure a common language and understanding of ecosystem services concepts across researchers and framework users, clear terminology developed early in the program is required. Definitions should have relevance to a wide range of disciplines, sectors and decision making contexts; therefore terms should be developed by a wide range of stakeholders with multi-disciplinary expertise (16, 17, 18, 19, 40, 54ii, 54iii, 55).

44) **Correlation between assessment units and defining ecosystem services:** there is direct correlation between units for assessing ecosystem services and how ecosystem services are defined. For example, a fundamental difference between defining ecosystem services as ‘benefits’ or ‘components of nature’ is whether human systems are an element of the assessment unit (36, 37, 38, 43).

45) **A common list:** a list of ecosystem services should be developed by stakeholders with a broad range of expertise to ensure the resulting classification system has relevance to a wide range of decision making contexts (including at different scales). Developing this list early in the program will allow for consistency, comparability and scalability across stakeholder assessments (15, 16, 17, 18, 19, 40, 41, 43, 44, 52, 54ii, 54iii, 55).

46) **Full range of ecosystem services:** the full range of ecosystem services must be captured in this list to prevent creating dysfunctional incentives, to maximise net benefits to society and to make ethical and informed policy, planning and management decisions. The following 15 ecosystem services provide the basis for a comprehensive list: food; aesthetic values; fuels; pest and disease regulation; pollination; climate regulation; natural hazard regulation; air quality; water purification and waste treatment; usable water; water regulation; sense of place; spiritual value; recreation; and fibre provisioning (45).

7.2.5 Determining the value of ecosystem services

Across the schools of thought on incorporating values for ecosystem services in assessment frameworks, it is unequivocally agreed that people value ecosystem services because they contribute positively to different aspects (or constituent parts) of their lives (MA 2005a; Wallace 2007; EPA 2008; Haines-Young and Potschin 2010a, 2013; Maynard et al. 2010, 2012, 2015; TEEB 2010; Costanza et al. 2011; UK NEA 2011a, 2011b; Landers and Nahlik 2013). The UK NEA (2011b, p. 1076) says that to conduct a valuation three pieces of information are required: 1/ ‘an understanding of the change in provision of the good under consideration given changes in the environment, policies and societal trends’; 2/ ‘robust and reliable estimate of the marginal value’; and 3/ ‘knowledge of how 2/ might alter as 1/ changes’.

The MA’s concept of ecosystem services (Figure 1.1) and conceptual framework (Figure 2.2) show the five categories of well-being (Basic Materials for a Good Life; Freedom of Choice and Action; Health; Social Relations; and Security) and associated COWB included in its framework. The MA’s categories and constituent parts were based on outcomes from surveys of poor people from 23 countries asking them to discuss good and bad aspects of their life (Narayan 2000; MA 2005a). For the SEQ regional framework these categories were adopted but stakeholders redefined them to better reflect the affluent nature of the SEQ community; and how changes in ecosystems and ecosystem services would impact on the resilience and sustainability of the SEQ community (SEQ Catchments 2012). Based on these reflections the MA’s list of COWB was further developed using schools of thought by Abraham Maslow (1943), Max-Neef (1991) and Costanza et al. (2007).

In the ESRP Lexicon under Core Terms human well-being is defined similar to the MA (2005a) and SEQ (Maynard et al. 2010). The MYP 2008-2014 states ecosystem services need to be characterised by human health and well-being (HHWB) across the whole program and thus HHWB was included in projects at the place scale and at the national (EPA 2008). One US Lead stated the aim of the well-being research at the national scale was to develop a human well-being index that will “become a predicted endpoint for a decision support tool that bundles relevant service flow measures from capital-based modules” (e.g. social, economic and natural capital) (also in Smith et al. 2012). The key piece of literature providing data was the "Canada Index of Wellbeing”. Other important pieces included “the General Social Survey, the Gallop Survey, National Education Statistics, American Time Use Surveys, Labour Statistics, and the Census Bureau".

Different to the MA and SEQ frameworks human health and human well-being are researched separately in the ESRP. "People” were said to “respond to mortality and morbidity issues (e.g. childhood obesity, asthma, premature mortality)", so greater buy-in from stakeholders was thought possible by specifically focusing on ‘human health’. Although due to EMAP research the EPA had access to a large body of knowledge on the links between ecosystem health and human physical health, all programs found limited health and well-being information and data available, particularly data and information on mental health. One US Lead said as there were large gaps in health information and most information was not available at scales finer than national, indicators would need to be developed and this could be achieved through new survey questions in the national Census.

Well-being within the UK NEA consists of economic values, health values and shared social values; they say this provides a holistic and pluralistic perspective of the value of ecosystem services in the UK (UK NEA 2011b). Like the MA, SEQ and the ESRP, in the UK NEA (2011b) the links between ecosystem services and human health rest predominantly upon a wealth of existing experimental and epidemiological research with few new analyses prepared partly or wholly for the program. One UK Lead noted the problem with applying existing information, especially health information, in ecosystem services assessments is: “there are potentially huge volumes of data out there which would be demanding of the best statisticians ... to unravel all the potentially confounding variables that influence a particular distribution of a health statistic ... and there will be socio-economic and environmental things compounded”.

Common to the MA, SEQ, US and UK frameworks is the innovative approach to communicating ecosystem services values based on the change in its provision, and/or the relative value of ecosystem services. This was especially true for ecosystem services not able or easily translated into monetary terms. For example, scoring systems were used to represent the relative values of ecosystem services listed in the SEQ framework in terms of their contributions to the well-being of the community (Maynard et al. 2010, 2015). In the UK NEA (2011b) positive and negative changes in health values were recorded with either plus or minus signs (+/-) and shared social values were recorded in smiley or sad faces (☺/☹) (UK NEA 2011a, 2011b).

Although the UK program recognises the need for a holistic and pluralistic perspective of the value of ecosystem services and that the value of some ecosystem services cannot be effectively determined or understood through dollar values alone, the Technical Report states 'it is not accepted that the complete absence of economic monetary data in ecosystem management and decision making is an acceptable situation' (UK NEA 2011b, p. 1071). The UK approach to valuing ecosystem services includes both monetary and non-monetary values of ecosystem service flows to people at the multi-national and national scale. In SEQ methods for determining monetary values were considered 'inappropriate under the circumstances given the extent and diversity of valuations required; limited budget to conduct the work; concern about what monetary values really meant; how decision-makers would make trade-offs using the information; and a tight timeline for completing the framework in order to incorporate it in statutory plans within the current policy cycle' (Maynard et al. 2015, p. 25). In contrast, it was only at the place-based scale in the US program (which is comparative in scale to the SEQ regional program) that monetary valuations were conducted (but as this research is focused on the US national scale program discussing these valuations is beyond scope).

Expert and local input formed an essential element of the SEQ, US and UK non-monetary valuation approaches. These inputs were fundamental where information currently did not exist on interconnections between ecosystem services and human well-being and their relative values. One US Lead working at the place-based scale described their approach to "applying professional opinion assigned as relative importance values and to rank data in conjunction with public perception to evaluate well-being in terms of the relationships among ecosystem services, domains and their constituent elements" (also Smith et al. 2012).

In SEQ, driving this approach beyond the lack of information was also ethical questions of 'whose values should count?' and therefore 'who should be the agent valuing ecosystem services?' (e.g. government, business, community, researchers) (Maynard et al. 2015). The SEQ framework remained deliberately flexible in their modelling and valuation approach to account for these questions and freedom of choice of valuing agent depending on the context of framework application (see Section 7.3.3). A similar form of 'deliberative valuation', referring to a process by which 'people confer, ponder, exchange views, consider evidence, reflect on matters of mutual interest, negotiate, and attempt to persuade each other', also provide for the ‘qualitative expression’ of shared values in the UK NEA (2011b, p. 1188).

The first finding into the analysis of valuing ecosystem services in different frameworks is the information required to conduct a valuation includes: 1/ an understanding of the change in provision of ecosystem services due to changes in (direct and indirect drivers such as) policies and trends; 2/ an estimate of the marginal value of goods; and 3/ knowledge of how the marginal value might change based on the change in provision of ecosystem services impacted by drivers (UK NEA 2011b) (Recommendation 47).

The second finding supports those in Section 7.1.1 which revealed that due to the wide range of possible applications of the framework the valuation of ecosystem services must extend beyond the methods used in the MA (2005a). Methods for conducting both monetary and non-monetary valuations are required to ensure the framework’s usefulness in different decision making contexts. Depending on the decision making context different agents will need to determine values so the methods of valuation included in a framework must be non-prescriptive and allow for flexibility of application. Innovative ways of communicating to stakeholders (changes in) ecosystem services values will likely be required.

The third finding is that all frameworks analysed included a categorised form of ‘well-being index’. These indexes served similar purposes to lists developed for assessment units, ecological processes and ecosystem services (e.g. to guide the research and for consistent assessments) (MA 2005a; Maynard et al. 2010; UK NEA 2011b). The variation in categories and lists developed globally show the context dependency of valuations and how people perceive what constitutes human well-being differently. Although the components of well-being are categorised along different lines, in the broadest sense all frameworks recognise people value ecosystem services for environmental, social and economic reasons (UK NEA 2011a, 2011b; Smith et al. 2012).

Fourthly, frameworks developed at all scales placed strong emphasis on the human health component of human well-being. It is therefore evident greater ‘buy-in’ to the framework and program from stakeholders is possible by specifically focusing on human health.

The fifth finding is that at all scales limited health and well-being data and information was available particularly on mental health. In the programs analysed, determining the links between ecosystem services and human health rested predominantly on existing research. One US Lead said there were large gaps in this information and most information was not available at scales finer than national. One UK Lead said the problem with using existing information (especially health information) in ecosystem services assessments is the “huge volumes of data” that require “unravelling … potentially confounding variables” (e.g. environmental, socio-economic) that influence the “distributions of health statistics”. New indicators may require development; this could be possible through new survey questions in national Census.

Finally, the need for expert and local knowledge as input, especially where information currently does not exist on interconnections between ecosystem services and human well-being and their relative values, is highlighted from this analysis. Outcomes of deliberations can also confirm (un)certainty of previous research. Deliberative valuation where 'people confer, ponder, exchange views, consider evidence, reflect on matters of mutual interest, negotiate, and attempt to persuade each other' are important to ‘social learning’ and developing ‘shared understandings’ UK NEA (2011b, p. 1188). Recommendations based on these findings into the analysis of how the valuation of ecosystem services is being included in frameworks are presented in Box 7.9.

Box 7.9: *Recommendations on valuing ecosystem services to support a multi-scale framework.*

47) Information required to conduct a valuation: four key pieces of information required to conduct an ecosystem services valuation are: 1/ information on the current stock of natural capital and ecosystem service provision; 2/ an understanding of the change in this provision due to direct and indirect drivers; 3/ an estimate of the marginal value of ecosystem services; and 4/ knowledge of how the marginal value might change based on change in ecosystem services provision resulting from influencing drivers (3, 43, 48, 51, 61i).

48) **Use of existing information:** it should not be assumed data exists on the interconnections between ecosystem services and human well-being. Even when data and information do exist, as they were developed for different purposes and therefore have inherent biases, the data and information require analysing to determine their fit-for ecosystem services valuations (34, 35, 47, 64iv).

49) **Information required to conduct a valuation:** four key pieces of information required to conduct an ecosystem services valuation are: 1/ information on the current stock of natural capital and ecosystem service provision; 2/ an understanding of the change in this provision due to direct and indirect drivers; 3/ an estimate of the marginal value of ecosystem services; and 4/ knowledge of how the marginal value might change based on change in ecosystem services provision resulting from influencing drivers (3, 43, 48, 51, 61i).

49) **Use of existing information:** it should not be assumed data exists on the interconnections between ecosystem services and human well-being. Even when data and information do exist, as they were developed for different purposes and therefore have inherent biases, the data and information require analysing to determine their fit-for ecosystem services valuations (34, 35, 47, 64iv).

50) **Flexibility of valuation methods:** to ensure the framework's usefulness to valuing different ecosystem services in a wide range of decision making contexts the approach to including valuations in the framework must remain flexible; and allow for both monetary and non-monetary valuations to be conducted and communicated (which may require innovative approaches). Not only will different stakeholders require the use of different valuation methods, but depending on the decision making context different stakeholders will also use different valuing agents (3, 47, 48, 50, 51).

51) **Toolkits and guidelines:** to help guide valuations yet remain flexible, it is suggested a toolkit consisting of recommended valuation methods for different ecosystem services and a set of guidelines to its use be included in the framework (rather than being method prescriptive) (3, 47, 49).

51) **Deliberative valuations:** applying deliberative valuations methods is strongly encouraged. Deliberative processes allow people to consider evidence, ponder, exchange views, reflect on matters of mutual interest, and negotiate and attempt to persuade others. The methods applied in deliberative valuations to gather information create social learning and shared understandings across disciplines, sectors and stakeholders. Outcomes can address existing data and information gaps and confirm (un)certainty of previous research (3, 16, 17, 18, 19, 28, 35, 47, 48, 56, 62, 64iv).

52) **The development of a Well-being Index:** due to the context dependency of valuations there is likely no existing 'well-being index' that is directly transferable to another area (e.g. region or nation). To capture the (environmental, social and economic) interconnections between ecosystem services and human well-being at multiple scales, a collaborative and multi-disciplinary approach is required across stakeholders to develop a relevant index (3, 16, 17, 18, 19, 20, 47, 48, 53).

53) **The inclusion of human health:** human health (e.g. asthma, childhood obesity, premature mortality, depression) is a core component of human well-being. A focus on human health can lead to better stakeholder 'buy-in' of the ecosystem services concept, to the framework and program (3, 18, 19, 20, 47, 48, 52).

This concludes the analysis of methodologies under Line of Enquiry 2. The 25 Recommendations listed in Boxes 7.5, 7.6, 7.7, 7.8 and 7.9 were derived from this analysis of information supporting frameworks at regional, national, multi-national and global scales. These Recommendations will assist researchers with determining the *appropriate information to support a framework for ecosystem services assessments across multiple scales.* The following section provides outcomes of the analysis of methodologies through the third Line of Enquiry, tools to support a multi-scale framework.

7.3 Tools: Findings and Recommendations

As a result of synthesising the document review in Chapters 1 and 2 which included an in-depth review of the MA methodology, Section 3.1.3 described the third Line of Enquiry aimed at answering the research question: *what tools are required to support a framework for ecosystem services assessments across multiple scales?* From this synthesis the following key topics were identified for further analysis: conceptual frameworks; scenarios; maps and dynamic models; and websites and technical reports.

This section of the thesis compares and contrasts outcomes from the analysis of the SEQ, US and UK methodologies using these key topics. It primarily draws from the relevant Sections 4.3, 5.3 and 6.3 describing the SEQ, US and UK tools, but similar to the previous two sections it also draws on relevant outcomes from other sections. The SEQ, US and the UK tools are also compared and contrasted to the MA and other schools of thought revealing if they are consistent with current theories on tools or if they provide new insights. Recommendations derived from the cross analysis of methodologies and schools of thought are presented in boxes below each topic's findings. Conceptual frameworks are first discussed.

7.3.1 Conceptual frameworks

The MA (2005a, p. 34) states 'given the complex interactions between ecosystems and human well-being a prerequisite for both analysis and action is agreement on a basic conceptual framework'. The previous chapters discussed and presented conceptual frameworks developed at the global scale (i.e. MA - Figure 2.2; TEEB - Figure 2.3), the multi-national scale (i.e. CICES - Figure 2.4; UK - Figure 6.2); and regional and place-based scales (i.e. SEQ - Figure 4.1; place-based studies in the US program – Section 5.3.1). Although a conceptual framework was not developed to support the US national scale framework it was agreed some form of conceptual framework would be provided if another place-based project was started. The documents reviewed, the SEQ experience, and the responses by UK Leads provided the following reasons for developing conceptual frameworks:

- to further inform the process of developing the framework (Maynard et al. 2012);
- to develop a shared vision for ecosystem services across disciplines and stakeholders (MA 2005a; UK NEA 2011b);
- to guide the concept of ecosystem services into a usable and consistent format that all researchers/stakeholders could follow (MA 2005a; Wallace 2007; TEEB 2010; UK NEA 2011b; Maynard et al. 2012; Haines-Young and Potschin 2013);
- to provide consistency of approach to applying the framework and conducting assessments (MA 2005a; Maynard et al. 2010; UK NEA 2011b; Haines-Young and Potschin 2013);
- allowing assessments at different scales to be integrated and outcomes to feed both bottom-up and top-down (MA 2005a; Maynard et al. 2010; UK NEA 2011b);
- to help guide the writing up and reporting of assessment outcomes (MA 2005a; UK NEA 2011b); and
- to raise awareness of the program and assessment outcomes (MA 2005a; Maynard et al. 2010).

Across these conceptual frameworks there are similarities and differences in the information chosen for inclusion. Where the MA (2005a), TEEB (2010) and UK NEA (2011b) conceptual frameworks acknowledge the role of biodiversity in ecosystem service provision, the SEQ (Maynard et al. 2010) and CICES (Haines-Young and Potschin 2010a) conceptual frameworks do not. The SEQ (Maynard et al. 2010), UK NEA (2011b), TEEB (2010) and CICES (Haines-Young and Potschin 2010a) conceptual frameworks give strong emphasis to ecosystems and ecological processes, which are not included in the MA (2005a). All conceptual frameworks emphasised how ecosystem services contribute to human well-being.

The direct and indirect drivers of change in the MA (2005a) and UK NEA (2011b) conceptual frameworks are similar to the Drivers-Pressures-State-Impacts-Responses (DPSIR) model describing causal interactions in socio-ecological systems (Ash et al. 2010, UK NEA 2011b); and as applied in Australia and globally in environmental reporting and policy analyses (Ash et al. 2010; State of Environment Committee 2011). The MA (2005a), TEEB (2010), CICES (Haines-Young and Potschin 2010a) and the UK NEA (2011b) conceptual frameworks all show, albeit in inconsistent ways, where social, institutional, policy, economic, governance, and other decision making strategies and interventions can alter the dynamics of the system and limit pressures on ecosystem services.

There are also similarities and differences in the level of dynamics included in the conceptual frameworks. The least dynamic is that supporting the SEQ framework which shows a linear one-way simplification of how ecosystems contribute to human well-being (Maynard et al. 2010). Unlike conceptual frameworks supporting the MA (2005a) and the UK NEA (2011b), in SEQ there is no representation of how acquiring human well-being through the provision of ecosystem services (i.e. drivers of change) impacts positively or negatively on ecosystems, ecological processes or services. The most dynamic is that supporting the MA (2005a) which built on the DPSIR model by including feedback loops and assessments across multiple temporal (i.e. short and long term) and spatial (i.e. regional, national and global) scales (Ash et al. 2010).

This analysis of conceptual frameworks also revealed the importance of developing glossaries or lexicons (MA 2005a; Wallace 2007; EPA 2010b; TEEB 2010; UK NEA 2011b). Where most glossaries or lexicons were developed to support the conceptual frameworks the US ESRP, who as mentioned previously did not develop a conceptual framework, put great emphasis on the development of a comprehensive Lexicon to guide their research (EPA 2010b). The result of not enforcing the use of definitions in the glossaries and lexicons is evident in the lists of ecosystem services in Appendix 8 that shows goods and services included in programs not consistent with definitions of ecosystem services (e.g. they are not ‘components of nature’) (Sections 7.2.1 and 7.2.4). One UK Lead who was also involved in the development of the MA framework spoke about their experience in developing conceptual frameworks and glossaries early in the program:

… I was very keen [when working on the UK NEA]… that we got the conceptual framework and methods agreed before everyone set about doing the work … one of the problems [with the MA) has been methods being developed in parallel with the assessment … so what I wanted to do… was to get all the terminology, the definition of ecosystem services and even a list of agreed ecosystem services before all the … authors really got going with their work.

Although the SEQ program did not develop a comprehensive glossary or lexicon, the need for consistency of terms to ensure consistency of research and assessments was recognised early in the program and stakeholders developed 'agreed' definitions and classification systems for the four Components for Assessment: ERCs, ecosystem functions, ecosystem services and COWB (Maynard et al. 2010). Section 7.2.2 and 7.2.4 found the MA (2005a) and UK NEA (2011b) programs also developed lists and classifications of assessment units and ecosystem services early in the program. When reflecting on areas for improvement in the program US Leads discussed the importance of agreed lists to improve the potential to aggregate and synthesise projects within their program (hence the late development of environmental classes and the FEGS classification).

The first finding from this analysis into conceptual frameworks is the importance of creating a shared understanding (vision) across researchers and stakeholders of how ecosystem services are derived (e.g. biodiversity, assessment units, ecological processes), how they are valued (e.g. ecosystem services, how people benefit from ecosystem services), and how humans impact on ecosystem services provision (e.g. direct and indirect drivers) (Recommendation 54). To ensure the conceptual framework captures the relationship between the natural world and human-kind it is fundamental the conceptual framework includes information on the dynamics of the system such as feedback and feedforward loops and multiple temporal and spatial scales.

The second finding builds on those from the analysis of other key topics; elements of frameworks developed at all scales were held constant for consistent use by researchers working within the program and by stakeholders using the framework (Recommendation 55). These constant elements were conceptual frameworks, comprehensive glossaries or lexicons with clear terms and definitions, and classification systems listing items for assessment under the framework (e.g. biodiversity, ecosystems, ecological processes, ecosystem services and COWB). Developing these elements early in the program improves the potential for standardised, repeatable, transferable, scalable and comparable approaches to conducting assessments; hence greater potential for outcomes of these assessments to be integrated across purposes and scales.

Box 7.10 provides Recommendations on tools required to support a framework as they are related to this key topic of analysis on conceptual frameworks. The following section provides the findings and Recommendations for scenarios.

Box 7.10: *Recommendations on conceptual frameworks to support a multi-scale framework.*

54) **Developing a shared understanding:** a shared understanding across stakeholders and disciplines of the socio-ecological system assessable using the framework is necessary to: inform the process of developing the framework; ensure a shared vision across stakeholder objectives; provide a consistent format to developing elements of the framework; provide consistency of approach to applying the framework and conducting assessments; allow assessments at different scales to be integrated; help guide the writing and reporting of assessment outcomes; and raise awareness of the program and assessment outcomes. The following three tools are fundamental to creating this shared understanding:

    i. **A conceptual framework:** a conceptual framework (diagram) providing a simplified representation of the socio-ecological system the framework aims to assess is required. It is important all components for assessment are represented in the conceptual framework, as well, the dynamics of the system such as direct and indirect drivers, spatial and temporal scales, and feedforward and feedback loops (5, 16, 17, 18, 19, 29, 61i).

    ii. **A glossary or lexicon:** a glossary is a list of words with definitions. It provides a common language across stakeholders and disciplines by clearly defining core terms underpinning the framework (e.g. biodiversity, ecological processes, ecosystem services, and benefits) (5, 16, 17, 18, 19, 29, 30, 40, 43, 54iii).

    iii. **Classification systems:** within the boundaries of core terms for framework components, items for assessment under each component should be classified, described and listed. Tiered and nested classification systems are required to allow for integrated multi-scale assessments (5, 16, 17, 18, 19, 41, 45, 52, 54ii).

55) **Development early in the program:** the tools and information supporting them should be developed early in the program to improve the potential for consistent, standardised, repeatable, transferable, scalable and comparable approaches to conducting assessments; hence, greater potential for assessment outcomes to feed into other assessments across purposes and scales (29, 30, 40, 41, 43, 45, 50, 52, 63, 66).

7.3.2 Scenarios

The MA recognises the use of scenarios as ‘a way to explore possibilities for the future that cannot be predicted by extrapolation of past and current trends’ (MA 2005c, p. 225)**.** It is important to note scenarios are not forecasts, projections, predictions or recommendations about the future, but they can assist in revealing possible long term consequences if certain trends continue and conditions are met (IPCC 2000; MA 2005c; UK NEA 2011b). The UK Technical Report describes scenarios as 'a set of conceptual tools that enable people to collectively deal with a particular type of problem that involves high uncertainty and complexity' (UK NEA 2011b, p. 1191).
A fundamental difference between the SEQ and US programs, and the MA and UK programs, is the former programs specifically aimed to develop a framework (the information and tools) for use by the coordinating organisation and other stakeholders and they did not attempt to conduct an actual ecosystem services assessment. Although in the UK and MA programs scenario outputs were important to providing information to support the framework (especially where information currently did not exist), scenarios were primarily used to promote the framework (and program) and raise awareness of possible future environmental, social and economic implications of human choices and actions (MA 2005c; UK NEA 2011b).

This research showed the high use of scenarios in large scale programs; the MA (2005c) and IPCC (2000) both looked at four plausible futures through scenario use. Chapter 2 described Reid et al.’s (2006, p. 10) account of lessons learnt from the MA, including improved scenario development by involving user groups at different scales in their development leading to ‘impact benefits’ of ‘improved relevance, utility, ownership and legitimacy of the assessment with decision makers’. If stakeholders are involved in scenario development it also provides opportunity to voice conflicting opinions (IPCC 2000; MA 2005c; UK NEA 2011b).

One UK Lead said the six UK scenarios “followed pretty much the MA model” which ranged from a preservationists’ perspective to business as usual to a high focus on economic growth (Section 2.1.2). They continued to say that ”with scenarios it’s often in the process of doing it that you learn things, and certainly when you run six scenarios … then it’s the contrast between them that is the most informative”. In the UK it was thought there would be “too many political issues” if national scale scenarios were run so only multi-national scenarios were conducted. No national scale scenarios were developed to support the US framework either.

In Maynard and Cork‘s (2011) review of local to regional scale ecosystem services programs in Australia only Binning et al. (2001) used scenarios. The limited resources to develop the SEQ framework limited the ability to conduct assessments. Although at the US national scale no scenarios were run, all place-based studies ran scenarios and outcomes of these further informed the development and refinement of their frameworks. Section 5.1.4 discussed the varied context of the place-based studies which influenced the choice of scenario applied. Depending on the type of scenario, different combinations of information are required to run them (e.g. biodiversity, ecosystems, ecosystem services, human well-being, monetary values, economic and technological forces, climate change) (IPCC 2000; MA 2005a; UK NEA 2011b). Four of the five US place-based studies conducted scenarios on climate change and another four of the five studied the costs and benefits of introduced nitrogen (EPA 2011b).

The first finding from this analysis is that scenarios can be a powerful set of tools that provide a platform to think about various options in the face of complexity and future uncertainties (see Recommendation 56 and 57). Scenario outputs are: important to providing information to support the framework where information currently does not exist (MA 2005c; UK NEA 2011b); they can be used to promote the framework and program (MA 2005c; UK NEA 2011b); and raise awareness of possible future environmental, social and economic implications of human choices and actions (IPCC 2000; MA 2005c; UK NEA 2011b).

The second finding is the context under which the framework is developed will determine the type of scenario required to be conducted and the information needed (Recommendation 58). At global and multi-national scales scenarios have focused on climate change, preservationists’ perspectives of nature, business as usual, and on economic growth (MA 2005c; UK NEA 2011b). At smaller scales scenarios have also focused on climate change, but also nitrogen as a stressor on ecosystems that impact the provision of ecosystem services (EPA 2011b).

The third finding is that scenario use can be politically sensitive; and the benefits of scenario use are not well demonstrated in the literature or understood by researchers

(Recommendation 59). As the usefulness of scenarios in small scale research is the least demonstrated and understood, this is an area for further research (Recommendation 60). Box 7.11 provides Recommendations into tools required to support a framework as they are related to this analysis of scenarios. The following section provides the findings and Recommendations based on the analysis of maps and models.

Box 7.11: *Recommendations on scenarios to support a multi-scale framework.*

56) **The power of scenarios:** scenarios are a powerful tool to raise awareness of possible future environmental, social and economic implications of human choices and actions. Scenarios can: enable people to collectively deal with problems involving high uncertainty and complexity; provide information to support the framework where information currently does not exist; help develop a shared understanding across sectors and disciplines; and promote the framework and program in general (16, 17, 18, 19, 28, 54i, 54ii, 54iii, 57, 61i, 67).

57) **Multiple scenarios:** the power of scenarios is enhanced when multiple scenarios are conducted. With scenarios it's often the process of running them that you learn things, and when you run multiple scenarios it's the comparison between them that is the most informative (56, 58).

58) **Choice of scenarios:** the choice of scenario(s) to include is dependent on the decision making context driving the development or application of the framework. The type of information (and tools) required to run a scenario is dependent on the topic chosen (2, 56, 57, 59, 61i).

59) **Scenarios at local to national scales:** although the usefulness of scenarios in large scale programs is well documented, the usefulness of scenarios in place scale research is yet to be determined and requires further research and consideration when developing a multi-scale framework (25, 26, 56, 57, 58).

60) **Participatory scenario development:** scenario development can be improved by involving stakeholders (user groups at different scales) in their development. Participatory scenario development can provide an opportunity for stakeholders to voice conflicting opinions and it can lead to improved relevance, utility, ownership and legitimacy of the assessment with decision makers (5, 16, 17, 18, 19, 25)

7.3.3 Maps and dynamic models

Chapter 2 discussed the inconsistent use of maps and dynamic models to assess ecosystem services (Bagstad et al. 2013; Crossman et al. 2013). The literature shows both *maps* and *dynamic models* have been used to: identify, measure and value ecosystems and ecosystem services in terms of human well-being (Troy and Wilson

2006; Maynard et al. 2010; Petter et al. 2012; Crossman et al. 2013; European Union 2013; Vila et al. 2014); the changes in ecosystems and trends in ecosystem service provision (MA 2005a; UK NEA 2011b); and the environmental, social and economic implications of trade-offs in terms of the distribution of the costs and benefits derived from ecosystem service use (Binning et al. 2001; Troy and Wilson 2006; Raymond et al. 2009; Segan et al. 2011; Sherrouse et al. 2011; Vogl et al. 2013; Sharp et al. 2014). Attempts have been made to reduce this inconsistency within programs through the development of modelling plans (EPA 2011e), and across programs by developing mapping blueprints (Crossman et al. 2013).

This inconsistent use of maps and models is also evident across the frameworks analysed through this research. This research reveals the resources available to programs drove the choice of maps and models thus contributing to this inconsistency. For example, the SEQ program with the least available resources (i.e. funding, expertise) had no capacity to develop spatially dynamic models or train in their use. Therefore, SEQ relied heavily on maps, but also constructed matrix models using pro-bono expert knowledge of SEQ ecosystems, the economy and community (Maynard et al. 2010, 2015). Responses from US Leads working at a similar scale said at the regional or place-based scale maps could be "useful for displaying information", for example, for "local parishes and local community groups not having an awful lot of resource or technical capability". Both the US and UK Leads described maps as "simple", "straight forward" and "easy to understand" whilst "not requiring a whole lot of complicated software development or machinery.

In contrast, the US national scale program with the largest budget of all programs relied heavily on both maps and spatially dynamic models. Figure 5.1 showed the largest percentage (37%) of the US ESRP's approximately $70 million dollar budget (per year) was dedicated to achieve LTG2: Mapping, Modelling and Monitoring Ecosystem Services across Multiple Scales (EPA 2008). The result was the development of the National Atlas of Ecosystem Services and a wide range of dynamic models developed for place-based and national scale assessments. One US Lead said the lack of consistency in models used across the ESRP brought "innovation" to the program.

Another driver underpinning the choice of maps and dynamic models is who the proposed users of the tools are. For example, developing these tools for 'external stakeholder' use (whilst recognising stakeholders have various capacities to understand and apply ecosystem services concepts) was a primary goal of the SEQ regional program. Figures 4.2, 4.3 and 4.4 discuss the maps developed to support the SEQ framework and the matrix model describing interconnections between Components for Assessment. The primary user of the US framework was the (comparatively highly resourced) EPA itself especially the Program and Regional Offices (Sections 3.2.3.1 and 5.2). However, the EPA (2008) suggests the same as quoted in Neale (2011), that developing 'a publicly accessible, scalable, digital National Atlas of Ecosystem Services to inform decision-making at multiple levels' was of major importance to the ESRP.

Different to the goals of the SEQ and US programs, the MA (2005a) and UK NEA (2011b) did not develop maps and dynamic models specifically for use by external stakeholders to these programs. Rather, the goal of the MA (2005a) and UK NEA (2011b) programs was to conduct (sub)global and (multi)national assessments and use the outcomes to raise external stakeholder awareness of relevant existing and emerging environmental issues (e.g. biodiversity loss, climate change, over-exploitation of resources, human dependence on ecosystems). The MA and UK frameworks were developed and assessments were conducted simultaneously during the course of each program; the development of the frameworks (especially the conceptual framework, definitions, and classifications) guided the collection and development of the data, information and tools used to conduct assessments (e.g. through scenarios).

Papers describing the SEQ framework discuss how maps can improve knowledge and assist decision making by constructing and coordinating information into a simplified visual form (Maynard et al. 2010; Petter et al. 2012). Both US and UK Leads said maps "spoke easy to people" and were "able to reach many more people than technical model output". It was thought this was because maps were "visual" and "if people can see where these things are coming from then there is a huge difference in how they become interested in them". "Decision makers, like 99% of people, actually understand pictures better than words. … so then maps become useful". People were said to "trust" and "relate" to maps, that it was more difficult to get people to have "faith" in dynamic models.

One US Lead said the inclusion of ecological processes (or intermediate services) in a framework or assessment "reside in the domain of the ecological process modellers who have the task of understanding the workings of the ecosystems that produce the FEGS" (Section 5.2.3). Point models were said to be insufficient because one ecological point is not necessarily representative of other points in the landscape (more sampling points are required). Also, "because it is not just where we have databases, it has got to be where we don't have databases, it has got to be where we don't have data period, and then you have to calculate something new and point models just can't do that". One UK respondent said "there is a problem ... what I tend to call *the tyranny of GIS* ... because you can map something it can develop a sort of integrity and reality that it doesn't really have". One respondent from a national government said "from a national policy perspective often maps are quite dangerous … they are quite misleading because they make everything look simple and decided".

US Leads said maps were great for looking at what you had now and trying to make some assessment of current conditions, particularly at the operational level (e.g. decisions about "how much of some land-use should be protected, how much should be certified for agriculture, or should it all be multiple use") - but they did not cover the interactions and dynamics required to understand the context of ecosystem services decision making and assessing alternative futures (e.g. through scenario analysis). US and UK Leads said you can't just have a "printed map or even a fixed map – it's got to be one that responds to some sort of system that responds to the type of change that may be happening and what the impact of that would be". The MA (2005e, p. 48) states 'dynamic models are required to describe interactions among components of the system' [e.g. biodiversity, ecosystem services and human well-being]' and 'examine assumptions and responses to driving forces' (e.g. feedbacks, feed forwards, non-linear relationships and time-lagged responses between ecosystems and people).

Although dynamic models enable us to better understand the context of decision making, assess alternative futures and calculate new data, in contrast to maps US and UK Leads described dynamic models as "complicated", "complex", "time consuming", "back-boxish" and "having to have technical expertise and time – because you can't just give someone a model and say 'trust me all this stuff works". All place-based studies in the ESRP developed dynamic models or used existing ones so to conduct scenario analysis relevant to their decision making contexts. However, in the Australian local to regional scale programs reviewed by Maynard and Cork (2011) only maps were used along with participatory scoring and conceptual modelling; and only Binning et al.

(2001) applied the use of scenarios. One Lead discussing the usefulness of maps and dynamic models in scenarios said:

> *The trouble is that if they're too black box nobody understands what the scenario is. I found the mapping as one of the most accessible ways into this… they're both a product … but they can also be an input to the scenario creation. So I think mapping is still an under-used resource in terms of scenarios. I mean, people have tended to use them simply as a way of showing what the model predicts, but I think they can be much more imaginatively used than that.*

As shown by experiences in SEQ and the US, regardless of the scale of program a large number of data sets are required to adequately represent the provision of ecosystem services through maps and models. For example, 59 unique data sets were applied to map ecosystem functions supporting the SEQ regional framework (Petter et al. 2012) and one US Lead said "over 60 data layers have been included in the [National] Atlas". Although some data sets were developed specifically for the frameworks analysed in this research, the maps and models primarily relied on existing data sets. Along with the resources available and proposed users of the frameworks, the large amount of data required and the desire to easily integrate the framework with existing initiatives drove the use of existing data sets.

In the frameworks analysed, to be considered for inclusion in maps or models the data sets underpinning them needed to provide full coverage of the largest area able to be assessed using the framework (e.g. data sets that cover the entire SEQ region, and national data sets in the US) (EPA 2008; UK NEA 2011a; Petter et al. 2012). The EPA also has a clause stating all data sets included in the National Atlas require a peer reviewed journal article (Section 7.1.4). Common foundational data sets used to map assessment units, ecosystem functions and services in the SEQ, US and UK frameworks include: Land Cover, Land Use, soils, and habitats or ecosystems. For frameworks that adopted existing assessment units such as the UK (i.e. Broad Habitats) and SEQ frameworks (i.e. Regional Ecosystems), generally these foundational data sets were easily accessible and freely available for use.

The need for nested spatial units to support a multi-scale framework is shown through this analysis of maps and models. For example, in the SEQ regional framework ecosystem functions were mapped in 25 m^2 grids (Petter et al. 2012). Included in the US National Atlas of Ecosystem Services were "three spatial scales: 1/ the national scale (maps were based on 12 digit HUCS; 83 000 unique hydrologic unit codes mapped in 30 m grids); 2/ the community scale; and 3/ the special study areas" (such as place-based projects which used 'National Hydrology Data" that divides the US into about two million catchments "nest[ed] within HUCS"). "In the UK NEA "the scale of mapping ranged from 25 m^2 grids to 5 km^2 grids depending on the scale and type of valuation or scenario conducted". As noted in Section 2.1.2, the MA (2005a) maps ranged from 10 m – 8 km resolution depending on availability of data and the scale of assessment (e.g. sub-global, global).

Overall, both maps and dynamic models were considered by Leads as necessary for ecosystem services assessments; "maps and simulation models are not isolated and juxtaposed ... they often are used in concert". The majority of US and UK Leads said that "decision makers" would not be happy with only maps. Being unable to identify the uncertainty that underlies map images was said by many Leads to be a major dis-benefit and barrier to their use. Another dis-benefit and barrier is the fact that maps often have very discrete boundaries and this is rarely the case in nature.

Experience in 'participatory mapping and modelling' was found to be a positive and learning experience; "if you have people working with the model and developing the model they can learn more about the outputs". In SEQ stakeholders identified and determined relevant data sets to support ERC and ecosystem function maps (Maynard et al. 2010; Petter et al. 2012); and at each stage in the development of maps and models they were presented for review in open forums (Think Tanks) of stakeholders to the natural resources of SEQ. A collaborative approach working predominantly with other US federal agencies was applied to develop the Atlas; "involving stakeholders in identifying the maps required [to support the framework] is important to the acceptance and credibility of the final outputs". The process of developing the Atlas also allowed participants "to work within their specialist areas of expertise". US Leads said the information and tools they would have developed if they had not consulted with stakeholders would have been "more complex" than these stakeholders require or have capacity to use.

The first finding into maps and dynamic models included in frameworks is that driving the inconsistent use of these tools is: 1/ the resources available to programs; and 2/ who the proposed user of the maps and models are. Different stakeholders will have varying capacities to understand and apply information and tools on ecosystem services (Maynard et al. 2010, 2012, 2015). High resources (e.g. software, machinery, money, technical capability), often beyond the capacity of some stakeholders, are required to understand or apply dynamic models. The result of a tool increasing in complexity and requiring high resources is potential reductions in the use of the tool by the broadest range of stakeholders (see Recommendation 61).

Secondly, this analysis of maps and models in different scale frameworks highlighted the different uses of these tools in ecosystem services assessments. Maps are important for taking stock of natural capital and assessing their current conditions, particularly at the place scale or operational level. Because maps are cheaper, “simple” and “visual” they are "able to reach more people" and are more “trusted”. However, maps do not capture the interactions between components for assessment and the dynamics underpinning the context of ecosystem services decision making. Dynamic models are required to assess alternative futures through the use of scenarios.

The third includes the following findings into determining data sets to support a multi-scale framework: 1/ a large number of data sets are necessary to develop the required maps and models; 2/ to be included data sets must provide full coverage of the largest area able to be assessed using the framework; 3/ for increase credibility of maps and models data sets should have a peer reviewed journal article; 4/ foundational data sets required to develop maps to support the framework include: Land Cover, Land Use, soils, and those used to spatialise assessment units (e.g. habitats, ecosystems); 5/ to more easily integrate the framework with existing initiatives the use of existing data sets should be explored; and 6/ data sets should be scalable so to conduct integrated ecosystem services assessments across different scales (Recommendation 63 and 64).

The need to determine the level of uncertainty of data, and the outcomes of applying the data in maps and models, is the fourth finding from this analysis (Recommendation 62). Any recognised gaps in data, assumptions made, or principles applied need to be recorded and made available to stakeholders. The potential to integrate the framework and outcomes of assessments with current initiatives is easier when including existing data sets, but existing data sets come with inherent biases based on their original fit-for-purpose (see Section 7.2.). Being unable to identify the uncertainty that underlies map images was said by Leads to be a major dis-benefit to the use of maps compared to dynamic models.

The fifth finding is that participatory mapping provided a positive learning experience for both stakeholders and those employed to develop frameworks at regional and national scales (Recommendation 65). One approach that worked well in the US was stakeholders being involved in the development of data layers up front and therefore avoiding the frustration of trying to standardise data later. It was said "if you have people … developing the model [i.e. identifying and determining relevant data sets] they can learn more about the outputs". “Involving stakeholders” was also said to be “important to the acceptance and credibility of the final outputs”. Box 7.12 provides Recommendations into tools required to support a framework as they are related to this key topic of analysis on maps and dynamic models. The following section provides the findings and Recommendations based on the analysis of websites and technical reports.

Box 7.12: *Recommendations on maps and dynamic models to support a multi-scale framework.*

61) Determining maps and dynamic models: consideration should be given to the following factors when determining appropriate tools (e.g. maps and dynamic models) to support a framework:

i. Capabilities of maps and models: maps and dynamic models have different capabilities and therefore are most useful for addressing different issues. Maps are important for taking stock of natural capital and assessing their current conditions. However, dynamic models are better at capturing the interactions between components for assessment and the dynamics underpinning the context of ecosystem services decision making (56, 57, 58, 59).

ii. Available resources: the resources available (e.g. funding, expertise, time, software, machinery) will determine the feasibility to develop different types of maps and models. Generally, maps are a least resource alternative to dynamic models (10, 11, 15, 26).

iii. Capacity of stakeholders: stakeholders have very different capacities (e.g. funding, access to software, technical capability) to understand and apply ecosystem services frameworks and conduct assessments. The potential use of tools by a wide range and large number of stakeholders is reduced with increased resource needs and complexity (2, 5, 17, 19, 42, 67, 68).

iv. **Access and availability to existing data:** the accessibility and availability of the large amount of data that will be required to develop maps and run dynamic models as a component of the framework requires consideration (7, 24, 35, 48, 64iv).

62) **Levels of uncertainty:** the data underpinning maps and models, and the outcomes of assessments using maps and models, have different levels of uncertainty. As well, different assumptions have been made and principles were used when developing these. Rating the uncertainty of data and making this available to stakeholders is important for transparency and credibility of assessment outcomes using the framework (28, 61i, 66).

63) **Developing a plan or blueprint:** a plan or blueprint for mapping and modelling should be developed collaboratively with stakeholders early on in the program to improve consistency of approach by those working on the framework and consistency of assessments using the framework (17, 19, 55).

64) **Determining data sets:** consideration should be given to the following factors when determining appropriate data sets to support maps and dynamic models:

i. **Full coverage data sets:** data sets must provide full coverage of the largest area able to be assessed using the framework (36);

ii. **Peer reviewed data sets:** to improve credibility of tools the data sets underpinning them should be supported by a peer reviewed journal article (27);

iii. **Foundational data sets:** foundational data sets required to assess ecosystem services include: Land Cover, Land Use, soils, and those used to spatialise assessment units (e.g. habitats, ecosystems) (35);

iv. **Use of existing data sets:** the use of existing data sets increases the potential to integrate the framework with current initiatives and requires less resources than developing new data sets (35, 48);

v. **Scalable data sets:** data sets should be scalable so to allow ecosystem services assessments to be conducted at different scales depending on the decision making purpose (25, 38, 54iii).

65) **Participatory mapping and modelling:** participatory mapping (e.g. involving stakeholders in data identification and development) has benefits of social learning; reducing complexity; and developing relevant tools to meet stakeholder needs (16, 17, 18, 19, 60).

7.3.4 Websites and technical reports

The last tools analysed under this Line of Enquiry are websites and reports developed to support ecosystem services assessments, communicate outcomes of assessments, or provide details on the program. Table 1.1 listed the primary websites, reports and journal articles developed to support the MA, SEQ, US and UK methodologies; and used to guide research, provide data, and develop outcomes for this PhD (including those I (co)authored on the SEQ program). Programs analysed at all scales produced academic journal articles communicating elements of the methodology and how the research built on the current state of knowledge of ecosystem services (the use of journal articles is discussed more in Section 7.4).

Large technical reports in the form of books were developed to support frameworks developed at global (i.e. the MA and TEEB) and multi-national (i.e. UK NEA) scales. These technical reports ranged from 399 pages in the MA (but this is only one report in a five volume series) to the UK NEA's hardcover Technical Report at 1466 pages with 27 chapters and "weighing four and half kilograms". A number of UK Leads questioned the usefulness of such documents to stakeholders beyond academic studies due to the "awkward' size and weight and "depth of detail". A synthesis of these technical reports into summary publications (generally glossy and highly pictured) for general or specific stakeholder use was also produced for each program (MA 2005f; TEEB 2009, 2014; UK NEA 2011a). These were thought by UK Leads to be more useful to a broader range of stakeholders than large technical documents.

Most large scale programs also made high use of websites to house information, tools and other details and outputs of the program (e.g. MA, TEEB, UN SEEA, CICES, UK NEA). The technical reports described above are available for stakeholders to purchase in book form or download free on these websites. The UK NEA provides the most detailed of websites; as well as housing the technical report it also provides details of the process applied to develop the framework and conduct ecosystem services assessments (including names and contact details for those participating on the Secretariat, User Group, Expert Group and the Client Group) (UK NEA 2012). In contrast, little information on the US framework was available to external stakeholders through the EPA website. This is likely a function of all potential journal or EPA publications requiring peer review prior to public release. ORD established an intranet to allow cross-project (e.g. nitrogen studies, wetland and stream workshop outcomes, and place-based studies) interaction across EPA employees, and a platform for housing and sharing ESRP administration and project outputs. Access to the intranet by external stakeholders sponsored by EPA employees was also possible (EPA 2013b).

Unlike the large scale programs as described above, no ‘over-sized’ technical reports or books were developed for the local to regional scale frameworks reviewed in Maynard and Cork (2011). At these scales the documentation of methodologies was primarily through grey literature such as fact sheets, conference proceedings, short project reports and journal articles. Resources (time and money) limited a formalised process for communicating or documenting the development of the SEQ framework. Only one program reviewed by Maynard and Cork (2011) had a dedicated website at the time of its writing. However, the SEQ Ecosystem Services Project later developed a website to provide free and open access of the framework and transparency of process to all stakeholders (SEQ Catchments 2012).

The need for longevity of access to information and tools supporting a framework is shown from this analysis of reports and websites to support a framework (Recommendation 66). Reports, websites and journal articles require different resources to develop and also have different maintenance levels and capacity’s to be updated. Consideration of the capacity of stakeholders to access (up-to-date) information and tools during and after the funding and program ceases, and for the coordinating organisation to maintain and update the information and tools on an as needed basis, is required when determining, designing and developing tools to communicate the framework and program. The following findings build on this insight.

The second finding from this analysis builds on those from other key topics, and that is the importance of obtaining credibility of the framework (and assessment outcomes) through peer review. This is evident by: the development of journal articles discussing the methodologies developed; the prominent and preferred use of peer reviewed research to support information and tools developed (Sections 7.1.4 and 7.3.3); the development of large technical reports which, similar to journal articles, are primarily targeted at the academic sector whose review, use and reference will influence the credibility and acceptance of the framework and program to other stakeholders; and (as also discussed in Section 7.1.4) all programs analysed included a process for peer review in the program’s structure (see also Appendix 4).

The third finding into websites and reports to support a framework is the need to determine the target audience for written material (Recommendation 67). Large technical reports might be beneficial to documenting the process and framework developed but are cumbersome to read and unlikely to attract stakeholders beyond the academic community. The development of glossy and highly pictured summary publications is one approach to developing more useful reports for targeted stakeholders (MA 2005c or d; TEEB 2009, 2014; UK NEA 2011a). The development of grey literature (e.g. fact sheets, conference proceedings, short project reports) is particularly important to local communities and stakeholders operating at smaller scales.

The fourth finding is the need for a platform to house the information and tools supporting the framework. Free and open access by stakeholders to the information and tools developed is required to ensure stakeholders of all capacity have opportunity to use the framework (i.e. not just stakeholders with finances to pay for journal subscriptions or technical reports) (Recommendation 68). As Cash et al. (2002) say, one of the ways audiences judge the legitimacy of a process is by who participated and who did not (Section 7.1.4). Providing details (similar to the UK NEA) on this platform of who was involved in the development of information and tools improves transparency and legitimacy of the program's process. Box 7.13 provides Recommendations into tools required to support a framework as they are related to this key topic of websites and reports.

Box 7.13: *Recommendations on websites and reports to support a multi-scale framework.*

66) Documenting the methodology: for transparency, legitimacy and credibility reasons it is important to document in detail both the technical elements of the framework and the process of developing it. Documenting the technical elements and process should begin early in the program. Consideration should be given to the longevity of access and maintenance of the documentation when determining, designing and developing them (11, 67, 68).

67) Relevant methods of documentation: understanding the capacity and needs of the target audience is important to determining the best methods of documentation to develop (e.g. technical reports, fact sheets, summary documents, journal articles, websites) (17, 19, 42, 61iii, 66, 68).

68) Free and open access: to support the program and framework a platform is required to house information on the methodology developed and provide free and open access to stakeholders (42, 66, 67).

This concludes the analysis of methodologies under Line of Enquiry 3. The 15 Recommendations listed in Box 7.10, 7.11, 7.12 and 7.13 were derived from this analysis of tools supporting frameworks at multiple scales. These Recommendations will assist researchers with determining *appropriate tools to support a framework for ecosystem services assessments across multiple scales.* The following section provides a synthesis of outcomes of the analysis of methodologies as they specifically relate to a multi-scale framework.

7.4 Focus on a multi-scale methodology

Chapters 1 – 7 have discussed the need and provided examples of multi-scale ecosystem services frameworks. Appendix 9 is the culmination of this research as discussed in Chapters 1 - 7. The design of this research (Figure 3.1) allowed methodologies developed in different contexts to be analysed, and in this current chapter the case study methodologies (i.e. SEQ, US, UK) were cross-analysed (along with the MA and other schools of thought) as shown in Figure 3.5. The table in Appendix 9 is structured similar to each the four tables staggered in Figure 3.5 showing these methodologies developed at different scales (regional, national, multi-national, global). Appendix 9 represents the bringing together of these other methodologies empirically to determine an appropriate methodology for multi-scale assessments.

Findings from cross-analysing methodologies through the Lines of Enquiry and key topics were developed into 68 Recommendations (Boxes 7.1 to 7.13). These Recommendations are listed in Appendix 9; and their interconnections with other Recommendations are listed and coloured according to the code in Figures 3.1 and 3.5 for each Line of Enquiry (LoE 1: Process = Blue; LoE 2: Information = Orange; and LoE 3: Tools = Green). From the key findings and Recommendations described in Sections 7.1, 7.2 and 7.3, and the information presented in Appendix 9, it is revealed the process applied to develop a multi-scale framework is just as important, if not more important, than the final information and tools developed. Aspects of this research supporting this proposition are the focus of this final section of this chapter.

The high number of interconnections between multi-disciplinary input (16), collaborative approaches (17), diverse forms of knowledge (18), and sector participation (19) with Recommendations derived from other Lines of Enquiry, shows the importance of these to developing an appropriate multi-scale framework (information and tools). Key findings into processes identified the need for a large number and diverse range of experts to be engaged; the number of experts engaged in programs ranged from over 190 to develop the SEQ regional scale framework to over 1300 to develop the MA global scale framework. A large number of experts are required due to the multi-disciplinary nature of ecosystem services and because different stakeholders operating in different contexts (including different scales) hold different types of information necessary to support a framework. Importantly, engaging stakeholders in the framework's development is shown to reduce the complexity of information and tools and improve their relevance to stakeholder needs.

The improved credibility of information and tools due to a carefully structured program that engages stakeholders was discussed. Credibility was improved through a detailed peer review process in all programs. Four ways peer review was used to strengthen the credibility of a methodology or assessment outcomes were: 1/ all programs developed journal articles communicating elements of their methodology and how the research built on the current state of knowledge of ecosystem services; 2/ data sets with a peer reviewed journal article describing its development were most commonly used in maps, models and scenarios; 3/ peer review was conducted throughout the program as stages were completed; and 4/ in all programs the peer review process was conducted by expert stakeholders from outside the coordinating organisation.

In determining an appropriate methodology for multi-scale assessments much can be learnt from the multi-scale design of the MA, such as the need to hold key framework components constant so when the framework is implemented the findings from assessments at different scales feed both bottom-up and top-down (MA 2005d). Appendix 9 shows that highly interconnected with Recommendations 16, 17, 18 and 19 is the consistent and clear use of terms (40, 43); common lists (41, 45); the use of existing information (35); and the need for developing a shared understanding through a conceptual framework, a glossary/lexicon, and classification systems (54i, 54ii, 54iii). Recommendations 16, 17, 18 and 19 are also highly interconnected with many other Recommendations showing the need for 'a concerted effort toward standardisation' of assessment approaches including agreement on valuation methods (51, 52), scenarios (56, 60) and mapping and modelling approaches (65) so to 'enhance the transparency and transferability of research outputs' (EPA 2008, p. 27).

At the heart of the MA is its conceptual framework (Figure 2.2) which provided a shared vision across stakeholders; and guided the concept of ecosystem services (Figure 1.1) into a usable format that all researchers developing aspects of the framework, and stakeholders applying the framework and reporting on assessment outcomes, could consistently follow (MA 2005a; Ash et al. 2010). The MA (2005a, p. 34) states ‘a prerequisite for both analysis and action is agreement on a basic conceptual framework’ by stakeholders. The importance of developing a conceptual framework to improve standardisation and consistent approaches is further evidenced by their inclusion as a tool in the SEQ (Maynard et al. 2010), UK NEA (UK NEA 2011b), TEEB (2010) and CICES (Haines-Young and Potschin 2010) frameworks.

Scale is fundamental to the assessment of ecosystem services and to providing meaningful assessment outcomes (i.e. outcomes with relevance to multiple stakeholders and purposes). Structuring place scale studies (e.g. at the NRM regional scale) in the broader program design (e.g. in Australia) is necessary because the nature, value and the aggregation of ecosystem services is all place-dependent (EPA 2008); and the biogeographic characteristics of a place are important to understanding ecosystem functions from which the services are derived (EPA 2008). Recommendation 25 discussing the need to apply parallel design components to ensure comparability of assessment outcomes, and that outcomes can be aggregated or up-scaled to provide assessments at larger scales, was the most interconnected of Recommendations presented in Appendix 9.

Outside of the use of an overarching conceptual framework, other parallel design components identified as necessary were: the use of common definitions; a common ecosystem services classification system; place studies adopting a collaborative and participatory process; and any other principles or policies supporting the framework agreed to. Hierarchal ordering of terminologies (glossaries and lexicons), common lists and classification systems will allow nested and integrated assessments across scales using the framework (e.g. place-base studies within national scale programs). Within the methodologies analysed, this need for hierarchal ordering so as to ensure transparent and transferable outcomes from applying the framework is most evident in the assessment units developed to support the MA (Section 2.1.2), TEEB (Section 2.2), SEQ (Section 4.2.2), US (Section 5.2.2), and UK (Section 6.2.2) frameworks. As well, ecosystem services and FEGS categorisations and classifications developed to support the MA (2005a), Wallace (2007), TEEB (2010), CICES (Haines-Young and Potschin 2010), SEQ (Maynard et al. 2010), UK NEA (2011b), and US ESRP (EPA 2010b) frameworks.

The use of existing data and information enabled the development of ecosystem services frameworks at all scales to better integrate with the current initiatives of stakeholders. However, the use of existing data and information came with limitations of inherent contextual biases such as: definitions developed under different paradigms of thought sometimes were not appropriate (e.g. biodiversity); the availability of resources (e.g. time, budgets, expertise) to develop information and tools under other initiatives hinder or enabled choices; previous researcher interpretations; the (in)ability to describe and document uncertainties (e.g. statistical errors); and scales of data collection and representation. As any new research using existing data, information and tools will be sensitive to the limitations of these biases, data, information and tools developed for one purpose (e.g. biodiversity assessments) may or may not have relevance for other purposes (e.g. ecosystem services assessments). Existing data, information and tools require stakeholder review for their potential ‘fit for purpose’ and where necessary new data, information and tools may require development.

Chapter 8 concludes this research by ensuring its outcomes respond to the original research question and the contribution to ecosystem services science is made clear. The strengths and limitations of this research are also made transparent and a way forward for further research is deduced.

Chapter 8

Conclusion

To reiterate in short the premise for this research which Chapter 1 adduced, to manage natural resources sustainably we need to mainstream ecosystem services into stakeholder decision making at different scales, and a *framework* (containing information and tools to assess ecosystem services) is required to meet this purpose. Previous chapters confirmed how an ecosystem services approach to managing natural resources is endorsed by many world leaders, national governments, researchers, community organisations and global environmental initiatives (IPBES 2015; UN 2015). Since the 2005 release of the MA there has been exponential growth in ecosystem services research and there is now a large number and wide range of methodologies (i.e. processes, information and tools) available for use (MA 2005a; EPA 2008; Maynard et al. 2010; TEEB 2010; UK NEA 2011b; Diaz et al. 2015).

The documents reviewed in Chapter 2 revealed how a methodology developed in one context (e.g. geo-jurisdictional scale, country, or for a specific purpose) may not be relevant, transferable or repeatable to other contexts; or the potential relevance, transferability and repeatability of the methodology is unknown. As data and information collected through use of one framework may not be the same as that acquired through use of another framework, outcomes from applying one framework are then limited in their ability to inform assessments using different frameworks. This reduces the potential effectiveness of both single and cross-scale environmental policy-program making and implementation (WRI 2007; Nahlik et al. 2012); and supports the need for an ecosystem services framework that can be applied by multiple stakeholders at multiple scales (MA 2005a).

This research was designed to learn from expert experiences in developing methodologies in different contexts (including scales). By better understanding drivers influencing the choice of methodology developed we can better understand *what an appropriate methodology is to enable ecosystem services assessments to be conducted at multiple scales.* This chapter concludes this research by re-examining Chapter 7's key findings and the Recommendations derived from investigating the sub-questions underpinning the three Lines of Enquiry (process, information and tools). Section 8.2

then affirms the contribution made to ecosystem services science through this research. The strengths and limitations of the research design (i.e. literature reviews, applied research and multiple case study analysis) are discussed in Section 8.3. An exploration of possible future directions for research finalises this chapter.

8.1 Synthesis of empirical findings as answers to research questions

The three Lines of Enquiry (Section 3.1) analysing methodologies broke this research into tractable components. Sections 3.1.1, 3.1.2 and 3.1.3 discussed these Lines of Enquiry into *processes*, *information* and *tools* (where information and tools form a framework) and introduced the sub-questions underpinning each of them. The *documents review* in Chapters 1 and 2 described different schools of thought on areas of framework development (e.g. who coordinated the development of the framework, definitions, assessment units, valuation approaches, conceptual frameworks), including an in-depth review of the MA methodology. From this review, key topics for further analysis emerged from similarities, differences and gaps in knowledge identified within the three enquiry areas.

The sub-questions and key topics guided the in-depth analysis of three programs developing ecosystem services frameworks in different contexts. Section 3.2.1 described the *applied research* where I played dual roles of PhD researcher and Project Manager; and Chapter 4 provided the outcomes of interacting with stakeholders (through meetings, workshops, expert panels) to develop an agreed ecosystem services framework for the SEQ region. Section 3.2.2 described the *multiple case study analysis* used to analyse national and multi-national scale methodologies; and Chapters 5 and 6 the outcomes of interviewing US and UK Leads working in areas related to the key topics. Chapter 7 brought outcomes of the document review, applied research and multiple case study analysis together by cross-analysing outcomes from the Lines of Enquiry into the SEQ, US and UK methodologies. As mentioned previously, Section 8.2 describes the strengths and limitations of this research. But for now and at the expense of some repetition, to verify this research has addressed each sub-question and the overarching research question, Sections 8.1.1, 8.1.2 and 8.1.3 re-examine the key findings and Recommendations for each Line of Enquiry.

8.1.1 What is an appropriate process to develop a framework for ecosystem services assessments across multiple scales?

An appropriate process to develop a framework is one where the organisation coordinating its development has legitimacy to do so in the eyes of stakeholders likely to use the framework or the outcomes of assessments. As demonstrated through this research, for a multi-scale framework this legitimacy is most likely held by organisations with existing networks; that have representation from stakeholders on their Board or as a Party to programs; and those who have as their mission contributing to a broad spectrum of NRM issues, policies and programs operating at different scales (not siloed or single scale missions). It can be determined from this research that the scale a framework is developed at is not an issue to engaging stakeholders in collaborative processes because, as noted by US Leads, “all local governments and stakeholders have groups that aggregate up".

The frameworks development should be conducted as a scientific process and independent of any politics or policies; and its scope should extend broader than any single organisation’s missions or mandates. Due to the multi-scale and multi-disciplinary nature of ecosystem services and the wide range of potential applications of a framework (Graymore 2005), a large number of experts and stakeholders with diverse knowledge are required to develop it (MA 2005a). Hence strong, independent, scientific leadership is required from highly respected and credible (Co)Leads with excellent people and coordination skills and experience on projects at the scale of framework development (e.g. national).

The process of developing the framework needs a well-coordinated, structured and facilitated effort as those contributing require clear directions, including knowledge of how their input will be used in the framework and whether they are contributing as a representative stakeholder or as a subject expert (Maynard et al. 2012). As an example, this research shows government representatives are best positioned to contribute as a key stakeholder: overseeing the program; to ensure outcomes have policy relevance; contribute to agenda setting; develop policy questions that the framework when applied will answer; communicate the program and outcomes to Ministers; and to assist with data identification, access, collection and its standards.

Adequate and flexible financial support (especially from government) is fundamental to developing an appropriate methodology. The funding available and any restrictions on its use will influence the information and tools able to be developed and possibilities of hiring any required extra skills and expertise. This research shows the following factors are important to consider when determining funding: whether new primary information is required or if it already exists; whether new tools are required or if they already exist; whether extramural support is required; and possibilities of pro-bono input. The program should seek to develop the initial framework within a four to five year period so to remain up to date with current knowledge and tools. A review of the framework in line with priority policy-program timeframes (e.g. State of Environment reporting) will ensure the frameworks continued relevance.

A structural feature common to all programs analysed is the inclusion of finer scale studies focused on a particular ‘place’ (e.g. local government community workshops to determine ecosystem services values in SEQ; place-based studies in the US ESRP; national assessments in the UK; sub-global assessments using the MA). The US EPA (2008, p. 92) states the ‘nature… value and the aggregation of ecosystem services is all place-dependent'. The frameworks developed at larger scales included definitions, standards, conceptual frameworks, principles and guidelines that allowed information, data and assessment outcomes to integrate bottom-up and top-down to further refine frameworks and inform assessments at different scales (MA 2005d). According to Leads interviewed, “guiding” the research through these “parallel design components” yet allowing researchers to do “things in a similar way in different places” is important to potentially upscaling, comparing and synthesising information across place scale studies. Choosing places for these studies requires: considering existing and potential governance scales and arrangements and balancing the level of (ecological, economic, social) representativeness of places across a nation; the amount of available data and information on the place; where the institutional resources exist that can be capitalised on; where agencies and organisations are willing to work together; and those places that show the greatest interest in being involved.

8.1.2 What information is required to support a framework for ecosystem services assessments across multiple scales?

From the documents review, data and information on the following five components are identified as necessary to support an ecosystem services framework: biodiversity, assessment units, ecological processes, ecosystem services and ecosystem service values. The inclusion of existing data (e.g. GIS data sets, units for spatial boundaries) and information (e.g. definitions, classification systems, concepts, expert local knowledge) that stakeholders use to both govern and meet the obligations of current environmental policies and programs is shown to improve the potential to integrate the ecosystem services framework into current NRM activities (Maynard et al. 2010, 2012, 2015; UK NEA 2011b; Petter et al. 2012). It should not be assumed existing data and information are available or appropriate to meet the needs of an ecosystem services framework, however. For example previously developed biodiversity data and information were collected under different paradigms of thought (i.e. the conservation of biological diversity, rather than the sustainable use of biodiversity in which abundance, area and extent of species and ecosystems are also important), so they come with inherent contextual biases and any new research using these will be sensitive to them.

There is strong agreement across researchers developing frameworks that a system with higher biodiversity is stronger, more robust, and resilient and sustaining in its delivery of ecosystem services than one with less biodiversity. This is described in the literature and by US and UK Leads as an “insurance role” in the provision of ecosystem services (UK NEA 2011b; SEQ Catchments 2012), and the framework should reflect this important role. Working with stakeholders to establish biodiversity’s position early on in a program is a proactive way to managing potential conflicts in different thinking held on valuing nature. Whether biodiversity is recognised as an ecosystem service or not is dependent on how both biodiversity and ecosystem services are defined and interpreted in the framework.

The choice of assessment unit to include in a framework requires consideration of the strengths and limitations of each possible unit in the identifying, measuring and valuing of ecosystem services (MA 2005a; EPA 2008; Maynard et al. 2010; TEEB 2010; UK NEA 2011b). For example, environmental classes capture ecosystem services provided by groundwater and atmosphere better than habitats or ecosystems, but unlike habitats, environmental classes and ecosystems do not allow for the linking of biodiversity functional groups with specific areas of the landscape providing ecosystem services. Consideration of the potential to aggregate and disaggregate units is fundamental to a multi-scale framework; a nested multi-scale classification of units is required for integrated ecosystem services assessments across scales (e.g. local to national) (MA 2005a; Maynard et al. 2010; TEEB 2010; UK NEA 2011b). Although units with overlapping boundaries better reflect real world interactions particularly at large scales (MA 2005a), the units incorporated in a multi-scale framework must have clearly defined boundaries to ensure the transparency, standardisation and repeatability of monitoring and assessment that many policies and programs require (e.g. environmental impact assessments, environmental-economic accounting, markets for ecosystem services) (Maynard et al 2010; Landers and Nahlik 2013).

Haines-Young and Potschins (2010a) discussed the importance of distinguishing between ecosystem structure, processes, functions and services. Fundamental to determining the capacity of an area to sustainably provide goods and services is an understanding of the ecological processes that support their provision (MA 2005a; Maynard et al. 2010; Petter et al. 2012; SEQ Catchments 2012). Ott and Staub (2009) and Staub et al. (2011) suggest Boyd and Banzhaf's FES approach is limited in its ability to assess ecological sustainability because it does not include intermediate services. Appendix 7 listing ecological processes, supporting services, ecosystem functions and intermediate services (terms used interchangeably) in the MA, SEQ and UK frameworks, shows soil formation and nutrient cycling included in frameworks at global, regional and multi-national scales; and climate regulation, water cycling, soil retention, pollination and primary production were included in at least two of these scales. Together these seven processes provide the bases for a comprehensive list of processes for inclusion in a multi-scale framework.

A definition of ecosystem services that makes clear the distinction between processes and services, and services and benefits, is required. This clear definition and a comprehensive list of ecosystem services developed early in the program encourages consistency in use of terms by stakeholders conducting assessments, and recording and communicating outcomes. Although ecosystem services are defined differently in the MA, SEQ, US and UK, four ecosystem services listed in Appendix 8 (i.e. regulation of pests and disease, water - regulation and quality, regulating or maintaining of climate, and natural hazard regulation) are included in these framework developed at global, regional, national and multinational scales. These four ecosystem services, and the nine others included in at least three of the four frameworks listed in Appendix 8 (i.e. food; aesthetic values; fuels; pollination; air quality; sense of place; spiritual value; recreation; and fibre provisioning), provide a baseline set of services for inclusion in a multi-scale framework.

It is unequivocally agreed across schools of thought that people value ecosystem services because they contribute positively to different aspects (or constituent parts) of their lives (MA 2005a; EPA 2008; Haines-Young and Potschin 2010a; Maynard et al. 2010; TEEB 2010; UK NEA 2011b). Because some ecosystem service values are best determined through monetary methods and others cannot be determined through dollar values alone (MA 2005a; TEEB 2010; UK NEA 2011b; Maynard et al. 2015), it is recommended a toolkit of valuation methods and guidelines for determining and communicating peoples' values for ecosystem services be developed.

The importance of information derived from national (government) data collection (e.g. General Social Survey, UK Census) to conducting valuations and well-being assessments is shown in MA, US and UK programs. Where information to conduct assessments is not available at useful scales new indicators need to be developed (e.g. through new questions in national surveys). Although determining the value of ecosystem services to human well-being requires a holistic and pluralistic approach (UK NEA 2011b), conducting valuations specifically on the contribution ecosystem services make to the economy and the health of communities is thought by US and UK Leads to improve government and other stakeholder buy-in.

8.1.3 What tools are required to support a framework for ecosystem services assessments across multiple scales?

Key findings into the required tools to support a multi-scale framework revealed the need for a conceptual framework developed by stakeholders that represents their shared vision. The conceptual framework provides a simplified description of the relationship between humans and the natural world, and for this reason it is important to include feed forward and backward loops and to show how interactions occur across temporal and spatial scales. The development of a conceptual framework facilitates cross-disciplinary and cross-sectoral understanding (MA 2005a; Maynard et al. 2010, 2012; UK NEA 2011b). As well, it guides the concept of ecosystem services into a usable and consistent format that all researchers developing the framework and stakeholders using the framework can follow (MA 2005a; Wallace 2007; TEEB 2010; UK NEA 2011b; Maynard et al. 2012; Haines-Young and Potschin 2013); it helps guide the writing up of assessment outcomes (MA 2005a; UK NEA 2011b); and it can raise awareness of the program and assessment outcomes (MA 2005a; Maynard et al. 2010).

The need for a glossary and detailed classification systems to guide research within the program, and for consistency of framework application across assessments, was said in Section 7.4 to be evident by their development in the MA (2005a), Wallace (2007), SEQ (Maynard et al. 2010), TEEB (2010), CICES (Haines-Young and Potschin 2013), UK NEA (2011b), and the US ESRP (EPA 2010b). Developing this common language broke barriers between disciplines and sectors and assisted with developing the shared vision expressed through the conceptual framework described above (Cork 2002b; MA 2005a; Maynard et al. 2010; Australia21 2012). Nested and integrated assessments across scales and stakeholder purposes is achieved by holding some information in the framework constant such as the conceptual framework and common language/definitions, but also clearly defined hierarchal assessment units and lists of ecological processes and ecosystem services.

Although scenario outputs can provide important information to support a framework where information currently does not exist, their primary use to date has been to conduct assessments using a framework. They were shown to be a powerful set of tools that provide a platform to think about various options in the face of complexity and future uncertainties. Scenarios are not ‘forecasts, projections, predictions or recommendations about the future’ but ‘a way to explore possibilities for the future that cannot be predicted by extrapolation of past and current trends’ (MA 2005c, p. 225). Outcomes of global scale scenarios have promoted the framework (and program) and raised awareness of possible future environmental, social and economic implications of human choices and actions (MA 2005c; UK NEA 2011b). However, the usefulness of scenarios at scales smaller than global requires greater research.

“With scenarios it’s often in the process of doing it that you learn things, and certainly when you run [multiple] … scenarios … then it’s the contrast between them that is the most informative”. The context under which the framework is developed will determine the type of scenario(s) to be conducted and the information needed, but the most common scenarios used to assess ecosystem services have been climate change, preservationists’ perspectives of nature, business as usual, economic growth and the impact of stressors (such as nitrogen) on ecosystem services (IPCC 2000; MA 2005a; EPA 2011b, UK NEA 2011b). Scenario use can be politically sensitive, however, so care should be taken and the choice of scenarios should be done in collaboration with stakeholders so to give them an opportunity to voice conflicting opinions (IPCC 2000; MA 2005c; UK NEA 2011b). Also, if stakeholders are involved in scenario development it ‘improves relevance, utility, ownership and legitimacy of the assessment with decision makers’ (Reid et al. 2006a, p 10).

Both maps and dynamic models are necessary to support a multi-scale framework because the capacity (e.g. budget, expertise) of the proposed users of the framework will vary and therefore ultimately determine what tools can be used by them to conduct assessments. Compared to dynamic models which were described as "complicated", "complex", "time consuming", "black-boxish" and "having to have technical expertise and time”, maps were described as "simple", "straight forward" and "easy to understand" whilst "not requiring a whole lot of complicated software development or machinery”. Maps were shown to be important in small scale frameworks, for example, in SEQ and also “local parishes and local community groups not having an awful lot of resource or technical capability" in the US. People were said to "trust" and "relate" to maps and because they are “visual” they are "able to reach many more people [including decision makers] than technical model output". However, "from a national policy perspective often maps are quite dangerous … they are quite misleading because they make everything look simple and decided".

Of importance when determining the development and use of maps and models is the ability of the actual tools to express a level of realism (e.g. maps often have very discrete boundaries and this is rarely the case in nature). Maps are important for taking stock of natural capital and assessing their current conditions but they do not capture the interactions between components for assessment and the dynamics underpinning the context of ecosystem services decision making; dynamic models are required to assess alternative futures through the use of scenarios. Also, of importance is the ability of maps and models to express the level uncertainty (e.g. error bars) of both the underlying data sets and the outputs of assessments. Any recognised gaps in data, assumptions made, or principles applied need to be recorded and made available to stakeholders.

From this research it is clear when determining data sets to support a multi-scale framework: 1/ a large number of data sets are necessary to develop the required maps and models; 2/ to be included data sets must provide full coverage of the largest area able to be assessed using the framework; 3/ for increase credibility of maps and models data sets should have a peer reviewed journal article; 4/ to more easily integrate the framework with existing initiatives the use of existing data sets should be explored; and 5/ data sets should be scalable so to conduct integrated ecosystem services assessments across different scales. Foundational data sets required to support maps and models for ecosystem services assessments include: Land Cover, Land Use, soils, and those used to spatialise assessment units (e.g. habitats, ecosystems).

Participatory mapping and modelling was described as positive and a learning experience at local and national scales (Maynard et al. 2012; Petter et al. 2012). Leads in the US said "if you have people working with the model and developing the model they can learn more about the outputs" and “involving stakeholders in identifying the maps required is important to the acceptance and credibility of the final outputs”. Allowing participants to be involved in the development of data layers up front and "to work within their specialist areas of expertise" avoided the frustration of trying to standardise data later. Without stakeholder input the tools developed will likely be “more complex” than stakeholders require or have capacity to use. The result of a tool increasing in complexity and requiring high resources is potential reductions in the use of the tool by the broadest range of stakeholders. The development of a blueprint or guidelines to ensure a level of consistency in mapping and modelling across stakeholders is recommended; but this should not be too prescriptive so to allow “innovation” in research and flexibility of approach to assessing ecosystem services.

Obtaining credibility through peer review is important to a multi-scale framework, as shown by programs at all scales producing academic journal articles that communicate elements of the methodology and how the research built on the current state of knowledge of ecosystem services. This development of journal articles also legitimises and incentivises scientist's efforts to develop such documents. The usefulness of large technical reports (beyond academic studies) is questionable due to their "awkward' size, weight and "depth of detail". Synthesis and summary publications (generally glossy and highly pictured) tailored to specific and general audiences are more useful (MA 2005f; TEEB 2009, 2014; UK NEA 2011a). Grey literature such as fact sheets, conference proceedings and short project reports are important to produce for communicating at local and regional scales. The development of journal articles, technical reports, synthesis reports and grey literature to support a framework shows the need for longevity of access to information and tools supporting a framework.

A 'central platform' to house the information and tools (described above) making them free and easily accessible to external stakeholders with different capacities is fundamental to the usefulness of a multi-scale framework. As one of the ways an audience judges the legitimacy of a process is by who participated and who did not (Cash et al. 2002), providing details (similar to the UK NEA) on this platform of who was involved in the development of the framework improves transparency and legitimacy of the program and framework. Consideration of the different resources (e.g. time, money, expertise, ability) to develop and maintain websites and reports by coordinating organisations during and after the funding for the program ceases is required when determining, designing and developing tools to communicate the framework and program. As well, consideration of stakeholders' capacity to access, understand and apply information and tools.

The following section discusses this synthesis of empirical findings into the process to apply to develop a multi-scale framework and the information and tools to support it in terms of their contribution to ecosystem services research.

8.2 Contributions to research

The first key contribution of this research is analysing drivers influencing processes applied to develop frameworks and the information and tools supporting them (methodologies). Chapters 1 and 2 introduce the MA whose intent was to be used 'as a framework and source of tools for assessment, planning and management' (MA 2005d, p. x). Although over the past decade the MA has been adopted by many leading global programs (Fischlin et al. 2007; WRI 2007; Secretariat Ramsar 2008; WBCSD 2011, 2012; CBD 2013), many other programs have either adapted elements of the MA framework (Maynard et al. 2010; Townsend and Thrush 2012) or developed a new methodology that shows little resemblance to the MA at all (EPA 2008; Haines-Young and Potschin 2013). There has been little exploration into why methodologies differ and therefore we have little knowledge of the implications of these differences to conducting assessments and deriving outcomes. This research provides a new understanding of the drivers, motivations and contexts that influence how ecosystem services assessment initiatives are shaped.

The second contribution made to research is the in-depth analysis of three methodologies developed in different context (e.g. different scales, countries, coordinated by different organisations, having different resources) and the bringing together of these empirically. Cross-analysing these methodologies (and those discussed in the literature) revealed where and how processes, information and tools developed in one context may not be relevant to others (MA 2005d). For example, the UK's use of Broad Habitats as assessment units (because the information currently exists; it is used in EU policy), would not be applicable to those in the US developing a framework (as Broad Habitats do not cover the US; US national environmental policies are not governed by the EU; it may not be socially accepted due to cultural differences on biodiversity; and it would be less useful to the EPA who do not have biodiversity as their mandate). Findings from this research are thought to have applicability to all nations (e.g. Australia) or other geo-jurisdictional areas (e.g. Murray Darling Basin) grappling with how to identify an appropriate framework to use or to develop one to suit their context, and what information and tools are required to support it.

The third contribution made to research is the Recommendations drawn from findings of the analysis of different methodologies through different research approaches, and the cross-analysis of these. The application of these Recommendations by researchers and programs will improve the transparency of approach to determining a methodology; and reduce the influence of any presupposition towards a methodology held by the researcher or the program's coordinating organisation. These Recommendations advance the knowledge of researchers working in the ever-expanding field of ecosystem services assessments, as these Recommendations will assist them to identify in a more sophisticated and explicit manner the appropriate process, information and tools.

The fourth contribution made to research is the analysis of methodologies developed at different scales. Nelson et al. (2001, p. 1) state 'what is needed [in ecosystem services research] are approaches that combine the rigor of the small-scale studies with the breadth of broad-scale assessments'. This was achieved in this research by conducting applied research at the regional scale in SEQ and case study analysis of (multi)national scale programs in the US and UK. This analysis provides two insights into scale: 1/ how the scale the framework was developed at influences and shapes methodologies for ecosystem services assessments; and 2/ the potential to scale up or scale down processes, information and tools for ecosystem services assessments. Scale was shown to highly influence the information included in frameworks but have little influence on the type of process applied to develop them or the tools included. As our ability to scale up and scale down data and information will influence our ability to design and carry out coherent policies and programs at different scales, tiered classification systems for elements of the framework (e.g. assessment units, classification systems) are required to support multi-scale assessments. The strengths and limitations of this research are discussed next.

8.3 Strengths and limitations of the research

The strengths of this research are its three pronged approach to analysing methodologies (i.e. document reviews, applied research and multiple case study analysis); the variety of sources and research methods used as part of this investigation (e.g. web searches, observations, notes, semi-formal semi-structured interviews); and the structure of the thesis. No individual research approach could cover the breadth and depth of analysis required to capture drivers that underpin methodologies developed in different contexts. The three pronged research approach combined the strengths of individual approaches such as the relatively cheap and easy access to documents that allowed a broad range and large number of methodologies and schools of thought developed over the past decade to be reviewed; and the ability of applied research and multiple case studies to analyse more recently developed methodologies in-depth.

Applying the three pronged research approach allowed a variety of sources and research methods to be used, combining the strengths and addressing the limitations of each method (Stakes 2006; Sarantakos 2005; Yin 2009). For example, documents and websites are important to providing background information on methodologies or to gain an understanding of a particular element of a methodology, but unlike interviews, documents and websites lack the ability to further scrutinise and probe for the further development of ideas or issues that I or other researchers considered important. Designing and coordinating workshops, think tanks and expert panels with stakeholders in SEQ provided a unique insight into potential problems that can arise in developing a framework in a ‘real world’ policy and planning environment. The interviews conducted in the US and UK addressed the issue of my influence in the development of the SEQ methodology by exploring in-depth contextual nuances underpinning methodologies developed without my influence.

Section 3.4 foretold of the large volume of data and information predicted from this research and that it would be collected and developed in a non-standardised format. The three Lines of Enquiry were therefore fundamental to breaking this research into tractable and comparable components. To provide ease of comparing and contrasting drivers and associated methodologies, these Lines of Enquiry and their key topics were also used to structure Chapters 4, 5 and 6 analysing the SEQ, US and UK methodologies. At the risk of being repetitious but to ensure the sequence and logic of the research, Chapter 7 was structured similarly to 4, 5 and 6, with key topics providing sub-sections and focal points for cross-analysing these different methodologies. Structuring this thesis in this manner strengthened this research by providing a transparent, consistent and robust approach to synthesising and communicating the research outcomes. While the three Lines of Enquiry worked effectively, Appendix 9 indicates strong interconnections that future work should not overlook.

The limitations of this research are its scope; method constraints (including my capabilities and influences); and the practical realities of conducting research (i.e. time, location and budgets). Beyond the scope of this research was discussion on the temporal or geo-jurisdictional scales of ecosystem service provision; or outcomes of the application of information and tools (frameworks) to assess ecosystem services. As Chapter 1 forecast, this research also did not delve into the pros and cons of biodiversity or ecosystem services approaches. The breadth of this research topic also meant that although there were specific areas within each Line of Enquiry that that would benefit from further analysis this research remained at the higher level only providing brief details on each key topic. It is recognised this research is merely an in-depth study into one aspect of a much larger field of research into how to identify, measure and value ecosystem services (across scales).

Methods to extract information and data under the Lines of Enquiry were different for each research approach. Methods under the applied research in SEQ and case study analysis in the US and UK provided the most opportunities for researcher bias. By facilitating workshops, expert panels and think tanks I inevitably played an influencing role in developing the SEQ methodology. Also, the data was developed or collected from less orthodox methods (e.g. in the form of reflections, conversations, maps and memos to self) than those under the other approaches (e.g. web searches, interviews), so I often had to make sense of and interpret information in terms of the meanings stakeholders brought to them. In the interviews conducted in the US and UK case studies bias is also possible in the design of research questions, the delivery of questions, as well as in the interpretation of responses. Retaining confidentiality of Leads through anonymity created limitations to detailing case study findings and their sources.

The practical realities of conducting research such as time, location and budget provided limitations. Applied research and case study analysis using interviews are money and time intensive hence limiting the number of cases that can be studied. More studies would provide greater insight and if case studies using developing countries could have been included this would lead to more robust results and greater relevance to these nations. In large programs such as the ESRP and the UK NEA there are many suitable and desirable people to interview but again within the realms of time, location and budgets it was only possible to interview a limited number of people. These same practical restraints also prevented analysing projects or case studies (e.g. place-based studies, sub-global assessments) nested within the broader scale frameworks analysed (e.g. the US, MA); and analysing any follow-up stages to case studies such as Phase 2 of the UK NEA, and the Sustainable and Healthy Communities Research Program of the US ESRP.

A goal of this thesis is to relay the most accurate and comprehensive account of activities on which understanding and research constraints permit. Triangulating outcomes of the applied research with those from document reviews and multiple case study analysis strengthened and challenged the methods used and outcomes derived from individual approaches generating greater rigour and robustness of conclusions. Sometimes there can be a tendency to dismiss overseas work as not relevant for other country contexts. However, from the position of ecosystem services all communities are equally dependent upon healthy ecosystems to underpin their daily lives and economies. The following sections discuss avenues and opportunities for building on this research.

8.4 Future Research

This research reconfirms the premise that a multi-scale framework (rather than a single-scale or single purpose framework) is needed for nested, interlinked, but semi-independent ecosystem services assessments to be conducted across a nation at various scales and levels of organisation (MA 2005d; Reid et al. 2006a; Ash et al. 2010). The MA supports the conducting of multi-scale assessments ‘because it better reflects the multi-scale nature of decision-making, allows the examination of driving forces that may be exogenous …, and provides a means of examining the differential impact of ecosystem changes and policy responses on different regions and groups within regions’ (MA 2005a, p. 8).

By analysing ecosystem services assessment methodologies developed in different contexts, this research has provided a new understanding of the drivers that influence how ecosystem services assessment initiatives are shaped and what an appropriate methodology for ecosystem services assessments across multiple scales should contain. It is recognised, however, that if more case studies were analysed in depth a greater understanding of drivers influencing the development of methodologies could be achieved. As well, although it is considered the Recommendations have relevance to all nations grappling with how to develop ecosystem service assessment methodologies, to better understand the applicability of Recommendations to less developed nations than Australia, the US and UK, further analysis of methodologies from less developed nations would certainly advance this research.

In terms of the process to develop a framework, fundamental to its development is national government support through the provision of adequate funding. To ensure the credibility, legitimacy and saliency of the final product to stakeholders careful thought is required into who should lead the program, what organisation should coordinate the development of the framework, and the structure of the program. The challenge then is to create the scientific and political space within a nation to allow different knowledge systems (e.g. GIS, expert and empirical knowledge) and knowledge holders (e.g. Indigenous, local persons, scientists, economists, policy makers) to inform each other both top-down and bottom-up. Further research into dynamics, discourse and power relationships within and across stakeholder sectors would benefit decisions regarding the lead, coordination and program structure required to maximise information and impact benefits potentially resulting from the development of a multi-scale framework (Reid et al. 2006a).

For an ecosystem services framework to be accepted, developed and implemented by stakeholders a paradigm shift from traditional schools of thought and approaches to conserving biodiversity and nature for its own sake, to one of conserving biodiversity and nature for people’s sake, will be required by some nations. Although the use of existing information (e.g. definitions, classification systems, assessment units, valuation methods) can improve the integration of a new framework with current initiatives it cannot be assumed information developed for previous programs under different paradigms of thought are appropriate to support an ecosystem services framework Investment in the form of time, money and stakeholder engagement is necessary to identifying information incorporated in current initiatives, knowledge gaps, and to develop new forms of information suitable for ecosystem services assessments. While research has been escalating globally on how ecosystems provide benefits to humans, the effects of human well-being on ecosystem service provision is a significantly under researched area requiring further attention.

To reduce impediments to stakeholder decision making at multiple scales the tools developed to support a framework should assist stakeholder understanding of ecosystem services concepts and/or allow for the comparative analysis of ecosystem services and the impacts of decisions on human health and well-being (EPA 2008). What tools will effectively support the decisions of different stakeholders will vary across stakeholders, as different stakeholders will require different types and scales of information and they have different capacities to understand, develop and use tools. Flexible and non-prescriptive tools and guidelines developed in collaboration with stakeholders will assist in understanding the complexity of tools required by them, remembering as complexity increases the range of stakeholders able to apply the tools decreases. A central platform is required to house information and tools for free and easy access and use by stakeholders; discussions with stakeholders into what this platform might look like would be beneficial.

Theoretically, the knowledge gained from the application of a multi-scale framework would allow for transparent links to be made between national economic systems, markets, state and local government planning, resource use and protection, conservation policies and programs, investments and incentives, and on-ground property management. The consistent application of a coherent framework would enable practitioners and decision makers to monitor and evaluate ecosystem service provision over long time frames, set targets, clearly state objectives, communicate findings and coordinate actions. Further research is required into how a framework can enable the environmental, social and economic costs and benefits of natural resource degradation and management to be better incorporated into relevant policies and programs at different scales.

Beyond the theoretical however there are practical realities of applying a multi-scale framework and managing for ecosystem service provision across a nation. A question requiring further research is what kind of institutional and governance structures will facilitate their management across geographic, political, and temporal boundaries within a nation. The evaluation of ecosystem services through application of the multi-scale framework will assist with determining which stakeholders can effectively manage which services and the ecosystems that underpin their provision. Mechanisms are needed to improve accountability for decisions that affect ecosystem services. Fundamental to sustainable development is the question of how to manage ecosystem services at the appropriate spatial scale whilst also recognising the cumulative impacts of our decisions. Just as collaboration across stakeholders is paramount to developing a multi-scale framework so too is collaboration between stakeholders managing for service provision.

The key finding derived from this research is the process applied to develop a framework, is just as important, if not more important, than the information and tools (the framework) developed!

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Appendices

Appendix 1: Key features of the process applied to develop the MA, SEQ, US and UK frameworks.*

Program / Feature	MA	SEQ	US	UK
Factors influencing program initiation	CBD; Convention to Combat Desertification; Ramsar Convention; Convention on Migratory Species	MA; population growth	MA; National Academy of Sciences report; existing policies; decrease in budget	MA; climate change; CBD Biodiversity Targets 2010; European policy
Call for research	UN Secretary-General in response to governments Party to the four conventions listed above	SEQ stakeholders through the NRM Plan workshops & RLOSAC	US EPA ORD	DEFRA - based on a report by the House of Commons Environmental Audit Committee
Funders	Global Environment Facility; UN Foundation; David & Lucile Packard Foundation; & World Bank. Additional support by International Agricultural Research; Food & Agriculture Organization; Government of Norway; Rockefeller Foundation; UN Development Program; UNEP; National Aeronautic & Space Administration	Originally federal government - then state government, after federal elections & political parties & funding programs changed	Federal government	NERC; ESRC; Northern Ireland Environment Agency; Scottish Government; Countryside Council for Wales; Welsh Assembly Government; DEFRA
Scale of program**	Global Area: 510 072 000 km^2 Population: 7 293 000 000	Regional Area: 23 000 km^2 Population: 3 500 000	National Area: 9 181 000 km^2 Population: 322 500 000	Multi-national Area: 243 000 km^2 Population: 63 500 000

* See Acronym list (page xviii) for translation of acronyms.
** Area and population numbers were obtained from the Australia Bureau of Statistics, Queensland Treasury, UK Office of National Statistics, US Census Bureau, Worldometer and the World Atlas on 1 December 2015. Each area is rounded to the nearest thousand. Population numbers are rounded to the nearest half million.

Program / Feature	MA	SEQ	US	UK
Coordinating sector	Non-government organisation	Non-government organisation	National government	Non-government organisation
Coordinating organisation	UNEP	SEQC	US EPA	UNEP-WCMC
Program aim(s)	1. To assess the consequences of ecosystem change for human well-being 2. To establish the scientific basis for actions needed to enhance the conservation & sustainable use of ecosystems & their contributions to human well-being	1. To develop an 'agreed' ES framework for SEQ 2. To incorporate ES & the framework into NRM, planning & policy in SEQ	Vision: Contribute to theory & practice for characterising, quantifying & valuing ES, to ensure their relationship to human well-being is consistently incorporated into environmental decisions Mission: Provide information & methods needed by decision makers to assess the benefits of ES to human well-being for inclusion in management alternatives Goal: Transform the way decision makers understand & respond to environmental issues by making clear the ways our management & policy choices affect the type, quality & magnitude of ES	1. Assess the status & trends of ecosystems & the ES they provide at multiple spatial scales 2. Describe key drivers of change affecting ecosystems 3. Examine plausible futures (scenarios) for ecosystems & the ES they provide 4. Outline response options to secure continued delivery of ES 5. Value the contribution of ES to human well-being
Coordinator	2 x Co-Chairs	1 x Project Manager	1 x National Program Director	2 x Co-Chairs
# people	>1360 involved	1 assigned (> 190 involved)	272 assigned (> ? involved)	? assigned (> 500 involved)
Timeframe	4 years	4 years	5 years	2 years
Budget	US$24 million (over 4 years)	AU$80,000 (per year)	US$70 million (per year)	£1.3million (over 2 years)

Appendix 2: Questions guiding the semi-formal, semi-structured interviews with US and UK Leads. Questions are related to the three Lines of Enquiry, as well, interviewees were asked to reflect back on their program.

Line of Enquiry 1: *What is an appropriate process to develop a framework for ecosystem service assessments across multiple scales?*
What are your professional qualifications and training?
What is your position/specific role in the program?
What year did you begin working on the program?
Was anyone working in this position before you?
How many people in the program are working with you on your section of the program?
At what scale is your research taking place (e.g. site, regional, national)?
Were you given a time frame to complete this research?
What were the significant factors underpinning the establishment of the program?
What is the primary goal of the program?
What is the budget for the program?
Who are the funders of the program?
How did you identify the skill base required to conduct the research?
Would you say you applied a structured process or a more organic and adaptively managed process?
Were there discussions with other departments/ offices /organisations about working on the program together in some form of collaborative approach?
Was a stakeholder analysis conducted (in the beginning) of the program?
What do you think are the benefits and dis-benefits of government coordinating this research (as opposed to a non-government organisation, private or academic institution)?
What do you think is the role of government in developing ecosystem services assessment methodologies?
From your position, what do you see as the importance of stakeholder engagement in the development of frameworks?
What sort of process have you applied (in terms of stakeholder engagement) to develop your information and tools?
Based on your professional experience (not just within this program), what have been the benefits and dis-benefits of working collaboratively with other organisations, and even trans-disciplinary with other sectors and disciplines?
Would the program have different outcomes if different people were involved?
To what extent do you think the resources available to work on the program have influenced the process applied and the information and decision support tools produced?

What factors underpinned the choice of place-based projects?
Are the place-based studies equally funded?
What is comparable or different across the place-based projects?
How do you think (if at all) the scale of the place-based/sub-national studies has influenced the different processes applied in these studies?
Do you think the governance of the states/sub-nations has influenced the process applied or the information and tools produced in the place-based studies?
Line of Enquiry 2: *What information is required to support a framework for ecosystem service assessments across multiple scales?*
What type of information is required to conduct an ecosystem services assessment?
Who are the end users of the information and tools produced through the (multi)national program?
Who are the end users of the information (and tools) that you have developed?
How will the information you are developing be used/applied?
What scale are you predicting people will use the information you are developing?
How have you been extracting or collecting information for your research component (e.g. collaboratively, use of existing information)?
What do you think is the role of quantitative and qualitative information in ecosystem service frameworks?
What is the role of biodiversity in ecosystem service assessments? Is biodiversity an ecosystem service or not?
The terms ecological processes, ecosystem functions and intermediate services are often used interchangeably in frameworks, what are your thoughts on this interchangeable use of terms?
Are ecological processes assessed within your framework? Where does information on ecological processes sit within your framework?
What is the definition of ecosystem services you use in your research?
Is the definition of ecosystem services/FEGS/FES included in the program's lexicon/glossary consistently used across projects/researchers within the program?
Within your program/framework, is there a list of ecosystem services for consistent use by researchers/stakeholders?
How was the list of ecosystem services determined/developed (e.g. collaboratively, in-house, an existing list developed for another framework was used)?
In the literature, one of the criticisms of the FEGS/FES terminology is that it creates barriers between sectors and disciplines because different organisations and disciplines have different abilities to understand and use information on ecosystem services (e.g. when is a service an intermediate or final). What is your response to these thought paradigms?
Do you mean 'ecosystem services' when you talk about 'benefits'?
Does your role require you to work on the valuation of ecosystem services?

Is the program/project valuing ecosystem services in both dollar and well-being terms?
What is your opinion on monetary valuations and well-being indexes?
Have you received any preference from stakeholders for a particular form of valuation (e.g. in $ or scores)?
Who is doing the dollar valuations of ecosystem services for the program?
What do you see as the importance of stakeholder engagement in the valuation and prioritisation of ecosystem services?
What sort of ecosystem services valuations are the place-based/sub-national studies doing (i.e. monetary or well-being)?
Human health and well-being assessments are separate in your project, why is this so?
What type of information is required to conduct a human well-being assessment?
What type of information is required to conduct a human health assessment?
To develop a framework, do you start with assessing ecosystems and move through to well-being, or do you start at well-being and beneficiaries and move through to ecosystems? Do you think the direction will affect the overall design of a framework?
How often should information on human health and well-being be updated or reviewed?
How are you managing geographical and temporal scale issues in your assessment methodology?
How and where do you see your research fitting into the overall program?
What key pieces of literature have fed input into your research?
How are you planning to synthesise the information across the program?
Line of Enquiry 3: *What tools are required to support a framework for ecosystem service assessments across multiple scales?*
What types of decision support tools have been developed at the (multi)national scale to support the overarching framework?
How important is the development of a conceptual framework to support an ecosystem services framework?
Was a conceptual framework developed to support your overarching framework?
Was a conceptual framework developed to support each place-based/sub-national project within your program?
What information should be depicted in a conceptual framework?
How important do you think the use of scenarios are, and why?
What scale were scenarios developed at (e.g. (multi)national, place-based)?
How were scenario topics chosen? What or who determined the topic?
What do we need to consider most, or be most careful about, when developing and communicating scenarios (e.g. risks, robustness of scenarios, temporal and geographic scales)?

Were the outcomes of scenarios useful from a government perspective?
What sort of information do we need to develop maps and dynamic models for ecosystem service assessments?
What are some of the issues we should be aware of in terms of aggregating or disaggregating data and information in maps and dynamic models?
What maps and dynamic models are being used in the program?
Are all place-based studies/sub-national projects using both maps and dynamic models?
What types of maps and dynamic models are being used in the place-based studies /sub-national projects within your program?
What maps and dynamic models are being used in your section of the program? Why were they chosen?
How do you see your research interacting with the modelling and mapping components of the overall program?
Two common mapping approaches researchers use to assess ecosystem services are 'land use mapping' and 'land-cover mapping'? What do you think are the differences (including benefits and dis-benefits) of using each of these approaches?
What scale are the maps you are developing?
What are the most common data sets underpinning your maps?
How much did you rely on existing data sets? Were data sets specifically developed to support your framework?
Were there any prerequisites underpinning or determining the use of data sets to support maps or dynamic models?
What resources were required to develop maps and dynamic models supporting your framework (e.g. money, time, skills)?
What do you think are the benefits and dis-benefits of maps and dynamic models as tools to extract and communicate information on ecosystem services (and their use in isolation)?
How are you planning to deliver information and decision support tools to stakeholders so they can conduct ecosystem service assessments?
In what form(s) have you documented the framework and its development (e.g. technical reports, fact sheets, websites)?
Have you/ are you tailoring reports, websites and other forms of media for specific audiences?
Reflecting on the Program
What do you think are the limitations of the approach you have taken to develop the framework?
How do you think, if at all, the resources made available (e.g. staff, money, time) have contributed/influenced the process that was applied as well as the information and tools that were developed?
Reflecting back, do you think there were any sectors or stakeholders that could have been engaged better in the process, or were under-represented?

Looking back at the program and what you have done to date, is there anything you would do differently if doing it again? What has worked well and what hasn't?
How will you measure the success of the overall program?
How will you measure the success of your section of the program?
If you had unlimited resources, what would be the next steps in your research? How would you build on your research from here?
Do you have a 'wish list' for future resources for your research?
Do you have a wish list for the next phase of the program?
How are you planning to synthesise information across the program?

Appendix 3: The tertiary qualifications held by the Project Manager for the SEQ program, and the 13 US and 17 UK Leads interviewed; and the number of Leads holding each qualification in each program.

Qualification	SEQ*	US	UK
Biology	-	7	4
Ecology	-	5	2
Behavioural ecology	-	-	1
Systems ecology	-	2	-
Population ecology	-	-	1
Antarctic marine ecology	-	-	1
Evolutionary ecology	-	-	1
Comparative ecology	-	-	1
Physicist	-	-	1
Biochemistry	-	1	-
Zoology	-	2	5
Natural science/environmental science	1	3	3
Marine science	-	2	-
Marine biology	-	-	1
Plant science	-	1	-
Botany	-	1	-
Forestry	-	1	-
Limnology	-	1	-
Agricultural engineering	-	1	-
Biological oceanography	-	1	-
Statistics	-	2	-
Biometrics	-	1	-
Policy	-	1	-
Philosophy history & policy of science	-	-	1
Environmental management	-	1	1
Natural resource management	1	-	-
Land reformation	-	-	1
Psychology	-	2	-
Public health	-	2	-
Human geography	-	-	1
Geography	-	-	1
City planning	-	1	-
Economics	-	-	3
Chartered surveying	-	-	1
Participatory approaches	-	-	1

***** The qualifications of those working on the SEQ program on an ‘as required basis’ (i.e. Professor of Economics, the Manager Planning and Innovations, and the two Cartographers) are not recorded in this table. Only the qualifications of the Project Manager are listed as this was the only position funded through the budget for the program.

Appendix 4: The structure of the MA, SEQ, US and UK programs in terms of who was engaged and the roles they played in the development of the framework.*

Who	MA	SEQ	US	UK
Coordinating Organisation or Secretariat	**Who:** UNEP (& 5 other institutions provided Secretariats for sections of the MA program). **Role:** To coordinate the development of the framework; coordinate different assessment activities; core administrative activities; host coordinators & logistical & technical support to the working groups & committees; administer grants; coordinate engagement & outreach & internal meetings.	**Who:** SEQC **Role:** To coordinate the development of the framework; core administrative activities; facilitate & provide logistical & technical support to the working groups & committees; develop tools; coordinate engagement & outreach.	**Who:** US EPA **Role:** To coordinate the development of the framework; core administrative activities; logistical & technical support to Leads; develop tools; coordinate engagement & outreach.	**Who:** UNEP-WCMC. **Role:** To coordinate the development of the framework; coordinate different assessment activities; core administrative activities; facilitate & logistical & technical support to the working groups & committees; develop tools; coordinate engagement & outreach.
Board	**Who:** Users; audiences for findings; key partner/funder institutions; governments; scientific communities; civil society; private sector. **Role:** To ensure the MA produced information & built capacity needed by users at multiple scales; to appoint Directors & Chairs of the Assessment Panel & Working Groups; to approve the budget & work plan; to select institutions for administrative support; to receive & approve findings.	-	-	-

* See Acronym list (page xvii) for translation of acronyms.

Who	MA	SEQ	US	UK
Steering Group	-	**Who:** Funders; potential key framework users; program partners. **Role:** To oversee the development of the framework.	-	-
Client Group	-	-	-	**Who:** A 12 member group of organisations who commissioned & funded the program (DEFRA, administrations of N. Ireland, Scotland & Wales, NERC & ESRC). **Role:** To provide guidance & oversight.
Assessment Panel	**Who:** Co-chairs of each working group; three at-large members; & the Panel Co-Chairs. Members were appointed by the Board & were selected to reflect the diversity in the MA; balance North/South, natural & social sciences & gender. **Role:** To direct the scientific process.	-	-	-
Expert Panels	-	**Who:** Approx. 60 referred technical experts with expertise in defining & assessing indicators of biodiversity, ecosystems, services & community well-being & their characteristics in SEQ. **Role:** To develop the information to support the Framework.	-	**Who:** 27 of the UK's leading natural scientists, economists & social scientists sourced from academic institutions. **Role:** To design & lead the assessment process - to provide separation between information produced & government agendas.

Authors	**Who:** Over 1300 authors from 95 countries organised into 4 working groups; together with 44 governments & 9 affiliated scientific organizations; **Role:** To write & produce technical documents & reports.	-	-	-
Working Group	-	**Who:** An open forum of stakeholders from local, regional, state & national scales. **Role:** To oversee more detailed technical aspects & to ensure outputs have relevance to a broad range of stakeholders.	-	-
User Group	-	-	-	**Who:** A 22 member group with representatives from gov't, NGOs & the private sector. **Role:** To inform the approach & to ensure outputs have relevance for different audiences.
Peer Review	**Who:** 44 governments & 9 affiliated scientific organisations, over 600 individual reviewers worldwide; overseen by an independent Board of Review Editors composed of Chapter Review Editors. **Role:** To ensure all review comments were adequately handled & responded to by authors.	**Who:** The Working Group - an open forum (Think Tank) of stakeholders working mostly at local, regional & state scales. **Role:** To review each step of the program as it evolves.	**Who:** SAB & the BOSC **Role:** SAB - to advise the EPA on technical matters; BOSC - to provide advice, information, & recommendations about the ESRP.	**Who:** Invited independent reviewers. **Role:** To provide peer review.

Appendix 5: The role of biodiversity in ecosystem services assessments as described by Leads in the US and UK programs. Responses from US Leads are numbered 1 to 9. Responses from UK Leads are numbered 1 - 17.*

Question: ***What is the role of biodiversity in ecosystem services assessments? Is biodiversity an ecosystem service or not?***		
#	**Y/N**	**US Ecosystem Services Research Program**
1	No	Biodiversity (b'diversity) is an important structural component of ecosystems. Therefore, what & how ecosystems produce components or attributes people care about are dependent upon b'diversity. However, few 'normal people' value b'diversity & therefore it is not a FEG. It could be an 'ecosystem service' (ES) since ES, while fairly clearly defined, are not rigorously & consistently utilised in the scientific literature.
2	?	The threats to b'diversity are very real – whether you tackle that with ES language or with basic conservation isn't as clear to me because how do you value b'diversity? This is more philosophical than for our agency practical. As a regulatory agency we tend to be more pollutant regulatory orientated in nature – so our methods of environmental problem solving haven't involved l& use which is key to protecting b'diversity – so we don't have as much authority through legislation to tackle this so it is an interesting problem of how & where to tackle it. I haven't given it much thought as to whether it is an ES or underpins ES. As a nation we are not quite oriented in that way (i.e. towards b'diversity).
3	No	It supports the continued provision of ES (i.e. one animal could do everything for you – but if you have five animals that could do that job for you then the ES will continue). B'diversity is the insurance policy for ES in that basically, if you have redundant functionality due to a diverse biology those functions are going to be more resilient to disturbances.
4	Yes	It absolutely is an ES. There is a public perception of b'diversity that gives them comfort to know there is a lot of different types of animals & organisms out there & there is a more professional perception of b'diversity that in order to maintain the services that ecosystems provide there needs to be certain amount of resiliency & redundancy in that functionality in order to ensure the continued existence of those ES & is one of the drivers in that resilience & redundancy.

* See Acronym list (page xvii) for translation of acronyms.

5	No	B'diversity is not an ES. People do value it obviously, but it is too subjective (i.e. if I remove 25% of the b'diversity in an area what happens to that area?) That kind of research has never been done – to me it is a faith-based measure – it makes sense, the arguments are perfectly reasonable, but I just don't see that as the kind of quantitative information we can get & use on ES – so I think it is something different to ES. I think you can do a pretty good job at damaging b'diversity & still do a really good job at ES – the two do not necessarily have to be compatible.
6	No	I do not believe that b'diversity in its own right is an ES, but I do believe that providing habitat to maintain b'diversity is an ES. We have proven as a society that we care about b'diversity, because we send so much money to non-government organisations; we have international organisations in place whose entire role is to preserve b'diversity. So for that reason alone, I think, it's okay to say that providing habitat to preserve b'diversity could be a recognisable service. But I also think that it is something that we have to pay attention to no matter what.
7	Yes	Certainly existence value if nothing else but there's all kinds of things that b'diversity enhances in terms of quality of life. I do think it's important. I think a lot of people care about b'diversity even though there are also many people that say it's not that important. It's one of the services & there are enough people that care about it & certainly there are other federal agencies [who deal with b'diversity].
8	No	When I think about ES I would say we tend to talk about FES. No, b'diversity is not a service. Unless you're talking about existence value, but in my opinion that's not what the MA was about, existence value for people who care about the environment. Those people 'are' going to care about b'diversity. But, I've seen b'diversity be very important to contributing to a service like pest regulation. I guess, it's the R selected species that proliferate wildly? So you need to have enough K selected species to keep those in check. That's a critical role of b'diversity to have that compositional component in the environment of the different species. Then there's structural diversity & diversity at different scales again, genetic to landscape. I think if we're taking a very utilitarian view of the ecosystem in order for people to value it and protect it, they need to know what's in it for them. Also when you talk about something like food production, we really want b'diversity and genetic diversity in those food species too because monocultures can get wiped out so diversity will enable resilience. It's not a service in and of itself. So I think there's more – it's more than just b'diversity to get to the service. It's totally essential. But it's not the end service.
9	No	B'diversity is more of a structural thing – a system that has higher b'diversity will be stronger & more robust in its delivery of ES & will therefore sustain ES better & they will be able to withstand insults better – so I do not think it is an ES itself but a component of the matrix of the integrity of the ecosystem.

#	Y/N	UK National Ecosystem Assessment
1	Yes	B'diversity is clearly a very important part of ecosystems. It is certainly associated with the function of ecosystems & delivering lots of other ES. I don’t think all of b'diversity is necessarily an ES. Some aspects of b'diversity are ES, as they provide ES in their own right. Therefore, the numbers of birds that you see, those birds actually provide enjoyment to people & inspiration & many cultural services. At another level, the microorganisms in the soil that will detoxify pollutants are providing another service. In that case, I think it’s the regulation service that’s actually the ES. It is not the b'diversity itself. Without the b'diversity the ecosystem wouldn’t be an ecosystem because it’s a combination of living things in their environment. Sometimes b'diversity is an ES when it’s actually appreciated as b'diversity. Some of the delight that people take in nature is the fact that it’s hugely complex & diverse & they know that there are lots of different organisms around & that in itself is a cultural ES. I think it’s a bit more complicated than saying b'diversity is a service.
2	Yes	We vacillated backwards & forwards on this. You can either count it as an ES or not. One way of counting it as an ES if you want to, & it doesn't matter you can go either way – is the diversity itself gives you more resilience to environmental change, or to any threat to it. Therefore, b'diversity itself, by the fact it is diverse, is an ES to give the system resilience. It doesn't matter at the end of the day. Who cares? B'diversity – I mean, with no b'diversity you don't have any ecosystems, let alone ES. So does it matter where you call it a service? It was controversial. I think in the end we did count it as an ES in the UK, whereas we did not count it as an ES in the MA. It really doesn't matter.
3	Yes	It's both process & ES, & you have to just acknowledge that. As a final ES, things like wild species diversity are both a provisioning & a cultural ES. That's one of the problems we had. Undoubtedly wild species diversity produces medicines; produces things we can eat as well, like mushrooms. At the same time, wild species that we don't harvest, we culturally value. I think b'diversity has to be in there as a driver of change; you know, as something that is one of the processes affecting ES, because b'diversity to me isn't just some sector. It's about the different species interacting with each other & creating environmental change. It's whether you could come up with different terms ... I sort of batted down, that, we talk about b'diversity as a driver, & then we just talk about species. No, people didn't want to go down that route, & I can sort of understand there's not enough writing about it, so we come up with this three-way division. My view is, yes, it has to be in there, & I think it moved things on by putting it in ecosystem assessments, because otherwise for too long b'diversity has been treated separately. I think there's, at times, a public policy backlash against it. 'We're valuing animals over humans' is the constant thing you hear when people hear about b'diversity designations. By separating b'diversity, you separate out certain species from humans & therefore people don't see the linkages. It's actually bringing b'diversity back into a broader environmental debate that to me is valuable for b'diversity.

4	Yes	It's really confusing because it's difficult to characterise different people's perspectives but we talk about two really. There's perspective on this which thinks of b'diversity as an ES - this is the species based conservation view. These people just think of ecosystems as producing b'diversity that has got conservation value. The reason that's a dodgy opinion in terms of thinking about ES more generally is that it fails to recognise all the functional roles of b'diversity that nobody actually cares about in a conservation sense. You know, microbes, fungi, lower plants, all the skrotty organisms that have no public kudos. Their functional roles don't play any main role in the conventional conservation assessment of b'diversity. So those people think of b'diversity as an ES. There's a kind of ecosystems perspective, which actually is the opposite which thinks about b'diversity as a functional part of a system. So it isn't a service its actually part of the processes that underpin them. It would be more an intermediate ES, that view is a threat to the conservationist's view because they see ecosystem assessment & ecosystem approaches as a way of effectively focusing on things that are useful. They're both right, b'diversity fits into this system both as a part of the engine room of an ecosystem that makes it work. It fits in because it is a final ES in some ways. It's also a 'good'. Actually most of conservation is about b'diversity is a 'good' because it's actually the organism itself or the species that has value. If you look at the whole framework, it fits in three different places - "What role did it play in processes? What role does it play in services? What role does it play in goods? & how does that vary from b'diversity group to b'diversity group?"
5	?	Because we have a system which would in theory at least deliver b'diversity action, it seemed logical to me that b'diversity forms part of this. B'diversity is an intrinsic part of how an ecosystem works. You have lots of different bits of b'diversity, or b'diversity going on to delivering an ES, so in that sense its part of it. It seemed to me that perhaps there is an argument - & people who champion b'diversity would disagree I'm sure with me - but there seems to be an opportunity in this that in effect is potentially a new way of thinking about things across the environment. I don't know if b'diversity is an ES. I think it's part of delivering a variety of ES. There might be an assumption that a sustainable healthy ecosystem might be something more biodiverse than another one that isn't as sustainable, & seemingly there's a presumption that by looking after your b'diversity you will look after ES delivery - that might be a pretty obvious assumption to make. B'diversity is part of this rather than the other way around.
6	Yes	It's definitely an ES in a cultural sense. I think both particular habitats - which are representative of a degree of b'diversity - are culturally incredibly important. So up here these heather moors are generated by man, they've been around for 200 years, they are very much part of our cultural landscape. The Scottish brand is sort of open heather moor, the sort of relative wilderness as far as we get wilderness in this small country. Also, it's very clear that b'diversity is absolutely fundamental to provisioning & regulating services, but its micro-organism diversity. Of course the whole b'diversity thing in terms of particularly conservation agencies & the public view is it's about charismatic animals & plants & charismatic places & habitats. But the fundamental microbiological fungi microorganisms & all the lower plants, that we wouldn't have a natural water purification without those sorts of things, or wouldn't be able to grow crops with the sort of yields that go with that. So it's really important to recognise how fundamental some elements of b'diversity are for delivering other ES.

7	Yes	I don’t think it is & I think it is - it’s something that underpins some of the ES – pollination is a very, very clear & direct link e.g., one of the regulating ES where b'diversity is critical for those world pollinators; no question about it. Some of the other ones – e.g. if we look at soils & we look at greenhouse gas fluxes there appears to be a large amount of functional redundancy so you can zap 90% of the population that’s there & you can probably still get (in terms of soil microbes) largely the same function. It really is context-specific & talking about b'diversity for b’diversity’s sake is important but it’s not the same thing as calling it an ES & incorporating it as an ES. You can go with the ES framework & treat b'diversity as yet another important underpinning condition to allow the ecosystem to deliver that service & that would probably be, in a consistent framework, that’s the way I would look at it. There is the idea that b'diversity, in itself, is something that we as humans might consider a good or benefit. If we consider it as one of the goods or benefits of the ecosystem then we can value it in that way as a separate thing. I wouldn’t see why there’s necessarily a tension between the two but I can see why there’s confusion among the stakeholders of thinking that b'diversity is a “good thing” without considering its role. The whole point of ES is to consider all of these different things & balance them up so b'diversity should be in the mix but unless we, as a society, decide that we want to protect it per se, as a separate thing, & then it belongs in the mix, not over the mix.
8	Yes	I’m in agreement with the side that says “b'diversity underpins a lot of our services”. In some cases you don’t need to have really rich b'diversity to get the certain service out of it but I think it still underpins a lot of it for the most part. I see it as a service. I think it’s something that we rely on & it’s something that we get benefits from in all sorts of different ways & in all different aspects of various services as well.
9	No	B'diversity in a sense can become a stumbling block within ES because it is the one issue that seems to engage people more in ES, or people see it as being all about b'diversity. I think that the key to that also is that people then focus on the actual species, or what they call keystone species, or the actual – koala bear or the lizard, or whatever that they love in their area. They don’t actually then think about the health of the habitat, one step back in a sense. So that is part of the problem … Also the other problem with all this is if you focus too much on the b'diversity associated with a particular habitat you can end up trying to manage that habitat, & putting millions & millions of dollars or pounds into managing that habitat for a particular species, when in actual fact because of climate change & wider environmental change that habitat would not support that particular b'diversity species. So you can end up putting a lot of money into trying to stop change, some change is going to go on anyway & this is where b'diversity needs to be seen as a critical part of the project focusing on the b'diversity really matters as a path of that particular habitat. That is the challenge, & I think getting b'diversity interests to look at it from that point of view, & to recognise that we will lose some species in some regions, but we would also gain some. What we really need to be focussing on is managing that ecosystem, that habitat for the benefit to keep it healthy, but different species may be actually a part of keeping that healthy. I think to me it {the service] would be habitat not b'diversity, so I wouldn’t have b'diversity in its own right, no I would have the habitat types as opposed to the b'diversity.

10	Yes	It is & it isn’t. It can be an ES & it can also be to do with functions or structures & process. The program has three components of b'diversity in ecosystem assessments. So an iconic species - going out & doing bird watching in that sense is an ES. A worm in my garden is an intermediate ES in the sense that it produces good quality soil & I can grow carrots which might be the final ES. So b'diversity can be everything. You can’t have ES without b'diversity. I sign up to the MA where b'diversity in that conceptual framework, it’s at the bottom. The reason people have come up with the ES argument is the argument about the importance of b'diversity, not just the number of species but the functional diversity. Once you start diluting ES & saying it is any natural output from the environment, then I think we start to weaken that. So there was quite a discussion e.g. should we have a chapter on geodiversity? I've been in discussions with people in Europe saying salt is an ES. Marine aggregates are an ES. Snow is an ES. Now, I don’t deny that these are all natural products but I don’t think they’re ES in the sense they are things immediately generated by living processes. So I’m a bit of a purist - I think ES are contributions which living processes make to human wellbeing.
11	Yes	I don't think we have any inkling of how much or what there is that may go that we might wish we still had in terms of all sorts of things, like medical things. There's things out there that can help you get better that you don't even know about. So I would say that you just have to keep as much as you can of it – at least representative populations of whatever you can, wherever you can find them, because you never know how in the future they may be useful to you. So I don't know what the full role [of b'diversity is] – I don't know the answer to that question at all. But I just think that we do have to look after b'diversity definitely – because, ES kind of means different things to different people, & it depends which kind of services you're talking about. Yes, it would be on the list, yes, yes, definitely, yes.
12	Yes	I would say it’s fundamental to the delivery of some of the ES, whereas the ES approach maybe moves the focus from b'diversity directly, it certainly draws attention to the fact that it’s there, supporting, it has a supporting role. Sometimes also more directly, people visiting b'diversity for example is a cultural service. I think it’s a really interesting way of thinking about b'diversity & outlining that it’s a complicated relationship.
13	Yes	It's both an input & an output because the preservation of ... is an output; nobody believes that ... gives us any significant environmental service except people like them being there. So it’s this final output of whatever decision you’re making but obviously other bits of b'diversity – the nutrient recycling & the trees that hold back flood waters – are crucial inputs to providing other ES so in a way it’s inevitably both. Ideally you find places where it can serve both functions but I think it has to be regarded as both & there are some bits of b'diversity which are obviously only outputs & not inputs; & there are other bits of b'diversity which no-one really cares about. There are some things which are super-abundant & you still want more of it like sphagnum moss – there’s no danger of that becoming extinct but you want more of it because that’s what gives you your healthy peat lands. I do think it’s got to be both. In terms of ES, we more often talk about a healthy natural environment or healthy ecosystems rather than b'diversity. It’s got to be both an input & an output but it’s best not to worry about it too much. Where you’ve got a real decision-maker making a real plan for a particular purpose – one that will be obvious at that stage because they talk to their stakeholders & consider their objectives it will be obvious what they need to protect & what is going to be a useful building block to achieve other objectives. I think once you stop thinking about it & start doing it, it should become obvious which bits fit in where.

14	Yes	In some parts of the world it's quite easy. B'diversity is the stuff that underpins it. But here, & I think the same thing in Australia, you’ve got people who conserve b'diversity for b'diversity’s sake & that’s a cultural thing - what do you do then with that? It’s not b'diversity as a whole, its specific wild charismatic species that you’ve got to try & capture in a framework - in the MA it's an under arching thing that you need - your resilience policy. So we put it there & then we embedded it within the provisioning services, with the genetic diversity within crops & rare breed cattle, which is quite a big thing in the UK. But then it came back to, where do you put bird watchers & butterfly watchers. There’s this big culture in the UK of people going out & collecting & monitoring single species groups – in some ways it’s this trick of not trying to belittle what they’ve been doing. How do you incorporate that kind of data & their value systems into a framework so they can see themselves in that framework & see the value of their data being used in that framework. So we ended up having wild species as a final service. That’s to capture albatrosses, puffin colonies ... It is a quite important question to solve at the very beginning because a lot of people have been working in the b'diversity paradigm for a really long time. We’ve spent all this time convincing governments that that’s what they should be worried about. To suddenly now turn around & say, “Oh, it’s about ES,” without making the link is quite dangerous. I think you have the potential then also to alienate so many stakeholders who, you know their thing is koalas or protecting that bit of bushland. ... You can get good without much b'diversity. If you go on to do the economic values, one of these things is that you have got to split the goods off from the services because you can’t value the service; you’ve got to value the goods. But it might come back to how do you fit b'diversity in a high level of service rather than just underpinning everything? This then will help capture the cultural & ethical values that people hold. It depends if you move into more urban centres. And their view on these things is so vastly different to farmers & people who are out there conserving big tracts of bushland. I think it is a service. I don’t think the link between b'diversity & ES is completely thought out yet - but I think fundamentally it’s there for resilience & I don’t think any amount of research will ever dispel that. Yes, it is a service. It’s anything from the genes that are there in crops & in populations & in the provisioning services & cultural side of things. I think that helps capture people’s ethics, spirituality & religious connections to the environment. I think you do get people saying “I don’t know what b'diversity is & it doesn’t mean a thing to me.” But I think if you really nutted it down they do hold an ethical value about something - & they would get irate. It’s just that they always see b'diversity as koalas.
15	Yes	B'diversity appears at more places in the chain than anywhere else. So b'diversity is probably a supporting service, it is definitely a regulating service, contributes to regulation services. It’s a cultural service, people enjoy looking at b'diversity. Most unusual of all, it’s what an economist would call also a non-use value that it’s something that we value with no contact, no consumption, no anything apart from just the knowledge that it’s there. B'diversity is without doubt the most complex element of it & it appears right the way through the chain. We deliberately said we’re going to do this using a habitats approach - we can split the country up into habitats, we’re going to recognise that some of them overlap, they’re going to have all habitats talking to all other habitats, but that’s a practical way forward. However we’re going to almost on top of that have a b'diversity theme right the way through because of the complexity of b'diversity pops up at all these different places. I think that was the right way to do it. It’s a pragmatic way to do it. A pure b'diversity only point of view, b'diversity is the only thing that matters & that’s what we should be assessing, I think, is the quickest way to damnation & extinction that I could possibly think of. The recent report of the CBD basically proves that because

		everybody met seven or ten years ago & said right we’ve got to halt the sliding b'diversity & reverse it, & they haven’t even reduced the pace of losses. So it’s not working. You have to have a radically different approach - I don’t think that trying to make b'diversity this completely separate thing will work. I can see the attractions of that argument, but look at the track record, its rubbish. And why? Well because unfortunately if you set b'diversity up in obvious opposition to everything else, well yeah long term I want b'diversity but today I want sand or I want wheat, & so I’ll sort b'diversity out tomorrow ... & you know about tomorrow. So I don’t think that’s the right way to do it. The ES side also sounds a little bit worrying if it doesn’t recognise the very special role that b'diversity plays within the delivery of ES. The fact that it also is a service itself, b'diversity is this strange thing. It generates value because it underpins so many things. Soil b'diversity, absolutely crucial to production of crops. I don’t want to look at it. It’s not very interesting but it’s absolutely vital. However cranes, eagles ... I like looking at them. Then we get this weird thing that I really value the continued existence of the polar bear. I have no interest in going to the Arctic at all - I value it but it’s this very unusual non-use value. Personally I think that the best thing to do is to make it very overtly integral but with this very special recognition that actually many ES ultimately do depend on b'diversity.
16	Yes	When people say b'diversity there are three different ways that people tend to think about it. Broadly there’s the strict scientist’s definition of it, it means diversity of everything, measures of composition & numbers of species & true diversity. Then there are people who see it just as wildlife, plants & animals. Then there are people who just see it as a synonym for nature, all that’s natural. How people treat b'diversity depends on where they’re coming from & what they see in that. I’ve seen it in different aspects of ecosystem assessments. Personally, where I come to my conclusion is that it’s an unfortunate confusion which I doubt whether we’re going to get over to try & bring b'diversity & ES together. They are different concepts coming from different directions coming from different places. B'diversity was about conservation of species & habitats originally & the diversity of life & for whatever reasons you want to do that. But there is not much ecology in the thinking of b'diversity because of its origins. ES is about benefits from ecosystems & the functioning of ecosystems. Ecology actually, although some of the ecologists are interested in diversity & the question of how much diversity you need in a community to give you services, that’s one way of looking at it. It’s more useful to think of ecosystem functioning to give you services & the service of b'diversity conservation as one of those services. In the UK at least most b'diversity conservation in terms of rare species & habitats is what I would call a cultural service. This is, you’ve got little pockets & a few rare species & things & it’s not going to make much difference to the rest the provisioning & regulating ES whether we lose that butterfly or dragonfly or flower. They’re already naturally rare. The only reason to conserve them is because we like them. We would be sad if they’re gone. That’s a cultural service & absolutely fine & valid & should be really important. But to recognise it as such rather than to try & twist that we have these naturally rare organisms that are important for other ES in terms of having diversity there. In terms of having ecosystem functioning to give you services you want, like food & clean water, you can often have a very simplified community in terms of diversity, although structurally, physically the assessment provides 90 per cent of what you want. Many farming landscapes are e.g. of that. So I feel its confusion & sometimes disingenuous to try & twist the b'diversity conservation agenda into saying that it gives you ES. It’s better to keep it separate & say, “Most of what we want out of b'diversity conservation is, in the UK context at least, a cultural service & it’s valid for that”. Then the question is how much diversity & biomass you need to give you the services you want.
17	Yes	I’ve thought about this a lot because when I first started working on the MA the group expected me to treat b'diversity as an ES along with food & energy & climate regulation. I said at that time, b'diversity is not an ES it contributes to the underpinning set of ecological functions & processes that deliver ES. There was a lot of debate in the MA about that. What I now think is that there isn’t a single role for b'diversity. There are some bits

		of b'diversity e.g. the amount & variability of microorganisms in the soil or varieties of crop – varieties or crop relatives, varieties or livestock relatives that are underpinning FES & therefore goods. There's also an ES that is b'diversity which is mainly around aesthetic recreational values. People like to see lots of wild birds & corals, coral reef fish & some landscape diversity. That b'diversity doesn't particularly correlate with the underpinning role of b'diversity. Then there's a third type which is at the goods level. But sometimes the goods themselves have to be diverse & the best e.g. there is around that diversity is there are novel pharmaceutical products, where it's actually the chances of finding novel drugs or new foodstuffs is directly correlated with the amount of diversity there is at the goods level. It's a real mistake to only have it as an ES which is what I think has been a problem in a lot of the US assessments that they simply use the number of endangered bird species or something as a matrix for b'diversity. Yet we know that would not in any way represent soil microbial diversity or fresh water diversity that relate to good quality soils & clean water systems. It's more complicated than a yes or no answer. There's a load of papers that do these special correlates at all sorts of scales of species richness as a surrogate for b'diversity, & then the quality of some other ES - they do or do not show that they match up - & I just think that's a really pointless analysis. There is another argument that I've heard which I sort of agree with which is that the ecologists have been over dominant in ES science - that there's a lot of physical, chemical processes that don't get the amount of attention that the biology does & that probably ought to. The b'diversity thing is a kind of confounding factor in that many of the people who support ES science do it because they think it's going to be a way to do conservation biology - that's been pushing the science towards ecological diversity & natural communities of diverse species & away from thinking about the physics, chemistry & earth systems that are involved as well. Your question is very complicated & it very much depends on what you mean by b'diversity & what you mean by ES. But it has got confused by the conservation biologists who have wanted it to be the same basically. The intrinsic value turned out to be very controversial. There is a lot of muddled thinking about intrinsic value that it's something you can't measure. But if you can't measure it, it's not a value it's just an absolute. From a philosophical standpoint, if it has intrinsic value … that all other species have an equal right to exist that we do, & its then equal & infinite, then there is no way to make any kind of decision. It's a belief system & there are many people who do believe that. But if you're asking people to make decisions then by definition they're representing one thing against another & then it has to have some sort of value. It may be not an economic or monetary value, it could be how much food you are willing to forego in order to have 27 bird species instead of 7 - but that is trading it off - it's some sort of instrumental value. The problem is that people use the word intrinsic value to mean all those other things which are value. Whereas philosophically intrinsic value is just the belief that everything has a right to be there & do its own thing in the world. The really difficult ones to measure are those about how much are you willing to forego to know that elephants still exist in Africa? If you ask people they'll go, "Oh, yes. I really want there still to be elephants." But if you go, "Well, are you willing to accept that they raid the crops of these farmers' fields & there's so much in lost agricultural productivity," then people start thinking about it very differently. So it's not really an intrinsic value it is a trade- offable value.

Appendix 6: Assessment units in the MA (global), SEQ (regional), US (national) and UK (multi-national) frameworks.

MA	SEQ	US		UK
Reporting Categories	**Ecosystem Reporting Categories**	**Ecosystems**	**Environmental (Sub)-Classes**	**Habitats**
Marine	Deep ocean	-	Open oceans & seas	Marine
Coastal	Pelagic	-	-	-
-	Benthic	-	-	-
-	Coral reef	Coral reef	-	-
-	Seagrass	-	Near coastal marine & estuaries	Coastal margins
-	Rocky shores	-	-	-
-	Dunes	-	-	-
-	Beaches	-	-	-
-	Coastal zone wetlands	Wetlands	Wetlands	-
Inland Water	Palustrine wetlands	-	-	-
-	Lacustrine wetlands	-	Lakes & ponds	Freshwaters
-	Riverine wetlands	-	Rivers & streams	-
Forest	Rainforests	-	Forests	-
-	Sclerophyll forests	-	-	-
-	Native plantations	-	-	-
-	Exotic plantations	-	-	-
-	Native regrowth	-	-	-
Dryland	Native & improved grasslands	-	Grasslands	Semi-natural grasslands
-	Shrubland - woodland	-	Scrubland-woodland	Woodlands
Island	Moreton Island	-	-	-
-	Bribie Island	-	-	-
-	North Stradbroke Island	-	-	-
-	South Stradbroke & other Bay Islands	-	-	-

MA	SEQ	US		UK
Reporting Categories	Ecosystem Reporting Categories	Ecosystems	Environmental (Sub)-Classes	Habitats
Mountain	Montane	-	-	Mountains, moorlands & heath
Cultivated	Horticulture – small crops	-	Agro-ecosystems	Enclosed farmland
-	Horticulture – tree crops	-	-	-
-	Other irrigated crops	-	-	-
-	Sugarcane	-	-	-
Urban	-	-	-	Urban
-	Dams	-	-	-
-	Hard surfaces	-	Barron	-
-	Residential gardens	-	-	-
-	Parks & gardens	-	Created green space	-
Polar	-	-	Ice & snow	-
-	-	-	Groundwater	-
-	-	-	Atmosphere	-
-	-	-	Tundra	-

Appendix 7: The supporting services, ecosystem functions, ecological processes and intermediate services included in the MA, SEQ and UK frameworks.

#	MA	SEQ	UK
	Supporting Services	Ecosystem Functions	Ecological Processes, Intermediate Services
1	Production of atmospheric oxygen	-	-
2	-	Gas regulation	-
3	-	Climate regulation	Climate regulation
4	-	Disturbance regulation	-
5	-	Water regulation	-
6	-	Water supply	-
7	Water cycling	-	Water cycling
8	Soil formation	Soil formation	Soil formation
9	Soil retention	Soil retention	-
10	Nutrient cycling	Nutrient regulation	Nutrient cycling
11	-	Waste treatment & assimilation	-
12	-	Pollination	Pollination
13	-	Biological control	-
14	-	-	Disease & pest regulation
15	-	Barrier effect of vegetation	-
16	Provisioning of habitat	Supporting habitats	-
17	-	Food	-
18	-	Raw materials	-
19	Primary production	-	Primary production
20	-	-	Wild species diversity
21	-	Genetic resources	-
22	-	Provision of shade & shelter	-
23	-	Pharmacological resources	-
24	-	Landscape opportunity	-
25	-	-	Decomposition
26	-	-	Weathering
27	-	-	Ecological interactions
28	-	-	Evolutionary processes

Appendix 8: The ecosystem services, final ecosystem goods and services (FEGS) and final ecosystem services (FES) listed in the MA, SEQ, US and UK frameworks.

#	MA	SEQ	US*	UK
	Ecosystem Services	**Ecosystem Services**	**Ecosystem Services/FEGS**	**FES**
1	Food	Food products	Food & fibre production	-
2	-	-	Fish populations & habitat	Fish
3	-	-	-	Livestock
4	-	-	-	Crops
5	Fibre	Building & fibre resources	Food & fibre provisioning	-
6	-	-	-	Trees, standing vegetation
7	Fuel wood	Fuel resources	Fuels	-
8	-	-	-	Peat
9	-	Iconic species	-	-
10	Genetic resources	Genetic resources for cultivated products	-	-
11	Biochemicals	Biochemicals, medicines & pharmaceuticals	-	-
12	-	Ornamental resources	-	-

* This list of ecosystem services and FEGS is not the definitive list applied across the ESRP. Rather, this list includes all the ecosystem services assessed in projects within the program as identified in literature, interviews and websites.

#	MA	SEQ	US	UK
	Ecosystem Services	Ecosystem Services	Ecosystem Services/FEGS	FES
13	Pollination	Pollination	-	Pollination
14	Disease regulation	Regulate pests & disease	Pest & disease regulation	Disease & pest regulation
15	Pest regulation	-	-	-
16	-	-	Biological regulation	-
17	-	-	Biogeochemical cycling	-
18	-	-	-	Detoxification & purification in air, oils & water
19	Erosion regulation	-	-	-
20	-	-	Nutrient erosion	-
21	-	Maintaining habitable climate	A stable climate	-
22	-	-	Biological greenhouse gas regulation	-
23	Climate regulations	-	Climate regulation	Climate regulation
24	-	-	Atmospheric regulation	-
25	-	Buffering against extremes	-	-
26	Natural hazard regulation	-	Disturbance & natural hazard regulation	Hazard regulation
27	-	-	Flood protection	-
28	-	-	Protection from weather hazard	-
29	-	-	Usable air	-
30	Air quality regulation	-	Air quality regulation	-
31	-	Air quality	Air quality	-

#	MA	SEQ	US	UK
	Ecosystem Services	Ecosystem Services	Ecosystem Services/FEGS	FES
32	-	-	Clean Air	-
33	Fresh water	Water for consumption	Usable water	-
34	Water purification & waste treatment	-	Clean water	-
35	-	-	Water quality regulation	-
36	-	-	Water provisioning	-
37	-	-	Water supply	Water supply
38	-	-	Provision of drinking water	-
39	-	Water quality	Water quality & quantity regulation	-
40	Water regulation	-	Water quantity/ timing	-
41	-	-	Flow regulation	-
42	-	Noise abatement	-	Noise regulation
43	Sense of place	Sense of place	Sense of place	-
44	Spiritual & religious	Spiritual & religious values	Spiritual value	-
45	Cultural heritage values	Cultural diversity	-	-
46	Social relations	Effect on social interactions	-	-
47	-	-	Existence value/ bequest value	-
48	Recreation & tourism	Recreational opportunities	Recreation	-
49	Aesthetics	Aesthetic values	Culture & aesthetics	-
50	Inspirational	Inspiration	-	-
51	-	-	Green space	-

#	MA	SEQ	US	UK
	Ecosystem Services	Ecosystem Services	Ecosystem Services/FEGS	FES
52	-	Productive soils	-	-
53	-	-	Soil & sediment regulation	-
54	-	Arable land	-	-
55	-	Transport infrastructure	-	-
56	-	Iconic landscapes	-	-
57	-	Therapeutic landscapes	-	-
58	Knowledge systems	Knowledge systems	-	-
59	Educational values	-	-	-
60	-	-	-	Environmental settings
61	-	-	Habitat refugia	-
62	-	-	Wildlife populations & habitat	-
63	-	-	Habitat/ Maintenance of biodiversity	-
64	-	-	Biodiversity support	-
65	-	-	Biodiversity	-
66	-	-	-	Wild species diversity
67	-	-	Downstream aquatic ES	-
68	-	-	Forest health	-

Appendix 9: The full set of Recommendations for determining an appropriate methodology (process, information and tools) to develop a multi-scale framework. Interconnections between Recommendations for each of the components of the methodology are numbered and colour coded accordingly: LoE 1: Process = blue; LoE 2: information = orange; and LoE 3: tools = green.*

Multi-scale Methodology	Line of Enquiry 1: Process	Line of Enquiry 2: Information	Line of Enquiry 3: Tools
	factors underpinning programs 1) The MA as program validation 2) Contextual differences of stakeholders (5, 7, 17, 19, 34, 61iii) 3) Beyond MA valuation methods (47, 49, 50, 51, 52, 53)	**the role of biodiversity** 29) Managing diverging paradigms of thought (16, 17, 18, 19, 20, 30, 31, 32, 33, 39, 43, 54i, 54ii, 54iii, 55) 30) Defining biodiversity (17, 29, 31, 32, 33, 35, 54i, 54ii, 64iv) 31) The insurance role of biodiversity (29, 30, 32, 33, 39, 54i) 32) More than one position & role (29, 30, 31, 33) 33) Co-dependence of biodiversity & ecosystem function (29, 30, 31, 32, 39)	**conceptual framework** 54) Developing a shared understanding: i. a conceptual framework (5, 16, 17, 18, 19, 29, 61i); ii. a glossary/lexicon (5, 16, 17, 18, 19, 29, 30, 40, 43, 54iii); iii. a classification systems (5, 16, 17, 18, 19, 41, 45, 52, 54ii) 55) Development early in the program (29, 30, 40, 41, 43, 45, 50, 52, 63, 66)
	the coordinating organisation 4) Legitimacy of the coordinating organisation (2, 5, 6, 16, 17, 18,19) 5) Consideration of broad missions (2, 4, 17, 19) 6) Arm's length of politics (4, 13, 14, 22) 7) Government as a stakeholder (2, 8, 9, 17, 19, 20) 8) Government involvement at small scales (2, 7, 9, 18) 9) Government as the funder (7, 8, 10, 26, 61ii)	**assessment units** 34) Integrate with other initiatives (16, 17, 18, 19, 35, 48, 64iv) 35) Use of existing information (17, 19, 20, 29, 31, 32, 33, 34, 36, 37, 38, 61iv, 64iv) 36) The full range of assessment units (34, 35, 37, 38, 44, 64i) 37) Defining unit boundaries (34, 35, 36, 38, 40, 43, 54i, 54ii, 54iii) 38) Nested assessment units (35, 37, 54iii, 64v)	**scenarios** 56) The power of scenarios (16, 17,18, 19, 28, 54i, 54ii, 54iii, 57, 61i, 67) 57) Multiple scenarios (56, 58) 58) Choice of scenarios (2, 56, 57, 59, 61i) 59) Scenarios at local to national scales (25, 26, 56, 57, 58) 60) Participatory scenario development (5, 16, 17, 18, 19, 25)
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