Capturing natural capital in decision making

Updated stocktake of recent literature

NZIER report to The Treasury and Natural Resource Sector Agencies

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Key points

This report describes a review of recent literature on capturing natural capital in decision making, with a focus on approaches to measuring natural capital that have been implemented, rather than the extensive range of academic and grey literature.

Failing to value natural capital leads to sub-optimal decision-making

The basic premise of natural capital approaches is in recognising some value for natural resources that are commonly regarded as value-less in economic terms. Without a value, natural resources are prone to under-weighting in decision processes and excessive use, causing externality effects on current and future generations.

This shows up in a focus on GDP and flow effects in national economic debate, regardless of any deterioration in natural capital stocks that may occur, and also in local project decisions that imply low value being given to natural resources that may be scarce or otherwise perform functions that support human activity.

Natural capital approaches can counter this by providing estimates of the stocks of natural resources which provide both material goods and services used in market production and non-market contributions to quality of life. The term capital is used because nature provides flows of goods and services that can be inputs into production of benefit to humankind. The value of natural capital is ideally expressed in monetary terms as this is most useful for informing decisions about economic trade-offs in the use and retention of natural resources, but as value also depends on the physical extent and condition of resources, natural capital approaches also cover non-monetary measures of natural assets.

Numerous options for assessing natural capital exist

There is a broad spread of methods relevant to natural capital measurement such as:

- **Prices and other economic instruments** like transferable fish quotas or payments to preserve natural habitats for the public good can also be regarded as treating natural resources as economic capital
- **Wealth accounting** is the complement to income accounting of the System of National Accounts – total wealth comprising physical, financial, natural, human, institutional and social capitals
- **Extended income accounting**, which removes natural resource depletion from gross income measures to obtain net economic welfare or green GDP
- **Ecosystem services** approaches measure service flows from specific natural resource/asset classes that make them valuable to human well-being
- A range of other **market and non-market valuation** techniques can apply to a wide range of natural capital, but are not consistent with the production frameworks of national accounting because of their focus on consumer well-being.

Since the Natural Capital Protocol was issued in 2016, private corporations now have tools for assessing their dependence on natural capital and risks around its continued availability and use, across their whole value chain including across national borders. The application of the Protocol and its consequential impact has varied. The Natural

Capital Coalition Hub includes a range of case studies on the application of the Protocol.[1] The case studies show that the Protocol has been used as mechanism to raise corporate awareness of natural capital in value chains, which has influenced decision making even if the natural capital has not been comprehensively quantified or monetised.

Academic approaches are difficult to implement in practice

There is broad division in literature between:

- peer reviewed literature aimed at an academic audience, some theoretical and some empirical estimates, the practicality and use of which is unclear
- officially sanctioned attempts at compiling natural capital measures – from international bodies such as the World Bank, OECD, UN (SNA and SEEA), and statistical offices such as Australian Bureau of Statistics, Statistics New Zealand, UK Office of National Statistics – in which natural capital is often part of a broader general wealth measurement
- proprietary software tools to enable effects on natural capital to be recorded (InVEST).

Most of the literature is about methods, their application and potential uses. A search of literature about natural capital reveals relatively little about how natural capital is taken into account in actual decisions.

The UN SEEA is commonly used

The current focus on practical natural capital accounting has been on natural assets that are most readily measured or estimated from existing data and converted to market values. This is now enshrined in the UN System of Environmental and Economic Accounts (SEEA) which provides a set of internationally agreed standards for preparing such accounts, covering both flow and transaction accounts and both physical measures and their valuation. The sectors and resources where natural capital accounting is being applied internationally include the following:

- non-renewable resources including oil and hydro-carbon stocks and other mineral resources, including precious metals, base metals and phosphate
- renewable resources (less frequently accounted for) including timber resources of forests; non-timber forest resources (e.g. carbon sequestration); land
- more experimental natural capital stocks such as:
  - protected areas (a rough and ready indicator of the extent of biodiversity)
  - accessibility of natural resources for outdoor recreation and tourism
  - fisheries (may not be included in natural capital if implicitly and inextricably included in physical capital for the fishing industry)
  - water (difficult to quantify and often excluded altogether)
  - soils (difficult to quantify and often omitted or partially included for carbon accounting)

[1] http://naturalcapitalcoalition.org/category/case-studies/

- negative flows (e.g. of pollutants) or reductions in stocks often excluded altogether, although SEEA provides for their recording in non-monetary terms.

It is unclear how effective natural capital measures have been in informing decision-making

The extent to which decisions have relied on natural capital measures (or what they have used instead) is the most difficult issue to discern from the literature. The adoption of the SEEA as an international standard provides a basis for improved comparison of issues between countries and over time, and facilitates further analysis around matters such as green growth indicators and productivity, but it is unclear what difference this has made to decisions involving natural capital.

There appears to be little literature providing thorough ex-post investigation of how decisions were made, how natural capital was treated in those decisions, or what were the key contextual factors (or barriers) that led to that treatment. What literature there is suggests that non-market valuation is less influential in decisions that its practitioners believe, and that high level natural resource accounts are more useful in raising awareness of potential value than in guiding of management or policy decisions.

Internationally, natural capital approaches have been identified as influencing decisions on user fees for tourists in national parks, securing government investment in conservation initiatives, and setting fines and compensation for environmental damage. Detailed case studies would be required to understand the usefulness of these approaches, barriers to their implementation and what best practices are.

No approach is perfect: each involves tough trade-offs

The choice of natural capital approach depends on the policy purpose it is intended to inform:

- general measures to balance with the income flows of GDP are not necessarily the best for detailed monitoring of natural capital stocks, as they reflect physical stock and value data which may change independently making total value highly volatile
- such natural capital stock values say little about the management of resources such as biodiversity because the aggregate figures obscure local diversity, and monitoring would be better served by underlying stock indicators on which accounts are built, rather than by the aggregated natural capital accounts themselves.

The value of using or conserving non-market natural capital requires methods that reveal preferences of the affected publics. Economists rely on prices of market goods and have devised non-market valuation methods for environmental goods, but there are few quality studies in New Zealand and these techniques have not been relied on in public decision processes.

Preferences for natural capital use change and evolve over time, to which institutional and legal frameworks often respond imperfectly. When introducing new approaches, careful consideration is needed of how they affect existing expectations and proprietary rights, which may create calls for mitigation or compensation.

Natural capital approaches are highly relevant for Māori resource issues

Literature on iwi/Māori resource management practices suggest there is little formal or systematised measurement of natural capital currently in use by those communities. Distinct processes to reflect Māori interests in natural capital may need to be developed in view of their position as Treaty parties, their role in resource areas after Treaty settlements, and the holistic approach taken to matters such as the mauri of waterways which makes unitising of natural capital difficult.

Notwithstanding the current lack of a shared approach to natural capital frameworks there are several factors – such as the completion of Treaty settlements, the increased scale and sophistication of iwi/Māori governance arrangements, and independent public sector initiatives – that in combination are likely to lead to increased investment in natural capital management methodologies.

The private sector is becoming more aware of natural capital

While natural capital approaches have been developed in the context of informing public policy decisions, private businesses are also becoming interested in accounting for natural capital, because of the risks posed by potential scarcities and cost increases in key natural inputs, the risk of regulations for natural capital protection resulting in stranded assets, and risk to their company reputations if seen to be acting in ignorance of natural capital considerations. The release of the Natural Capital Protocol in 2016 has provided guidance on how such assessments can be made, but retains flexibility to different companies' specific circumstances. Private sector assessments may be trans-national in scope where risks apply to a supply chain and distribution to markets spread across many countries.

Use of natural capital must be developed within New Zealand

Internationally, natural capital accounting is being driven by the need for comparable statistics from international agencies such as the UN, World Bank and OECD. Trans-national requirements of the EU have also prompted improved use of non-market valuation techniques in member countries. In New Zealand, international agreements have prompted revisions in environmental statistics aligned to UNSEEA standards and in developing a climate change inventory, but statistical coverage is less informative in other environmental domains, and there is no international standard approach to using ecosystem services or non-market valuations to inform decisions on natural capital. While the SEEA is likely to become a standard across countries in the next few years, each country will have different priorities for applying it. Improving the reliability of information on ecosystem services, non-market valuation, and the perspectives of Māori on natural capital and improving the capabilities of decision makers to use these approaches needs to be initiated within New Zealand, prioritising those matters that are most policy relevant to New Zealand.

Recommendations

The key recommendations from this literature review are to:

- recognise that natural capital approaches cover a range of different methods for demonstrating non-zero value of natural resources, so prioritise actions in developing methods that best suit clearly defined policy purposes

- continue with developing statistics and accounts in line with international standards of the SEEA, but investigate their use for informing domestic policy needs and overcoming barriers to uptake
- for other approaches there are no international standards so improving consistency and reliability requires direction from within New Zealand:
  - provide standard definitions to improve the usefulness of ecosystem services as an organising framework, but do not pursue monetised ecosystem service accounts which change the accounting framework
  - support non-market valuations of environmental resources that use consistent methods and control for contextual variables, which could form the basis of more reliable value transfers
  - work on uses of natural capital frameworks with long term focuse for Maori concerns, which reflect a context unique to New Zealand which will not be addressed elsewhere
- For all decision makers in the environmental and natural resources fields, investigate what use they make of natural capital approaches and what they would need to use them more
- Drawing on overseas examples, establish the relative scale of the main contributors to New Zealand's stock of natural capital on a recurring basis, to give a high-level indicator of trends in natural capital
- Drawing on private sector examples, develop workable base estimates of New Zealand's dependency and risks around key natural resource inputs, as a high level indicator of risks to security around key natural inputs and as a spur to efficiency in use and development of substitutes, in such matters as sources of energy and phosphate fertilisers.

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1. Introduction

The purpose of this literature stocktake is to provide a concise summary of the literature on capturing natural capital in the decision-making process to inform the wider Natural Resources Sector's (NRS) programme of work about making decisions about natural capital. The review was first undertaken in 2015 and then updated in 2017 to capture some new developments.

The scope of our literature stocktake is limited to a desktop literature review.

This stocktake:

- consults and reports on a wide range of key domestic and international literature. This includes:
  - best practice examples in New Zealand and overseas
  - the range of values identified as natural capital (ideally consistent with in New Zealand's environmental domains of atmosphere and climate, air, freshwater, land, marine and biodiversity)
  - techniques available to capture the suite of natural capital values (including both market and non-market values)
  - any gaps in research and data
  - how decisions are currently made (processes and institutions) and who makes them (key people and their level of influence).
- pulls together information unearthed through the case studies, which are focused on narrow, topic-specific information.
- identifies and provides recommendations regarding potential opportunities to improve/develop how natural capital in decision-making is captured in New Zealand.

We have been asked to look specifically at these six areas:

- data, databases and methodologies
- biodiversity and ecosystem services
- public preferences and cultural values (overall and Māori specifically)
- valuation methods for market and non-market uses of natural capital
- policy decision-making frameworks and tools
- case studies selected for the project to examine examples from government and regional authorities using natural capital to inform decision-making.

The development of the case studies in a separate project from the literature stocktake so the extent to which we can look at these depends on how other projects progress.

1.1. Definitions and purpose

Capturing natural capital in decision making could be approached descriptively by examining how natural capital is weighed up in actual decisions, but literature searches reveal there is very little literature which does this in a systematic manner. When

natural capital is entered into a search engine, the majority of the titles retrieved refer either to the design of various methods that measure natural capital, or their uses.

This review is driven by the literature to reflect the range and scope of approaches to capturing natural capital for use in decisions. We draw on various economic frameworks to divide up the methods – the total economic value framework, ecosystem services approach, measurement of subjective well-being – which are elaborated in Appendix B of this report.

The fundamental characteristic of natural capital approaches is recognising the value derived from natural resources, and giving due weight to these values in decisions involving use of natural and environmental resources. If that value is not recognised, resources can be overused, giving rise to external effects that fall on third parties such as pollution of air and water or congestion of recreation spaces.

Recently natural capital has been seen as a set of natural resources that form an asset class comparable to man-made physical and financial assets, and less tangible assets of human capital and social (and/or institutional) capital. It is primarily a stock measure, but it generates flows of goods and services of use to people and it both supplies current consumption and can be degraded by it (OECD 2013).

Various definitions exist, such as that from the UK's Natural Capital Committee (2014):

"Natural Capital refers to the elements of nature that produce value to people, such as the stock of forests, water, land, minerals and oceans … providing food, clean air, wildlife, energy, wood, recreation and protection from hazards".

Similarly, the Global Nature Fund (2012) defines natural capital from conventional capital definitions as "*the inventory of natural resources that can be used for production of goods and services*".

The Wealth Accounting and Valuing Ecosystems Services partnership (WAVES n.d.) defines natural capital to include *"the resources that we easily recognize and measure such as minerals and energy, forest timber, agricultural land, fisheries and water. It also includes ecosystems producing services that are often 'invisible' to most people such as air and water filtration, flood protection, carbon storage, pollination for crops, and habitat for fisheries and wildlife. These values are not readily captured in markets, so we don't really know how much they contribute to the economy or what it would cost if we lose them"*.

Helm (2015) defines natural capital in more discursive terms. Capital is an input into production, which in turn produces a flow of goods and services of benefit to humankind. Natural capital is not produced by human activity, but provided by nature for free – although there may be some cost in harnessing it for human purposes, e.g. in catching fish from the sea, extracting minerals from the ground or collecting water and storing its potential energy. Natural capital consists of resources that may be non-renewable, in the sense that there is fixed recoverable amount which is depleted by use (e.g. subterranean oil and gas reserves), or renewable, with a potentially infinite yield at zero cost (such as the energy embodied in rivers and the wind). Some resources are more accurately described as conditionally renewable in that they are infinitely renewable if managed within limits: examples include fisheries and forests which are renewable if harvested at less than their rate of replenishment, and the assimilation capacity of air, water and soils to absorb contaminants and wastes at levels which do not cause harm to human activities.

The economic value of natural capital is most usefully expressed in monetary terms consistent with other assets and inputs in production activities. Putting a price on nature is highly contentious but shying away from it misses the point of economic valuation: this arises because there are not infinite resources to devote to protecting nature, so hard choices need to be made about using or conserving natural resources. Commensurate values for all potential uses or non-uses are useful for informing those choices. Some bits of nature cost more than others to protect, and some are valued more highly than others because they yield more benefits. Economic valuation informs choices, but as a resource's price reflects the relationship between its supply and demand for what it provides, value also depends on accurate measures of the physical extent and condition of natural resources.

Such definitions are still relatively vague, but they give a flavour of what measures of natural capital need to capture. These include:

- value is an encapsulation of a stream of services expected from natural resources over future years
- such services are of benefit to, and valued by, people
- natural capital value needs to reflect the scarcity or abundance of the services derived from it relative to their demand.

The precise definition of natural capital is important

Definition is important, because natural capital is often referred to loosely in literature as if it is universally known what it is, but in practice efforts to quantify and value natural capital depend on data quality (which may be deficient) and varying assumptions and inputs that can produce quite different results. If natural capital value is viewed in a conventional economic sense as the capitalisation of a stream of future benefits, the rate at which the stream occurs, the value attached to the services in the future, and the discount rate applied to future flows can all materially change the result of natural capital calculations.

Natural capital is invoked for various purposes which affects the choice of technique:

- adjusting the national accounts that generate Gross Domestic Product (GDP) to reflect depreciation of natural assets, e.g. a Net DP or Green GDP
- providing a balance sheet of assets to be viewed alongside the GDP derived from the UN's System of National Accounts (SNA)
- providing for sustainable income by identifying a share of the proceeds of liquidating natural assets to invest in other assets yielding continuing income
- providing a clearer basis for monitoring changes in natural asset stocks than is provided by various ad hoc indicator sets
- in some (but by no means all) cases providing a basis for unitising natural assets and attaching an economic instrument to improve the choice of management options (e.g. greenhouse gas emission inventories as a basis for emissions trading, fish quota as a basis for sustainable harvesting).

1.2. Evolution of natural capital approaches

This review concentrates on recent literature, mostly from the past 15 years. The term natural capital has been in use in environmental and natural resource circles since the 1980s, but it encompasses techniques that have been around for much longer.

Natural capital approaches apply the concepts of economics to the natural environment, to counter the tendency to treat natural resources as having low or zero value and to leave them out of accounts – of national, corporate and public bodies. Access to marketable natural resources does impact on company valuations: obtaining fishing quota or land with water rights attached will impact on a company's asset values, and obtaining consent for mining will affect a company's stock market value and ability to raise financial capital for its activities. However, if there are missing markets for natural resources, such effects provide no way of knowing whether natural capital is being maintained, enhanced or degraded, and no way of knowing what might be lost. There are distinct precedents for natural capital accounting in economics, in the evolution of natural resource economics, non-market valuation, national accounting and ecosystem services.

1.2.1. Natural resource economics

Natural resource economics has since the 19th Century been concerned with defining stocks of natural resources to determine how to make the most of their utilisation over time. The 1849 Faustmann formula established the optimal forest rotation to maximise value on the basis of assumptions on timber yield, expected prices and discount rate (Bowes and Krutilla 1985). The theory of optimal depletion of finite exhaustible resources was established by Hotelling (1931) and harvesting a sustained yield from a renewable fish stock by Gordon (1954) and Scott (1955).

Early concerns were with depleting and running out of raw materials – food (Malthus 1798), energy (Jevons 1865) – but these products are traded in markets in which prices signal impending scarcity and create incentives to find new sources or substitutes. More recently, attention has shifted to natural and environmental resources important to human well-being for which no market signals and ready substitutes exist (OECD 2013).

Such market limits change over time, as resources are used up and become more scarce, or as demands change relative to supply. Increasing demand and scarcity raise the price of resources and prompt the search for new resources or technological innovation to utilise existing resources better, or sometimes to shift demand to completely different resources.

The fundamental characteristic of natural resources is that they are supplied by natural processes, so the human role in production is in the capture or extraction of the resource. This is obvious for hunting and fishing of wild stocks but also applies to harvesting wild forest, extracting sub-soil minerals and utilising water. The margin between revenues earned from the products and the full costs of producing them – including costs of extraction, processing and due allowance for the risk involved in committing to finding and developing the resource – provides a residual economic rent or "super profit" to be earned from natural resource utilisation. One role for a resource

royalty is to extract some of that rent for owners of the resource once they have been identified

For non-renewable mineral and energy resources, recognition that extraction means the once-only conversion of resource stock into revenue led to Hartwick's 1977 proposal that the economic rent from resource depletion should be invested in other capital. El Serafy (1989) provided a formula for dividing the net revenues from resource extraction between Hicksian income (that which can be consumed without being left worse off) and an amount for investment to provide a continuing income stream.

Evolving public expectations and awareness of externalities forced new demands on forest management (Samuelson 1976). Hartmann (1976) established that when a standing forest has value, for its non-market benefits for recreation, watershed management or biodiversity, it is optimal to lengthen rotations and defer harvesting that destroys such value.

1.2.2. Non-market valuation

Non-market valuation has formally developed since the 1940s with distinct techniques to estimate the value of environmental and natural resources for which no market prices exist, based around public willingness to pay for them. These techniques estimate a demand curve for a non-market attribute, from which a consumer surplus can be estimated as a measure of value of the attribute, irrespective of whether it is actually feasible to charge for the benefit or not.

Travel cost analysis of visits to recreational sites emerged in the 1960s. Stated preference techniques like contingent valuation developed in the 1970s and choice modelling from the 1990s. These stated preference techniques are able to elicit values not just for non-market attributes but also for non-use values that are not apparent in revealed preference methods. This has given rise to the notion of Total Economic Value of environmental and natural resources comprising a mix of current and future values and actual use and non-use value, as explained in Appendix B.2.

1.2.3. National accounting

The current international system of national accounts was codified in the 1950s by the UN to help manage post-war reconstruction and has since evolved to become the pre-eminent measure of economic progress. But it primarily measures flows rather than stocks and since the 1970s its limited coverage of capital items including natural capital, has been criticised and prompted various proposals for natural resource accounting to rectify this limitation. These include:

- calculating the depletion of natural resources as depreciation to be deducted from GDP as a Net Domestic Product
- making further adjustments by deducting "defensive expenditures" – economic activity that only restores or maintains wealth – from GDP, to make it closer to a measure of economic welfare or well-being.

Related to this has been the use of accounts to provide measures of sustainable income over time, by viewing income flows and changes in physical and natural capital concurrently. This led to the ideas of weak sustainability (in which capital is maintained

if natural capital is converted to man-made physical capital) and strong sustainability which views some natural capital as non-substitutable and needing to be maintained at its current level or higher (Pearce et al 1989). Difficulty in deciding what constitutes non-substitutable natural capital and defensive expenditures has limited the development of these adjusted measures.

Such adjustments are more problematic in practice than in principle, with estimates subject to volatility and uncertainty, so national statisticians have resisted admitting such numbers into the GDP, preferring to prepare such accounts outside the GDP as satellite accounts to be viewed alongside it.

The UN has developed a System of Environmental and Economic Accounts (UNSEEA) to provide an agreed set of standards for how this can be consistently done across nations. Since the 1990s the World Bank has been working on measures of the total wealth of nations that form the basis of a balance sheet of total capital stocks – artificial physical capital, financial capital, natural capital, human capital and social (and institutional) capital.

1.2.4. Ecosystem services

The term ecosystem services has emerged relatively recently in the 1990s to bring together economic and ecological thought and formalise what was being done on a more ad hoc manner previously. It received some attention after Costanza et al (1997) published their estimate of total worldwide value of ecosystem services and found it to be about three times the value of global GDP for the same year.

Since then the UN initiated the Millennium Ecosystem Assessment to provide a common analytical framework that distinguishes the following types of ecosystem services:

- **Provisioning services**, supplying materials, food, fibre and energy for human use
- **Cultural services**, supplying settings and conditions for other forms of human benefit, such as outlets for recreational, scientific and spiritual enrichment
- **Regulating services**, such as natural controls over excessive water flows and climatic extremes
- **Supporting services**, such as water and nutrient cycling and plant pollination that underpin a wide range of other human activity.

Estimating the future streams of ecosystem services and converting them to a net present value provides a measure of the natural capital from which they are derived. However, correctly identifying and quantifying all the streams of service, and avoiding double counting between intermediate and final outputs has been challenging. Supporting services are sometimes omitted because of complexity and double counting issues.

Since the Rio+20 Conference in Rio de Janeiro in 2012, the United Nations has adopted 17 Sustainable Development Goals containing 69 targets to act as its Post-2015 Development Agenda. These replace the Millennium Development Goals but do not change the approach to measuring natural capital, so the approaches identified in the

Millennium Ecosystem Assessment remain relevant for capturing natural capital in future.

1.2.5. Environmental pricing

Giving effect to natural capital in decision processes requires weighting them against other items in a cost benefit analysis or alternative balancing process. There is a long tradition of developing economic instruments for environmental policy to provide market-like price incentives for less degrading use of the natural environment. An evolution of this approach is the idea of payments for ecosystems services which uses the ecosystem services approach explicitly to estimate the value provided by the environment, to whom it accrues and whose actions affect the supply, so as to devise instruments in which beneficiaries pay the suppliers of such services.

A variant of such pricing is the idea of biodiversity offsets, which comprise payments made by developers (in money or in kind) to compensate for the degradation of natural resources caused by their activities. This has been one of the foci of the United Nation's Environment Programme (UNEP) and its workstream on the Economics of Ecosystems and Biodiversity (TEEB). Much of TEEB's work is involved in making environmental effects more relevant to private businesses. It is also implicit in the idea of "weak sustainability" under which it is sufficient for natural capital losses to be made up by gains in other forms of capital. This is distinct from "strong sustainability" which regards natural capital as non-substitutable and requires losses i to be made good with replenishment of the same types of natural capital (Pearce and Warford 1993).

TEEB also commissions other work with more explicit links to natural capital, such as its 2013 report on *Natural Capital at Risk* (Trucost 2013), which estimated the value of unaccounted for externalities of 100 regionally-based business sectors and ranked them in terms of their adverse environmental cost. Coal power generation in Eastern Asia was assessed as having most cost to natural capital in view of its greenhouse gas emissions. Under this accounting, many industries were found to be unsustainable in having costs that exceed their revenues earned, but industry categories are very high level. The report prompted companies to evaluate the effects of their individual operations and supply chain activities on natural capital.

1.2.6. Recent developments

The term natural capital has become widely used relatively recently, drawing on these older economic traditions. It has been associated with increasing interest from private corporations, which since the 1990s have been experimenting with triple bottom line (people, planet, profit) reporting, representing a significant change to the traditional focus of judging businesses predominantly by financial performance.

In 2010 following its Conference of Parties in Nagoya, Japan, the United Nations published *The Economics of Ecosystems and Biodiversity (TEEB)*, which recommended disclosure of biodiversity information in corporate accounting reports. It also proposes setting "no net loss" and "net positive impact" as targets as well as considering an offset system. *The Natural Capital Declaration (NCD)* prepared in 2012 by the United Nations Environment Program Finance Initiative (UNEP FI) required that natural capital be evaluated in the same way as social and financial capital. "The 50/50 Project,"

launched by the World Bank in 2012, also aimed to incorporate natural capital into government accounting in 50 countries and corporate accounting at 50 companies.

In 2013, the TEEB Business Coalition evolved into the Natural Capital Coalition. In that year the International Integrated Reporting Framework (IRFW), drafted by the International Integrated Reporting Council (IIRC) and the Sustainability Reporting Guidelines G4, drafted by the Global Reporting Initiative (GRI), were published. The IRFW specifies natural capital as one of six capital assets that support corporate activities, while GRI-G4 recognizes economic assessments of natural capital as an important information disclosure item for companies.

These changes have culminated in national government initiatives with an emphasis on accounting, and in the Natural Capital Protocol for businesses released in 2016.

1.3. Report outline

As natural capital approaches apply the language of economics to natural resource use decisions, this review takes primarily an economic viewpoint. Economics requires commensurate consideration of the costs and benefits of resource use, for which monetary valuation is the most commonly used unit of measure. Valuation depends on the identification of what is gained and lost from different uses of natural resources, and accurate quantification of the scale and timing of effects. There is a vast literature on measurement and understanding of biophysical processes and effects, but as natural capital approaches are about improving the commensurability of considerations of natural resource and economic outcomes, this review focuses on literature that is informative about economic values and preferences.

This report briefly outlines the approach and method of the review before discussing its findings: how different economic approaches fit together (or not) in practice, identifying what the literature says about comparisons between the approaches, identifying what experience with the approaches says about best practice and indicating what this means for case studies of natural capital. It ends with discussion and conclusions.

2. Approach and methodology

The literature review has proceeded by using NZIER's in-house library resources and staff, and the research team's knowledge and experience of the subject matter to review established frameworks and approaches that measure natural capital. This involved a desktop review of the English-language literature.

2.1. Search procedures

We started the literature review by conducting a series of searches. The sources we searched included: electronic bibliographic databases such as ScienceDirect, Econlit, REPEC, JSTOR; international bodies such as the United Nations, World Bank, European Commission, European Environment Agency; national agencies like the Natural Capital Committee in the United Kingdom and Google Scholar.

Search terms included 'natural capital', 'decision-making', 'evaluation', 'valuation', 'review', 'framework', 'value'. We didn't include the phrase 'Ecosystem services' specifically as one of our search phrases as it returned too many 'out of scope' hits, but material focused on 'ecosystem services' appeared in many of our results.

We supplemented these searches by doing some citation searches on key recurring references that appeared frequently in the bibliographies of recent articles and reports that surveyed the topic area.

2.2. Screening and sorting

The initial screening process focused on title and abstract relevance. We focused on identifying articles and reports that evaluated natural capital frameworks in use. Theoretical and academic articles that hypothesised about approaches to measuring natural capital were filtered out unless they appear to have been widely cited in more practical implementation of natural capital measurement.

High relevance is ascribed to papers that considered:

- the scope of natural capital coverage – e.g. is it just inputs into production of market goods or does it include non-market services (e.g. recreation, biodiversity provision)?
- the practicality of the approach – is it:
  - a one-off or
  - has it been produced continuously over a number of years?
- the robustness of the approach – how reliable is the base data, and how informative is the approach in the absence of some key information?
- the usefulness of the approach – has it been used to support decisions with financial consequences, or is it more an academic exercise?

Lower relevance is ascribed to papers that are:

- about an untested or hypothetical framework to measure natural capital

- a discussion of natural capital that contains no framework or methodology that is measured or evaluated
- primarily concerned with measuring ecosystem functions or services in biophysical terms without clear linkage to economic uses and value
- more than 15 years old (unless frequently cited by most recent papers).

2.3. Assessment frame

Natural capital is fundamentally about applying economic concepts to natural resources, treating them as part of the asset base on which economic activity and society functions. Accordingly, the focus of the assessment of literature in this search is on papers that apply economic methods to the question of natural capital, and show how they can be practically implemented and what they can be applied to.

Economics is about resource use choices, the trade-offs that are made between alternative resource uses, and how to choose uses so as to make the most out of available resources. In examining choices over use of natural or environmental resources it is useful to apply a three-stage procedure:

1. Identifying effects, whether they are positive or negative to people's well-being, and when they are likely to occur
2. Quantifying effects to the extent possible
3. Converting effects to a common currency for comparison through monetary valuations made time-consistent through discounting.

For example, in the **Capturing Natural Capital in Decision Making Project** case study of wilding pines, a first set of questions is identifying in what ways well-being is affected by the presence of pines, for instance the nuisance and loss of production of grazing land infested by wilding trees, the expenditures incurred by trying to contain and control them, the offense to aesthetic or cultural associations with the area, impacts on survival of biodiversity habitat and any consequent effects on water or nutrient cycling in the area.

The next step is the quantification of these effects relative to a feasible alternative (e.g. removal of pines), which may be expressed in various physical measures, such as an area of native habitat affected, reduction in productive stocking rate, reduction in numbers of people choosing the area for recreation and so on.

The third stage is to attach a monetary value to each of these effects, which can be summed to indicate the total value of the impact of wilding pines and what is it worth to remove them, i.e. how much is society willing to pay in view of the costs incurred in not taking action.

In this process the most useful stage for capturing natural capital is the valuation stage, as this provides a value commensurate with other values created by transforming a natural asset by development. But valuation depends on a sound basis for quantification and identification of all effects that have a significant impact on well-being. While our literature view tends to focus on the more numerate end of quantification and valuation and gives less attention to literature that only loosely invokes natural capital without indicating how it might be implemented, it also looks for articles that are informative of the identification stage as well.

3. Findings

3.1. Techniques for approaching natural capital

This section provides some brief explanatory narrative around the heading structures provided in the RFP, to clarify how each heading fits within the broad subject of capturing natural capital for decision-making.

3.2. Data, database and accounting methods

There is a lot of literature and a long history of building databases and accounting frameworks for dealing with natural resource impacts in a comparable manner to monitoring of other economic aggregates. This encapsulates the broad range of motives and purposes that natural capital accounting is intended to serve.

Attempts to deal with natural capital in a natural resource accounting framework can be traced back to the 1970s, as described in Appendix B.3. This was approached through two strands: the calculation of depreciation of natural capital to adjust the national economic accounts, and compilation of natural resource stock accounts to give better indication of availability and impending scarcity for management purposes. Early attempts had limited data and appear to have been little used in practical policy settings.

Since the 1990s, however, there has been some convergence of the two strands in seeing Natural Capital as one of a series of capital stocks supporting economic activity and well-being. This has been driven by the UN Statistical Commission, the World Bank, and bodies such as the WAVES Partnership.[2]

Countering the view of natural capital as having zero value

The starting point is to recognize that natural capital is typically treated as if it has zero value and is not properly taken into account in public policy deliberations at national and regional level, or in private corporate decision making.

Steps in countering this zero value view are:

- decide to have a balance sheet – to counteract the distorted view from national income, expenditure and production measures, which are all flows, not stocks, and take no account of declining environmental condition (apart from often hidden figures on environmental remediation spending)
- create a natural capital balance sheet, with an asset register of the main categories of natural assets and a way of screening and sorting to prioritise assets most at risk – including entries for assets for which estimates are not yet available
- decide on a way of valuing assets from the services expected from them – in general this will not involve mixing market and non-market values as the latter include consumer surplus that is inconsistent with the structure of

[2] Wealth Accounting and Valuation of Ecosystem Services (WAVES) Partnership, a World Bank supported non-profit body that aims to promote sustainable development by mainstreaming natural resources into national economic considerations.

the national accounts. A first approximation may be the replacement cost of the asset at risk, or the cost of obtaining its services in the future from an alternative if it is lost

- provide for natural capital maintenance, for instance linking movements in the capital value to natural capital maintenance expenditure across both public and private agencies
- create a process for compensation and offsetting, which means paying for depletion, and provides both incentive to reduce damage to natural assets and a means of restoring or replacing damage if it occurs
- embed natural capital into public policy by standardising accounting rules, ensuring effective mechanisms for capital maintenance and offsetting, and developing a plan for long term enhancement of natural capital.

These steps are aspirational rather than an expression of what is actually being implemented in any country, although they do align with the UK government's pronouncements on enhancing that country's natural capital (Helm 2014). They do however indicate the **importance of knowing what purpose a natural capital approach is intended to serve**, because not all techniques are equally suited to separate aims such as correcting national accounting framework, monitoring the state of stocks, or deciding at a local project level what value would be gained or lost from a change in natural capital.

Numerous practical approaches are being used

Figure 1 summarises three practical approaches to national level wealth accounting currently being implemented by international or national agencies. They distinguish between those for marketable resources consistent with the UNSEEA central framework,[3] and more experimental accounts covering non-market resources.

Figure 1 Coverage of selected wealth accounting approaches

<table>
<tr><th>UNSEEA</th><th>World Bank</th><th>UK ONS</th></tr>
<tr><td rowspan="2">Central Framework</td><td>Comprehensive Wealth
Inclusive Wealth</td><td rowspan="2">Marketable resources</td></tr>
<tr><td rowspan="2">Genuine Savings Indicator</td></tr>
<tr><td>Experimental Accounts</td><td rowspan="2"></td><td rowspan="2">Non-market resources</td></tr>
<tr><td>Extensions/applications</td></tr>
</table>

Source: NZIER

The UN System of Economic and Environmental Accounting (SEEA) provides a central framework of agreed standards for preparing natural resource accounts consistent with the economic accounts, focused on resources that give rise to marketable

[3] The SEEA uses the terms environmental assets and natural resources, rather than natural capital. It provides for transaction accounts covering environmental protection spending, making it more observable than in the standard SNA accounts.

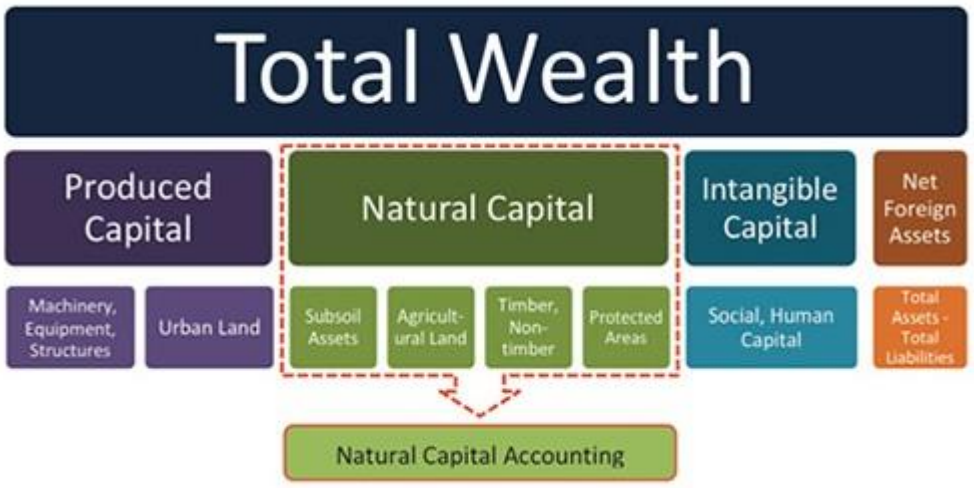
products. It gives suggestions on extensions and applications of such accounts and also provides guidance on experimental accounts that cover non-market resources..

The World Bank has developed frameworks for considering the wealth of countries (Comprehensive Wealth and Inclusive Wealth), incorporating economic, financial, natural, human and social capital components, which are consistent with the UN SEEA central framework. It has also developed a Genuine Savings Indicator which spans the SEEA's Central Framework and Experimental accounts: for instance, whereas its Wealth measures are not adjusted for the value of externalities such as pollution damage, its genuine savings indicator does cover this in valuing changes to natural resource and environmental quality, thus providing a broader indicator of sustainability (Khan et al 2013).

National agencies such as the UK's Office of National Statistics (ONS) are preparing accounts consistent with the central framework for marketable natural resources like oil and gas and timber, but also more experimental accounts for ecosystems and their services such as recreational and cultural uses.

Figure 2 shows the position of Natural Capital within the World Bank's total wealth accounting framework. There are four broad sub-categories of natural capital – subsoil assets (minerals and hydro-carbons), agricultural land (cropping and pasture), forestry products (timber and non-timber) and protected areas as a proxy for nature conservation assets. Other accounts in the wealth framework cover produced capital, intangible capital (social, institutional and human) and net foreign assets, which is largely a balance of financial assets and liabilities held in other countries.

Figure 2 Position of Natural Capital within Comprehensive Wealth



Source: NZIER, drawn from the WAVES website

Table 1 shows the coverage of the World Bank's Comprehensive Wealth and Inclusive Wealth measures. They have close similarity in their coverage, except that Comprehensive Wealth excludes Fisheries but includes Protected areas as a proxy for the state of ecosystems and biodiversity, whereas Inclusive Wealth includes Fisheries but excludes Protected areas.

Comprehensive Wealth is the older of the two measures and results from the pragmatic exercise of estimating comparative wealth across 120 countries (World Bank 2011). The Inclusive Wealth measure is based on a theoretical framework based on social welfare theory to address the multiple issues in sustainable development (Arrow et al 2012). That paper expands the definition of wealth to include health and time as assets, although Inclusive Wealth treats them as separate from the other capital assets, as small changes in health capital could dwarf any changes in the other three assets – produced, human and natural.

Table 1 Distinctions between World Bank wealth measures

Non-renewable resources		Renewable resources
Oil	Iron ore*	Protected areas ŧ
Natural gas	Lead*	Timber resources
Hard coal ʒ	Nickel*	Non-timber resources (e.g. carbon)
Soft coal ʒ	Phosphate*	Crop land
Bauxite*	Tin*	Pasture land
Copper*	Silver*	Fisheries ł
Gold*	Zinc*	

Note: Unshaded items are the same in Comprehensive Wealth and Inclusive Wealth

* Minerals included in single Total Minerals Figure

ŧ Protected areas included in Comprehensive Wealth but not Inclusive Wealth

ł Fisheries included in Inclusive Wealth but not in Comprehensive Wealth

ʒ Hard coal and Soft coal are separate in Comprehensive Wealth but combined as Coal in Inclusive Wealth

Source: NZIER, drawing on Khan (2013), UK Office of National Statistics

The Comprehensive Wealth measure is estimated as the sum of Produced capital plus Natural capital plus Intangible capital (human capital, social capital and quality of institutions). Most natural capital was valued as the Net Present Value of future resource rents over an assumed lifetime, which is feasible because all the natural capital items give rise to streams of marketable goods and services.

Produced capital was estimated using the perpetual inventory method, whereby value is the sum of additions, minus subtractions, made over time from an initial stock. Intangible capital was calculated as a residual of natural and produced capital taken away from total capital, the latter estimated as the Net Present Value of future consumption.

Ecosystem services that supported production of goods and services would be captured in total wealth through the residual of intangible assets, but not through the natural capital figure. But many cultural and regulatory ecosystem services were not valued or included in total wealth. Assets such as water were omitted and no adjustments were made for the impacts of externalities, such as pollution damage, on capital values.

The Comprehensive Wealth measure is thus rather limited in scope, although it provides a broad comparison across a wide range of countries.

The UK approach

Individual countries have been producing natural capital accounts reflecting both the SEEA and World Bank approaches. The UK ONS, for instance, has produced monetary asset accounts for oil and gas reserves within the UK's continental shelf; for fuel use, energy consumption and emissions; material flow accounts; environmental taxes; environmental protection spending; and the environmental goods and services sector. They have also attempted broader environmental accounts more in line with the experimental accounts of the SEEA. For instance, Table 2 shows an initial estimate of Woodland ecosystem services in the UK, divided between provisioning, regulating and cultural services. These are expressed in physical units and there are gaps in coverage that preclude full monetisation at present.

Table 2 Initial UK Woodland Ecosystem Services Account

Class	Examples	Services 2012
Provisioning Services		
Wild plants and their outputs	Wild berries, mushrooms	154 tonnes (2010)
Wild animals and their outputs	Game, honey	3,700 tonnes (2010)
Fibres and other plant materials	Timber, flowers	9,520 tonnes (2012)
Genetic materials from all biota	Medicines	15 tonnes (2010)
Plant-based energy resources	Wood fuel, straw, energy plants	1,300 tonnes (2011)
Regulating Services		
Global climate regulation	Carbon sequestration	9.7 million tonnes
Watershed and flood protection	Reduced frequency & flood damage cost	n.a.
Cultural Services		
Experiential use of nature	Bird watching, landscape sightseeing	n.a.
Physical use of landscape	Walking, climbing, recreational hunting	38 million visits (England 2011)
Cultural and heritage uses	Visits to cultural and heritage sites	24% of unique visitors (2011)
Symbolic values and associations	Emblematic plants, national symbols	6% of unique visitors (2011)
Bequest and existence value	Willingness to pay to preserve ecosystems	n.a.

Source: NZIER, drawing on Khan et al 2013, ONS

3.3. Biodiversity and ecosystem services initiatives

Ecosystem services is a relatively recent manifestation of what has been attempted over a much longer timeframe – expressing the "worth" of natural resources in terms of the service flows for human activities that can be obtained from them over time, including effects which are relatively hidden from view but would entail real value impacts if natural resources were degraded.

The term ecosystem services came into common use in the 1990s and provided a more coherent frame for various ad hoc valuations being already undertaken. It received prominence in 1997 when Costanza et al published in *Nature* magazine an estimate of the value of the world's ecosystem services which concluded they were collectively worth about three times the world's total GDP output in that year. This drew on a range of market and non-market valuation techniques to assign value to particular services, although it was criticised by many economists for mixing valuation concepts and not providing meaningful values for marginal changes in ecosystem service outputs.

In a 2014 update of this study, Costanza et al concede that their estimate could not be used for marginal analysis. But was still useful as an illustrative tool in drawing attention to the unstated values associated with ecosystem services.

The concept of ecosystem services has since been formalised by the UN's Millennium Ecosystem Assessment (MEA 2005), which divided services into cultural, provisioning, regulating and supporting categories (see Appendix B.4). This prompted implementation at a national level in the UK's National Ecosystem Assessment (2011), which had extensive quantification and valuation of some services.

Internationally direction on dealing with biodiversity is being given under the UN Convention on Biodiversity and the achievement of high level targets under the Aichi accord (CBD n.d.). The secretariat of the Intergovernmental Panel on Biodiversity and Ecosystem Services is developing guidelines on the conceptualisation of values and on policy support tools and methodologies (including payments for ecosystem services and assessment tools, and the use of multi-criteria analysis and cost benefit analysis) but these are not yet at an operational stage (IPBES n.d.).

Vardon et al (2017) suggest that so far the developments of the IPBES have not significantly engaged with the processes surrounding the SEEA, but there are likely to be increased opportunities to do so in future as more countries implement SEEA. One such opportunity is in linking payments for ecosystem services programmes, such as biodiversity offsetting, more explicitly to accounts which reflect the physical extent and scarcity of natural habitats and species. Such linking however would depend on accounting frames requiring more localized or regional detail than national level.

While the capitalisation of service flows fits well with the idea of natural capital, for some things the capital description is less useful e.g. biodiversity, for which diversity is critical, may be managed better through a suite of separate indicators of the different components of diversity, than by fitting into a natural capital account which homogenises detail and implies that one type of capital is substitutable for another.

3.4. Public preferences and cultural values (including Māori interests)

The usefulness of the natural capital framework depends on its scope, so it is important to be clear what's defined in or out of a natural capital framework. Are there aspects of public preference that are not covered by natural capital practices but which could practically be?

Natural capital approaches seek to put natural capital on a commensurate basis with economic considerations, with a measure of value being people's preferences for the use or non-use of the components of natural capital. Economists rely on prices to reveal preferences for market goods, and have developed non-market valuation techniques to do the same for non-marketed goods.

An irony recognised in the non-market valuation literature is that those methods that are potentially most useful for addressing intangible non-use values are also most difficult to verify (Atkinson et al 2012), so other ways of gauging public preferences may be better for weighing things that people are not familiar with valuing in monetary terms. Such methods might include a straight voting model (i.e. numbers for and against, regardless of willingness to pay), deliberative processes like citizen juries, and focus groups to examine an issue in detail and come to a group preference choice.

It is challenging to obtain a sound expression of such preferences that is reconcilable with economic values, and particularly with respect to Māori preferences which reflect a worldview and experiences unique to Aotearoa New Zealand, and for which international literature provides relatively few leads.

Cultural values, including Māori interests, represent a subset of social preferences. Non-Māori cultural values can be recognised through the same processes, institutions and mechanisms that recognise public preferences in general. Iwi/Māori interests, in contrast, receive special consideration in light of the partnership established between Māori and the Crown under the Treaty of Waitangi, the biculturalism that implies, and specific provisions at law that provide different rights to iwi/Māori, such as provisions under the Resource Management Act (RMA) or Treaty settlement redress, for example. This in turn suggests that a future natural capital framework for Aotearoa New Zealand may involve unique cultural dimensions, and hence reflect different trade-offs to those made in other countries.

There is a lack of Māori-specific natural capital data

Challenges include reflecting Māori-specific non-monetary values in natural capital frameworks, especially when many of these values emphasise relationships and responsibilities between people, between people and resources, and across generations. The available literature relating to iwi/Māori resource management practices in Aotearoa New Zealand suggests that there is very little, if any, formal or systematised measurement of natural capital currently in use by those communities.

The regional, policy-focused iwi management plans which first appeared just prior to the passage of the RMA (e.g. Tau et al 1990) continue to be promulgated, and especially at the localised district and regional council planning levels, with some 87 iwi management-related documents being found on the Bay of Plenty, Waikato and Canterbury Regional Council websites alone. We are now also seeing the emergence

of regional and national Māori economic development plans (e.g. He Mauri Ohooho 2014 in the Bay of Plenty and He Kai Kei Aku Ringa 2012, respectively). However, none of these documents attempt to measure, manage or report on the value of natural capital stocks in the environment – or propose research into new frameworks to do so – and propose instead standard environmental and economic performance metrics.

Existing approaches are relatively narrow in focus

Iwi/Māori natural resource planning and monitoring efforts to date have tended to follow an ecosystem services approach, and principally focus on the mauri (life force, productivity, resilience) of water bodies especially, and utilise utilitarian resources as the primary indicators of environmental wellbeing, such as the availability and the suitability for purpose of mahinga kai (natural resources and the places they are located).

For example, tuna (eels) are a traditionally important resource used as a contemporary measure of environmental wellbeing (e.g. Ian Ruru n.d.), like the keystone species used in some biodiversity management. The existing documents mostly take a holistic approach, and incorporate a range of social, cultural and spiritual values in their frameworks, leaving open the question of the relative weightings given to each dimension (e.g. Ruru, Harmsworth 2014, Tipa and Teirney 2006). Further, the various capitals are viewed as merely the means with which to achieve individual and collective wellbeing ends.

The literature and overseas experience also note that monetary valuation of natural capital can elevate Western over indigenous values (Farley 2012 and Noa Lincoln 2015). In combination these approaches make both the unitising of natural capital and the direct comparison of competing projects difficult.

Models have been developed that attempt to identify 'additional' or 'different' values in resource descriptions and thereby highlight to others the importance of these additional dimensions to Māori. Harmsworth and Awatere (2013) suggest indigenous Māori have a strong sense of ecosystems and their services expressed through concepts such the mauri of waterways, and also refer to more formal models for taking these into account. These include:

- the Mauri Model (which has been applied to land transport and geothermal projects) overlays statistics with subjective measures of perceived relative good and bad, requiring careful interpretation
- the Mauri Compass (Ruru n.d.) with its human/fishery/vegetation dimensions emphasises holistic and interdependent set of relationships and the "reciprocal obligations" aspect of the Māori belief system, but requires subjective 'measures' for each of the dimensions in its current form
- the Cultural Health Index approach (Tipa and Tierny 2006) captures values for past importance (as far as it is remembered/known at least), current mahinga kai productivity, and therefore contemporary utility in a pragmatic set of measures, but has relies on subjective values for a limited number of dimensions.

Harmsworth (2014) differentiates the Māori, community and scientific values as (roughly) the relationships/identity lens, the utilitarian lens, and the data-centric lens respectively. He shows how mapping of technical toxicity limits against taonga/

indicator species of cultural value, such as eels, lamprey could be used to inform decisions at a practical level.

Māori interest is high but resources are limited

The increasingly detailed recent annual reports of the larger post-settlement iwi make no reference to natural capital measures or related work programmes (e.g. Waikato-Tainui 2013, Te Rūnanga o Ngāi Tahu 2014). Those reports do, however, note the ongoing expenditure of considerable financial and human resources on continued efforts to secure and protect interests in natural resources, such as the long-running iwi/Crown freshwater discussions, for example, and a continued focus on the maturation of their governance and management institutions.

Given that Treaty-related settlements are still relatively recent it appears that iwi/Māori at the institutional level are still settling their Treaty claims and consequent enabling legislation, establishing their governance and management structures, and operationalising multi-faceted tribal development plans. These entities are also still engaged in establishing the nature and extent of their rights in various natural resource domains. The all-consuming demands of this type of work on emergent and skills-poor communities, and the consequent monopolising of available resources, are regularly and significantly underestimated.

The relatively slow adoption of natural capital frameworks notwithstanding, there are multiple indications of increasing interest in identifying new ways to manage and monitor natural capital stocks and flows, both in the iwi/Māori sphere and more widely. By way of example:

- the Ngāi Tahu settlement returned ownership of Te Waihora/Lake Ellesmere to the iwi and its restoration is now overseen by a voluntarily established co-governance board made up of Environment Canterbury and tribal representatives
- a 2010 NIWA report to support planning for the restoration of the Waikato River as part of the Waikato-Tainui settlement included an entire section on non-market values
- the Tūhoe and Whānganui settlements involve significant and novel resource transfer and future management implications, both of which will need to be supported by new management frameworks
- Crown Research Institutes, such as Scion and Manaaki Whenua/Landcare Research, have work programmes dedicated to environmental ecosystem research, and
- the Department of Conservation has just released a comprehensive report on wellbeing and research on ecosystem services in the New Zealand context (Roberts et al. 2015).

Natural capital frameworks constantly evolve as public views change

More generally, frameworks for managing natural capital – including the processes and institutions for identifying public preferences and resolving conflicts between those preferences – are necessarily a perpetual work in progress. They evolve in response to changing needs and circumstances, and also changing mores (Samarasinghe et al

2013). For example, halting losses in biodiversity has become regarded as sufficiently important that it is now the subject of international, regional and local agreements (e.g. Scottish Executive (2004), European Union (EU) Committee of the Regions (2014)).

At a fundamental level, these frameworks are also a function of community and political forces. In fact, even changing public preferences is in some cases a stated objective of natural capital frameworks (Scottish Executive 2004).

Frameworks must be able to respond to changing preferences and adapt existing mechanisms, for example, in light of identified shortcomings or improved technologies. Ensuring that stakeholders all have access to the best new and existing knowledge can also be an objective of natural capital frameworks (Scottish Executive 2004). Devising natural capital frameworks is accordingly challenging, with existing mechanisms reflecting only a subset of the possible current or future preferences.

These frameworks need to:

- be adaptable to local contexts and not overly prescriptive, recognising diversity in social and cultural factors (Voora and Venema 2008)
- incorporate decentralised decision-making to benefit from local information and incorporate local preferences (EU Committee of the Regions 2014), and
- incorporate feedback and incentive mechanisms to ensure they are delivering on stated objectives, and align with changing preferences (Scottish Executive 2004, EU Committee of the Regions 2014).

Furthermore, such frameworks often respond to changing preferences only imperfectly. Introducing new mechanisms can create conflicts with old ones (for example the introduction of the ETS has been predicted to impose disproportionate restrictions on Māori in some respects, such as in the development of pre-1990 forest land (Insley and Meade 2008). They therefore require careful consideration of how best to align or compensate various equity and distributional interests (Farley 2012, Samarasinghe et al 2013). Even greater complications arise when trading off inter-generational interests (Samarasinghe et al (2013)), or when attributing non-anthropomorphic interests (e.g. protecting biodiversity in the interest of nature instead of humankind).

Measuring and maintaining public preferences is therefore important

Complementary mechanisms exist for determining public preferences and reflecting them in natural capital frameworks. These include direct approaches for eliciting public preferences, as well as novel governance mechanisms. Ultimately, governance arrangements determine how public preferences are reflected and implemented.

At the simplest level, such preferences can be elicited through direct voting mechanisms. More generally, multi-level governance arrangements – combining multiple stakeholders in collaborative and cooperative decision-making processes – are seen as necessary (Scottish Executive 2004, EU Committee of the Regions 2014). Such arrangements internalise the trade-offs and compromises necessary to resolving conflicts of interest between those stakeholders in devising and implementing frameworks. International examples include the Scottish Biodiversity Forum and the

EU Committee of the Regions, with the Te Waihora Co-Governance Board and the Waikato River Authority being local examples.

Natural capital frameworks are likely to become more widely used in New Zealand

In sum, and despite a tentative start, there are reasons to believe that Aotearoa New Zealand is likely to increasingly engage with the possibilities provided by natural capital frameworks.

Significant resources are currently being mobilised within iwi/Māori communities. As a result of Treaty settlements, indigenous value sets and cultural preferences are being progressively adopted into mainstream policy settings. And the positive impact of increasingly professionalised management and governance structures on iwi/Māori assets is already being felt.

Further, the initial early stage experiments that are forming in this country – supported by government departments and public good institutions – will be influenced and encouraged by the increasing number and scale of global initiatives grappling with systemic environmental and resource constraint challenges.

It therefore seems likely that the influence of natural capital frameworks on the way natural resources are managed and measured in Aotearoa New Zealand will increase over time.

3.5. Market and non-market valuation of uses and non-uses

Some elements of natural capital produce services with market values but some do not, raising the question of how to assign values to them. This is the role for which non-market valuation techniques have been developed, but there is a wider range of valuation options.

The economic values are based on observed willingness to pay for the market or non-market goods and services from the natural resource, using the Total Economic Value framework that is now accepted for valuing environmental goods, covering current uses, future uses (option value) and non-use (existence and bequest) values, as explained in Appendix B.2.

Where a value is required for a natural resource with non-market attributes, a range of methods could potentially be employed. These include:

- valuing solely at the value of marketable output from the resource, for instance the sales value of timber or non-timber produce from a forest – a partial value of Total Economic Value as the non-market values are omitted
- estimating the economic impacts associated with the resource, for instance the value of timber plus the value for tourist accommodation and other services derived from recreational visitors to the forest – this is still incomplete but captures part of the value associated with non-market use, and it is aligned to the national accounting framework, allowing value added and incomes to local employees and business owners to be inferred from the output values

- estimating the economic rents from the resource, which is the surplus value attributable to the natural resource after the full costs have been deducted from all other inputs in producing those outputs (such as timber) – this solely applies to the revenues from marketable goods, and if it is not calculated, the rent usually accrues as a producer surplus to the operation that creates the revenue stream
- estimating the consumer surplus associated with the non-market use or non-use of the resource, i.e. the value in the resource simply being there, retained for future use or just for its own sake.

There is a long history of economic non-market valuation techniques being developed to assist in weighing up effects on the natural environment, including intangible aspects that affect well-being (such as option values and existence values). The distinctions between cost-based measures, revealed preference measures and stated preference measures are described in more detail in Appendix B.2

There are compatibility challenges with some techniques

The most sophisticated of these techniques calculate a consumer surplus value that is incompatible with natural capital accounting (or at least cannot be incorporated in national accounts unless the consumer surplus values for all other things are explicitly taken into account).[4] So these non-market valuation techniques have limited relevance to high level natural capital accounting. They can still be used in project appraisal and informing lower level decisions about individual site use. They have had limited influence on decisions in New Zealand, although have been more influential elsewhere (see section 3.9 later in this report).

3.6. Policy decision-making frameworks and tools

New Zealand has a range of policy making frameworks in which measures of natural capital could be used, although not necessarily explicitly required to be used.

- The Treasury's Living Standards Framework[5] refers to natural capital as one of a four-capital framework, and refers to biodiversity, climate and water as indicators in its sustainability dimension in assessing well-being – although to date there is little guidance on how the sustainability dimension is to be measured or valued in practice
- The Natural Resources Sectors framework[6] has obvious parallels, although the term natural capital does not appear to be used in the framework, which is more about the processes for identifying effects, values and consulting with people affected than the measures needed to enumerate them

[4] National accounts represent a snapshot of production values for a specific point in time or year, so it would be uneven to count consumer surplus values for say recreation activity, but not the surpluses enjoyed on other goods. When valuing a marginal change in activity through the lens of the national accounts, a gain in consumer surplus in one sector may give rise to increased spending and consumption in other sectors, so viewing consumer surplus for non-market activities alone can overstate total value by omitting the offsetting effects of other expenditure recorded elsewhere in the national accounts.

[5] http://www.treasury.govt.nz/abouttreasury/higherlivingstandards

[6] http://nrs.mfe.govt.nz/content/natural-resources-framework

- While the framework has been applauded for applying a systemic approach to natural resources, Scott (2014) has suggested it is weak in problem definition and not well suited to examining how a system works to produce the outcomes it does, or how to tweak it to perform better
- The 1991 Resource Management Act and the 2012 EEZ and Continental Shelf Act both have a purpose of promoting the sustainable management of natural and physical resources, an implication of which is management of stocks of renewable natural resources at levels at which they do not disappear, which is closely aligned to some approaches to natural capital and sustainability. However, to date it is not obvious that decisions under these Acts pay more than lip service to natural capital, and a number of decisions have explicitly found quantitative economic evidence on matters beyond output and job creation to be of limited assistance to their decisions (see Christensen and Baker-Galloway 2013 and section 3.9 below)
- Other frameworks and strategies, such as the Biodiversity Strategy and the Fishery Management System, look to be amenable to natural capital approaches, although not explicitly required to in practice
- The Greenhouse Gas Emissions Inventory, used for monitoring progress in controlling greenhouse gas emissions net of carbon sequestration, can be viewed as a form of natural capital account, representing a negative stock (emissions) giving rise to a liability under international trading obligations, rather than an asset. Other emissions or discharge control regimes could apply a similar approach.

Tools for aiding decisions

Tools for aiding decisions can be divided broadly into a number of categories:

- informal "balancing" frameworks supporting judgement calls – in practice these are widely used and may be simple in reducing transaction costs, but have a drawback of lack of transparency that may result in different decisions implying widely varying values for the same outcome
- formal frameworks for integrated policy assessment or multi-criteria analysis, in which different classes of outcome (which may include economic measures, and less tangible social or economic outcomes) are weighted or scored according to consistent criteria – these are useful but can still lack transparency and obscure the monetary values and trade-offs implied in the eventual decision
- formal economic frameworks, including cost benefit analysis (which values all changes from the status quo and can in principle be extended to include values for environmental effects), cost utility analysis (which compares costs against an index of other changes, including environmental effects) and cost effectiveness analysis (which compares the costs of varying options for obtaining a single given outcome)
- combinations of the above.

Cost benefit analysis (CBA) requires consistent values for all items that appear in the analysis, for which purpose non-market valuation techniques have been developed. While CBA as a technique can be traced back to the writings on marginal utility by Jules

Dupuit in the mid-19th Century and has been routinely used in practice in many countries since the Second World War, in recent decades it has been taking on the concepts of natural capital covered in this review. A good example of this is HM Treasury's (2015) *Green Book on Appraisal and Evaluation in Central and Local Government*, which has a supplementary guidance document on Environmental Impacts which accepts the use of non-market valuation techniques in weighing up impacts on well-being. There is other supplementary guidance on air quality, the use of stated preference techniques and multi-criteria decision analysis. These documents also refer to an earlier Introductory Guide to Valuing Eco-system Services (DEFRA 2007) which explicitly uses ecosystem services to define environmental impacts to which non-market valuation techniques are applied. The techniques of natural capital assessment are well embedded within policy guidance in the UK.

Most economic analyses are partial in the sense that not everything can be valued, so some things are either omitted or consigned to an intangibles balance sheet (as has been used in New Zealand transport evaluations), and their effect on the result is decided through weighting processes or judgement. General guidance on the use of such techniques as multi-criteria analysis is found in sources such as HM Treasury's (2009) multi-criteria analysis manual, but a role for these and their variants with specific respect to natural capital has not emerged from the literature search.

Recognising natural capital in decision processes requires either giving them a value to weigh up against other items in a cost benefit analysis or alternative balancing process, or attaching a price to them in transactions to provide market-like incentives to use the environment more sparingly. Such incentives are recognised in a growing literature on payments for ecosystem services, which is a recent development in a longer tradition of economic instruments for environmental policy. Such instruments can be divided between **market creating** instruments, such as traded permits for emissions, discharges or fish quota which involve changes to property rights, and **market adjusting** instruments such as taxes and surcharges on existing market transactions and subsidies to provide public goods. Such instruments have not always been explicitly linked to natural capital in the past: for instance, waste levies have been commonly set at a level to produce a targeted revenue or a price response that reduces waste creation, regardless of any measurable environmental cost caused by incremental additions to such waste.

The UK has issued a Best Practice Guide to devising such ecosystem service payments (DEFRA 2014), building on its own and other European countries' long experience of land stewardship and environmentally sensitive area payment schemes, which provide payments from government funds for land management activities that supply public good benefits in maintaining landscape for wildlife protection and recreation activities. These payment schemes evolved to counter the production-biased subsidies of the EU's common agricultural policy, but the new guidelines include steps for identifying who benefits from ecosystem services and for devising public, private and joint public-private payment schemes.

Another tool developed for informing decisions is the biodiversity offset, in which compensation in money or kind is provided to offset degradation in natural capital caused by new developments. This has been a particular focus of the Business and Biodiversity Offsets Programme under the United Nations' Environment Programme's TEEB project, which now lists a number of projects in which offsets appear to have been influential in gaining approval for developments in natural areas. There remains

debate around the effectiveness and appropriateness of such offsets, for instance around whether offsets need to be "like for like" habitat restorations or can allow degradation of one type of habitat to be compensated by improvements in other types of habitat; or whether some sorts of natural asset are not capable of being offset, because of uncertainty around what would be lost (Walker et al 2009).

3.7. Incorporating natural capital in private sector investment decisions

Thinking about natural capital is not limited to public sector policy decisions. The private sector is also interested in natural capital, because environmental risks can directly or indirectly affect investment and business prospects.

Incorporating natural capital in private sector investment decisions appears to be an emerging trend – one that goes beyond market-related natural capital like minerals. The rationale and driver behind the uptake of the natural capital framework in the private sector is a greater focus on systematic risks following the global financial crisis. These systematic risks from a commercial perspective on environmental factors include such matters as the potential impact of climate change on investment, the stability of fish stocks and security of water rights.

Apart from the official work of TEEB, private entities have also addressed the implications of natural capital for business activity. The HSBC (2013) research report entitled 'Natural capital: Identifying implications for economies' is one example of the emerging awareness of the commercial importance of incorporating natural capital in private sector investment analysis. In this report HSBC say "We think that natural capital factors are becoming a bigger driver of overall economic productivity and that, increasingly, policymakers will act to manage change. Ultimately this will impact the potential return profile of assets." (HSBC 2013, p. 1).

The report recommends that investors should be incorporating natural capital by:

- identifying the contribution of natural capital to national economic activity
- evaluating whether natural capital is well managed and above sustainability thresholds
- assessing the future risks and potential economic consequences.

The first two steps are generally considered to be something done by policymakers and academics rather than investors. The third is a recurring theme in business-oriented literature on natural capital, which identifies three broad components of natural assessment:

- natural capital's impact on an organisation – internalised financial costs of using natural capital directly or indirectly through its value chain
- how the organisation's use of natural capital impacts on society's well-being and social capital – and hence the organisation's social licence to operate
- the organisation's dependence on natural capital, and the risks its faces from changes in access to, or pricing of, natural capital.

Another example of the emerging private sector interest in incorporating natural capital is the UNEP Finance Initiative (2010) CEO briefing summary. It advises business

leaders that natural capital is more than a factor for consideration of demand and supply risks, it also relates to the following areas:

- management of reputational risks
- legal challenges
- societal contribution
- regulatory hurdles, costs, and risks.

The briefing also suggests natural capital can be factored into lending, investment management, investment ownership and insurance.

CIMA (2014) positions natural capital accounting as an important emerging issue in business decision making. It describes natural capital as being invisible in traditional business accounting practices and business decisions. The increased recognition of the pressures on the natural environment and the natural capital used by businesses means accounting for natural capital risks and opportunities will become increasingly important in the 21st Century.

Natural capital is seen as the capital that underpins all other capitals and the foundation on which economies, societies and businesses are built. However, natural capital has been absent from business considerations due to six systematic reasons:

1. An embedded flawed assumption of infinite resources and perpetual equilibrium in the ecosystem.
2. The domination of GDP, profit and other economic or financial measures of success.
3. A legacy of accounting practices developed in an era when nature's abundance was assumed to be endless.
4. Reliance on business models and practices that do not reflect the wider system that businesses now inhabit.
5. The short term focus of much business planning and performance monitoring.
6. The lack of a framework and systems to account for the relationship between natural capital, business strategy and performance.

In July 2016, the Natural Capital Protocol[7] was launched by the Natural Capital Coalition as a framework to help generate credible and actionable information to inform business decisions. The purpose of the protocol is to provide "a framework designed to help generate trusted, credible, and actionable information the business managers need to inform decisions."

To support the use of the Protocol by businesses a primer has been designed to communicate what the Protocol does, why it is useful to businesses and how it can be used. The primer includes a description of the scope the Protocol and positions the Protocol as a new lens through which business risks and opportunities can be considered. A related *Natural Capital Hub*[8] provides access to all the latest material and information on natural capital, allowing searches through a growing database of content developed by Coalition members.

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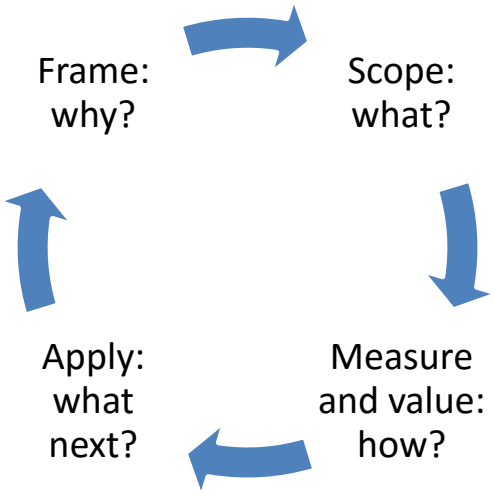
[7] http://naturalcapitalcoalition.org/protocol/

[8] https://naturalcapitalcoalition.org/hub/

The Natural Capital Protocol has four stages which form an iterative cycle shown in Figure 3.

Figure 3 Natural capital protocol cycle



Source: National Capital Coalition

Four principles underpin the protocol:

Relevance – Businesses should ensure they consider the most relevant issues throughout their natural capital assessments, including the impact and/or dependencies that are most material for each business and its stakeholders.

Rigor – Assessments should use technically robust information, data and methods that are fit for purpose.

Replicability – Assessments should ensure that all assumptions, data, caveats, and methods used are transparent, traceable, fully documented and repeatable.

Consistency – Businesses should ensure that the data and methods for an assessment are compatible with each other and with the scope of the analysis, which depends on the overall objective and expected application.

Friedman (2015) notes that natural capital has begun to appear as a feature of financial markets, through mechanisms such as green bonds, sustainable indices, and sustainability reporting (e.g. triple bottom-line). This has created an interest in the development of common reporting standards to ensure comparability and transparency. For example, the ASX has guidelines for sustainable reporting.

Friedman (2015) stresses that critics argue that the market cannot accurately price securities without public disclosure on resource use and sustainability. There are several organised efforts to promote the integration of environmental, social and governance (ESG) criteria into financial markets. According to Friedman (2015) there were 180 policies on sustainability disclosure in 45 countries and regions; and 72 percent of these policies are mandatory. The issue is not the relevance of natural capital or that ESG should be part of company information, but the methods used to account for it.

Høst-Madsen et al (2014) report how the Danish Environmental Protection Agency commissioned a triple-level natural capital assessment for the Danish apparel industry to determine the impacts of apparel production, where they occur in the supply chain and what monetary value of these impacts might be. The analysis focused on the following levels of the apparel sector:

- national sector-level (including all apparel consumed within Denmark)
- company-level (including all subsidiaries)
- fibre-level (agricultural/raw material production phase of individual fibre types).

This was intended to help stakeholders understand the natural capital dependencies in the supply chain and consider policies on approaches to managing the impacts. Høst-Madsen et al (2014) found the main impacts to be greenhouse gas emissions, air pollution and water use in the production of raw materials, much of which happened outside of Denmark. They estimated the costs of the monetised impacts to be equivalent to 11.7% of sector revenue and almost the typical profit margin in the industry. If these costs were internalised within the industry it would result in a net loss across the industry.

Bonner et al (2012) investigated how natural capital accounting is perceived within the accounting profession. They found that the perceptions of risks and opportunities associated with biodiversity and ecosystem services varied among accountancy practitioners, and the materiality of natural capital on company performance depends on which industry is in focus. They also found that in some cases existing financial reporting and disclosure standards can be applied to natural capital. However, in practice, many significant risks and opportunities are unquantified not valued, and are therefore excluded from quantitative reporting. The barriers to corporate action were found to be:

- the lack of a standardised business case treatment of environmental risks
- low or lacking market values for biodiversity and ecosystem services
- some accounting principles.

Corporate perspectives are also filtering into some of the literature on natural capital from multi-national agencies. Brandt et al (2013) present a framework for incorporating natural capital into a productivity measure at the national accounts level. The purpose of the approach is to improve the measurement of national accounts, rather than environmental reporting. It utilises the improved information available through the System of Integrated Environmental Economy Accounts.

Radermacher et al (2014) recommend investment in the development of natural capital accounts, but also to be aware of the limitations, especially with regard to monetisation. Some types of natural capital are easier to measure and monetise than others, and how the monetisation is done can critically affect the results. Radermacher et al (2014) suggest accounting for physical stocks and flows is key before proceeding to monetisation. They also conclude that natural capital accounting alone is not adequate for monitoring sustainable development.

3.8. Best practice examples

Identifying "best practice" examples would ideally be based on detailed comparison of the implementation and uses of the different approaches against common criteria, but this is beyond the scope of this current review of literature. Instead we look at what the literature tells us is most commonly being employed, noting any assessments or conclusions that the literature has made.

The adoption of the UNSEEA as a recognised standard is a clear example of best practice in natural capital approaches, although at present countries appear to be applying it to different areas according to their individual policy priorities. The OECD is co-ordinating implementation across countries which is likely to lead to convergence on more consistent approaches in future.

The ecosystems services framework could also fill a similar role with respect to the ordering of environmental statistics and reporting, although the fact that ecosystem services accounts are regarded as experimental in the SEEA indicates that there is still some way to go before standards are accepted. Part of the difficulty is in consistent valuation of the different categories of ecosystem service. Non-market valuation has been developed to overcome that and the literature has identified validation checks that show some methods are better than others. But there is still a broad range of such valuation techniques that could be used depending on circumstances, which makes it difficult to define a clear set of best practices.

3.8.1. International examples

Most of the apparent activity in capturing natural capital is in the preparation of natural capital accounts. Below we summarise the approaches in a selection of countries.

Australia

The Australian Bureau of Statistics (ABS) currently produces a range of separate environmental accounts for water, energy, waste, land and environmental assets as part of the national balance sheet. In 2014, it brought these together into a single consolidated document providing a snap-shot and time series back to the mid-1990s of such matters as the intensity of greenhouse gas emissions, water use, energy use and waste disposal by industry; revenues earned from water and energy sales; environmental taxes paid by industry and households; and land cover change.

These accounts are underpinned by the SEEA and there are plans to include more information on matters such as expenditure on environmental protection, water and air pollution, valuation of water and fish, and greater geographic and industry breakdowns (ABS 2014).

The Australian Bureau of Meteorology (ABM) prepared a Guide to Environmental Accounting, which summarised its own national water (availability) account, the ABS's energy, land, waste and water accounts, the Department of Environment's greenhouse gas emissions inventory and other initiatives such as a Victorian Experimental Ecosystem Account and trial regional environmental accounts (ABM 2013). It also included numerical estimates of the Australian Natural Capital Base in dollar terms, concentrating on market values consistent with the national accounts.

There has also been investigation of GIS based models to account for nature impacts in specific trial regions (Karanja et al 2008), including such measures as native vegetation asset scores, weed distribution, and the condition of separate assets as soils, wetlands and groundwater. The modelling is currently experimental and in search of continued funding (Cosier and Sbrocchi 2013).

Canada

Statistics Canada today publishes annual estimates of the value of Canada's energy, mineral, timber and land assets. Those assets currently account for about 40% of Canada's national wealth. It also prepares accounts for Natural Resource Stocks, Material and Energy Flows and Environmental Protection Expenditures, but these remain outside the economic accounts and do not alter GDP. These estimates are revised regularly but gain little public or official attention when released (Smith 2013).

Statistics Canada is also involved in compiling Measures for Ecosystem Goods and Services (MEGS), which report on land cover, human modification, potential of arboreal forests, biomass extraction and marine, coastal and wetland ecosystem goods and services. There have also been assessments of the natural capital of specific ecosystems (Anielski and Wilson 2015) and land use types (Olewiler 2004). Canada's basic data on water, pollutants, ecosystems and other environmental issues remain inadequate, while methods for valuing non-market environmental assets are still experimental.

European Union

With assistance from EuroStat and the European Environment Agency (EEA), EU members like France, Germany and Italy are implementing natural capital accounting, consistent with the UNSEEA (European Commission n.d.). The EU also has a workstream on developing natural capital accounts for companies. There is a strong interest in improving the mapping of natural resources in ways that would support natural capital accounting (Maes et al 2012, MAES 2014, Petersen and Cochiva 2015), and also in broader but more experimental ecosystem accounts (EEA 2011).

In September 2015 the EU Commission announced an *Integrated Natural Capital Accounting (INCA)* system to be developed to provide a multi-purpose tool that can be used for a range of policies at different stages of the policy cycle, demonstrating in monetary terms the benefits of investing in nature and sustainable management of resources.[9] Proposed applications include EU Forest Strategy, reviews of the Common Agricultural Policy, evaluating land use planning proposals, enumerating contribution of natural resources to climate change objectives – but documentation of how INCA would address such diverse issues remains elusive at this time.

Natural capital underpins many EU environmental laws and policies. The EU Circular Economy Package is a comprehensive set of measures and targets aimed at reducing society's net consumption of raw materials (or 'natural capital'). Similarly, climate change regulation and initiatives, such as the EU Emissions Trading System, the EU Energy Efficiency Directive and the EU Renewable Energy Directive, are focused on

[9] European Environment Agency (2015) *The Added Value of Natural Capital Accounting for EU Policies* http://ec.europa.eu/environment/nature/capital_accounting/pdf/The%20Added%20Value%20of%20Natural%20Capital%20Accounting%20for%20EU%20policies.pdf

reducing activities that deplete specific types of natural capital, specifically the impacts on the atmosphere and climate of emissions from fossil fuel combustion and their sequestration by forests.[10]

While still piecemeal at present, the integration of a natural capital 'mindset' into policy could yield a more holistic set of future environmental policies which are better suited for (1) understanding the environmental trade-offs of human activity and (2) informing strategic business and investment decisions. Corporates and investors need to be ready for a future where natural capital impacts and dependencies are assessed, reported, and possibly subject to liabilities and taxable.

In a recent paper, Ruijs and van Egmond (2017) examine 5 case studies from the Natural Capital Netherlands programme to see how government agencies, businesses and nature-promoting organisations include natural capital in their decision processes. They distinguish three classes of decision settings: sustainable entrepreneurship, in which businesses maintain natural capital for its contribution to their operations; entrepreneurial nature management, in which nature-promoting and protecting organisations seek revenue streams from nature with which to support their activities and build a supportive client base; and area development, in which needs and interests of many parties are balanced in land use and planning decisions. They find that the weighing up of natural capital is often not reliant on monetary valuation, and where such valuation is used, it is more to raise awareness of the scale of natural capital issues than to be used as an explicit value for services provided. Each category of decision requires a different approach to natural capital appropriate to the different questions being addressed.

Norway

In the 1970s Norway was one of the first countries to prepare natural resource accounts in both physical and monetary terms, covering energy, minerals, quarry resources, forests, fish, land use, freshwater, air pollution and waste. By the mid-1980s it was apparent that most accounts were under-utilised by decision-makers, apart from energy which was used for energy and emissions planning (Lone 2015). So fish, forest and land use accounts were continued at minimum levels and mineral accounts abandoned.

From the 1990s the focus shifted from management of resources to tackling environmental deterioration. Since 1992 Norway has been developing an indicator set based around National Wealth as its unifying concept. This requires reporting on both monetary and physical terms, the latter enabling monitoring of critical natural capital which is not substitutable with other capital. Monetary valuation is based on the estimation of economic rents from the key marketable resources (Liu 2013).

Norway investigated adjusting GDP for natural resource depletion, but discovered that with the scale of its sub-surface oil and gas stocks, relatively small price variations could cause fluctuations larger than annual national GDP. Norway has actively embraced the Hartwick Rule in diverting the royalties from its oil and gas resources to a Sovereign Wealth Fund largely invested in other countries, to provide for continuing income after the resources are depleted (Moe 2007). It has also used some royalties

[10] http://inlinepolicy.com/2016/natural-capitals-future-in-uk-policy-after-brexit-and-the-protocol/

for investment in infrastructure within Norway, particularly in new roads, bridges and tunnels to improve communications across the country.

United Kingdom

The United Kingdom's Office of National Statistics (ONS) produces Natural Resource Accounts in physical flows and monetary units consistent with the UN SEEA and oriented to producing national wealth accounts. These cover principally sub-soil assets, forestry assets and rural land (Kahn 2013, ONS 2012, ONS 2014). The ONS is also developing experimental ecosystem service accounts, the first being one for woodland expressed in physical units (Kahn et al 2014).

In 2011 the UK published its National Ecosystem Assessment, following the approach of the Millennium Ecosystem Assessment (MEA) (NEA 2011). This was a heavily resourced one-off exercise, compiling a wealth of detail on ecosystem services at both national and regional level. The NEA assessment focused on the changing patterns in ecosystem services by identifying the level of impact from certain drivers of impact (e.g. habitat change, pollution, invasive species) since the 1940s and how the intensity of that impact changed since the 1990s. It also presented six scenarios of alternative futures with different orientations towards environmental protection to illustrate the effects of changes in the mix of environmental pressures and drivers.

The aim was to provide decision-makers with guidance on the relative importance of the drivers of impact on ecosystems in the UK. It drew on a wide range of experts to present material in a graphical way to illustrate the extent of decline or stability in different ecosystem components. It concluded that 30% of ecosystem services it identified were declining, as a result of which government issued a white paper committing to mainstreaming the value of nature across society.

The NEA put substantial effort into examining environmental services for recreation, with a model that combined forecasting recreational demands and the supply of countryside recreation capacity at regional level, and applying values for different recreational activities drawn from a meta-analysis of non-market valuations (Sen et al 2011). The UK has an objective of increasing its forest cover, and this recreation modelling approach has been proposed to inform both how much new forestry to provide but also where to locate it (Bateman et al 2013).

In 2012 Government appointed a Natural Capital Committee to assist the Office of National Statistics (ONS) to develop a full set of environmental accounts by 2020, trial a methodology for corporate natural capital reporting in conjunction with private partners (EFTEC 2014), and work to an over-arching objective of bequesting to future generations a natural environment in a better state than at present (Natural Capital Committee 2014).

The UK continues to be active in developing its capabilities in natural capital accounting. The ONS has a Natural Capital Accounting 2020 Roadmap, which it reviewed in 2015. This identified a number of limiting issues with the progress in preparing its natural capital accounts, including:

- producing reasonable time series which can highlight changes and trends
- assessment of stocks (assets) as well as flows (services) so that accounts shed light on sustainability considerations

- limitations in data and methodological approaches which need to be clearly understood so that they are not misinterpreted
- the extent to which it is practical to include restoration or maintenance cost information into the accounting framework
- the possibility of non-linear thresholds in ecological systems and service provision, requiring further scientific understanding of these systems.

Despite these limitations, in 2016 ONS released its UK natural capital monetary estimates of annual service flows and asset values by estimating the economic rent associated with different natural assets (see Table 3), and more experimental accounts for farmland and freshwater. Although monetary estimates are described as partial and preliminary, they still produce very substantial values. Expressed as an asset value over just 25 years, the ONS estimated these limited components at £1.6 trillion, a value broadly equivalent to the UK's national financial debt (around £1.4 trillion) and also broadly equivalent to the annual value of economic output as expressed by GDP (£1.62 trillion in 2011).

Whilst methodologies are still to be refined, nature-based recreation appears to produce very high values within the aggregate UK estimates. Travel costs and the value of time together make up the overall "price" that visitors are willing to pay for the recreational service, indicating that this estimate is not consistent with the system of national accounts: travel costs like vehicle and fuel expenses reflect monetary transactions that accrue to other sectors in the national accounts, but travel time is not, being based on income forgone from time not working.

Table 3 UK natural asset value estimates

£ billion 2014 prices

Environmental service category	Natural Capital asset category	Opening stock Year end 2007	Closing stock Year end 2014
Provisioning services	Agricultural biomass	14.9	32.4
	Fish	7.9	9.1
	Timber	3.3	4.2
	Water	31.9	29.2
	Minerals	1.6	3.7
	Oil, gas and coal	190.2	22.6
	Wind energy	11.0	45.3
	Hydropower	10.2	9.2
Regulatory services	Carbon sequestration	51.1	60.7
	Air pollution removal	129.0	114.2
Cultural services	Recreation	213.5	166.3

Source: Office of National Statistics UK Natural Capital monetary estimates 2016

The estimates in Table 3 point to a significant decline in the value of some natural capital assets. ONS has committed to developing a fuller set of natural capital accounts by 2020.

The Natural Capital Committee, which came to the end of its tenure in 2015, was re-established in 2016 and continues to act as a steering group for the efforts of the ONS and other initiatives in furthering natural capital assessment. These include a 25-year Environmental Plan being led by the Department for Environment, Food & Rural Affairs (Defra), working towards the government's aim of being the first generation to "leave our environment in a better state than we found it". The plan will set out the government's approach to maintaining and enhancing the natural environment over the next 25 years, properly valuing the environment, and making global environmental ambitions relevant to local situations.

Natural capital is likely to feature prominently in the plan, which was first suggested by the Natural Capital Committee. In its 2017 report on *Improving Natural Capital*, the Committee noted development of the 25-year Plan had been considerably slower than expected and desired, in part due to the BREXIT referendum and its aftermath.

USA

The USA produced integrated environment and economic accounts in the early 1990s but Congress suspended this pending a review of the national accounting requirements. That review, culminated in a 2002 report, Nature's Numbers, by economist William Nordhaus, which concluded that there were substantial environmental costs from air pollution and other externalities that needed to be reflected in the national accounts (Nordhaus 1999). He subsequently proposed some principles for designing a set of augmented accounts that would cover both market and non-market economic activity, but excluding the consumer surplus component of value.

Officially progress on natural capital accounting in USA appears to be slow, and there is a technical discrepancy between US accounting practice, which views depreciation of sub-surface minerals to be unnecessary (because depletion has zero marginal cost in the presence of new discoveries and new technologies of material recovery) and the UNSEEA which views depletion as having a positive marginal cost that needs to be accounted for in depreciation.

The US retains an interest in ensuring accountability and value for money from environmental improvement programmes. The EPA has been developing micro-level tools, such as the Relative Valuation of Multiple Ecosystem Services Index, which employs elements of value transfer from literature for each ecosystem service and weights it by stakeholder preferences for a variety of ecosystem services to arrive at a composite value that can be used to assess a change in ecosystem service mix in particular locations (Jordan et al 2010).

Mexico

Mexico has been generating environmental accounts for more than 20 years that not only illustrate in physical terms the status and quality of natural resources and environment (cubic metres of water, tonnes of emissions, etc.), but also estimate the economic value of the depletion and degradation of resources. Results of the

environmental accounts are aligned with updates of the base year of Mexico's System of National Accounts (WAVES n.d.).

Information about environmental costs enables measurement of the impacts of economic activities on the environment. Accounts also provide Environmental Protection Expenditures (EPE)—the monetary efforts that the society as a whole puts aside to compensate such damages, which is 1 percent of Mexico's GDP.

They may also be informative in the decoupling (separation) of environmental damage from GDP growth, by highlighting which sectors use energy and material resources and generate waste and emissions. Accounts are prepared of the Total Costs of Depletion and Environmental Degradation (CTADA) and cover costs of associated depletion (of forest resources, groundwater, and hydrocarbons) and environmental degradation (solid waste, air emissions, wastewater and land degradation). Compared to national GDP, CTADA has decreased year after year, from 8.5 percent in 2003 to 5.7 percent in 2013.

The results of the environmental accounts have been an input in development of other national and international initiatives such as the national development plan, the environment sectoral programme, green growth and green economy indicators, mining indicators, among others.

At the national level, they have been useful in strategic development plans and environmental public policy. Accounts that quantify the cost of environmental pollution and depletion of natural resources have been used to prepare an Ecological Net Domestic Product and "Green GDP" as indicators of sustainable development.

Preparation of accounts is guided by technical advisory committees for: water; climate change; emissions, waste and hazardous substances, basic geographic information; energy; land use, vegetation and forest resources; and cadaster and registry information.

Other countries

Guerry et al (2015) report briefly on examples from a range of countries where natural capital and ecosystem service approaches appear to have been aimed at influencing decisions.

China has announced plans to harmonise economic development with nature and to track natural capital and ecosystem services through a new metric call "gross ecosystem product", to be reported alongside GDP.

Costa Rica pioneered payments for ecosystem services (PES) at a national scale, over a period in which it transformed itself from having the world's highest deforestation rate to one of the few countries with net reforestation, with forest cover on farmland increasing from 11% to 17% over 8 years as a result of PES contracts (although it is difficult to fully disentangle the influence of PES from other policy measures).

Across Latin America, since 2006 more than 40 schemes funded by payments from downstream users to upstream landowners have been used to improve water quality and water quantity for urban extraction.

In Portugal, the Gulbenkian Foundation has created the Marine Ecosystem Services Partnership to share ecosystem services information between economic entities.

Sweden has incorporated ecosystem services into urban planning and green area management. A similar initiative appears to have been tried in the UK, exemplified by the London Assembly's *At home with nature* which aims to encourage biodiversity in new housing developments by reviewing the extent of biodiversity provision in such developments over the past 10 years, and drawing on good practice from other cities across Europe such as Malmö and Hamburg.

3.8.2. New Zealand examples

New Zealand has recently reformed its environmental reporting framework from collecting Pressure, State and Response statistics and preparation of decadal State of Environment Reports (MfE 1997, 2007). It is now working to provide updated reports on a three-yearly cycle and has now identified the Pressure-State-Impact framework as the most appropriate for current use, providing a more impartial set of statistics than one that commented on policy response. It also considered the Driving-Force-Pressure-State-Impact-Response framework of the European Environment Agency and the UK NEA, but regarded these as more data intensive exercises. The reporting framework must be implementable now with existing data and with a plan for continuous refinement and improvement (MfE 2014).

Statistical data and accounting

Between 2000 and 2010, Statistics New Zealand prepared a range of natural resource satellite accounts, for minerals, energy, forestry, fisheries and water. These included a mix of stock accounts and flow accounts for the physical volumes of particular resources' availability and use and, in some cases, their monetary value. They were prepared in accordance with earlier guidelines of the SEEA and it is not clear if they have informed any policy decisions. There have been partial revisions of the fish and forestry monetary stock accounts and the forestry and water physical stock accounts to cover the period 1996-2016, and Statistics New Zealand are seeking feedback on how they can be used and improved.[11]

Statistics New Zealand has also produced similar accounts for central and local government expenditure, from which it is possible to extract public expenditures on environmental protection. Their most prominent satellite account is the one prepared for Tourism which has been regularly updated. However, there is little reliable data with which to infer how much tourism activity and value is associated with use of natural environments (Clough 2012).

Statistics New Zealand produced a report on the Marine Economy covering 1997-2002, and more recently for 2007-2013 which identified contributions to GDP of industries associated with the maritime area (e.g. fishing, shipping, boat-building etc). These are therefore accounts of flows rather than stocks and like the tourism satellite account in extracting a share of sectoral activities attributable to a particular activity. They have little to say about the ecosystem services, or the value of natural capital, obtained from the sea.

[11] http://www.stats.govt.nz/browse_for_stats/environment/environmental-economic-accounts/2017-updates-environmental-accounts.aspx

More recently Statistics New Zealand and the Ministry for the Environment have led the development of an environmental domain plan, in consultation with other experts from central and local government, research institutes and Māori stakeholders (SNZ 2013). To achieve clarity and agreement about the main statistical priorities and co-ordinate resources across agencies the domain plan identified enduring questions across 10 topic areas: atmosphere, climate change, coastal and marine environment, ecosystems and biodiversity, energy, freshwater, land, Māori environmental statistics, materials and waste and mineral resources, reflecting the Natural Resource Sector framework.

A stocktake of relevance of official information on the environment to 61 enduring questions assessed that only 4 questions were highly informed by current statistics, 25 had medium information and 32 had low information. The highly informed questions were in climate change (atmospheric composition and greenhouse gas emissions) and land (land cover and land use), two areas with significant research investment in recent years in response to international agreements on climate policy (and land use change). This stocktake has informed the selection and development of priority statistics for New Zealand's Environmental Reporting, the list of which is due to be released in mid-2015.

Some regions have also applied the ecosystems services approach to extend or supplement models or accounts for their regional economies. Waikato Regional Council followed the lead of Costanza et al's 1997 paper to estimate regional ecosystem services were of a similar magnitude to regional GDP (Huser 2015).

Outside of official agencies there is active investigation of methodologies for monitoring the physical state of environment that could be the basis of natural capital accounts (Dominati et al 2010, Dominati et al 2014). Official databases such as the National Exotic Forest Description (already used in forestry accounts noted above) and the Greenhouse Gas Emissions Inventory could contribute to this, while private consultancies and Crown Research Institutes also hold data on land cover, soil types, forests and geology that could also contribute to such natural capital accounts. There have also been estimates of total economy and ecosystem accounts in the style of Costanza et al (1997), containing elements of national production accounts and consumer surplus components for non-market effects (Patterson and Cole 2013).

Some of the Government's current science challenges are focused on natural systems, including those of Biological heritage, Sustainable seas, Land and Water and the Deep South. These identify some research gaps, but the emphasis is in improving understanding of bio-physical processes rather than economic consequences.

Valuing the environment

Well over 100 non-market valuation studies of natural and environmental resources have been undertaken in New Zealand over the past 40 years and recorded in the Lincoln University Non-market Valuation Database. These cover a narrow range of subjects (mostly recreation, water quality, species preservation) and have variable quality.

Other attempts at linking natural resources to economic activity include economic impact studies of areas like Fiordland and Abel Tasman National Park, which record expenditures generated by visitors and the suppliers of services to them in a manner consistent with national accounting but these are not informative of how marginal

value adjusts with changes in the underlying extent or condition of the resource. In its report on the value of conservation, DOC (2006) records several such studies, and also an estimate of costs averted for water treatment in Dunedin by retaining natural land cover in the catchment area.

Environmental pricing

Until recently, New Zealand's list of environmental charge mechanisms reported to the OECD was limited to the Fuel Excise Duty on petrol, the waste levy, and a levy on shipping to cover the costs of remediating oil spills. Since 2008 this list could be expanded with the emissions trading scheme for greenhouse gas emissions and the Lake Taupo and Waikato nitrate trading scheme.[12] However, Fuel Excise Duty was only included because there was an excess of revenues collected over expenditures on transport management that could be argued to "price" unspecified environmental effects of road transport, such as contributions to air and water pollution, noise and natural habitat degradation. Since 2008 all road use charges, including fuel excise duty revenues, have been hypothecated to be spent on transport projects, so there is no longer any surplus to attribute to pricing the environment.

Various other measures broadly resemble pricing for ecosystem services, such as local council's rates relief on private land retained for public purposes or the QEII National Trust's Open Spaces Covenants scheme, which provides assistance in funding surveying and fencing of protected areas. However, we have found no study or literature on whether these measures adhere to the concepts of natural capital covered in this review, or whether they are consistently applied.

The TEEB Business and Biodiversity Offset Programme cites the Stockton Mine consenting as an example of the use of biodiversity offsets to inform decisions. This example of a compensatory offset measure involved relocation of snails and plants to a new habitat elsewhere. Offsets have been cited in other consenting cases although are subject to criticism that they may not be closely compensating for the environmental degradation at issue. In the consenting of the Escarpment Mine at Denniston, for instance, where the open cast mining would destroy habitats that ecological experts on both sides of the case agreed were extremely rare (2 or 3 other sites known in the country), so that the removal of one would materially affect the probability of survival of the habitat and its constituent species, the offset involved paying for predator control on the Heaphy Track, which was hardly remedying the risk of biodiversity loss. More generally offsets have been criticised because relocation has a high failure rate, because of the inherent assumption that environmental features are substitutable for each other, and because in highly complex ecosystems it is difficult to identify and measure exactly what is at risk, and hence what needs to be remedied (Walker et al 2009).

Summing up, in natural resource accounting New Zealand has prepared accounts for most of the resources covered in other countries, but these have not been regularly updated and although future developments according to the SEEA framework are alluded to on Statistics New Zealand's website, they are not specified. With respect to Non-market valuation studies, New Zealand has fewer local studies from which to

[12] Individual transferable quotas in marine fisheries are primarily aimed at managing a stock of extractable fish rather than environmental conditions, and were thus excluded from the scope of the OECD survey.

draw on and questions around the quality of some that may affect the confidence that decision-makers have in using the estimates in specific local contexts.

Private consultancies are also working on natural capital, in building up databases and analytic capabilities, in particular pushing the ecosystem services approach to measuring impacts and also the use of environmental assessment tools like InVest. They are engaging with landowners and other stakeholders on what natural capital means for them finding the consideration of both impacts and dependencies easy to understand and useful, given the RMA focus on impacts rather than dependencies (Greenhalgh and Hart 2015).

Cross country comparison

Figure 4 summarises the coverage of the natural capital accounting initiatives in the various countries surveyed above. The table puts this into the context of the Natural Resource Sector framework of resource domains, with extension of the "Other" category to reflect the focus of current accounting work.

Figure 4 Selected countries' coverage of natural resource accounts

			Australia	Canada	Mexico	Norway	UK	NZ
Environmental and natural resources	Air		√		√			
	Climate		√	√	√	√	√	√
	Freshwater		√	√	√			√
	Marine							√
	Land		√	√		√	√	
	Other	Biodiversity						
		Energy		√		√	√	√
		Forests		√		√	√	√
		Fisheries				√		√
		Sub-soil resources	√	√	√		√	
		Wastes	√		√			
		Environmental Taxes	√	√				
		Public environmental spending	√	√	√			√
Social	Economic							
	Cultural, including Maori							

Source: NZIER

The table shows the coverage that the literature identifies as being prepared consistent with the national economic accounts, and shades those categories that do not appear to be covered. An exception to this is climate, where a red tick indicates that countries do maintain inventories of greenhouse gas emissions for reporting purposes, but acknowledges these are for a different purpose, and not necessarily aligned to, national accounting protocols. The table shows that a lot of current work is in the subsets of the "Other category" in the NRS domain framework. This has been directed in part by the orientation to stock assessments of resources yielding marketable products for inclusion in national wealth accounts.

There will be many other monitoring frameworks and indicators being prepared in these countries which are not directly tied to the SNA accounts. The UK's NEA pushes its boundaries into non-market environmental territory with its coverage of recreation values associated with ecosystem services, but as that is a one-off exercise rather than

a continuing commitment it has not been shown here. The New Zealand entries also all refer to one-off preparations under earlier UNSEEA guidelines that have not been updated under the latest (2012) guidelines.

3.8.3. Comparative assessment of approaches

Detailed comparison of the approaches to giving effect to natural capital and how they have been used would require case studies that are beyond the scope of this current review. However, some comparison and assessment is available from the literature, which can be summarised below.

Table 4 summarises results of a report to the Nordic Council of Ministers on the strengths and weaknesses of some of the most prominent international approaches to natural capital accounting (Mazza et al 2013). That assessment is particularly oriented to the policy goals and institutions of the Nordic countries and has a particular focus on suitability of the method for dealing with biodiversity, but also provides some general insight. The methods appear in the table in decreasing order of complexity.

The UK's NEA approach is the most comprehensive and inclusive of biodiversity, with valuation of ecosystem services such as the provision of recreation settings. That however was a well-resourced one-off study that may not be repeated.

The SEEA provides a central framework for routine compilation of accounts, but admits only monetised estimates of natural capital that produces market-related goods and services, although it does record some residuals and pollutants in non-monetary terms. SEEA consigns non-marketed components such as biodiversity or the ecosystem services to recreation to a separate "experimental" set of accounts which are currently not commensurate with the central framework.[13] The Canadian Measures of Ecosystem Goods and Services are comprehensive but not yet monetised.

The Ecosystem Capital Accounts are an initiative of the European Environmental Agency, designed to provide a readily implementable accounting for natural capital, but this is only in physical units.

Finally, InVEST is a proprietary software programme developed by the Natural Capital Project (n.d.), to provide a tool for officials, consultants and others to assess the impacts on environmental functions and services of a given development. Unlike the higher level national accounting measures this is a low level project appraisal tool, and it is already used by some environmental consultants in New Zealand.

The Nordic assessment finds a high degree of complementarity between the different approaches and recognises the potential uses of the UK NEA's broad range of ecosystem service categories, but it also notes a lot of resources have been invested in its preparation (Mazza 2013).

More generally, while the authors recognise that natural capital accounting can contribute to identifying ecosystems under stress, the ecosystem services at risk of being lost, and which sectors are most responsible for creating pressures on ecosystems, all the methods are constrained by data limitations.

[13] Note that in the latest monetary estimates of the UK's natural capital by the Office of National Statistics, non-market services of recreation, air filtration and carbon sequestration together accounted for two-thirds of the overall value of natural capital (which includes oil and gas reserves)

Table 4 Assessment of five accounting approaches

Approach	Aims/objectives	Particular strengths / value added	Assessment
UK NEA	National biophysical assessment with monetary add-on for selected valuation (e.g. recreation services).	Very good problem identification. Good on supporting implementation. Outputs easy to understand. National and regional focus.	Practical application of MEA, with wide consultation but very resource intensive. Found 30% of ES in decline and prompted government policy response.
SEEA	National asset accounts that link the physical accounts to the economy (accounts for material flow water etc.).	Understandable. Well-developed methodologies. Legal requirement in EU member states for six modules.	Central framework primarily informative on provisioning services – unsuited to quality of ecosystems of biodiversity which are consigned to more experimental ecosystem condition accounts.
Measures of Ecosystem Goods and Services	Mapping of ecosystem types and selected ecosystem services across national territories, with on-going work on monetary valuation.	Good for exploring links of economy and ecosystem service flows.	Experimental accounts of ecosystem stocks and flows of services. Oriented more to provision than cultural services and biodiversity.
Ecosystem Capital Accounts	Physical accounts for land use types, carbon, biomass and water, A simplified system that excludes value aspects of services and degradation.	Quite good indicator development, especially on links between land use, carbon, biomass and water.	Consistent with experimental accounts in SEEA. Broad scope to show availability for use without degradation. Ambitious and methodologically challenging.
InVEST	Local spatial biophysical assessment, including a value module for selective services (mainly water related).	Good for modelling impacts of different policy options and support local implementation (especially regarding water).	A tool developed jointly by universities and NGOs to map and value goods and services from nature. Not designed to be linked to macro-economic accounts or SEEA compatible.

Source: NZIER, drawing on Mazza et al 2013

Moreover, they note that approaches to natural capital accounting are not designed for monitoring trends in species, habitats, or ecosystem resilience, as too much detail is lost in the high level description and valuation of the stock. None of the approaches is ideally suited to monitoring biodiversity, where the focus on diversity suggests a more disaggregated approach would be preferable. Such frameworks have already been used and developed and provide part of the foundation for compiling aggregated natural capital accounts.

3.8.4. Where to use natural capital approaches

From this literature review a number of features can be discerned in the evolution of natural capital approaches in recent years. The approaches are heterogeneous and not necessarily directly compatible with each other, but as they are different ways of viewing the same issue - the lack of clear value markers for natural resources – they can be complementary and inform each other.

Macro-level accounting approaches

Much of the most obvious effort in natural capital is in the area of macro-level accounting. The focus of that effort has changed markedly from the early attempts at producing a green GDP or new economic welfare measures. Now natural capital is seen as part of the development of balance sheets to monitor the liabilities faced by an economy, alongside similar efforts to view human capital as a function of educational and immigration policies, and social capital as a function of a wide range of legal and institutional policy settings.

The purposes to which these natural capital accounts can be put include:

- general awareness raising of the broader costs of economic growth paths
- putting resource inputs into the economy on a common footing, to enable or facilitate changes over time within and across natural resource domains
- enabling comparison of performance across countries, for instance through international studies of how natural resource use affects productivity (Brandt et al 2013).

These accounts can be used across a wide range of resource domains where the absence of market signals of impending scarcity could cause problems for the economy. One current example is New Zealand's greenhouse gas inventory, which measures annual flows of emissions that accumulate to a stock of potential liability. That inventory has proved volatile due to fluctuations in international prices of carbon and uncertainty about the future shape and coverage of greenhouse gas limitation agreements.

Micro-level approaches

At the level of assessment of individual regulations or policies, approval of consents or appraisal of projects, the question arises as to what weight to give to natural capital when considering its use or retention against developments that transform it in some way. Here the question is what will be gained or lost by the transformation, given that development gains are expected and readily quantified but the impacts of natural capital loss on the community are less obvious?

The ecosystem services approach provides a formal way of drawing links between ecological processes and functions and the services of value they provide to people, such as harvestable materials, carbon storage or flood risk reduction, and contributions to human well-being in the form of material income and reductions in safety risks. These have economic value in the form of costs avoided from averting property damage or productivity losses, or enhanced value reflecting people's preference not to be flooded or risk enhanced climate change in future. By identifying what these values are and where they accrue, the ecosystem services approach

provides both a means of quantifying the values at risk and of identifying who gains or loses most, which is important in considering liabilities and who has greatest incentive to contribute towards providing ecosystem services.

Unless they are traded in markets the value of ecosystem services has to be assessed in other ways. This may be by expert judgement, in which case values are implicit and may vary between individual decisions. It may be by judgement weighted by the number of people affected (e.g. recreational uses of an open space) but this says little about the strength of preference for that particular use of a resource. Alternatively, they can be weighted by economic value, such as the number of recreational users multiplied by a unit value per use. Or they may be assessed by other scoring criteria in a multi-criteria analysis in which economic considerations may be just one part.

Economists have devised non-market valuation techniques to provide economic values. Revealed preference techniques tend to be limited by the availability of observations of relevant behaviour; stated preference techniques are more flexible but subject to doubts about the reliability of answers to hypothetical questioning. Stated preference techniques have evolved from market research methods which have been shown to provide reliable results for market products, but reliability cannot be verified when applied to non-market natural capital that people are unfamiliar with paying for.

Questions also arise about whether the approach of non-market valuation, in trading off incremental gains and losses in environmental condition, is appropriate for all natural capital. For species which are critically endangered, there is a risk of incremental trade-offs pushing a resource beyond a critical threshold from which it is difficult and costly to recover. With their holistic approach to natural resources, Māori also may also view economic valuations as having limited scope in determining environmental values.

The ecosystem services approach has broad application to measuring the effects of natural resource domains that are affected by biological processes, including water quantity and quality, biodiversity, soil retention, land cover and associated emission and carbon storage characteristics, wild stocks like fish and insect pollination. Non-market valuation also has potentially wide application, but it is dependent on accurate depiction of the environmental effects being valued and the existence of credible trade-offs.

A common thread to all natural capital approaches is the importance of reliable physical inventory or stock of the resources being assessed. Scarcity matters, raising the probability of loss and the value in averting loss. Stocks are fundamental to accounts and they are also important for monitoring the condition of ecosystems, in both quantitative and qualitative terms. Stock issues such as scarcity of a resource or accessibility to substitutes are also influential on economic value, but are less obviously given prominence in non-market valuation studies.

3.9. How decisions are currently made – processes, institutions and people

Decisions on natural capital in New Zealand settings are made by various central government agencies, local and regional government, as well as by private developers

and consultants in the field. There are also co-management arrangements with iwi and other hybrid structures for natural resources and industry self-management with respect to natural capital (e.g. fisheries), and all these processes are ultimately adjudicated by legal processes and the judiciary.

Beyond identifying which agencies in other countries are pursuing Natural Capital initiatives, the international literature is rather thin on decision processes and institutions. Identifying best practice in these areas would require a comparative analysis of institutional structures and processes beyond the scope of this review.

A paper by Blignaut et al (2013) reviewed 1,575 peer-reviewed papers on natural capital restoration published between 2000 and 2008 to assess whether they considered economic and policy implications of their research and possible relevance to emerging markets in payments for ecosystem services. They found only 8% of papers referred to markets and/or ecosystem services, and they concluded that potential benefits of restoration were not being integrated in development planning.

Crown Research Institutes and private consultancies in New Zealand have developed databases and models for aspects of natural capital that are beginning to be introduced into public policy processes. To date however they have shown mixed results in influencing decisions made under these frameworks.

Clothier et al (2012) recount two cases in which modelling of ecosystem services was used explicitly in Resource Management Act hearings, in one of which it appeared to be influential on the decision to decline consent for urban encroachment onto highly versatile soils, and in the other where the rules it supported were rejected as inequitable. They conclude that although the RMA and ecosystem services approach appear to be complementary, there was little evidence of that being the case. However, more recently these researchers have noted the Land Use Capability classification system has been accepted as a proxy for natural capital, and used as a basis for setting leaching limits on fertiliser application and land use, in more than one case (Clothier 2015).

There has been no such acceptance of economic measures relating to natural capital, however. A recent review of what the courts have said about valuation of natural assets found that while the RMA does not prevent a quantitative cost benefit analysis being introduced into evidence, courts have generally expressed severe reservations about the usefulness of economic valuations of natural assets or effects on them (Christensen and Baker-Galloway 2013). It is a moot point whether this is because the valuations are not fit for purpose in a court setting, or because the hearing process is not seeing enough economic evidence presented on natural assets, preferring to hear evidence from experts in highly specialised disciplines like recreation and ecology than from economists who can explain how scarcity, renewability and irreversibility affect the economic consequences of an environmental effect on different resources.

3.10. What's the use of natural capital approaches?

While there is a lot of literature recognising that the value of natural capital has traditionally not been explicitly included in decisions, resulting in the environment being over consumed and under-invested in, there is relatively little literature that sets

out specifically to examine the potential for natural capital approaches to rectify that. The few papers that do suggest that natural capital approaches have still only had a modest detectable influence on decision making.

Potential uses have been identified by the UK's ONS in its 2015 Road Map review as helping to inform and improve decision-making, to get better overall outcomes for society (ONS 2015a). Natural capital accounts can:

- shine a light on the losses, gains and relative importance of services provided by natural assets
- highlight links with economic activity and pressures on natural capital
- inform priorities for resourcing and management decisions.

The UK's Natural Capital Committee in 2017 identified three general decision contexts for which information on the value of natural capital and its services is useful (Natural Capital Committee 2017b). They are:

(1) Determining priorities for investments in natural capital

(2) Determining actions affecting natural capital to (i) achieve target improvements; (ii) avoid deterioration; or (iii) compensate for losses

(3) Determining overall progress with objectives to protect and improve natural capital (including at the aggregate level).

The approach depends upon the context. Items 1 and 2 above are micro-applications suited to assessing natural capital effects in projects or programmes, which can be informed by a welfare calculation from a cost benefit analysis drawing on non-market valuation of ecosystem services. The third is a more strategic macro-application which focuses on market prices or near surrogates, and is a more appropriate use of natural capital accounting consistent with SEEA.

There appears to be more literature claiming the influence on decisions of natural capital accounting than there is for valuation. A paper for the WAVES Partnership (WAVES 2017[14]) notes that all its developing country members – Botswana, Columbia, Costa Rica, Madagascar and The Philippines – have developed national or regional water accounts to assist in establishing the cost of water management and attributing use to different industries for cost recovery purposes, often facing limitations in data. But this paper also includes accounts from developed countries indicating a broader range of uses tailored to each country's individual priorities, largely derived from the ability of accounts to indicate stock levels to complement financial flows.

It reports the Netherlands government used environmental accounts of energy use and emissions to raise awareness of the scale of the problem when it entered an agreement with 46 industrial partner organisations to share responsibility and make commitments to achieving targeted energy savings and lowering greenhouse gas emissions. The environmental accounts were particularly useful to energy policies as they relate to national policy issues to which generic solutions can be applied (WAVES 2017 Chapter 17). The Netherlands has also used water accounts for analysing cost recovery and attributing changes in natural capital capacity to industries that use water, and some states in Australia have used them in similar ways. Water accounting

[14] WAVES Partnership 2017 *Better Policy through Natural Capital Accounting – Stocktake and Ways Forward*, 7th WAVES Annual Partnership Meeting Edition, IBRD/The World Bank, Washington DC

can be used in analysing current water uses and future environmental and financial implications, assisting with demand forecasting, monitoring availability of supply and determining the cost effectiveness of options for managing demand or supply (WAVES 2017 Chapter 25).

WAVES (2017) notes that through its systematic, standardized and consistent approach to measurement, natural capital accounting supports monitoring of goals like reducing resource intensity, decoupling growth from waste generation and improving net savings in emissions and discharges to the environment. But it acknowledges that such accounting needs to move away from the supply-side focus on account preparation towards the demand-side requirements that would help decision-makers in difficult trade-offs between policy options. While countries like Australia, the Netherlands, Sweden and UK with long established natural capital accounting programmes have developed capacity and relationships between users and accounts producers to enable more effective use in policy, there remain challenges to improving the uptake and usefulness of natural capital approaches in the short term focus of much policy making, the credibility and acceptance of natural capital measures, and in the communication of complex information and what it can illuminate (Chapter 3).

In a much-cited paper, Laurans et al (2013) describe a literature blind spot in demonstrating the use of natural capital concepts or associated techniques in actually influencing decisions. They identify three categories in which ecosystem services valuation (ESV) can be used:

- Informative – for awareness raising, justification and/or accounting purposes
- Technical – for establishing damage compensation or for price setting
- Decisive – to assess trade-offs, as an environmental management criterion.

Use of ESV ranges from a simple reference in discussions to a clear integration in the analysis of various management options, e.g. as input into cost benefit analysis.

Other papers have focused on the observable influence of ESV on decision-making. Waite et al (2015) examine more than 100 studies in the Caribbean that contain monetary values of coastal ecosystem goods and services, but find only 17 that appear to have been referred to in decisions, and only 4 in which their influence is well documented. ESV has been used to:

- justify the establishment and level of user fees for tourists in Bonaire National Marine Park
- justify the establishment of fines for damage to coral reefs in the Florida Keys (USA)
- support development of Belize's national Integrated Coastal Zone Management Plan
- secure government investment in conservation initiatives on the islands of Bonaire, Saba and St Eustatius.

Marre et al (2016) come to similar conclusions of limited influence after a nation-wide survey of 88 decision-makers from a diversity of management organisations concerned with coastal and marine management in Australia. While most decision-makers were familiar with economic valuation and considered it useful, they had rarely based decisions on such valuations. Decision-makers had more confidence in market-based

valuations for things like commercial fishing or navigation, than in non-use, recreational, aesthetic or indigenous/customary values. The main limits to usefulness of ESV selected by respondents where that the methods were not accepted widely enough (64%), ESV was too simplistic for complex ecosystem service decisions (50%), methods and techniques needed improvement (44%) and decision-making frameworks may not allow ESV to be used (43%).

Marre et al's conclusion is that ESV, although presented and perceived as useful, in practice appears to be rarely relied on and has a weak influence on policy. This echoes earlier findings of Rogers et al (2015), who interviewed both non-market valuation (NMV) practitioners in academia and consultancies and decision-makers in environmental agencies and found a marked disconnect in the two groups' views of the uses of NMV. NMV practitioners identified 49 studies that they believed had influenced policy, but after reviewing, only in 20% of cases was there some evidence of their use in a formal documented process, a third of the 49 studies were subsequently reconsidered as having had no influence on decisions. While NMV practitioners considered decision-makers' concerns about the validity of NMV or the assigning of monetary values to the environment were the most important barriers to wider uptake of NMV, Rogers et al suggest lack of awareness of techniques among decision-makers is a greater impediment. They conclude that at present most environmental NMV studies do not get used by decision-makers, and where they are used they are more likely to justify existing decisions rather than change them.

In a paper called *Natural capital and ecosystem services informing decisions – from promise to practice,* Guerry et al (2015) found relatively limited instances where natural capital and ecosystem services could be shown to have influenced decisions. But they did find some examples, as outlined in the Other countries heading in section 3.8.1 above.

3.11. Gaps in research and data

A principal gap in the literature uncovered in this review concerns understanding how the approaches to natural capital have been used in policy settings and the influence they have had on outcomes. While natural capital concepts have influenced the way statistics are being collected and the policy frameworks used, there are very few instances in the literature demonstrating how a natural capital approach has clearly influenced the outcome of a decision involving natural resources, nor on what alternative methods are relied on in decisions, or why these are preferred to economic measures of natural capital.

We have not found retrospective assessments of why past decisions were made and whether they turned out as expected. Filling this gap depends on understanding the drivers and detailed context of past decisions, and could be examined through case studies of the values implicit in decisions on natural resource use.

The techniques for capturing natural capital tend to follow a fundamental three step process.

- identify and assess the affected aspect of natural capital and the implications for various groups in society
- demonstrate and estimate the quantity or scale of the natural capital impact caused by the decision in question

- capture the value of the natural capital in the decision-making process and evaluate the options and outcomes.

These steps encapsulate three challenges for capturing natural capital in decisions:

- the availability of data for quantification and assessment
- the choice of framework and valuation methodology
- the type of decision-making process.

The availability of data is a critical input for capturing natural capital in the decision-making process. Gathering information on a case-by-case basis in a bespoke fashion is costly and time-consuming, often requiring a long lead time before policy decisions can be considered. It is frequently not practical or possible to facilitate bespoke information gathering.

To overcome data gaps individuals, organisations and governments have begun compiling databases of natural capital data and analysis. These take the form of collections of natural capital studies which tend to focus on valuation of natural capital more than decision making, or statistical databases of physical capital stocks related to the System of Environmental and Economic Accounts (SEEA). Organising environmental data in a common, coherent framework to allow comparison across issues within and between countries over time is a major benefit of the SEEA. Such standardisation of approach is viewed as a prerequisite for maximising the value for new research efforts (UKNEA 2011). Choice of approach depends partly on the information available, but it should also reflect the policy purpose it is intended to inform. Accounting measures are simply a form of indicator which can be used either as "dials" or targets for setting the direction of natural resource use, or as "can openers" that signal abnormality requiring deeper investigation. A natural capital account might be a "dial" for a reforestation objective (as in the UK's woodland restoration scheme) but a "can opener" for the state of biodiversity where many factors may influence the outcome.

If the intention is to provide a "corrective" to the income flows of GDP, a macro level natural capital approach may be most useful, although not without its problems in interpretation: accounts combine physical stock and value data, both of which may change independently, so the aggregate value of account by itself says little about the management of the resources.

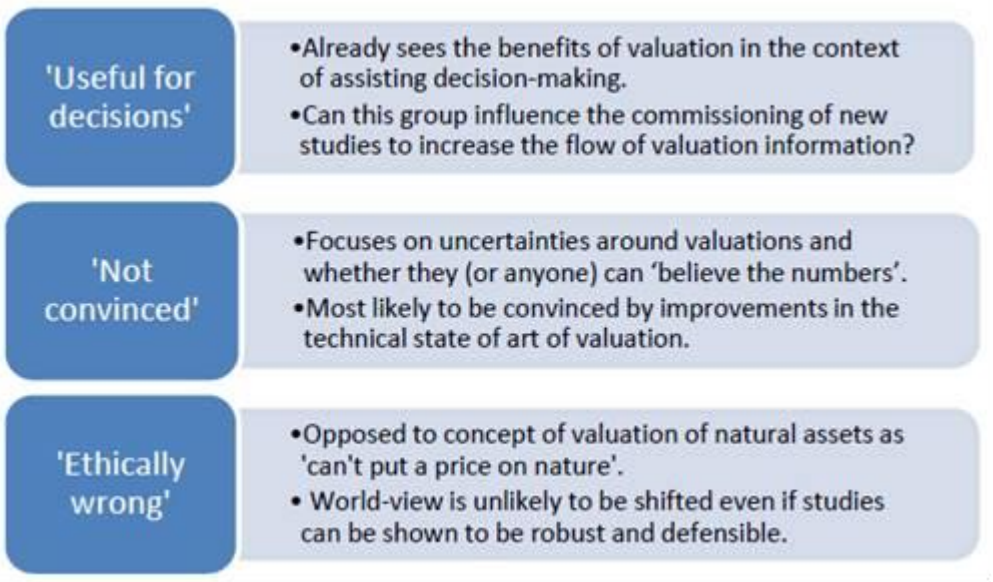
For this reason natural capital accounts are also not necessarily the best for detailed monitoring of natural resources whose loss would be irreversible and for which there are no close substitutes: e.g. biodiversity management may be better served by underlying indicators of habitat extent and condition, rather than by the aggregated natural capital accounts themselves.

If the purpose is to provide a value for natural resources to give them due weight in a local project or decision making, non-market valuation studies or benefit transfer drawn from sources such as the New Zealand Non-market Valuation Database hosted by Lincoln University or the Environmental Valuation Reference Inventory (EVRI) led by the Canadian Government and co-sponsored by New Zealand's Ministry for the Environment can be useful. However, it is hard to find reliable New Zealand studies for many environmental conditions, and international sources reflect different demographic and income characteristics that are hard to control for.

If non-market valuation or benefit transfer of such values is to be viewed as reliable for use in New Zealand, greater effort is required in meta-analysis of existing studies to establish what variables influence the values, to enable the transfer of functions rather than simple values, between one setting and another.

There is a theme particularly in some of the grey literature on natural capital that views it with suspicion, as some sort of device for unitising and privatising natural assets that have previously been viewed as public goods. This criticism stems partly from the view that economic instruments are reductionist and unsuited to handling the complexity of natural systems, and therefore create incentives to diminish the variety and resilience of these natural systems. It also stems partly from mistrust of the agendas of some of the proponents of natural capital approaches. [15] This reflects public attitudes to environmental valuation, which falls broadly into three groups as outlined in Figure 5.

Figure 5 Public perceptions of environmental valuation



Source: NZIER 2013

There are philosophical issues raised by the plurality of attitudes towards environmental valuation. The "ethically wrong" group is often vocal and influential in the perception of unreliability surrounding economic valuation of environment, reflecting fundamental questions about the ethics of guiding decisions on allocations and use of collective natural assets as if they were just accumulations of private purchase decisions.

But ethical concerns do not remove the need to make hard choices between using or retaining natural assets, which implies placing economic value on them: if an asset is retained it is worth more than the opportunity cost of other uses forgone, and if it is used and depleted it is worth less. Similar issues arise in the economic valuation of

[15] See for instance https://www.theguardian.com/environment/georgemonbiot/2014/jul/24/price-nature-neoliberal-capital-road-ruin

health and safety measures, which has also used non-market valuation methods such as hedonic pricing and contingent valuation to estimate public willingness-to-pay to reduce the risks of accidents and fatalities occurring across the travelling public. The corresponding value in environmental valuation is public willingness-t-pay to reduce the risk of decline or ecosystems and their constituent species.

There is currently a gap in the knowledge about the full contribution of natural assets to New Zealand's economic well-being, creating a risk that natural assets will be undervalued and overused to the point of degradation. Economic valuation and other approaches to natural capital measurement can narrow that knowledge gap.

This literature review suggests that there is a distinction between the assessment of natural capital and the uses made of them, and that while some natural capital approaches may lead to unitisation and design of such instruments as permit trading schemes, others are more oriented to establishing the level or direction of the state of natural assets and do not necessarily lead to unitisation or privatisation as policy responses.

4. Relevance to 'Capturing Natural Capital in Decision Making Project' case studies

We have been asked in this literature review to consider the relevance of its findings for "Capturing Natural Capital in Decision Making Project" case studies under the Government's natural capital stocktake. Two such studies have been identified, regarding the values associated with the Waikato river and values associated with wilding trees and their control.

4.1. Waikato river values

This case study involves a compilation of values from non-market valuation studies and also value preferences for Māori in the Waikato region. Marsh and Mkwara (2013) completed a review and meta-analysis of economic non-market valuation studies for Waikato Regional Council, the results of which are summarised in Figure 6.

Marsh and Mkwara survey the state of non-market valuation in New Zealand, noting that the limited number of reliable studies in New Zealand covers only a few of the varieties of ecosystem service. They also cite the views of other practitioners that it is difficult to find studies of a quality to support value transfer, and that given experience in various Environment Court cases the New Zealand judiciary is a considerable distance from accepting non-market valuation or value transfer.

Figure 6 Values for water services in the Waikato region

Waikato region non-market values for water uses

	Low	*Mid*	*High*	*per unit*	*H/L ratio*
Swimming/household/year	$ 70	$ 155	$ 239	hhd	3.4
Ecological health/household/year	$ 25	$ 140	$ 255	hhd	10.2
Economic/household/year	$ 85	$ 135	$ 185	hhd	2.2
Biodiversity/household/year	$ 23	$ 98	$ 172	hhd	7.5
Water quality/household/year	$ 18	$ 81	$ 143	hhd	7.9
Landscape Aesthetic/household/year	$ 12	$ 33	$ 54	hhd	4.5
Access/facility/household/year	$ 0.1	$ 13	$ 25	hhd	250.0
Rowing/person/year	$ 173	$ 205	$ 236	per	1.4
Fishing/person/year	$ 67	$ 67	$ 67	per	1.0

Source: Marsh and Mkwara 2013

The table shows the value estimates from studies surveyed for a range of activities or attributes associated with Waikato waters, with low, mid and high point estimates. The ratio of high:low estimates is very large in some instances, indicative of a high variability in underlying estimates, due to a mixture of methods being used.

These estimates indicate an average willingness to pay to secure continuation of each of these activities. Such values could be used in local project appraisal, although they represent a simple form of benefit transfer and do not allow the more reliable functional transfer (see Appendix B.2). The change of state that these payments are for is hard to discern from this value set.

Because of limitations of these values for representative benefit transfer, stage 2 of this case study entailed a new non-market valuation study, combining a revealed preference model of site choice for recreational and cultural purposes and the importance of water quality, and a stated preference choice experiment to estimated willingness to pay for water quality improvement (Phillips 2014). The report concludes by illustrating how these models may be used to analyse the benefits of two water quality policy scenarios, one involving a general improvement in water quality across the region and the other concentrating on improvement in the most frequented sections of waterways in the region.

The study combined survey information with GIS biophysical data, census data and qualitative water values from a survey collected by Waikato Regional Council. The revealed preference study analyses total travel cost and models destination choice from particular locations to identify perceived cleanliness of water as a significant factor in use of sites. The stated preference survey estimates willingness to pay for individual sites, allowing differentiation between willingness to pay to reduce infection risk from water contact and willingness to pay to improve ecosystem health, with results that can be disaggregated for different characteristics of respondents. The results are used to estimate willingness to pay for whole catchment improvements, defined as increases in the percentage of monitored sites meeting target standards for water quality, infection rates and good ecological condition. The aggregate willingness to pay across the populations of Waikato, Bay of Plenty and Auckland was estimated to be between $18.9 and $28.3 million per year for reduction in median nitrogen and phosphorus across the entire Waikato catchment, depending on the level of use, while in the second scenario preventing decline in quality in the upper and central catchment zones was estimated to be worth between $32.1 and $42 million per year in aggregate.

This study is more comprehensive and relevant to natural capital than most previous non-market valuation studies in New Zealand. The revealed preference is recognised as being rather limited in providing a value of total current use under current quality conditions, rather than being informative about marginal changes in quality. The stated preference study estimates values for changes in different quality parameters. In estimating values across the whole catchment or multi-site zones it is also implicitly aligned to natural capital and public policy issues: the region has a stock of waterways of varying mix of quality, and the relative values obtained are informative of how changing that mix in different ways would affect the aggregate public value. The study does find however that primary data collection is essential where existing studies do not reliably support value transfers, and it is also limited by existing data in selecting the regions from which potential beneficiaries of Waikato water quality are selected for surveying (Waikato, Auckland and Bay of Plenty).

A parallel study under this project was prepared on Waikato and Waipa River Iwi values (Henry 2014). This identified a range of Māori values associated with water and particular parts of the Waikato and Waipa catchments, but did not explore how these can be woven into the decision-making matrix alongside economic values.

4.2. Wilding trees

The second case study involves a request for proposals recently issued to ascertain the values associated with wilding exotic trees in New Zealand and measures to counter them.

Wilding trees are an example of weed plants and an issue for biosecurity management. There is a well-established framework for economic analysis of pests and weeds (Biosecurity New Zealand 2009). The economic damage caused by pests and weeds depends on:

- The actual damage caused by the weeds on the ground, e.g. productivity loss for other activities such as shading out grazing, outcompeting native plants, providing host habitat for other pests, obstruction of recreation access, and possible increases in risk of fire and wind-throw in exposed places etc.
- The costs of containing that damage, both in precautionary measures to reduce the likelihood of wilding tree spread, and in remedial measures to remove them and reduce the risks they pose
- The human costs caused by the loss of utility to people from knowing the trees are spreading and encroaching onto indigenous habitats and landscapes – the economic value of which is expressed in the community's willingness to pay to achieve an improvement on the current situation.

In this framework how much is done about the problem – the middle bullet – depends on how big a problem it is considered to be, which is partly a function of the extent of the problem – area covered and rate of spread – and partly on the intensity of damage or disutility to well-being it causes. The Capturing Natural Capital in Decision Making Project case study, which has yet to be completed, appears focused on the first and third bullets, with the aim of:

- Identifying the range of adverse effects caused by wilding pines (and possibly also by potential control measures requiring access onto sensitive sites)
- Indicating the strength of preference or value associated with each of these effects and the problem as a whole.

Establishing the extent of the problem could be approached through a spatial mapping or account of land infested and at risk of spread, but this does not require a full natural resource account approach. Rather what is required is an ecosystem service account, similar to that prepared for the UK woodland (Table 2 above).

Non-market valuation may provide value estimates in this case, but as people are unfamiliar with paying for ecosystem services of landscape quality it would be difficult to verify the results. There are also likely to be some people who object to such valuation as it appears to place responsibility on individuals for something seen as a community problem, rather than simply as gauging the community's willingness to pay through an average value from a survey of community members.

Any non-market valuation may need to be supplemented by other methods of preference revelation as indicated in section 3.4 above.

5. Discussion and conclusions

This report describes a review of recent literature on capturing natural capital in decision making, to inform government's stocktake on the state of natural capital. It concentrates on approaches to measuring natural capital that have been implemented, and their use in decision making, rather than the extensive range of academic and grey literature proposing new ways of treating nature.

Introducing natural capital into decision-making allows for a more nuanced assessment of trade-offs. The term natural capital has been in use for about 30 years but draws on ideas that have been around for longer. It starts with the recognition that natural resources are often treated as if they have no value and are overused as a result, generating economic externalities on current and future generations.

Natural capital approaches aim to counter overuse by treating nature like other capital in the economy, attaching value to it to give due weight in decision processes, recognise its depreciation and provide for its maintenance and renewal.

Recurring themes in the updated literature review reported here include:

- an emphasis on national level accounting by government statistical agencies, which can show high level changes and trends in the market value of natural capital categories consistent with national economic accounts
- increased interest by private corporations in natural capital assessments (given effect in the Natural Capital Protocol), which may be trans-national in coverage where corporations' risks and dependencies involve supply chains and markets that cross national boundaries
- variable use of natural capital methods to inform decisions at the micro-level, with some use of disaggregated stock accounts and some influence of non-market valuation methods in cost benefit analysis and in design of economic instruments and policies to alleviate overuse of natural capital.

The methods used to do this depend on the problem which natural capital is needed to address

If required as **a "corrective" to misleading GDP** – a production flow measure in which a country could show impressive short term growth by depleting its natural stocks of timber, minerals, fisheries and soils yet worsen longer term prospects for the future by depleting natural capital – the method is a macro-measure in the form of natural resource accounts to provide a balance sheet of the state of natural capital stocks. The UN System of Environmental and Economic Accounts (SEEA 2012) now provides internationally agreed standards for how this is to be done to prepare natural resource accounts consistent with the economic accounts. The SEEA is largely confined to valuing natural capital that creates marketable goods and services, like energy reserves and forests.

Early attempts at making adjustments to flow accounts to net off natural capital depreciation and **produce a Green GDP** have been found in practice to have widely varying results. Now international focus, prompted by the World Bank, has shifted to providing a natural capital stock account that can be combined with accounts of

physical capital, financial capital, human capital and social (including institutional) capital to provide comprehensive measures of wealth.

Compiling aggregate accounts is less useful for routine monitoring and management of natural capital than the disaggregated records of land cover and status on the ground for natural capital components like biodiversity, which may be subject to irreversible changes (extinction) and for which no close substitutes exist. The high-level viewpoint of natural capital accounting removes detail and diversity of the underlying capital and implicitly assumes that different capital components (e.g. species, habitats) are substitutable.

If **natural capital needs to be weighed against other inputs and outcomes** in local projects and decision-making, its value depends on its effects on people's well-being, which can be used in cost benefit analysis or other decision-making processes. Various economic techniques of non-market valuation have been developed which do that by estimating value for consumers of environmental goods and services, such as clean air and water and settings for recreation. However, these have yet to be widely accepted as reliable in resource use decisions in New Zealand.

Non-market valuation's inclusion of consumer value is inconsistent with the national economic accounts, which focus on production. While intermediate and final consumption appear in the national accounts, they are recorded at their exchange values, and the economic surplus enjoyed by consumers who pay less for goods and services than they are worth to them, is not included in the national accounts. Attempts to adjust national accounts by using non-market valuation are fundamentally misleading, unless consumer surplus is estimated for all products across the economy, a task with formidable data and methodological challenges. This does not mean there is no role for non-market valuation techniques; rather they are tools for assessing relative preferences for different outcomes at a micro level rather than for adjusting the national accounts.

The ecosystems services approach formalises a means of identifying how nature adds value to human activity, both in production and consumption activities. Natural capital assets can be valued by converting a stream of future service flows into a net present value. Attempts have been made to establish Ecosystem Service Accounts that go beyond the SEEA in covering supply of non-market services, but these are regarded as experimental and not yet subject to agreed standards of the SEEA.

Stocks are fundamental to accounts and they are also important for monitoring the condition of natural systems, in both quantitative and qualitative terms. **Stock accounts are informative of scarcity of a resource or accessibility to substitutes and can also influence economic value**, but rarely feature in non-market valuation.

There is little evidence of how useful these approaches have been

Internationally the usefulness of natural resource accounts has proved variable across countries, depending on particular issues of the countries concerned. The adoption of the SEEA as a standard means of accounting for some natural resources improves the comparability of statistics across countries, and supports cross country discussion about green growth indicators and studies of the influence of natural capital on productivity (Brandt et al 2013).

The recent international literature from Australia and the UK indicates that these countries have found it possible to prepare natural capital accounts that are indicative of trends in the value of marketed goods and services obtained from natural capital. These have uses in raising awareness of the scale of changes.

Non-market valuation has been relied on in a number of settings, particularly in North America and Europe where the range of studies is sufficiently broad to allow causative factors to be explained and values customised to particular contexts.

Although literature indicates various ways in which natural resource accounts or non-market valuation could be used to inform decisions on natural capital, relatively few sources comment on the actual usefulness of these approaches in practical policy decision-making. Those that do suggest non-market valuation practitioners tend to overstate the usefulness of their results, and attribute lack of uptake to technical problems with the methods rather than limited familiarity among decision-makers with what the techniques can do. A thorough assessment of usefulness in informing decisions would require more detailed case studies than is possible in this review.

New Zealand's treatment of natural capital has been patchy, but is improving

In New Zealand, natural resource accounts have been prepared for forestry, energy, fisheries, minerals and water up to 2010 but these have been only partially updated to 2016 for fisheries, forestry and water. There is little evidence of use of non-market valuation methods in judicial settings, and even practitioners in these methods admit it is hard to find robust and reliable estimates for a wide range of different environmental factors or effects.

Treasury's living standards framework includes sustainability as one of its 5 dimensions, although how it deals with natural capital in practice has yet to be finalised. The Natural Resources Sectors framework division of domains covers matters like Air and Marine that are largely outside the scope of the SEEA core framework (except to the extent that it covers expenditures on protecting environment or improving air quality and covers valuation of natural resources that provide marketed inputs to economic sectors, such as sub-soil minerals and energy, timber and fisheries (gross catch minus discards), water and soil). The natural assets supplying marketed inputs would require further subdivision in the NRS framework's "Other" category. In the SEEA Experimental Ecosystem Accounts the value of marine environments is captured as part of the various ecosystem services they generate, and the volume of water is not itself a measurement target.

International use of natural capital accounting has varied depending on countries' priorities

This review found several variants of experimental natural capital accounting that have been implemented in other countries, with varying degrees of complexity and quantification. It also includes some assessment of their uses and resourcing requirements. There is a concentration of effort on natural capital accounting now as part of total wealth accounting, but still limited to items most readily amenable to market valuations.

The adoption of the SEEA as a standard approach has put natural stock records on a common footing, enabling better comparison over time between issues within and

between countries. That would support moves to improve inter-operability of data between different agencies and their applications, although whether this requires standards to be set, industry co-management or voluntary initiative is a technical policy question that was not addressed by any of the literature in this review.

International initiatives by the UN, World Bank and OECD and the need for consistent accounting standards for international comparisons are driving the development of standards and the statistical data on which accounts are based. International promptings also led to uptake of non-market valuation in the UK, where the EU's Water Quality Directives necessitated the development of techniques that could assess the human costs and benefits of water quality changes.

New Zealand is affected by compliance with the international statistical and accounting requirements and also on matters relating to international climate change reporting, but there is no such international imperative with respect to means of valuing effects at the local level, where non-market valuations are perceived as of too variable quality to be relied on by decision makers. If natural capital considerations are to be given more weight against economic ones, direction on how to do this with respect to ecosystem services, non-market valuation and giving due weight to Māori perspectives must be developed within New Zealand to the point where their credibility is sufficient to be accepted as legal submissions.

Key findings

From this literature review it appears that:

- there are different methods and approaches to recognising the value of natural capital at macro and micro levels, and approaches vary depending on the policy issue at hand (e.g. biodiversity differs from fish stocks)
- after long gestation and much effort previously directed at natural resource accounting of limited usefulness, many countries' are implementing natural capital accounts consistent with the SEEA, oriented to building multi-capital wealth accounts to complement the GDP flow accounts, selecting their coverage to accounts that have highest priority interest in their countries
- some countries have produced accounts that show changes in the market value of services obtained from different types of natural capital
- ecosystem service accounts are more experimental at this stage and remain incompatible with national economic accounts to the extent they include consumer surplus in valuations, as this changes the boundaries of account coverage unless all other production values in the economic accounts are adjusted for their consumer surplus
- non-market valuation techniques in their current form are inconsistent with the national accounting framework because of their inclusion of consumer surplus, but they still have use in informing local decisions and individual projects and demonstrating non-zero values for natural assets
- non-market valuation techniques have had little traction in New Zealand resource management decision processes, partly because of the limited range and quality of studies and resistance to using them in official circles:

  - this presents risks of inconsistency in weight given to natural capital in decisions at the local level, creating uncertainty for investors and potential for contrary outcomes for environmental quality
  - that can be countered by improving assessment of the quality of non-market value estimates for use as benchmarks for informing decisions in similar settings, and on the demand side by providing guidance to decision makers on where and when such values can be used
- natural capital has conventionally been largely a matter for public sector agencies, but private businesses interested in the risk implications have increasing tools available for assessment since the Natural Capital Protocol was issued in 2016, looking beyond national boundaries at dependencies and risk along the value chain, including overseas supply sources; but data limitations remain, and there has been little penetration of the concepts exhibited by iwi or Māori agencies and processes to date
- potential uses of natural capital approaches increase with comparability of data across countries, issues and time periods so guidance on interoperability of systems and data is one option for broadening the recognition of natural capital in New Zealand.

Recommendations

The key recommendations from this literature review are to:

- recognise that natural capital approaches cover a range of different methods for demonstrating non-zero value of natural resources, so prioritise actions in developing methods that best suit clearly defined policy purposes
- continue developing statistics and accounts in line with international standards of the SEEA, but focus on those with uses in domestic policy
- for other approaches there are no international standards so improving consistency and reliability requires direction from within New Zealand:
  - provide standard definitions to improve the usefulness of ecosystem services as an organising framework, but do not pursue monetised ecosystem service accounts which change the accounting framework
  - support non-market valuations of environmental resources that use consistent methods and control for contextual variables, which could form the basis of more reliable value transfers
  - work on uses of natural capital frameworks with long term focuse for Maori concerns, which reflect a context unique to New Zealand which will not be addressed elsewhere
- For all decision makers in the environmental and natural resources fields, investigate what use they make of natural capital approaches and what they would need to use them more
- Drawing on overseas examples, establish the relative scale of the main contributors to New Zealand's stock of natural capital on a recurring basis, to give a high-level indicator of trends in natural capital
- Drawing on private sector examples, develop workable base estimates of New Zealand's dependency and risks around key natural resource inputs, as

a high level indicator of risks to security of key natural inputs and to provide a spur to efficiency in use and development of substitutes, in such matters as sources of energy and phosphate fertilisers.

6. Bibliography

ABM 2013. 'Guide to Environmental Accounting'. Canberra: Australian Bureau of Meteorology

ABS 2014. 'Australian Environmental-Economic Accounts'. Canberra: Australian Bureau of Statistics.

ACCA, Flora & Fauna, and KPMG. n.d. 'Is Natural Capital a Material Issue? An Evaluation of the Relevance of Biodiversity and Ecosystem Services to Accountancy Professionals and the Private Sector'.

Ambrey, Christopher L., Christopher M. Fleming, and Matthew Manning. 2016. 'The Role of Natural Capital in Supporting National Income and Social Welfare'. *Applied Economics Letters* 23 (10–12): 723–27.

Allen B. P. & Loomis J. B. (2008). The decision to use benefit transfer or conduct original valuation research for benefit-cost and policy analysis. *Contemporary Economic Policy* 26(1), 1-12,

Anielski, Mark, and Sara Wilson. 2015. 'Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems'. Accessed March 18. http://www.borealcanada.ca/documents/Boreal_Wealth_Report_Nov_2005.pdf.

Ares, J. O. 2007. 'Systems Valuing of Natural Capital and Investment in Extensive Pastoral Systems: Lessons from the Patagonian Case'. *Ecological Economics* 62 (1): 162–73. doi:10.1016/j.ecolecon.2006.06.001.

Argimon, M., T. Badura, D. D'Amato, M. Kettunen, S. Kinnunen, and P. Vihervaara. 2014. *Socio-Economic Importance of Ecosystem Services in the Nordic Countries*. Paris: Organisation for Economic Co-operation and Development. http://www.oecd-ilibrary.org/content/book/tn2012-559.

Aronson, James, Suzanne J. Milton, and James N. Blignaut. 2012. *Restoring Natural Capital: Science, Business, and Practice*. Island Press.

Arrow, Kenneth J., Partha Dasgupta, Lawrence H. Goulder, Kevin J. Mumford, and Kirsten Oleson. 2012. 'Sustainability and the Measurement of Wealth'. *Environment and Development Economics* 17 (03): 317–353.

Atkinson, Giles, Ian Bateman, and Susana Mourato. 2012. 'Recent Advances in the Valuation of Ecosystem Services and Biodiversity'. *Oxford Review of Economic Policy* 28 (1): 22–47.

Ausseil, A.-GE, J. R. Dymond, M. U. F. Kirschbaum, R. M. Andrew, and R. L. Parfitt. 2013. 'Assessment of Multiple Ecosystem Services in New Zealand at the Catchment Scale'. *Environmental Modelling & Software* 43: 37–48.

Australian Committee for IUCN. 2015 'Valuing Nature Protected Areas and Ecosystem Services'. 2015. Valuing Nature: Protected Areas and Ecosystem Services. Sydney: https://www.researchgate.net/profile/James_Fitzsimons/publication/279950469_Valuing_Nature_Protected_Areas_and_Ecosystem_Services/links/559f68ad08aeb40ee93c40f4/Valuing-Nature-Protected-Areas-and-Ecosystem-Services.pdf#page=131.

Azad, M. a. S., T. Anvec, and M. Harris. 2016. 'Valuing Natural Capital on Farms: A Soil Natural Capital Indicator'. http://ecite.utas.edu.au/110729.

Azqueta, Diego, and Daniel Sotelsek. 2007. 'Valuing Nature: From Environmental Impacts to Natural Capital'. *Ecological Economics* 63 (1): 22–30. doi:http://www.sciencedirect.com/science/journal/09218009.

Barbier, Edward B. 2014. 'Economics: Account for Depreciation of Natural Capital'. *Nature* 515: 32–33.

———. 2016. 'The Protective Value of Estuarine and Coastal Ecosystem Services in a Wealth Accounting Framework'. *Environmental and Resource Economics* 64 (1): 37–58.

Bartelmus, Peter. 2009. 'The Cost of Natural Capital Consumption: Accounting for a Sustainable World Economy'. *Ecological Economics* 68 (6): 1850–57. doi:http://www.sciencedirect.com/science/journal/09218009.

Bateman, Ian J., Amii R. Harwood, Georgina M. Mace, Robert T. Watson, David J. Abson, Barnaby Andrews, Amy Binner, et al. 2013. 'Bringing Ecosystem Services into Economic Decision-Making: Land Use in the United Kingdom'. *Science* 341 (6141): 45–50.

Baveye, Philippe C., Jacques Baveye, and John Gowdy. 2013. 'Monetary Valuation of Ecosystem Services: It Matters to Get the Timeline Right'. *Ecological Economics* 95: 231–235.

Bay of Plenty Regional Council (n.d.) http://www.boprc.govt.nz/council/kaupapa-Māori/hapuiwi-resource-management-plans/

Bell B., Yap M., Cudby C. & Scarpa R. (2008) Valuing indigenous biodiversity. Paper prepared for FRST Project NIMMO501.

Belt, Marjan van den, and Daniella Blake. 2015. 'Investing in Natural Capital and Getting Returns: An Ecosystem Service Approach'. *Business Strategy and the Environment* 24 (7): 667–77. doi:10.1002/bse.1895.

Bennun, L. A., J. Ekstrom, and J. Bull. 2014. 'Integrating the Value of Natural Capital into Private and Public Investment: The Role of Information'. Cambridge, UK: The Biodiversity Consultancy. http://www.thebiodiversityconsultancy.com/wp-content/uploads/2015/02/Natural-capital-information-and-metrics-Bellagio-White-Paper-4-Word_AT.pdf.

Berghöfer, Augustin, Claire Brown, Aaron Bruner, Lucy Emerton, Ersin Esen, Davide Geneletti, Marina Kosmus, et al. 2016. *Increasing the Policy Impact of Ecosystem Service Assessments and Valuations: Insights from Practice*. CIFOR. https://www.researchgate.net/profile/Augustin_Berghoefer/publication/300618037_Increasing_the_Policy_Impact_of_Ecosystem_Service_Assessments_and_Valuations_-_Insights_from_Practice/links/570aa87a08aed09e91714433/Increasing-the-Policy-Impact-of-Ecosystem-Service-Assessments-and-Valuations-Insights-from-Practice.pdf.

Bergstrom, John C. 2001. 'The Role and Value of Natural Capital in Regional Landscapes'. *Journal of Agricultural and Applied Economics* 33 (2). http://ageconsearch.umn.edu/handle/15025.

Bergstrom, John C., and John B. Loomis. 2017. 'Economic Valuation of River Restoration: An Analysis of the Valuation Literature and Its Uses in Decision-Making'. *Water Resources and Economics* 17 (January): 9–19.

Biodiversity Information System for Europe. 2015. 'Natural Capital Accounting'. *Biodiversity Information System for Europe*. Accessed March 18. http://biodiversity.europa.eu/maes/mapping-ecosystems/natural-capital-accounting.

Biosecurity New Zealand (2009) Economic Cost of Pests to New Zealand. Report prepared by Nimmo-Bell. MAF Biosecurity New Zealand Technical Paper 2009/31.

Blignaut, James, Karen J Esler, Martin P de Wit, David Le Maitre, Suzanne J Milton, and James Aronson. 2013. 'Establishing the Links between Economic Development and the Restoration of Natural Capital'. *Current Opinion in Environmental Sustainability*, Terrestrial systems, 5 (1): 94–101. doi:10.1016/j.cosust.2012.12.003.

Bonner, J., Grigg, A., Hime, S., Hewitt, G., Jackson, R., & Kelly, M. (2012). Is natural capital a material issue? ACCA, Flora & Fauna International and KPMG LLP.

Bowes, Michael D., and John V. Krutilla. 1985. 'Multiple Use Management of Public Forestlands'. *Handbook of Natural Resource and Energy Economics* 2: 531–569.

Brandt, Nicola, Paul Schreyer, and Vera Zipperer. 2013. 'Productivity Measurement with Natural Capital'. OECD Economics Department Working Paper No. 1092. Availability Note: Information provided in collaboration with the RePEc Project: http://repec.org.

British Ecological Society'. 2014. 'Valuing Our Natural Capital: Natural Capital Committee Pushes for Long-Term Thinking' http://www.britishecologicalsociety.org/blog/2014/03/14/valuing-our-natural-capital-natural-capital-committee-pushes-for-long-term-thinking/.

Brouwer, Roy, Luke Brander, Onno Kuik, Elissaios Papyrakis, and Ian Bateman. 2013. 'A Synthesis of Approaches to Assess and Value Ecosystem Services in the EU in the Context of TEEB'. VU University Amsterdam. http://lukebrander.com/wp-content/uploads/2012/05/Brouwer-et-al-2013-A-synthesis-of-approaches-to-assess-and-value-ecosystem-services-in-the-EU-in-the-context-of-TEEB.pdf.

Bullock, Craig, and Robert O'Shea. 2016. 'Valuing Environmental Damage Remediation and Liability Using Value Estimates for Ecosystem Services'. *Journal of Environmental Planning and Management* 59 (9–10): 1711–27.

Business and Biodiversity Offset Programme (BBOP). 2011. 'Guidelines'.

Campbell, Elliott, and Mark Brown. 2012. 'Environmental Accounting of Natural Capital and Ecosystem Services for the US National Forest System'. *Environment, Development and Sustainability* 14 (5): 691–724.

Caparros, Alejandro, Pablo Campos, and Gregorio Montero. 2003. 'An Operative Framework for Total Hicksian Income Measurement: Application to a Multiple-Use Forest'. *Environmental and Resource Economics* 26 (2): 173–98. doi:http://link.springer.com/journal/volumesAndIssues/10640.

Chiesura, Anna, and Rudolf De Groot. 2003. 'Critical Natural Capital: A Socio-Cultural Perspective'. *Ecological Economics* 44 (2–3): 219–31. doi:http://www.sciencedirect.com/science/journal/09218009.

Chris Nykoluk Consulting. 2013. 'What Are Native Grasslands Worth? Why It Pays to Conserve This Endangered Ecosystem'. http://www.saskforage.ca/Coy%20Folder/News/Native_Grassland_Ecological_Goods&Services-Ranchers_Stewardship_Alliance.pdf.

Christensen, M. 2008. 'Biodiversity Offsets - a Suggested Way Forward'. In *Resource Management Law Association Conference*.

Christensen, M., and M. Baker-Galloway. 2013. 'Valuation of Natural Assets–what the Courts Have Said so Far'. *Resources Management Journal*, 9–16.

Christensen, M., and S. Barnes. 2007. 'Biodiversity Offsets and Environmental Compensation in New Zealand-Where to from Here'. In *Proceedings of the Conserv-Vision Conference, University of Waikato. Http://Www. Waikato. Ac. Nz/Wfass/Conserv-Vision/Proceedings/ChristensenBarnes. Pdf (Accessed 7 September 2012)*.

Christov, Strahil. 2014. 'Natural Capital Accounting and Valuation of ES in the EU – Initial Conceptual Framework International Conference on the BIOMOT Research Consortium'. In *International Conference on the BIOMOT Research Consortium, 24/3/2014*. Brussels, Belgium. http://www.biomotivation.eu/conference2014/presentations/Strahil%20Christov%20-%20Natural%20Capital%20Accounting%20and%20Valuation.pdf.

CIMA (Chartered Institute of Management Accountants). 2014. 'Accounting for Natural Capital: The Elephant in the Boardroom', Ernst and Young/ IFAC/ Natural Capital Coalition, London: UK. Available at: http://www.cimaglobal.com/Thought-leadership/Researchtopics/Sustainability/Accounting-for-natural-capital-the-elephant-in-the-boardroom/

Climate Policy Initiative. 2013. 'Using Data Tools to Optimize Indonesia's Land Resources: An Overview of Natural Capital Assessment'. http://climatepolicyinitiative.org/wp-content/uploads/2013/06/Using-Data-Tools-to-Optimize-Indonesia%E2%80%99s-Land-Resources-An-Overview-of-Natural-Capital-Assessment.pdf.

Clothier, Brent, Alec Macay, and Estelle Dominati. 2012. 'Natural Capital and New Zealand's Resource Management Act (1991)'. *2012 Conference, August 31, 2012, Nelson, New Zealand*. Nelson, New Zealand: New Zealand Agricultural and Resource Economics Society. https://ideas.repec.org/p/ags/nzar12/136044.html.

Clothier B. (2015) Soil as natural capital – from the farm to the court, *AgScience* 47, 9, March 2015, NZ Institute of Horticultural and Horticultural Science Inc.

Clough P. (2013) The value of ecosystem services for recreation. In Dymond JR ed. *Ecosystem services in New Zealand – conditions and trends*. Manaaki Whenua Press, Lincoln, New Zealand https://www.landcareresearch.co.nz/__data/assets/pdf_file/0019/77050/2_4_Clough.pdf

Convention on Biological diversity (CBD n.d.) Aichi Targets : http://www.cbd.int/sp/targets

Coremberg, A. 2015. 'Natural Resource and Human Capital as Capital Services and Its Contribution to Sustainable Development and Productivity KLEMS + N (Natural Capital) Approach'. *Paper Prepared for the IARIW-OECD Special Conference: "W(h)Ither the SNA?" Paris, France, April 16-17, 2015*. Paris, France.

Cosier, P, and C Sbrocchi. 2013. 'Accounting for Nature - a Common Currency for Measuring the Condition of Our Environment'. *Environmental Defence Society Conference, 7-8 Aug 2013*. Auckland.

Costanza, Robert, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, et al. 1997. 'The Value of the World's Ecosystem Services and Natural Capital'. *Nature* 387: 253–60.

Costanza, Robert, Rudolf de Groot, Paul Sutton, Sander van der Ploeg, Sharolyn J. Anderson, Ida Kubiszewski, Stephen Farber, and R. Kerry Turner. 2014. 'Changes in the Global Value of Ecosystem Services'. *Global Environmental Change* 26: 152–58. doi:10.1016/j.gloenvcha.2014.04.002.

Costanza, Robert, Matthew Wilson, Austin Troy, Alexey Voinov, Shang Liu, and John D'Agostino. 2006. 'The Value of New Jersey's Ecosystem Services and Natural Capital'. Institute for Sustainable Solutions Publications. http://pdxscholar.library.pdx.edu/iss_pub/15.

Czúcz, Bálint, Zsolt Molnár, Ferenc Horváth, Gergő G. Nagy, Zoltán Botta-Dukát, and Katalin Török. 2012. 'Using the Natural Capital Index Framework as a Scalable Aggregation Methodology for Regional Biodiversity Indicators'. *Journal for Nature Conservation* 20 (3): 144–52. doi:10.1016/j.jnc.2011.11.002.

Daily, Gretchen C., Peter M. Kareiva, Stephen Polasky, Taylor H. Ricketts, and Heather Tallis. 2011. 'Mainstreaming Natural Capital into Decisions'. In *Natural Capital: Theory and Practice of Mapping Ecosystem Services*, 3–14. http://www.newbooks-services.de/MediaFiles/Texts/5/9780199589005_Excerpt_001.pdf.

Daniel, Terry C., Andreas Muhar, Arne Arnberger, Olivier Aznar, James W. Boyd, Kai M. A. Chan, Robert Costanza, et al. 2012. 'Contributions of Cultural Services to the Ecosystem Services Agenda'. *Proceedings of the National Academy of Sciences* 109 (23): 8812–19. doi:10.1073/pnas.1114773109.

Danish Environmental Protection Agency. 2014. 'Danish Apparel Sector Natural Capital Account'.

DEFRA. 2007. 'An Introductory Guide to Valuing Ecosystem Services'. London: Department for Food, Environment and Rural Affairs.

———. 2014. 'Natural Capital Accounting in the UK and Policy Applications: An Overview'. http://projects.eionet.europa.eu/ecosystem-capital-accounting/library/nca-expert-workshop-19-sept-2014/uk-discussion-paper-policy-applications/download/en/1/Natural%20Capital%20Accounting%20in%20the%20UK%20and%20Policy%20Applications%20PB%20paper.doc.

DePratto, B, and D Kraus. n.d. 'The Natural Capital Value of Forest Habitat Conservation'. Nature Conservancy Canada.

Dickie, Ian. 2016. 'Applying Economic Tools in Marine Decisions: Natural Capital Valuation and Accounting'. eftec Economics for the Environment Consultancy.

DOC (2006) *The value of conservation – What does conservation contribute to the economy,* Department of Conservation, Wellington.

Dominati, Estelle, Murray Patterson, and Alec Mackay. 2010. 'A Framework for Classifying and Quantifying the Natural Capital and Ecosystem Services of Soils'. *Ecological Economics* 69 (9): 1858–68. doi:10.1016/j.ecolecon.2010.05.002.

Dominati, E., A. Mackay, S. Green, and M. Patterson. 2014. 'A Soil Change-Based Methodology for the Quantification and Valuation of Ecosystem Services from Agro-Ecosystems: A Case Study of Pastoral Agriculture in New Zealand'. *Ecological Economics* 100 (C): 119–29.

Doring, Ralf, and Thorsten M. Egelkraut. 2008. 'Investing in Natural Capital as Management Strategy in Fisheries: The Case of the Baltic Sea Cod Fishery'. *Ecological Economics* 64 (3): 634–42. doi:http://www.sciencedirect.com/science/journal/09218009.

Droste, Nils, and Bartosz Bartkowski. 2017. 'Ecosystem Service Valuation for National Accounting: A Reply to Obst, Hein and Edens (2016)'. *Environmental and Resource Economics*, March 1–11. doi:10.1007/s10640-017-0146-3.

Economics for the Environment Consultancy. 2010. 'Valuing the Benefits of Regeneration: Economics Paper'. https://www.gov.uk/government/publications/valuing-the-benefits-of-regeneration.

Edens, Bram, and Cor Graveland. 2014. 'Experimental Valuation of Dutch Water Resources According to SNA and SEEA'. *Water Resources and Economics* 7 (September): 66–81. doi:10.1016/j.wre.2014.10.003.

EFTEC. 2014. 'Developing Corporate Natural Capital Accounts'.

Ekins, Paul, Sandrine Simon, Lisa Deutsch, Carl Folke, and Rudolf De Groot. 2003. 'A Framework for the Practical Application of the Concepts of Critical Natural Capital and Strong Sustainability'. *Ecological Economics*, Identifying Critical Natural Capital, 44 (2–3): 165–85. doi:10.1016/S0921-8009(02)00272-0.

El Serafy, Salah 1989. 'The Proper Calculation of Income from Depletable Natural Resources'. Chapter 3 in El Serafy, S, YJ Ahmad, and E Lutz, (eds). *Environmental Accounting for Sustainable Development*, pp 10–18, UNEP-World Bank Symposium, Washington DC.

Engelbrecht, Hans-Jürgen. 2009. 'Natural Capital, Subjective Well-Being, and the New Welfare Economics of Sustainability: Some Evidence from Cross-Country Regressions'. *Ecological Economics*, Special Section: Analyzing the global human appropriation of net primary production - processes, trajectories, implications, 69 (2): 380–88. doi:10.1016/j.ecolecon.2009.08.011.

Environment Canterbury (n.d.) http://ecan.govt.nz/services/resource-consents/engaging-with-ngai-tahu/Pages/canterbury-iwi-management-plan.aspx

European Commission. 2015a. 'European Commission - Basics - Natural Capital'. Accessed March 18. http://ec.europa.eu/environment/basics/natural-capital/index_en.htm.

———. 2015b. 'The EU Business @ Biodiversity Platform | Natural Capital Accounting | Outputs to Date'. Accessed March 19. http://ec.europa.eu/environment/biodiversity/business/workstreams/Workstream1-Natural-Capital-Accounting/Outputs-to-date.html.

European Commission, and European Environment Agency. 2015. 'The Added Value of Natural Capital Accounting for EU Policies '.

European Environment Agency. 2011. 'An Experimental Framework for Ecosystem Capital Accounting in Europe'. Publication. http://www.eea.europa.eu/publications/an-experimental-framework-for-ecosystem.

European Parliament. 2015. 'Ecosystem Services: Valuing Our Natural Capital: Briefing March 2105'. http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/551321/EPRS_BRI(2015)551321_EN.pdf.European Union Committee of the Regions, 2014, *Multi-Level*

Governance of Our Natural Capital: Local and Subnational Governments' Contribution to the EU Biodiversity Strategy 2020 and the Aichi Biodiversity Targets.

EY, IFAC, and Natural Capital Coalition. n.d. 'Accounting for Natural Capital: The Elephant in the Boardroom'.

Fanning, Andrew L. 2016. 'Contrasting Values in the Sustainability Debate: Limitations of Economic Valuations and Their Role in Decision-Making'. *International Journal of Sustainable Development* 19 (2): 185–200.

Farley, Joshua. 2008. 'Valuing Natural Capital'. In *Economics and Conservation in the Tropics: A Strategic Dialogue*. http://conservation-strategy.org/sites/default/files/field-file/Tropics_Conference_Farley_Valuing_Natural_Capital.pdf.

Farley, J., 2012, "Natural Capital", in Craig, R., Nagle, J., Pardy, B., Schmitz, O. and W. Smith (eds.), *Berkshire Encyclopedia of Sustainability*, Volume 5 – Ecosystem Management and Sustainability, 264-267.

Fenichel, Eli P., and Joshua K. Abbott. 2014. 'Natural Capital: From Metaphor to Measurement'. *Journal of the Association of Environmental and Resource Economists* 1 (1): 1–27.

Fenichel, Eli P., Joshua K. Abbott, Jude Bayham, Whitney Boone, Erin M. K. Haacker, and Lisa Pfeiffer. 2016. 'Measuring the Value of Groundwater and Other Forms of Natural Capital'. *Proceedings of the National Academy of Sciences* 113 (9): 2382–87. doi:10.1073/pnas.1513779113.

Foody, G. M. 2015. 'Valuing Map Validation: The Need for Rigorous Land Cover Map Accuracy Assessment in Economic Valuations of Ecosystem Services'. *Ecological Economics* 111 (March): 23–28.

Friedman, Sarah. 2015. 'Accounting for Natural Capital on Financial Exchanges'. https://news.mongabay.com/2015/01/accounting-for-natural-capital-on-financial-exchanges/.

Gillespie, Alexander. 2012. 'A Missing Piece of the Conservation Puzzle: Biodiversity Offsets'. Prepared for the Department of Conservation.

Gillespie, Robert, and Jeff Bennett. 2015. 'Challenges in Including BCA in Planning Approval Processes: Coal Mine Projects in New South Wales, Australia'. *Journal of Benefit-Cost Analysis* 6 (2): 341–68. doi:10.1017/bca.2015.12.

Global Nature Fund. 2012. 'How Business Values Natural Capital'.

Globe International. 2015. 'International Efforts towards Natural Capital Accounting'. Accessed March 19. http://www.globeinternational.org/assessments/international-efforts-towards-natural-capital-accounting.

Globe International, and UCL. 2014. '2nd GLOBE Natural Capital Accounting Study: Legal and Policy Developments in Twenty-One Countries'. http://www.bartlett.ucl.ac.uk/sustainable/documents-news-events/2nd_GLOBE_Natural_Capital_Accounting_Study.

Goodall A (1996) "Te Tangata Tuatahi", in Lake Ellesmere (Te Waihora) Resource Audit, Canterbury Regional Council, 1996.

Gordon, H. Scott. 1954. 'The Economic Theory of a Common-Property Resource: The Fishery'. *The Journal of Political Economy* 62 (2): 124–142.

Greenhalgh S & Hart G 2015 Mainstreaming ecosystem services into policy and decision-making: lessons from New Zealand's journey. Int. J. Biodivers. Sci Ecosyst. Ser. Manag. 3732, 1-11

Groom, Ben. 2015. 'Natural Capital: Valuing Our Planet'. *Journal of Economic Literature* 53 (4): 1043–45.

Guerry, Anne D., Stephen Polasky, Jane Lubchenco, Rebecca Chaplin-Kramer, Gretchen C. Daily, Robert Griffin, Mary Ruckelshaus, et al. 2015. 'Natural Capital and Ecosystem Services Informing Decisions: From Promise to Practice'. *Proceedings of the National Academy of Sciences* 112 (24): 7348–55. doi:10.1073/pnas.1503751112.

Harmsworth, Garth R., and Shaun Awatere. 2013. 'Indigenous Māori Knowledge and Perspectives of Ecosystems'. *Ecosystem Services in New Zealand–conditions and Trends. Manaaki Whenua Press, Lincoln, New Zealand* 57. https://www.manaakiwhenua.com/__data/assets/pdf_file/0007/77047/2_1_Harmsworth.pdf.

Harmsworth, G.(2014). Presentation to the Ruamahanga Whaitua Committee, August http://www.gw.govt.nz/assets/Ruamahanga-Whaitua/Garth-Harmsworth-presentation-to-Ruamahanga-Whaitua-Committee-04-08-2014.pdf

Harris, Michael, and Iain Fraser. 2002. 'Natural Resource Accounting in Theory and Practice: A Critical Assessment'. *Australian Journal of Agricultural and Resource Economics* 46 (2): 139–192.

Hartman, Richard. 1976. 'The Harvesting Decision When a Standing Forest Has Value'. *Economic Inquiry* 14 (1): 52–58.

Hartwick, John M. 1977. 'Intergenerational Equity and the Investing of Rents from Exhaustible Resources'. *The American Economic Review*, 972–974.

He Kai Kei Aku Ringa (2012): The Crown- Māori Economic Growth Partnership, Māori Economic Task Force, November

He Mauri Ohooho (2014): The Bay of Connections Māori Economic Development Strategy, February

Helm, D. 2014. 'Taking Natural Capital Seriously'. *Oxford Review of Economic Policy* 30 (1): 109–25. doi:10.1093/oxrep/gru005.

Helm, D 2015 *Natural Capital – Valuing Our Planet*, Yale University Press, London

Henry, J (2014) Waikato and Waipa River Iwi values document review – Waikato Economic Joint Venture Study

HM Treasury (2009) Multi-criteria analysis: a manual www.gov.uk/government/publications/green-book-supplementary-guidance-multi-criteria-decision-analysis

HM Treasury (2013) The Green Book: appraisal and evaluation in central government www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

Høst-Madsen, N. K., Damgaard, C. K., Jørgensen, R., Bartlett, C., Bullock, S., Richens, J., & Schmidt, J. (Eds.). (2014). Danish Apparel Sector Natural Capital Account. Danish Environmental Protection Agency.

Hotelling, Harold. 1931. 'The Economics of Exhaustible Resources'. *The Journal of Political Economy*, 137–175.

HSBC (2013) Natural capital – identifying implications for economics, in HSBC Climate Change November 2013

Hulse B (2015) Ecosystem services as a policy tool, AgScience 47, 10, March 2015, NZ Institute of Horticultural and Horticultural Science Inc

Iacobuta, Gabriela-Ileana. 2015. 'Comparison of Selected Natural Capital Accounting Frameworks'. ENR - 80436 MSc Thesis. Environmental Economics and Natural Resources, Wageningen. http://edepot.wur.nl/351477.

Insley, C. and R. Meade, 2008, *Māori Impacts from the Emissions Trading Scheme: Detailed Analysis and Conclusions*, report prepared for the Ministry for the Environment, January

IPBES (n.d.) Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES): http://ipbes.net/

Jayachandran, S, J de Laat, Eric F. Lambin, and Charlotte Y. Stanton. 2016. 'Cash for Carbon: A Randomized Controlled Trial of Payments for Ecosystem Services to Reduce Deforestation'. NBER Working Paper No. 22378. http://www.nber.org/papers/w22378.

Jevons W S (1865) The Coal Question, Macmillan and Co

Jordan S., Hayes S. E., Yoskowitz D., Smith L., Summers K., Russell M. and Benson W. (2010) Accounting for natural resources and environmental sustainability: linking ecosystem services to human well-being, *Environmental Science and Technology*, 44 1530-1536.

Jorgensen, P. W., D. C. Trotter, and T. R. Hill. 2016. 'Ecosystem Services Assessments in Local Municipal Decision Making in South Africa: Justification for the Use of a Business-Based Approach'. *Journal of Environmental Planning and Management* 59 (2): 263–79. doi:10.1080/09640568.2015.1009626.

Karanja, F., N. Reid, and O. Cacho. 2008. 'Economic Valuation of Ecosystem Services from Environmental Flow Provision in the Gwydir Catchment, North-Western NSW, Australia'. In *IAIA08 Conference Proceedings*, 1–6. https://www.iaia.org/iaia08perth/pdfs/concurrentsessions/CS7-11_biodiversity_Karanja.pdf.

Kareiva, Peter, Heather Tallis, Taylor H. Ricketts, Daily, and Stephen Polasky, eds. 2011. *Natural Capital: Theory and Practice of Mapping Ecosystem Services*. Oxford University Press. https://ideas.repec.org/b/oxp/obooks/9780199589005.html.

Kaval, Pamela, and Richard Yao. 2007. 'New Zealand Outdoor Recreation Benefits'. http://researchcommons.waikato.ac.nz/handle/10289/1611.

Keeler, Bonnie L., Stephen Polasky, Kate A. Brauman, Kris A. Johnson, Jacques C. Finlay, Ann O'Neill, Kent Kovacs, and Brent Dalzell. 2012. 'Linking Water Quality and Well-Being for Improved Assessment and Valuation of Ecosystem Services'. *Proceedings of the National Academy of Sciences* 109 (45): 18619–24. doi:10.1073/pnas.1215991109.

Kerr, Geoffrey N., and Basil M. H. Sharp. 2004. 'Benefit Transfer: Choice Experiment Results'. In *2004 Conference, June 25-26*. Blenheim, New Zealand: New Zealand Agricultural and Resource Economics Society. https://ideas.repec.org/p/ags/nzar04/97774.html.

Khan, Jawed. 2013. *Towards Wealth Accounting-Natural Capital within Comprehensive Wealth*. Office for National Statistics, at http://www. ons. gov. uk/ons/guide-method/user-guidance/well-being/guidance-and-methodology/index. html (accessed 17 October 2013). http://mdgs.un.org/unsd/envaccounting/ceea/archive/Framework/towardswealthaccounting.pdf.

Khan, Jawed, Peter Greene, Kah Wei Hoo, and others. 2013. *Measuring UK Woodland Ecosystem Assets and Ecosystem Services*. Office for National Statistics. London, UK. http://mdgs.un.org/unsd/envaccounting/ceea/archive/Forest/woodlandecosystemandecosystemservices.pdf.

Kokkelenberg, Edward C., and William D. Nordhaus. 1999. *Nature's Numbers: Expanding the National Economic Accounts to Include the Environment*. National Academies Press.

http://books.google.co.nz/books?hl=en&lr=&id=cjicAgAAQBAJ&oi=fnd&pg=PT10&dq=Nature%27s+numbers:+Expanding+the+national+economic+accounts+to+include+the+environment&ots=wLGww8MwUg&sig=LKm3wrkNHu83ZGd6ZeCpcxzy_M4.

Laurans, Yann, Aleksandar Rankovic, Raphaël Billé, Romain Pirard, and Laurent Mermet. 2013. 'Use of Ecosystem Services Economic Valuation for Decision Making: Questioning a Literature Blindspot'. *Journal of Environmental Management* 119: 208–219.

Levrel, Harold, Céline Jacob, Denis Bailly, Mahe Charles, Olivier Guyader, Schéhérazade Aoubid, Adeline Bas, et al. 2014. 'The Maintenance Costs of Marine Natural Capital: A Case Study from the Initial Assessment of the Marine Strategy Framework Directive in France'. *Marine Policy* 49 (November): 37–47. doi:10.1016/j.marpol.2014.03.028.

Liu, G. 2013. 'Wealth Accounting in Norway'. OECD Working Party on National Accounts.

Liu, Shuang, Robert Costanza, Austin Troy, John D'Aagostino, and Willam Mates. 2010. 'Valuing New Jersey's Ecosystem Services and Natural Capital: A Spatially Explicit Benefit Transfer Approach'. *Environmental Management* 45 (6): 1271–85. doi:10.1007/s00267-010-9483-5.

Lone, Oeyvind. 2015. 'Natural Resource Accounting: The Norwegian Experience'. OECD, Environment Committee, Group on State of the Environment, Paris. 1988. Accessed April 10. http://link.springer.com/chapter/10.1007/978-3-642-49977-7_24.

Loomis, John, Paula Kent, Liz Strange, Kurt Fausch, and Alan Covich. 2000. 'Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired River Basin: Results from a Contingent Valuation Survey'. *Ecological Economics* 33 (1): 103–117.

MacDonald, Kenneth Iain, and Catherine Corson. 2012. '"TEEB Begins Now": A Virtual Moment in the Production of Natural Capital'. *Development and Change* 43 (1): 159–84. doi:10.1111/j.1467-7660.2012.01753.x.

Maes, Joachim, Benis Egoh, Louise Willemen, Camino Liquete, Petteri Vihervaara, Jan Philipp Schägner, Bruna Grizzetti, et al. 2012. 'Mapping Ecosystem Services for Policy Support and Decision Making in the European Union'. *Ecosystem Services* 1 (1): 31–39.

Malthus T (1798) An essay on the principle of population

'Mapping and Assessment of Ecosystems and Their Services (MAES)'. 2014. In *High-Level Conference on Mapping and Assessment of Ecosystems and Their Serviced MAES)*. Brussels. http://biodiversity.europa.eu/maes.

Marre, Jean-Baptiste, Olivier Thébaud, Sean Pascoe, Sarah Jennings, Jean Boncoeur, and Louisa Coglan. 2016. 'Is Economic Valuation of Ecosystem Services Useful to Decision-Makers? Lessons Learned from Australian Coastal and Marine Management'. *Journal of Environmental Management* 178 (August): 52–62. doi:10.1016/j.jenvman.2016.04.014.

Marsh, Dan, and Lena Mkwara. 2013. 'Review of Freshwater Non-Market Value Studies'. *Report Prepared for Waikato Regional Council*. http://playpen.waikatoregion.govt.nz/PageFiles/30275/2997672Review_of_Freshwater_Non-Market_Value_Studies.pdf.

Mauri Model (Te Kipa Kepa and Brian Morgan): http://www.mauriometer.com/userfiles/NgapunaFinalReport.pdf

Mazza, Leonardo, Marika Bröckl, Sanna Ahvenharju, Patrick ten Brink, and Tiina Pursula. 2013. 'Natural Capital in a Nordic Context: Status and Challenges in the Decade of Biodiversity'. http://www.diva-portal.org/smash/record.jsf?pid=diva2:700596.

Meadows D.H., Meadows G., Randers J. & Behrens W.W. III (1972) *The Limits to Growth.* New York: Universe Books.

Ministry for the Environment. 2012. 'New Zealand Studies That Indicate Potential Value Magnitudes'.http://scholar.google.co.nz/scholar?q=New+Zealand+studies+that+indicate+potential+value+magnitudes&btnG=&hl=en&as_sdt=0%2C5.

Ministry for the Environment. (2014). *A Framework for Environmental Reporting in New Zealand*. Wellington: Ministry for the Environment http://www.mfe.govt.nz/sites/default/files/media/Environmental%20reporting/framework-for-environmental-reporting-final.pdf

Moe, Thorvald. 2007. *The Norwegian Model of Sustainable Development: A Policy Oriented Capital Framework for Measurement and Policies*. Ministry of Finance, Norway. http://www.esdn.eu/pdf/resources/The%20Norwegian%20model%20of%20sustainable%20development_jan07.pdf.

Murray, Kieran, and Sally Wyatt. 2015. 'The Incentives to Accept or Reject a Rights Regime for Fresh Water'. Iwi Advisors Group. http://www.maniapoto.iwi.nz/images/FINAL_2nd_Sapere_Report_-_Incentives_to_accept_or_reject_rights.pdf.

National Institute for Public Health and the Environment. 2002. 'Biodiversity How Much Is Left? The Natural Capital Index Framework'. http://www.globio.info/downloads/269/Natural+Capital+Index+folder.pdf.

Natural Capital Coalition. 2016a. 'Natural Capital Protocol Principles and Framework'.

———. 2016b. 'The Path towards the NATURAL CAPITAL PROTOCOL a Primer for Business'.

Natural Capital Committee. 2014. 'Towards a Framework for Defining and Measuring Changes in Natural Capital'. https://nebula.wsimg.com/efc0de70bf88dea33ef3fe26747f7b76?AccessKeyId=68F83A8E994328D64D3D&disposition=0&alloworigin=1.

———. n.d. 'Economic Valuation and Its Applications in Natural Capital Management and the Government's 25 Year Environment Plan'.

———. n.d. 'How to Do It: A Natural Capital Workbook: Volume 1'.

'Natural Capital Project - About'. 2015. Accessed March 18. http://www.naturalcapitalproject.org/about.html#tools.

Natural England. 2009. 'No Charge: Valuing the Natural Environment'. *Natural England, NE220*.

Natural Resource Sectors BIM workstream on Māori issues (produced by the NRS agencies): http://nrs.mfe.govt.nz/sites/default/files/nrs-bim-final.pdf

Nazar, Rojas, and Ursula A. 2013. 'Economic, Social and Biological Attributes of Two Marine Reserves within New Zealand'. http://researcharchive.vuw.ac.nz/handle/10063/3026.

New Zealand Government. 2014. 'Natural Resources Sector'.

NIWA (2010) The Waikato River Independent Scoping Study, Client Report HAM 2010-032, http://www.waikatoriver.org.nz/wp-content/uploads/2011/09/scoping.pdf?phpMyAdmin=fb2d981894c82972b5a614e87e61f778

Noa Lincoln, pers. comm. April 07 2015

Nordhaus, William D., and James Tobin. 1972. 'Is Growth Obsolete?' In *Economic Research: Retrospect and Prospect Vol 5: Economic Growth*, 1–80. NBER. http://www.nber.org/chapters/c7620.pdf.

Nordhaus, W. D, (1999). *Nature's Numbers – Expanding the national economic accounts to include the environment*. The National Academies Press.

Nordhaus WD (2006). Principles of national accounting for non-market accounts; Chapter 3 in *A new architecture for the US national accounts* by Jorgenson DW, Landefeld JS & Nordhause WD (eds), National Bureau of Economic Research

Norton, Bryan G. 2015. *Sustainable Values, Sustainable Change: A Guide to Environmental Decision Making*. Chicago and London: http://search.ebscohost.com/login.aspx?direct=true&db=ecn&AN=1606682&site=ehost-live.

Norton, David A. 2009. 'Biodiversity Offsets: Two New Zealand Case Studies and an Assessment Framework'. *Environmental Management* 43 (4): 698–706.

NZIER (2013) "Valuing Natural Assets" by Clough P, Hickman M and Stephenson J, Discussion Document, Working Paper 2013-03, NZ Institute of Economic Research, Wellington

Obst, Carl, Lars Hein, and Bram Edens. 2016. 'National Accounting and the Valuation of Ecosystem Assets and Their Services'. *Environmental and Resource Economics* 64 (1): 1–23. doi:10.1007/s10640-015-9921-1.

Ochuodho, Thomas O., and Janaki R. R. Alavalapati. 2016. 'Integrating Natural Capital into System of National Accounts for Policy Analysis: An Application of a Computable General Equilibrium Model'. *Forest Policy and Economics*, New Frontiers of Forest Economics: Forest Economics beyond the Perfectly Competitive Commodity Markets, 72 (November): 99–105. doi:10.1016/j.forpol.2016.06.020.

OECD (2013) Guidelines on measuring subjective well-being; Organisation of Economic Co-operation and Development, Paris http://www.oecd.org/statistics/oecd-guidelines-on-measuring-subjective-well-being-9789264191655-en.htm

Office for National Statistics. 2012. 'Accounting for the Value of Nature in the UK'. http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/publications/roadmap-on-natural-capital-accounting.pdf.

———. 2014. 'UK Natural Capital - Initial and Partial Monetary Estimates'. http://www.ons.gov.uk/ons/rel/environmental/uk-natural-capital/initial-estimates/index.html.

Ojea, Elena, Maria L. Loureiro, Maria Allo, and Melina Barrio. 2016. 'Ecosystem Services and REDD: Estimating the Benefits of Non-Carbon Services in Worldwide Forests'. *World Development* 78 (February): 246–61.

Olewiler, Nancy. 2004. 'The Value of Natural Capital in Settled Areas of Canada'. http://www.cmnbc.ca/sites/default/files/natural%2520capital_0.pdf.

ONS (2015a) UK natural capital accounting 2020 roadmap: interim review and forward look, Office of National Statistics, London.

ONS (2015b) UK natural capital: freshwater ecosystem assets and services accounts, Office of National Statistics, London.

ONS (2016a) UK natural capital: ecosystem accounts for farmland; Statistical Bulletin, Office of National Statistics, London.

ONS (2016b) UK natural capital: monetary estimates 2016; Statistical Bulletin, Office of National Statistics, London.

Pagiola, Stefano, Konrad Von Ritter, and Joshua Bishop. 2004. 'Assessing the Economic Value of Ecosystem Conservation'. https://openknowledge.worldbank.org/handle/10986/18391.

Patterson, Murray G., and Anthony O. Cole. 2013. 'Total Economic Value' of New Zealand's Landbased Ecosystems and Their Services'. *Ecosystem Services in New Zealand–conditions and Trends. Manaaki Whenua Press, Lincoln, New Zealand*. https://www.manaakiwhenua.com/__data/assets/pdf_file/0004/77062/3_2_Patterson.pdf.

Pearce, David William, Anil Markandya, and Edward Barbier. 1989. *Blueprint for a Green Economy*. Vol. 1. Earthscan. http://books.google.co.nz/books?hl=en&lr=&id=jMTupDDeWZ8C&oi=fnd&pg=PR12&ots=qzTIFFFiPX&sig=gYIxfm_DNmBxpfsr5yBh7e5lShw.

Pearce, David William, and Jeremy J. Warford. 1993. *World without End, Economics, Environment, and Sustainable Development.* Oxford University Press. http://www.sidalc.net/cgi-bin/wxis.exe/?IsisScript=iicacr.xis&expresion=DEVELOPMENT&cantidad=50&formato=2&proxdoc=2801&ascendente=&tc=.

Pemberton, J, and S Kerr. 2013. 'Value and Natural Capital: Examining the Economist's Perspective'. MOTU Note #14. https://motu.nz/assets/Documents/our-work/environment-and-resources/MN14-final.pdf.

Petersen, Jan-Elrik, and A Gocheva. 2015. 'EU Reference Document on Natural Capital Accounting Prepared under the EU MAES Process {DRAFT}'. http://projects.eionet.europa.eu/ecosystem-capital-accounting/library/reference-document-natural-capital-accounting/final-revised-reference-document-nca-consultation-january-

2015/download/en/1/NCA_draft%20reference%20document_for%20consultation_06-01-2015.pdf.

Phillips, Spencer, and Beth McGee. 2016. 'Ecosystem Service Benefits of a Cleaner Chesapeake Bay'. *Coastal Management* 44 (3): 241–58. doi:10.1080/08920753.2016.1160205.

Phillips Y (2014) Non-market values for fresh water in the Waikato region: a combined revealed and stated preference approach; Waikato Regional Council

Quaas, Martin F., Rainer Froese, Helmut Herwartz, Till Requate, Jorn O. Schmidt, and Rudiger Voss. 2012. 'Fishing Industry Borrows from Natural Capital at High Shadow Interest Rates'. *Ecological Economics* 82 (1): 45–52. doi:http://www.sciencedirect.com/science/journal/09218009.

Radermacher, W, and A Steurer. 2014. 'Do We Need Natural Capital Accounts, and if so, Which Ones?' In *Paper for HLEG Meeting, 22-23 Sept. 2014 in Rome, Session 1: Do We Need Capital Accounts for Other Types of Capital than Economic Capital (e.g. Human Capital, Natural Capital, Social Capital)?* Rome.

Ramsar. 2017. 'Integrating Multiple Wetland Values into Decision-Making'. Ramsar Policy Brief 2.http://www.ramsar.org/sites/default/files/documents/library/rpb_values_of_wetlands_e.pdf.

Raymond, Christopher M., Brett A. Bryan, Darla Hatton MacDonald, Andrea Cast, Sarah Strathearn, Agnes Grandgirard, and Tina Kalivas. 2009. 'Mapping Community Values for Natural Capital and Ecosystem Services'. *Ecological Economics* 68 (5): 1301–15.

'RePEc Snapshot'. 2015. Accessed March 16. https://ideas.repec.org/p/ags/nzar12/136044.html.

Repetto, Robert, William Magrath, Michael Wells, Christine Beer, and Fabrizio Rossini. 1989. 'Wasting Assets: Natural Resources in the National Income Accounts.' http://www.popline.org/node/363718.

Ricketts, Taylor H., and Eric Lonsdorf. 2013. 'Mapping the Margin: Comparing Marginal Values of Tropical Forest Remnants for Pollination Services'. *Ecological Applications* 23 (5): 1113–23. doi:10.1890/12-1600.1.

Roberts, Lin, Ann Brower, Geoff Kerr, Simon Lambert, Wendy McWilliam, Kevin Moore, John Quinn, et al. 2015. 'The Nature of Wellbeing: How Nature's Ecosystem Services Contribute to the Wellbeing of New Zealand and New Zealanders'. Wellington: Department of Conservation. http://www.doc.govt.nz/Documents/science-and-technical/sap258entire.pdf.

Robinson, D. A., N. Hockley, D. M. Cooper, B. A. Emmett, A. M. Keith, I. Lebron, B. Reynolds, et al. 2013. 'Natural Capital and Ecosystem Services, Developing an Appropriate Soils Framework as a Basis for Valuation'. *Soil Biology and Biochemistry* 57: 1023–33. doi:10.1016/j.soilbio.2012.09.008.

Rogers, Abbie A., Marit E. Kragt, Fiona L. Gibson, Michael P. Burton, Elizabeth H. Petersen, and David J. Pannell. 2015. 'Non-Market Valuation: Usage and Impacts in Environmental Policy and Management in Australia'. *Australian Journal of Agricultural and Resource Economics* 59 (1): 1–15. doi:10.1111/1467-8489.12031.

Roy, René, and Paul J. Thomassin. 2014. 'Estimating a Natural Capital Account for Agricultural Land'. 2014 Annual Meeting, July 27-29, 2014, Minneapolis, Minnesota 170516.

Agricultural and Applied Economics Association. https://ideas.repec.org/p/ags/aaea14/170516.html.

Ruckelshaus, Mary. 2015. 'Notes from the Field: Lessons Learned from Using Ecosystem Service Approaches to Inform Real-World Decisions'. *Ecological Economics* 115 (July): 11–21.

Ruggeri, Joe. 2009. 'Government Investment in Natural Capital'. *Ecological Economics* 68 (6): 1723–39. doi:http://www.sciencedirect.com/science/journal/09218009.

Ruijs, Arjan, and Petra van Egmond. 2017. 'Natural Capital in Practice: How to Include Its Value in Dutch Decision-Making Processes'. *Ecosystem Services* 25 (June): 106–16. doi:10.1016/j.ecoser.2017.03.025.

Ruru, Ian (n.d), The Mauri Compass, http://www.gdc.govt.nz/assets/CommitteeMeetings/14-254-X1-Appendix.pdf

Samarasinghe, O., Greenhalgh, S. and E.-T. Vesely, 2013, *Looking at Soils through the Natural Capital and Ecosystem Services Lens*, Landcare Research Science Series No. 41

Samuelson, Paul A. 1976. 'Economics of Forestry in an Evolving Society'. *Economic Inquiry* 14 (4): 466–492.

Schaefer, Mark, Erica Goldman, Ann M. Bartuska, Ariana Sutton-Grier, and Jane Lubchenco. 2015. 'Nature as Capital: Advancing and Incorporating Ecosystem Services in United States Federal Policies and Programs: Table 1.' *Proceedings of the National Academy of Sciences* 112 (24): 7383–89. doi:10.1073/pnas.1420500112.

Schägner, Jan Philipp, Luke Brander, Joachim Maes, and Volkmar Hartje. 2013. 'Mapping Ecosystem Services' Values: Current Practice and Future Prospects'. *Ecosystem Services*, Special Issue on Mapping and Modelling Ecosystem Services, 4: 33–46. doi:10.1016/j.ecoser.2013.02.003.

Schmidt, Amelia. 2012. 'Investing in Natural Capital: Estimating the Value of Open Space Nature Preserves in Wake County, North Carolina'. Masters of NAtural Resources Professional Papers, NC State University. http://repository.lib.ncsu.edu/dr/handle/1840.4/8125.

Schreyer, P., Nicola Brandt, and Vera Zipperer. 2015. 'Productivity Measurement with Natural Capital'. In *Society for Economic Measurement Annual Conference*. Paris.

Schultz, Lisen, Carl Folke, Henrik Osterblom, and Peter Olsson. 2015. 'Adaptive Governance, Ecosystem Management, and Natural Capital'. *PNAS : Proceedings of the National Academy of Sciences* 112 (24). http://www.pnas.org/content/112/24/7369.short.

Scott, A. D. 1955. 'The Fishery: The Objectives of Sole Ownership'. *J. Pol. Econ.* 63: 116.

Scott R. 2014 A systems perspective on the Natural Resources Framework: comment on Hearnshaw et al.; Policy Quarterly, 10(4), 59-62Scottish Executive, 2004, *Scotland's Biodiversity: It's In Your Hands*.

Sen, Antara, Amii Darnell, Ian Bateman, P. Munday, A. Crowe, L. Brander, J. Raychaudhuri, A. Lovett, A. Provins, and J. Foden. 2011. 'Economic Assessment of the Recreational Value of Ecosystems in Great Britain'. Report to the Economics Team of the UK National Ecosystem Assessment. http://www.infra.cbd.int/financial/values/unitedkingdom-recreationalvalue.pdf.

Smith, Robert. 2013. 'Why We Don't Really Measure Natural Capital but Really Should. IISD'. International Institute of Sustainable Development.

http://www.iisd.org/publications/why-we-dont-really-measure-natural-capital-really-should.

Solow, Robert M. 1986. 'On the Intergenerational Allocation of Natural Resources'. *The Scandinavian Journal of Economics*, 141–149.

Sukhdev, Pavan, Heidi Wittmer, Christoph Schröter-Schlaack, Carsten Nesshöver, Joshua Bishop, Patrick ten Brink, Haripriya Gundimeda, Pushpam Kumar, and Ben Simmons. 2010. *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB*. TEEB. http://library.wur.nl/WebQuery/clc/1948271.

Tau T.M., Palmer D., Goodall A. and Tau R. (Snr) (1990) *Te Whakatau Kaupapa: Ngāi Tahu Resource Management Strategy for the Canterbury Region.* Aoraki Press Ltd.

Te Rūnanga o Ngāi Tahu Annual Report 2014, http://ngaitahu.iwi.nz/annual-report-2014/

TEEB. 2015. 'Natural Capital Accounting'. *TEEB*. Accessed March 16. http://www.teebweb.org/areas-of-work/advancing-natural-capital-accounting/.

Tipa, Gail & Teirney, Laurel (2006) A Cultural Health Index for Streams and Waterways: A report prepared for the Ministry for the Environment, April 2006, http://www.mfe.govt.nz/publications/cultural-health-index-streams-and-waterways-tech-report-apr06

The World Bank. 2011. *The Changing Wealth of Nations Measuring Sustainable Development in the New Millennium*. Washington, D.C.: The World Bank.

Trucost. 2011. 'Universal Ownership: Why Environmental Externalities Matter to Institutional Investors'. A report for Principles for Responsible Investment (PRI) and UNEP Finance Initiative commissioned.

Trucost (2013) *Natural Capital at Risk: the Top 100 Externalities of Business*; report prepared for TEEB for Business Coalition

Turner, R. Kerry, and Marije Schaafsma eds. 2015. *Coastal Zones Ecosystem Services: From Science to Values and Decision Making*. Studies in Ecological Economics, vol. 9. http://search.ebscohost.com/login.aspx?direct=true&db=ecn&AN=1575556&site=ehost-live.

UK National Ecosystem Assessment. 2011. 'UK National Ecosystem Assessment: Synthesis of Key Findings'. http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx.

UK Natural Capital Committee. 2014. 'The State of Natural Capital - Restoring Our Assets'.

UK. Office for National Statistics. 2015. 'Natural Capital Accounting 2020 Roadmap: Interim Review and Forward Look'.

———. 2016a. 'UK Natural Capital: Ecosystem Accounts for Farmland (Experimental Statistics)'.

———. 2016b. 'UK Natural Capital: Experimental Carbon Stock Accounts, Preliminary Estimates'.

———. 2016c. 'UK Natural Capital: Monetary Estimates'. file:///X:/8.Library/Zotero%20library/storage/H7BDZKMZ/uknaturalcapitalpartialmonetaryestimates2016.html.

Ulgiati, Sergio, Amalia Zucaro, and Pier Paolo Franzese. 2011. 'Shared Wealth or Nobody's Land? The Worth of Natural Capital and Ecosystem Services'. *Ecological Economics* 70 (4): 778–87.

UNEP FI 2010 'CEO Briefing: Demystifying Materiality - Hardwiring Biodiversity and Ecosystem Services into Finance'. Biodiversity and Ecosystem Services Workstream. United Nations Environment Programme Finance Initiative:

———. 2012 Natural Capital Declaration; United Nations Environment Programme Finance Initiative:

United Nations, Economic Commission for Europe/Food and Agriculture Organization of the United Nations, Forestry and Timber Section, United Nations, Economic Commission for Europe, United Nations Environment Programme, and Food and Agriculture Organization of the United Nations. 2014. *The Value of Forests: Payments for Ecosystem Services in a Green Economy.*

Vardon M, King S, Juhn D, Bass S, Burnett P & Johansson S (2017) "Natural capital accounting for better policy "; paper to WAVES NCA Policy Forum, published in Vardon, M., Bass, S., Ruijs, and Ahlroth, S. (eds) 2017. *Better Policy through natural capital accounting: stocktake and ways forward.* WAVES World Bank, Washington D.C.

Vassallo, P., C. Paoli, E. Buonocore, P. P. Franzese, G. F. Russo, and P. Povero. 2017. 'Assessing the Value of Natural Capital in Marine Protected Areas: A Biophysical and Trophodynamic Environmental Accounting Model'. *Ecological Modelling* 355 (July): 12–17. doi:10.1016/j.ecolmodel.2017.03.013.

Vassallo, Paolo, Chiara Paoli, Alessio Rovere, Monica Montefalcone, Carla Morri, and Carlo Nike Bianchi. 2013. 'The Value of the Seagrass Posidonia Oceanica: A Natural Capital Assessment'. *Marine Pollution Bulletin* 75 (1–2): 157–67. doi:10.1016/j.marpolbul.2013.07.044.

Voora, Vivek, and Henry David Venema. 2008. 'An Ecosystem Services Assessment of the Lake Winnipeg Watershed'. Funded by and Prepared for: Environment Canada – Policy Development Division. http://search.iisd.org/sites/default/files/pdf/2008/ecosystem_assessment_lake_wpg.pdf.

Voora, V. A., and Henry David Venema. 2015. 'The Natural Capital Approach: A Concept Paper'. Accessed March 18. http://www.iisd.org/pdf/2008/natural_capital_approach.pdf.

Waikato River Independent Scoping Study, NIWA Client Report HAM 2010-032, September 2010, http://www.waikatoriver.org.nz/wp-content/uploads/2011/09/scoping.pdf?phpMyAdmin=fb2d981894c82972b5a614e87e61f778

Waikato Regional Council (n.d.) http://www.waikatoregion.govt.nz/Community/Your-community/iwi/Tangata-Whenua-Management-Plans/

Waikato-Tainui Annual Report 2013, http://www.waikatotainui.com/wp-content/uploads/2013/12/2013_annual_report.pdf

Waite, Richard, Benjamin Kushner, Megan Jungwiwattanaporn, Erin Gray, and Lauretta Burke. 2015. 'Use of Coastal Economic Valuation in Decision Making in the Caribbean: Enabling Conditions and Lessons Learned'. *Ecosystem Services*, Marine Economics and

Policy related to Ecosystem Services: Lessons from the World's Regional Seas, 11 (February): 45–55. doi:10.1016/j.ecoser.2014.07.010.

Walker, Susan, Ann L. Brower, R. T. Stephens, and William G. Lee. 2009. 'Why Bartering Biodiversity Fails'. *Conservation Letters* 2 (4): 149–157.

Wang, Pu, Gregory L. Poe, and Steven A. Wolf. 2017. 'Payments for Ecosystem Services and Wealth Distribution'. *Ecological Economics* 132 (February): 63–68.

WAVES. 2015a. 'Moving beyond GDP'. Accessed March 17. http://www.wavespartnership.org/sites/waves/files/images/Moving_Beyond_GDP.pdf.

———. 2015b. 'Wealth Accounting and the Valuation of Ecosystem Services'. Accessed March 16. http://www.wavespartnership.org/en

———. nd https://www.wavespartnership.org/.———. 2017 Better Policy Through Natural Capital Accounting – Stocktake and Ways Forward – 7th Waves Annual Partnership Meeting Edition, WAVES World Bank, Washington D.C. https://www.wavespartnership.org/en/knowledge-center/better-policy-through-natural-capital-accounting-stocktaking-and-ways-forward-7th

Williams, Evan, John R. Firn, Vanessa Kind, Mark Roberts, and Derek McGlashan. 2003. 'The Value of Scotland's Ecosystem Services and Natural Capital'. *European Environment* 13 (2): 67–78. doi:10.1002/eet.314.

World Bank. 2006. 'Where Is the Wealth of Nations?'

———. 2011. 'The Changing Wealth of Nations'.

World Environment Center. 2014. 'Business Approaches to Natural Capital Valuation'. http://www.wec.org/2014naturalcapitalvaluation.

Wu, Tong, Yeon-Su Kim, and Matthew D. Hurteau. 2011. 'Investing in Natural Capital: Using Economic Incentives to Overcome Barriers to Forest Restoration'. *Restoration Ecology* 19 (4): 441–45. doi:10.1111/j.1526-100X.2011.00788.x.

WWF. 2014a. 'Accounting for Natural Capital in Eu Policy Decision-Making a Wwf Background Paper on Policy Developments'.

———. 2014b. 'Accounting for Natural Capital in EU Policy Decision-Making a WWF Background Paper on Policy Developments'. http://d2ouvy59p0dg6k.cloudfront.net/downloads/background_accounting_for_natural_capital_in_eu_policy_decision_making_final.pdf.

———. 2015. 'The Natural Capital Project | Projects | WWF'. Accessed March 18. http://www.worldwildlife.org/projects/the-natural-capital-project.

Yee, Susan Harrell, John F. Carriger, Patricia Bradley, William S. Fisher, and Brian Dyson. 2015. 'Developing Scientific Information to Support Decisions for Sustainable Coral Reef Ecosystem Services'. *Ecological Economics* 115 (July): 39–50.

Yun, Seong Do, Barbara Hutniczak, Eli P. Fenichel, and Joshua K. Abbott. 2016. 'The Wealth of Ecosystems: Valuing Natural Capital in the Context of Ecosystem Based Management'. http://ageconsearch.umn.edu/bitstream/235737/2/AAEA2016_Yun_et_al.pdf.

Appendix A WAVES extracts

Natural capital includes, first of all, the resources that we easily recognize and measure such as minerals and energy, forest timber, agricultural land, fisheries and water. It also includes ecosystems producing services that are often 'invisible' to most people such as air and water filtration, flood protection, carbon storage, pollination for crops, and habitat for fisheries and wildlife. These values are not readily captured in markets, so we don't really know how much they contribute to the economy or what it would cost if we lose them.

The concept of accounting for natural capital has been around for more than 30 years. However, progress in moving toward implementation has been slow.

The SEEA provides an internationally agreed method, on par with the current SNA, to account for material natural resources like minerals, timber, and fisheries. The challenge now is to build capacity in countries to implement the SEEA and to demonstrate its benefits to policy makers.

Natural capital accounting can provide detailed statistics for better management of the economy. For example, land and water accounts can help countries interested in increasing hydro-power capacity to assess the value of competing land uses and the optimal way to meet this goal. Ecosystems accounting not only provides a tool to maximize economic outcomes but is also a means to measure who benefits and bears the cost of ecosystem changes, helping governments gauge whether their growth is inclusive.

SEEA provides a road map to guide implementation of environmental accounts. It begins with establishing institutional structures with clear lines of responsibility and commitments across government departments. Rather than taking on the challenge of compiling all natural capital accounts at once, countries are prioritizing which sub-accounts to begin with, based on important development challenges facing them.

The Wealth Accounting and Valuation of Ecosystem Services (WAVES) is a global partnership, led by the World Bank that includes the United Nations Environment Programme, the UN Development Programme, and the UN Statistical Commission ; the countries of Botswana, Colombia, Costa Rica, Madagascar, and the Philippines, which are implementing programs; as well as financial or other support from Australia, Canada, France, Japan, Norway, the United Kingdom, and several NGOs.

The partners want to take natural capital accounting beyond the SEEA-approved material resources, such as timber and minerals, to include ecosystem services and other natural resources that are not traded or marketed and are therefore harder to measure. That includes the "regulating" services of ecosystems, such as forests for pollination and wetlands for reducing the impact of floods. A Policy and Technical Experts Committee, working closely with the processes set up by the UN Statistical Commission, has been established to take this forward.

Appendix B Evolution of the concept of natural capital

Recognition of the reliance of human activity on the natural environment can be found in the writings of Plato, but the modern concept of natural capital in linking economics to the natural environment can be traced to four broad strands. These are the emergence of natural resource economics, the development of techniques for valuation of matters outside of market exchange, questioning of the limitations of national accounting frameworks that are the basis of GDP calculations, and most recently the idea of ecosystem services.

B.1 Natural resource economics

In natural resource economics the association of resources with capital led to methods for determining the stock of available resource and how to utilise it to best advantage. In forestry this goes back to the 1849 Faustmann formula for optimal rotation, which indicated when to harvest for maximum value on the basis of assumptions on timber yield, the expected future prices and the discount rate applied to the capital tied up in the forest (Bowes and Krutilla 1985). Mineral industries have long drawn distinction between resources (total known minerals) and reserves which are feasible to extract with current technologies and prices.

In the mid-20th century economists also turned their attention to obtaining sustained yields from fish stocks (Gordon 1954, Scott 1955), and at a similar period there emerged the theory of optimal depletion of exhaustible finite resources, building on the work of Hotelling (1931).

Renewed interest in natural resource availability arose in the 1970s, spurred by the Club of Rome's computer modelling in the publication of *Limits to Growth* (Meadows et al 1971). In forestry this led to Hartmann's 1976 observation that when a standing forest has value, for its non-market benefits for recreation, watershed management or biodiversity, it becomes optimal to extend the rotation period and defer harvesting that would destroy those standing values.

For non-renewable mineral and energy resources, the recognition that extraction meant the once only conversion of resource stock into consumable product led to Hartwick's 1977 proposal that the economic rent or "super profit" from resource depletion should be invested in other capital. Subsequently El Serafy (1989) provided a formula for dividing the net revenues from exhaustible resource extraction between Hicksian income (that which can be consumed without being left worse off) and an amount for investment in other capital to ensure a continuing income stream.

Important insights for natural capital from natural resource economics include the possibility of assessing the sustainability of resource use by examining whether the value of the total capital stock is maintained or declining i.e. whether depletion of natural resource is offset by creation of other forms of physical or financial capital. Another is that the share of net revenues between investment and consumption can be determined and will rise with increasing scarcity of the resource. In practice, however, new discoveries and new extraction technologies require frequent revision

of the fixed resource estimate used in optimal depletion theory, and application of this theory is rarely observed. Hartwick's rule has been influential on a number of governments in determining use of their mineral royalties, and has been linked to the diversion of royalties into the Norwegian sovereign wealth fund (Moe 2007).

B.2 Non-market valuation

The economic literature now recognises that "Total Economic Value" (TEV) of natural resources encompasses both market and non-market values, the components of which can be divided into various sub-categories.

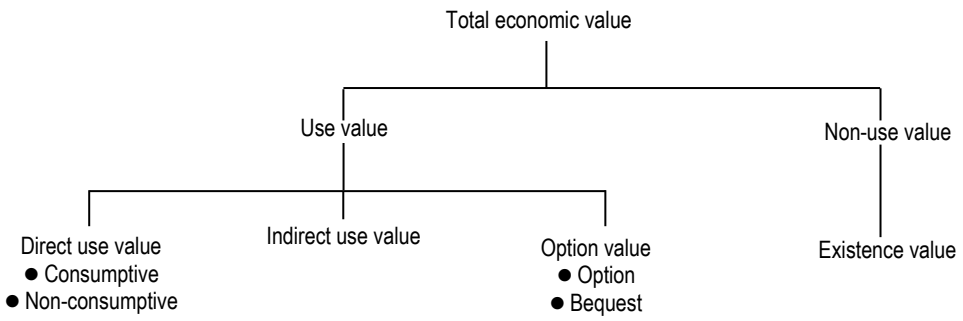
TEV = current use values + future use values + non-use values.

These components of environmental value can be summarised as follows:

- direct current use values, usually measured in terms of outputs of commercial commodities or services, but including some non-commercial services and effects (e.g. un-priced recreation).
- indirect current use (functional) values, mostly referring to environmental services which support or protect economic production, consumption or assets (e.g. flood reduction).
- future use values, i.e. the benefit gained from retaining resources for future consumption, particularly where there is a possibility that future technology will increase the usefulness of the resource, including both:
  - option value: the value of retaining a resource for own use in future;
  - quasi-option value: the value of retaining the resource until future information clarifies its potential usefulness (for example, archaeological sites have diminished value once disturbed, and may be best retained untouched pending new excavation techniques)
  - bequest value: the value of retaining a resource to pass to future users.
- non-use values (sometimes called passive-use values) reflecting current preferences to preserve the existence of the resource into the future, without prospect of any direct use benefit for those holding this preference.

These value components are summarised in Figure 7.

Figure 7 Components of Total Economic Value



Source: NZIER, drawing on Pearce & Warford 1993, Pagiola 2004

The direct uses above largely correspond to provisioning and cultural services of the ecosystem services framework, and indirect uses correspond to supporting and regulatory services. Option value can apply to the future use of any of these services and non-use value is a sub-component of cultural services.

A suite of techniques have been developed to infer how people value outcomes that are not amenable to market trading. These include:

- market based measures, such as inferring the value of a natural area's contribution to water purification from the cost of alternative ways of obtaining water of equivalent quality
- cost-based measures, such as valuing the loss of natural habitat at the cost of replacing it elsewhere, on the assumption that the total stock of that habitat should not be reduced
- production-based measures, such as inferring the contribution of water to agricultural production by analysing the value of outputs from production systems with and without availability of water.

Since the 1960s, developing from an idea postulated by Harold Hotelling, new techniques have been developed that focus on the value to consumers of non-market goods and services. The first of these was travel cost analysis, but more recently stated preference techniques have been developed that directly ask surveyed respondents their willingness to pay to secure particular outcomes:

- revealed preference measures infer a value for intangible goods from costs incurred on related matters, such as travel cost analysis to infer the consumers' surplus obtained by recreational visitors to specific locations, or hedonic price analysis of property values to infer the premium attached to those with higher environmental qualities
- stated preference methods use direct questioning of a sample of interested parties about their willingness to pay for different outcomes, including contingent valuation which asks about the value of specific outcome or scenario, or choice modelling which asks about people's preference for different combinations of attributes, yielding a price for each attribute.

With the growth of computing capacity and data to analyse, stated preference methods have become more prevalent since the 1980s and received some endorsement in the wake of the Exxon Valdez oil spill in Alaska, when a panel appointed by the National Oceanic and Atmospheric Administration (NOAA), including two Nobel prize-winning economists, found they could be reliable and informative. Stated preference measures are potentially very useful as they can be used to elicit people's willingness to pay for non-use values (e.g. existence value and bequest value), but their results have been shown to be more reliable for matters that are familiar than those that are unfamiliar or difficult to validate (Atkinson et al 2012). Non-market valuation (in particular stated preference methods) remain contentious because of the hypothetical nature of the questions, and the need to eliminate a range of potential biases in the results.

Economic valuations can be useful in addressing four broad categories of question:

- the total value contribution of environmental assets to the national economy

- the net benefits in value terms of a change in environmental condition
- the distribution of costs and benefits of changes in environmental condition
- the value of environmental condition to those with most interest in its upkeep.

The first bullet is about enumerating the aggregate scale of contribution of natural assets to economic activity comparable to other economic sectors. The flows can be approached through economic impact analysis which measures the impact of additional expenditures caused by a natural resource based activity, and its stimulus on other sectors. Examining flows over time can be converted to a present value of the natural capital stock.

The other three bullets are more focused on the value of changes in environmental condition or management. Different valuation approaches can be employed for each of these different questions.

In principle it should be possible to estimate different layers of value from the different services provided by natural assets. For instance, on New Zealand's conservation lands, the most readily quantifiable ecosystem services to compare against market values include commercial operations on those lands for tourism concessions, locations for filming, rentals for transmission facilities and so on, but there are also non-market services for downstream water use (flood moderation), contributions to biodiversity survival and non-priced recreational access.

Where trade-offs arise between commercial and non-commercial services, the latter can only be weighed in economic terms with some form of non-market valuation. Development or encroachment onto those assets is likely to increase the market value of commercial services obtained from them, but can also reduce the non-market values. A critical issue therefore is whether the total value of resource under development is greater or less than in its conserved state.

Benefit or value transfer is not a particular technique, but refers to the use of values obtained by any method in one context "transferred" to similar contexts elsewhere. It has the appeal of being relatively cheap to apply if the same value can be used over and again, but such repetitive use has potential to reduce its accuracy.

For a non-market use like outdoor recreation, the simplest approach would be to take a benefit value per visitor day and apply it to the number of visitors affected at a different site, but since the value of a site for recreation is likely to depend on context-specific factors such as the proximity to substitute sites and local population characteristics, this is unlikely to be particularly accurate. A slightly more sophisticated approach is to define the original site value as a function of variables around that site, and then apply that function to the transfer site.

Benefit transfer can provide valid estimates under certain conditions, such as close similarity between the commodity or service being valued in the original and comparative situation, and the transferred estimates being derived by a reliable application. However, most benefit transfers use the simple rather than the function approach described above, and there are many examples of benefit transfer being done badly (Pagiola et al 2004).

The recent approach informed by the notion of ecosystem services is focused on the stream of benefits from a particular site, and therefore more exacting in the use of

benefit transfer values – in recreation, the value per visit needs to reflect the attributes of particular sites and their surroundings. Even then choice modelling studies have shown significant differences in value between apparently similar situations, due to influences that have not been adequately recognised and controlled for (Kerr & Sharp 2004).

Such considerations also point to limitations in drawing on international studies for benefit transfer purposes, and limitations on the uses of valuation databases that have begun to emerge, such as the New Zealand Non-Market Valuation Database hosted at Lincoln University and the EVRI Database compiled by Environment Canada. Such databases may be influential in indicating the likely relative valuation of different types of environmental service, but are less reliable for determining the value to use in benefit transfer because of a range of variables that may not be fully accounted for in the valuation process.

Meta-analyses of studies undertaken in New Zealand cover a relatively small number of studies valuing a wide range of situations using different methods and locations, and produce some wide ranges in the average numbers (Kaval and Yao 2007). There are significant challenges in ensuring that valuation work and the compilation of databases are relevant for practical policy and management purposes (Allen & Loomis 2008).

As currently practised non-market valuation is a micro-economic technique, designed to examine values on a case by case basis. Extrapolation of values at a macro-level, for instance to infer the value of recreation nationwide from a few site-specific studies, is open to the criticisms of aggregation bias and double counting.

B.3 Natural capital accounting

One motivation for natural capital accounting is to counter the weakness of national economic accounting in dealing with balance sheet items in the accounts. The current SNA-based accounting from which GDP is computed accounts primarily for flows arising from transactions, and is deficient in coverage of assets. A country could deplete its fisheries, forests and mineral resources and show impressive income growth, without showing any qualification in the accounts for the loss of future potential earnings from irreversible depletion of natural stocks (Repetto et al 1989).

Accounting for natural capital depletion was first mooted in the early 1970s, when Nordhaus and Tobin (1972) proposed a number of changes to accounting practice to compute a new measure from the accounts that is closer to economic well-being than GDP. This involved providing for depreciation of some natural capital stocks (e.g. minerals and hydro-carbon stocks, fisheries and forests for some developing countries) and also drawing distinction between defensive expenditures which serve only to maintain well-being (such as pollution remediation) from growth expenditures that enlarge well-being. Such pursuit of new welfare measures – variously described as New Economic Welfare, Net Domestic Product or Green GDP - continued through the 1980s with a major exercise in Japan. However, they have faced substantial data difficulties and recurring challenges over how the distinction between defensive expenditures and real growth is drawn in the accounts.

Contemporary with this have been attempts to provide physical measures of natural stocks of economic importance, to be read alongside the national GDP accounts. Since

the early 1970s Norway began experimenting with compiling such accounts for energy and minerals, fisheries, forestry and water, and similar attempts have been made in other countries. Values attached to such accounts can be volatile because they change with the expected volume of available resource (e.g. in response to new discoveries or new extraction technologies like fracking for gas and oil) and with changes in the price of the resource. The Norwegian experience indicated that there was some use for energy modelling in planning activities, but other accounts were not used in policy settings (Pearce et al 1989).

Following the elevation of sustainable development in the 1987 World Commission on Environment and Development, in the early 1990s the UN devised ways of bringing natural resources into its System of National Accounts. Fearing they would introduce too much variability into the national aggregates and worsen their usefulness in comparative analysis across countries over time, the UN approved the development of satellite accounts for some natural resources that could be in either physical or monetary terms. These would be outside but read alongside the estimates of GDP and other measures from the System of National Accounts.

In 2012 the UN issued new guidelines on their System of Environmental and Economic Accounts (SEEA). These provide agreed procedures for the handling of environmental accounts for a selection of resources, principally those with financial implications for sectors in the economic accounts. They have three parts:

- the Central Framework contains agreed concepts, definitions, classifications and accounting rules for establishing agreed statistical standards for environmental economic accounts to be consistent with the economic accounts
- Experimental Ecosystem Accounting provide guidance following international consultation on how to prepare monetary accounts, which has not the status of a standard but has been followed by some individual countries (such the UK's Office of National Statistics, which prepared such accounts for woodland in 2013)
- extension and Applications outlines ways in which environmental economic accounting can be used in practice.

Outside of (but somewhat aligned to) the UN developments, the World Bank has also an interest in developing natural capital accounts. Initially this was in the form of measures of Genuine Savings, to see how much natural resource depletion was being offset by development of capital in the form of savings and investments. More recently this has evolved into a framework for Comprehensive Wealth Accounting, with the end goal of developing accounts covering five sets of capital: physical economic capital (plant and infrastructure), financial capital, natural capital, human capital (labour education and skills attainment), social (and institutional) capital. The scope of natural capital in this context is still focused on resources that give rise to direct economic worth, such as energy and mineral resources.

Other measures such as ecological footprint accounts have been proposed to monitor issues around natural capital use and depletion. However, these mostly use a currency of physical units rather than monetary values and are not compatible with the economic accounts, and have not been examined in this literature review.

B.4 Ecosystem services

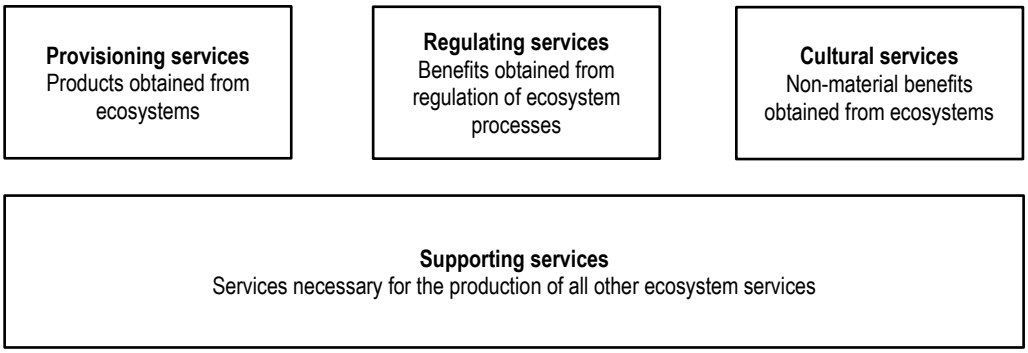
The term ecosystem services came into common use in the 1990s and provided a more coherent frame for various ad hoc valuations being already undertaken. It received prominence in 1997 when Costanza et al published in *Nature* magazine an estimate of the value of the world's ecosystem services which concluded they were collectively worth about three times the world's total GDP output in that year. This drew on a range of market and non-market valuation techniques to assign value to particular services, although it was criticised by many economists for mixing valuation concepts and not providing meaningful values for marginal changes in ecosystem service outputs.

In a 2014 update of this study, Costanza et al concede that their estimate could not be used for marginal analysis, but was still useful in drawing attention to the unstated values associated with ecosystem services.

In 2001 the UN initiated the Millennium Ecosystem Assessment, which was charged with assessing the consequences of ecosystem change for human well-being. It described ecosystems as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". It proposed in its 2005 report a four-fold division of the benefits of natural assets into the categories of provisioning, supporting, regulating and cultural services. This provides a framework for inferring the economic value of different functions and services.

These categories are summarised in Figure 8.

Figure 8 Categories of Ecosystem services



Source: UN Millennium Ecosystem Assessment (2005)

In practice the distinction between regulating and supporting services can be hard to draw and may be subject to double counting, so countries that have attempted to implement the MEA guidelines often omit the supporting services category.

The European Environment Agency has suggested a Common International Classification for Ecosystem Services (CICES) which would be used for translating the characteristics of a natural asset into services of value for people. This would follow a sequence of steps:

- Biophysical structure or process: e.g. woodland habitat or net primary productivity
- Function: e.g. slow passage of water or biomass production
- Service: e.g. flood protection or harvestable product
- Benefit: e.g. contributions to human well-being, health and safety, food and materials
- Value: e.g. willingness to pay for woodland protection, or value of harvestable products

Various countries have attempted to prepare natural capital accounts under the ecosystem services framework. One of the most ambitious has been the UK's National Ecosystem Assessment (2011), a highly resourced, one-off exercise that is more extensive than the Natural Capital and Wealth Accounts being prepared by that country's Office of National Statistics.

An extension of the UK NES work has been to use spatially explicit models with a GIS framework and valuation methods to calculate comparable economic values for services such as those from woodland, for instance timber production, carbon sequestration, open access recreation and biodiversity, as a guide to not only how much woodland is demonstrably net beneficial but also where it is most valuable to protect or enhance it (Bateman et al 2013).

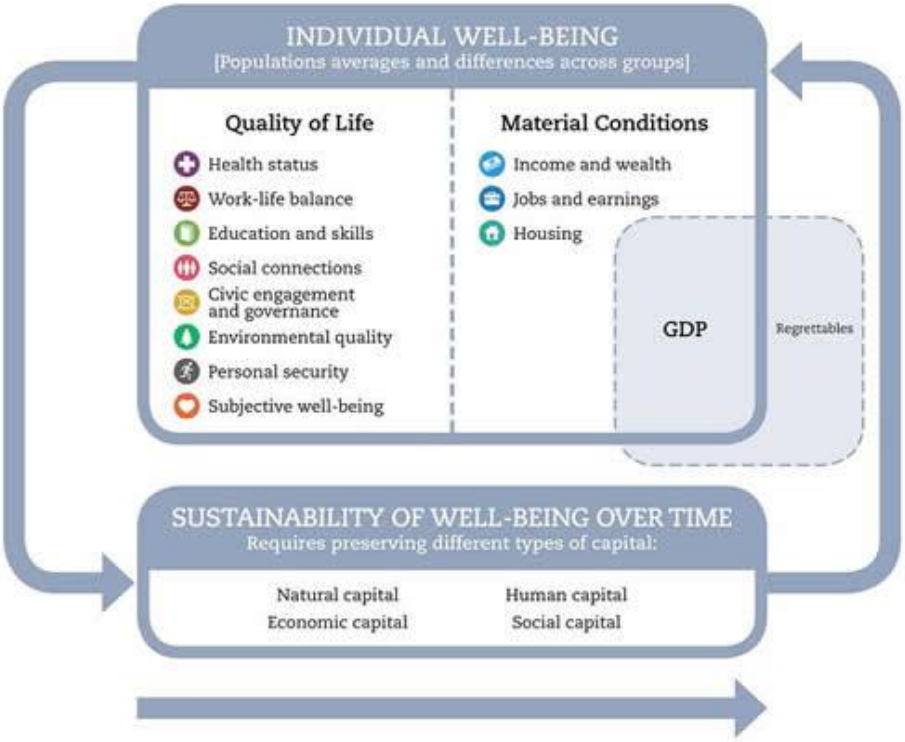
B.5 Natural capital and measures of subjective well-being

The OECD has recently been measures of subjective well-being, using the framework illustrated in Figure 9. This shows natural capital as one of society's four categories of capital. It is primarily a stock measure, but it also both supplies current consumption and can be degraded by it (e.g. through non-renewable depletion or externality effects on other stocks, like pollution of air and water quality).

It supplies inputs into both the material conditions that are measured within GDP transactions, and as such is largely an item of intermediate consumption. But it can also directly contribute to largely non-market components of quality of life, entering well-being as part of final consumption, through the environment that people experience in their lives (e.g. air quality, water quality, accessibility to green space).

Monitoring the level of natural capital can therefore in principle contribute to assessment of the sustainability of its goods and services over time and provide guidance on where and how much to reinvest in maintaining that capital into the future. It can contribute to understanding of changes in the levels of natural resources and their changing scarcity value as a basis for setting economic instruments and other management policy. And valuation on the basis of total economic value can contribute to measures of quality of life.

Figure 9 Natural capital and measures of subjective well-being



Source: OECD, 2013

Source: OECD (2013)