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Ecosystem goods and services in marine protected areas (MPAs)

Marjan van den Belt and Anthony Cole

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Cover: Ulva Island Marine Reserve. *Photo: Vincent Zintzen (DOC).*

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Abstract

The concept of ecosystem goods and services (ES) has become increasingly important in conservation management. This report provides an overview of how ES theory, classification, valuation methods and spatial modelling tools can be used to manage and protect New Zealand's existing marine parks, management areas, sanctuaries and the protected area network. Specifically, it summarises the ES of coastal and marine areas, including marine protected areas (MPAs), and provides an estimate of their values, based on a benefit-transfer of values from the literature. The rapid ecosystem services assessment (RESA) method was applied to seven New Zealand marine areas, including the Exclusive Economic Zone (and Territorial Sea), a marine mammal sanctuary and five marine reserves. These RESAs were based on GIS data, which generated a solid starting point for the valuations and highlighted the benefit of having clear definitions of biomes. Collectively, the case-study areas generated an average ES value of NZ$403B per year for 2010, which is about 2.07 times gross domestic product (GDP) for that same year (NZ$194B) and equates to a per capita ES value of NZ$92,245 per year. Qualitative analysis of the supply, demand and value of ES suggests that a change in the legal status of a marine or coastal area will only bring benefits if the value is perceived—which is often not the case for marine ecosystems. Therefore, this report concludes with an overview of the tools that are being developed for ES valuation, ranging from those that can be applied when the benefits are evident to those that are more suitable for when they are not.

Keywords: marine protected area, MPA, Exclusive Economic Zone, biome, ecosystem goods and services, RESA, benefit-transfer, MIMES

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1. Introduction

1.1 Ecosystem goods and services

An ecosystem consists of a biological community and its physical environment. Each ecosystem contains one or more biomes, which is a biological community occupying a habitat within the ecosystem. The conditions and processes of these natural systems, and the species that make them up, sustain and fulfil human life. Ecosystem services[1] are the benefits that people derive from ecosystems (MEA 2005), which include cleansing, recycling and renewal, the maintenance of biodiversity, and the production of goods such as seafood, timber, fuels, natural fibre and many pharmaceuticals. In some cases, people are conscious of their need for ecosystem services and therefore value the essential benefits derived from ecosystems; however, in other instances these benefits are not perceived. Figure 1 illustrates that the value of ecosystem goods and services (ES) can partly be calculated using market-based monetary values and partly using non-market monetary values, but there is an additional component of unknown quantity that simply cannot be reflected using monetary or other metrics. The shift to viewing the environment as comprising ES and a focus on the positive benefits that people derive from ecosystems (rather than simply the negative impacts people have on the environment) is relatively recent. This paradigm shift has the potential to bridge the science–policy divide, as it allows the transparent assessment of trade-offs associated with different management options (Farber et al. 2006).

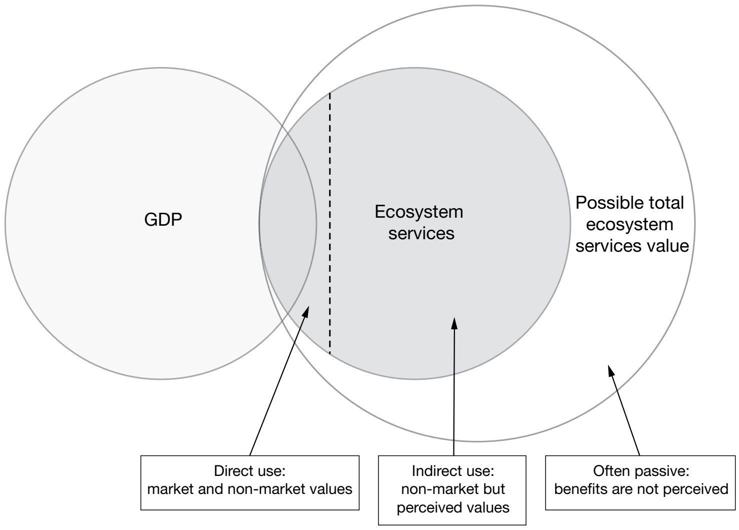

Figure 1. Perceived and non-perceived ecosystem goods and services values.

From the mid-1990s, ES and methods of valuing them received an increasing level of international attention. For example, Costanza et al. (1997) estimated the annual contribution of global ES towards estimates of global gross domestic product (GDP), thereby providing a 'rapid ecosystem service assessment' (RESA), and raising the profile of ES and the potential for high, unperceived value among scientists and policy makers. In 2005, the Millennium Ecosystem Assessment (MEA) built on this theoretical work. A panel of more than 1360 experts drew up an ES framework, whereby the ES of the world's ecosystems were divided into four broad categories: provisioning services (e.g. food and water), regulating services (e.g. flood protection and disease control), supporting services (e.g. nutrient cycling) and cultural services (e.g. spiritual values and recreation) (MEA 2005; Table 1). The MEA also appraised global ES, thus providing a state-of-the

[1] The natural world can supply goods and services that benefit wellbeing. These can be assessed at an energy, population, community and landscape level. An ecosystem services approach brings together the various perspectives.

Table 1. Definitions of ecosystem goods and services (ES), consistent with those developed in the Millennium Ecosystem Assessment (2005). (Source: Farber et al. 2006; reproduced by permission of Oxford University Press.)

ES	DESCRIPTION	EXAMPLE
Supporting functions and structure	**Ecological structures and functions that are essential to the delivery of ecosystem services**	
Nutrient cycling	Storage, processing and acquisition of nutrients within the biosphere	Nitrogen cycle; phosphorus cycle
Net primary production	Conversion of sunlight into biomass	Plant growth
Pollination and seed dispersal	Movement of plant genes	Insect pollination; seed dispersal by animals
Habitat	The physical place where organisms reside	Refugium for resident and migratory species; spawning and nursery grounds
Hydrological cycle	Movement and storage of water through the biosphere	Evapotranspiration; stream runoff; groundwater retention
Regulating services	**Maintenance of essential ecological processes and life support systems for human wellbeing**	
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	Biotic sequestration of carbon dioxide and release of oxygen; vegetative absorption of volatile organic compounds
Climate regulation	Regulation of local to global climate processes	Direct influence of land cover on temperature, precipitation, wind and humidity
Disturbance regulation	Dampening of environmental fluctuations and disturbance	Storm surge protection; flood protection
Biological regulation	Species interactions	Control of pests and diseases; reduction of herbivory (crop damage)
Water regulation	Flow of water across the planet surface	Modulation of the drought-flood cycle; purification of water
Soil retention	Erosion control and sediment retention	Prevention of soil loss by wind and runoff; avoiding build-up of silt in lakes and wetlands
Soil formation	Role of natural processes in soil formation and regeneration	Bioturbation; amount of topsoil (re)generated per ha per year
Waste regulation	Removal of breakdown of non-nutrient compounds and materials	Pollution detoxification; abatement of noise pollution
Nutrient regulation	Maintenance of major nutrients within acceptable bounds	Prevention of premature eutrophication; maintenance of soil fertility
Provisioning services	**Provisioning of natural resources and raw materials**	
Water supply	Filtering, retention and storage of fresh water	Provision of fresh water for drinking; medium for transportation; irrigation
Food	Provisioning of edible plants and animals for human consumption	Hunting and gathering of fish, game, fruits, and other edible animals and plants; small-scale subsistence farming and aquaculture
Raw materials	Building and manufacturing; fuel and energy; soil and fertiliser	Lumber, skins, plant fibres, oils and dyes, fuel wood, organic matter (e.g. peat); topsoil, frill, leaves, litter and excrement
Genetic resources	Genetic resources	Genes to improve crop resistance to pathogens and pests, and other commercial applications
Medicinal resources	Biological and chemical substances for use in drugs and pharmaceuticals	Quinine; Pacific yew; echinacea
Ornamental resources	Resources for fashion, handicraft, jewellery, pets, worship, decoration and souvenirs	Feathers used in decorative costumes; shells used in jewellery
Cultural services	**Enhancing emotional, psychological and cognitive wellbeing**	
Recreation	Opportunities for rest, refreshment and recreation	Ecotourism; bird-watching; outdoor sports
Aesthetic	Sensory equipment for functioning ecological systems	Proximity of houses to scenery; open space
Science and education	Use of natural areas for scientific and educational enhancement	A natural field laboratory and reference area
Spiritual and historic	Spiritual or historic information	Use of nature as national symbols; natural landscapes with significant religious values

art assessment of the wellbeing of global ecosystems and a baseline against which future actions for conservation and sustainable use could be considered or even measured. The scientific literature published since this time indicates the extent to which ES and methods of evaluating them have received attention around the world; for example, in 2012, the *Journal of Ecological Economics* included 1704 articles on ES, and Scopus, the Science Direct online publication database, listed 9809 published papers on ES.

In New Zealand, the concept of ES and methods of valuing them following the RESA approach were used in the development of the New Zealand Biodiversity Strategy (DOC & MfE 2000). When asked to place a dollar value on New Zealand's biodiversity, researchers at Massey University used the ES system of classification developed by Costanza et al. (1997) and that team's data as a starting point for biodiversity, and then adjusted the classification and values to the New Zealand situation (Patterson & Cole 1999). This approach of including both direct and indirect values of ES differed from those used previously as, until then, policy decision-making in New Zealand had been dominated by conventional market economic tools (see Fig. 1 and section 5 for valuation methods, and Appendix 1 for a discussion of 'value' versus 'price'). By contrast, this ecological economics oriented approach aimed to make explicit the direct and indirect trade-offs associated with decision-making, expressed in monetary value terms. This early RESA approach was later used in several New Zealand regional case studies (Cole & Patterson 1998; McDonald & Patterson 2003; van den Belt et al. 2009), integrated into regional economy-environment accounts (Cole & Patterson 2003), and subsequently adapted for use in stakeholder-led, whole-of-system participatory model building (Cole et al. 2003, 2006; Cole & Patterson 2010; van den Belt et al. 2012). More recently, research effort has been directed at seeking to position and apply such ES valuation methods in a Kaupapa Māori context (Crystall et al. 2008; van den Belt et al. 2012); and the international 'Treatise on Estuarine and Coastal Science' includes a volume featuring the latest thinking on ecosystem services of coastal ecosystems (van den Belt & Costanza 2011). RESA is the primary method underlying the investigation documented in this report (see Appendix 1 for more background information on RESA, benefit-transfer and neo-classical economic considerations toward valuation).

It is important to note here that RESA is just one of several tools that is currently available, and that its primary function is to serve as a 'conversation starter' rather than to provide a precise valuation. RESA as a tool sits along a 'valuation method continuum', at the opposite end of which are tools that use spatially explicit depictions to value ES, ecosystem structure and interlinkages, such as Seasketch (McClintock et al. 2012), InVEST (Daily et al. 2012) and ARIES (Villa et al. 2012), and tools that have a dynamic emphasis on changes across spatial, temporal and social dimensions, e.g. MIMES (Boumans & McNally 2012) (see section 5 for further discussion of these tools). All of these tools allow ecological sustainability, social fairness, logistics and cultural values to be incorporated into decision-making, and can help to improve understanding of values that arguably underpin management and protection decisions. Thus, these tools not only help to make values more explicit, but also facilitate new solutions and ultimately better long-term decision-making.

1.2 Objectives

This study was carried out in 2012 to assist in the development of decision-making tools for the conservation of New Zealand's marine and coastal resources, particularly its marine protected areas[2] (MPAs). Its primary aim was to review the ES provided by the marine environment in New Zealand, by analysing the supply, demand and value of ES in New Zealand's marine and coastal environment and the current MPA network, and by assessing currently available valuation methods. It was hoped that this would provide for better informed marine conservation management decisions, as well as important spatial data relating to use and value in the coastal marine environment.

To achieve this, RESA was applied to seven New Zealand marine areas, including the Exclusive Economic Zone (EEZ) (and Territorial Sea), a marine mammal sanctuary and five marine reserves. The methodology behind RESA is outlined in section 2, while section 3 provides the outcomes for each case-study area, and section 4 describes the supply, demand and value of ES in these areas. Finally, some of the valuation methods and tools that are available to consider value when the benefits of ES are and are not perceived, and the ways in which these can be applied for marine management and protection are discussed in section 5.

This report provides an overview of a rapidly evolving body of ES theory, systems of classification, valuation methods and spatial modelling tools, and how they can be used to manage and protect New Zealand's existing marine parks, management areas, sanctuaries and the protected area network. It also highlights some important gaps in the data and indicates knowledge that will need to be filled to move from using the ES concept as a 'conversation starter' to an 'organising principle' in decision support.

2. Case-study methodology

2.1 Data collection

Several specialised, publicly available databases of published literature were consulted to obtain suitable data on New Zealand's marine ES and their valuation. Eight studies were obtained from the Department of Conservation (DOC) and the New Zealand Non-Market Valuation Database.[3] However, monetary values for non-marketed ecosystem services associated with New Zealand marine ES are scarce. Thus, only a few of these studies were primary valuation studies, with most using benefit transferred values. Unfortunately, there were insufficient resources to comprehensively access university libraries to include postgraduate theses. Therefore, since there are so few readily accessible New Zealand examples, it was necessary to widen the scope to international sources, so that economic cost-benefit information could be 'transferred' to New Zealand.

Barbier et al. (2011) provided a comprehensive literature review of coastal ES and was deemed to be a good starting point, but we also searched several databases.[4] The most comprehensive ecosystem services database, which contains over 44 000 papers and abstracts, has been developed and is maintained by Earth Economics[5]. Initially, we considered that data from

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2 Under the New Zealand Marine Protected Areas Policy and Implementation Plan (DOC & MFish 2008), a marine protected area is defined as 'an area of the marine environment especially dedicated to, or achieving, through adequate protection, the maintenance and/or recovery of biological diversity at the habitat and ecosystem level in a healthy functioning state'.

3 www.lincoln.ac.nz/research-themes/ecosystem-services/Research-Projects-and-Websites/Ecosystem-Services-Valuation-Database/ (viewed 30 October 2013).

4 http://marineecosystemservices.org/; www.gecoserv.org/valuationdb.jsp (viewed 5 August 2012).

5 www.esvaluation.org/serves.php (viewed 6 December 2013).

Australia would be most suitable for 'benefit-transfer' to New Zealand. However, we found that there was little information available for the Southern Hemisphere, and so data from the USA and countries in the Mediterranean were also collected. In total, 87 articles were reviewed to obtain values that could be used as proxies in this New Zealand study (see Table A4.2 (Appendix 4)).

2.2 Case studies

Since we could only find a small amount of published information on marine ES valuation in New Zealand, we focused our attention on seven marine ecosystems with different legal protection and management arrangements in this report. In both the New Zealand Exclusive Economic Zone (EEZ; which also included the Territorial Sea) and the Banks Peninsula Marine Mammal Sanctuary, 'marine management tools' are being applied for both protection and extractive use. The five marine reserves (i.e. Whangarei Harbour, Poor Knights Islands, Te Angiangi, Westhaven (Te Tai Tapu) and Piopiotahi (Milford Sound)) are examples of MPAs and are fully protected, with the exception of carefully managed research and recreational activities (see Fig. 2 for the locations of these MPAs).

The seven case studies not only include areas with different statuses, but also cover a broad range of habitats/ecosystems (from estuaries to offshore islands), different biogeographic regions and varying spatial scales. The New Zealand EEZ is the largest of the case-study areas and, along with the Territorial Sea, encompasses the entire New Zealand marine environment. Together, these case studies provide useful comparative data for assessing the ES values related to marine reserves and sanctuaries, and also allow us investigate the role of resolution in ES valuation.

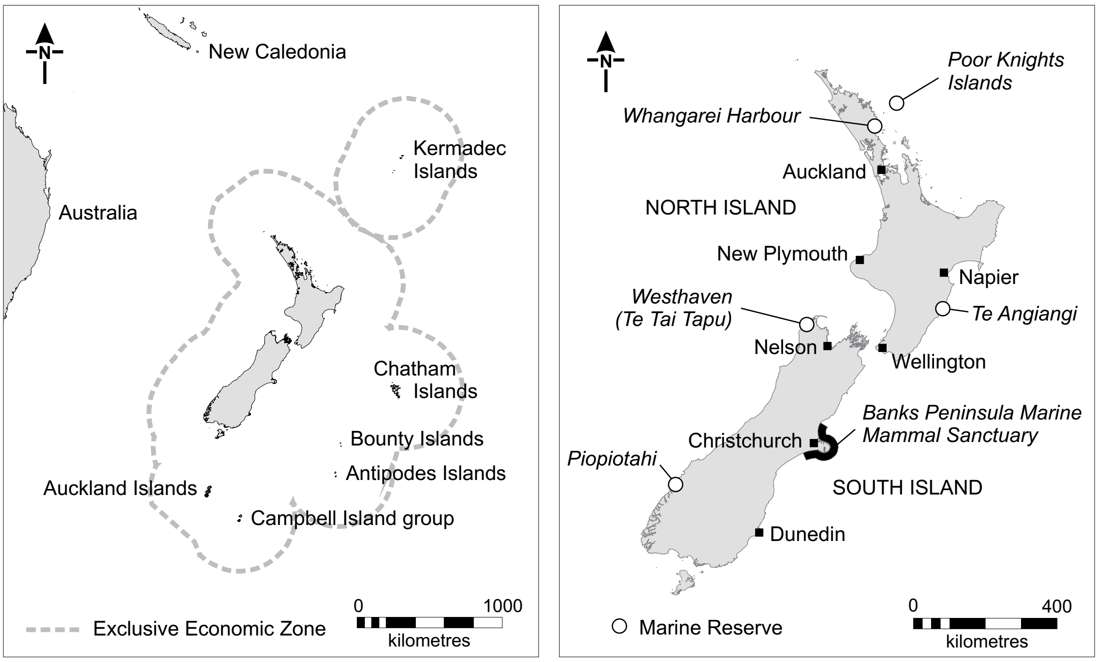

Figure 2. Marine protected areas (MPAs) of New Zealand, as of 2013.

2.3 A RESA of New Zealand's managed and protected marine ecosystems

Using the information from the seven case studies and the literature review, we undertook a RESA of New Zealand's managed and protected marine ecosystems.

To complete the assessment, we carried out the following steps of a typical RESA:

1. Identify all ecosystems of interest to the RESA and create an inventory of habitats or biomes in each.
2. Measure the area (in hectares) of each biome.
3. Create an inventory of all appropriate ES.
4. Assign value to each ES using benefit-transfer data.
5. Determine the total value of the ES of each ecosystem's biome by multiplying the total area of each given ecosystem biome by the ES value.

2.3.1 Identify relevant ecosystems and create an inventory of habitats/biomes in each

Researchers have developed a high-level system of classification for global ecosystems based on 17 different biomes (Costanza et al. 1997). However, there are currently no generally agreed on definitions of these biomes and no generalised system for the classification of spatial GIS data[6] for the purpose of deriving ecosystem services. Therefore, it is left to individual practitioners to apply the biome categories using standard textbook definitions (Allen 2005; Holzman 2008; Kuennecke 2008; Quinn 2008; Woodward 2008a, b, 2009, 2011). As this report goes to print, progress on marine ES classification from a biophysical supply perspective has progressed significantly, however (Townsend et al. 2011; MacDiarmid et al. 2013).

The simpler classification of ES that was developed by MEA (2005) and is shown in Table 1 has generally been used to date for several reasons. First, since researchers need to make the best use of locally available spatial data, the lack of ES biome categories should not prevent a RESA from taking place so that an important conversation concerning ES values can be initiated. Second, although efforts to define (more precisely and in greater detail) biome categories may result in slight changes to associated estimates of ES value, and these changes may appear to be improvements at first glance, the decision-making for which such ES valuation data are used arguably does not depend on such marginal changes—at least at this stage. Therefore, if the goal is to improve our valuation calculations, it may be better to invest time and funds in ensuring that GIS field data and monetary values are both at an appropriate resolution for all the ES categories following an ES organising principle, rather than focusing on defining biomes (see section 5 for further discussion around this).

The biome classification used in this research was derived from Costanza et al. (1997) and Barbier et al. (2011). Following discussion with DOC staff in early 2012, the marine biomes were combined into the following eight categories for the purposes of this report: open sea/ocean; continental shelf sea; estuary/lagoon/intertidal; salt marshes/wetland; seagrass/algae beds[7]; reefs; mangroves; and sand, beach and dunes (see the Glossary for a definition of each). Unfortunately, the need to create a useful set of biomes in relation to available valuation information means that effectively separate habitats, with distinctive and different values, have been combined into one ES biome category, which has then been assigned a single monetary value. In other words, the lack of resolution of valuation data has dictated the way in which biomes have been combined. Although we could have kept seagrass and algae beds as separate categories, such separation would not have helped us to illustrate or refine the

[6] Although a working group is currently investigating this: http://ecosystemcommons.org/group/esp-biome-and-thematic-working-groups (viewed 30 July 2013).

[7] Kelp is included in 'seagrass/algae beds'.

results from the RESA approach, as the available valuation data was the same for these biomes. To ensure that our assumptions associated with cross-matching spatial data and ES biome categories are transparent, we have listed the depth, exposure and habitat/substrate type (GIS feature-class characteristics) for each of our biome categories (except open sea) in Appendix 2.

2.3.2 Measure the area of each biome

The area of each biome can be measured most easily using GIS software, spatial habitat data and Excel workbooks. The spatial datasets that were used to estimate the area of the biomes in each case-study site are listed in Table 2.

The various GIS layers were processed using ESRI Arc Info version 10. Each GIS layer was clipped/erased using site-specific boundaries (GIS shapefiles) provided by DOC and added to site-specific files set up in Arc Info (NZGD 2000 New Zealand Transverse Mercator projected coordinate system). Coordinate system transformations were carried out in ArcCatalog 10. Several of the marine reserve GIS shapefiles needed to be re-drawn[8] because they poorly matched coastline and biological habitat features. Estimates of the ES biome areas were then calculated using the cross-referenced GIS feature-classes shown in Appendix 2.

Table 2. GIS datasets used to estimate the area of the ecosystem goods and services (ES) biomes in each case-study site.

CASE-STUDY SITE	SPATIAL DATASET
New Zealand's Exclusive Economic Zone (EEZ)	
Open ocean biome	New Zealand EEZ boundary, clipped (Koordinates website*)
Continental shelf biome	New Zealand Region Marine Bathymetry, clipped (Koordinates website*)
	New Zealand 250m Bathymetry Rainbow, clipped (Koordinates website*)
All remaining biomes	New Zealand Gaps Marine Biological Habitat layer, clipped (DOC & MFish 2011)
Banks Peninsula Marine Mammal Sanctuary	New Zealand Gaps Marine Biological Habitat layer, clipped (DOC & MFish 2011)
Piopiotahi Marine Reserve	New Zealand Gaps Marine Biological Habitat layer, clipped (DOC & MFish 2011)
Westhaven (Te Tai Tapu) Marine Reserve	New Zealand Gaps Marine Biological Habitat layer, clipped (DOC & MFish 2011)
Te Angiangi Marine Reserve	New Zealand Gaps Marine Biological Habitat layer, clipped (DOC & Mfish 2011)
	Blackhead GIS maps (Funnell et al. 2005)
Poor Knights Islands Marine Reserve	Northland Marine Biological Habitat layer, clipped (Kerr 2009)
Whangarei Harbour Marine Reserve	
Waikaraka	Northland Marine Biological Habitat layer, clipped (Kerr 2009)
Motukaroro	Northland Marine Biological Habitat layer, clipped (Kerr 2009)
	Motukaroro Marine Biological Habitat layer, clipped (unpublished spatial data held by National Office, DOC, Wellington)

* https://koordinates.com/layer/6549-proposed-rps-outstanding-natural-features/

[8] Shapefiles that were redrawn included Whangarei Harbour (Waikaraka and Motukaroro), Westhaven (Te Tai Tapu) and Piopiotahi Marine Reserves.

2.3.3 Create an inventory of relevant ES

We used fairly high-level definitions of ES and the 23 ES categories of Farber et al. (2006), both of which are standard practices in most RESA studies. According to Costanza et al. (1997), water regulation, water supply, erosion control (referred to as 'soil retention' by Farber et al. (2006)), soil formation and pollination (referred to as 'pollination and seed dispersal' by Farber et al. (2006)) are services that do not occur, or are negligible, in the marine ecosystem. However, these services were included in this study as some valuations associated with intertidal biomes were available for them.

When first devised by Costanza et al. (1997) and refined by Farber et al. (2006), these categories were intended to be a core set of ES that could be applied to biomes across the globe, and that could adequately capture human dependency for survival and wellbeing on ecological systems. However, while this generality makes them appropriate for a global RESA, it also results in a loss of specificity, especially when national or local RESAs are undertaken. By contrast, a bottom-up approach for each case-study locality would generate more accurate results, but has the obvious disadvantage of incurring additional costs with regard to both biosphysical and socio-economic assessments. A recent study by de Groot et al. (2012) found that many local studies have been undertaken since that of Costanza et al. (1997), which have led to two insights: the range of values is broad and locally defined; and the average value of bundles of ecosystem services is often higher than previously reported by Costanza et al. (1997). Ideally, top-down and bottom-up approaches would be integrated, accommodating a local, regional and national approach to valuation.

Clearly, any categories that are used need to be relevant in terms of both scale and data availability. Each of the 23 categories could potentially be disaggregated into a range of ES that are specifically matched to a given case-study site. However, such disaggregation is probably not feasible or useful in a RESA as it is not necessarily easier to find appropriate market or non-market value estimates for the additional ecosystem services categories that are generated. Indeed, as noted in section 2.1, our literature review located only eight specific case studies that provided ES values for marine ecosystems in New Zealand; and even after performing benefit-transfer from 87 international valuation papers, we have perhaps captured only one-quarter of the potential value of these marine ES for the biomes of interest to this study. The reason for this lack of non-market valuation data is the time-consuming and costly nature of this research, which means that it generally only occurs in high-priority research and/or particular problem-solving contexts. Therefore, if such a disaggregation of categories were to be done, site-specific studies that aimed to generate new data and information would be preferable to a RESA.[9]

A further limitation with the ES categories is that, in a RESA, they are used in static estimations of absolute monetary values. Presumably, it would also be possible to define a more detailed set of not only supply but also demand categories for ecosystem services. In Appendix 3, we have attempted to demonstrate that it is possible to disaggregate the 23 ES categories of Costanza et al. (1997) into more detailed categories of ES supply and ES demand, which highlights that the demand for ecosystem services comes from both market and non-market sectors. Published attempts to do this also exist—for example, de Groot et al. (2002) and MacDiarmid et al. (2013), with the latter providing detailed categories for ES supply in New Zealand. Furthermore, each of these supply and demand categories can be related to appropriate sectors of the United Nations System of National Accounts (SNAs) and demand profiles for multi-scale integrated assessments of ES (Appendix 3; see section 5 for more detail on these entities). These approaches constitute the higher end of the 'valuation method continuum', and their application is beyond the scope of this report.

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9 However, disaggregation of ES categories would be of advantage when building system dynamic models because it would provide detailed information on ecosystem structure that could then be used to focus attention on the complex web of interlinkages that add value to ecosystem structure or its parts. For similar reasons, it might also be desirable to focus attention on supply and demand values and their use as marine ecosystem management tools (i.e. rules, limits, use policies and guidelines).

2.3.4 Assign value to each ES using benefit-transfer data

Relevant information from each case-study document or international publication was tabulated (see Table 3 for the format used). Our confidence in each entry's similarity to a relevant part of New Zealand was then rated, based on the study site's latitude (it was assumed that if latitudes were similar, coastal and marine biomes would also be similar), socio-economic structure (a combination of indigenous and western culture) and study quality (including method applied, age of study and validity of statistical analysis). Ratings ranged from very confident (+++) to not confident (---). If the biome was not specified, or if the valuation included several biomes, the data were categorised as 'overall/habitat unspecified'. Of the 176 ecosystem service values desired for a complete benefit-transfer, i.e. 8 biomes × 22 ecosystem services in Table 1, 55 (31%) were available and collected.

Table 3. Table layout used for recording the results of the literature review for the benefit-transfer. See Appendix 4 for the full data table.

BIOME	MEA* CATEGORY	ECOSYSTEM SERVICE PER TABLE 1	METHOD	VALUE AND UNIT	GEOGRAPHIC AREA	REFERENCE OF CASE STUDY	ADDITIONAL INFORMATION

* Millenium Ecosystem Assessment (2005).

In order to make the data commensurable across time, we standardised monetary values, following the method of Kerr & Latham (2011). First, consumer price indices for each of the countries were used to adjust to year values in the currency concerned; and the currency was then converted using consumer purchasing power parity rates. As the rates for private and individual consumption for 2011 were not yet available, values were converted to $NZ\$_{2010}$. When a given study did not mention the currency's year, it was assumed that the currency was for the year in which the interviews were undertaken; and when this information was not available, the year in which the paper was submitted was used, followed by the year of publication. Once data collection had been completed and tabulated (see Appendix 4 for the ES values (albeit incomplete) for each ES biome), value data for each of the four ES categories were extracted and placed in an Excel table. These data are summarised by ES category in Table 4 as average (and maximum and minimum where possible) estimates of value for each ES biome. Finally, an Excel worksheet was created whereby monetary value data were combined with the ES biome area estimates to produce estimates of the value[10] of the annual direct and indirect ES benefit flows ($NZ\$_{2010}$/yr) for each case-study area.

It was difficult to locate ES values for the New Zealand reef biome, mainly because international studies on marine reef habitat deal with coral reef ecosystems, whereas New Zealand reef ecosystems are based on boulders and rocks, and sedimentary and extrusive igneous habitat substrates. Consequently, little international research was suitable for benefit-transfer. This is unfortunate because New Zealand reef ecosystems play a vital role in providing refuge, food, biodiversity, disturbance buffering, population regulation and cultural services. However, we considered that data on coral reef ecosystems provided comparable estimates of what New Zealand reef ecosystems achieve functionally (e.g. coral reefs and New Zealand boulder/extrusive volcanic rock reefs are capable of performing the same role in disturbance regulation—an ES with one of the highest monetary values for a reef at $NZ\$_{2011}$5612 ha^{-1} yr^{-1}, and a range of \$527–10,696 ha^{-1} yr^{-1}) (see Appendix 4), so we chose to perform a benefit-transfer. Our assessment of 'comparable' also included information about the supporting services associated with artificially created 'replacement' reef ecosystems. Based on the actual cost of reconstructing a New Zealand reef (which was carried out to reconstruct habitat, which is a supporting ES), we

[10] See the Glossary for definitions of different types of value, e.g. direct and indirect value.

Table 4. Mean values (NZ$$_{2010}$ ha^{-1} yr^{-1}) for New Zealand's marine ecosystem goods and services (ES), by biome (with ranges in parentheses). See Appendix 4 for sources of data.

BIOME	SUPPORTING FUNCTIONS	REGULATING SERVICES	PROVISIONING SERVICES	CULTURAL SERVICES	TOTAL
Open sea/ocean	$250 ($131–368)	$92 ($11–172)	$32	$161 ($15–306)	$535 ($189–878)
Continental shelf	$3,024 ($1,589–4,458)	$82	$15	$148	$3,269 ($1,834–4,703)
Estuary/lagoon/ intertidal	$45,082 ($23,956–66,207)	$1,363	$1,491 ($116–2,865)	$867 ($464–1,270)	$48,802 ($25,899–71,705)
Salt marshes/ wetland	$48,075 ($3,243–92,906)	$17,355 ($1,775–32,934)	$1,711 ($97–3,324)	$1,559 ($7.20–3,769)	$68,700 ($5,122–132,933)
Seagrass/algae beds	$40,139 ($21,126–59,125)		$4.20		$40,130 ($21,130–59,129)
Reefs	$15	$5,612 ($527–10,696)	$494 ($1–987)	$6,356 ($34–12,677)	$12,477 ($577–24,375)
Mangroves	$10,121	$28,200 ($26,300–30,100)	$6,267 ($61–12,472)	$1,263 ($603–1,922)	$45,851 ($37,085–54,615)
Sand, beach and dunes*					
Total	$146,456 ($60,181–233,200)	$52,704 ($30,058–75,620)	$10,014 ($326–19,699)	$10,354 ($1,271–20,092)	$220,087 ($91,836–348,338)

* Not available in $ ha^{-1} yr^{-1}.

estimated the replacement cost of reefs in New Zealand to be approximately NZ$$_{2011}$350 ha^{-1} yr^{-1} (Loyd Hoskings, pers. comm.; www.reaf.org.nz/htmlfiles/reefworkshop.html (viewed 19 November 2013)) with a range of $233–700 ha^{-1} yr^{-1}, which is considerably higher than the $15 ha^{-1} yr^{-1} derived from international studies as a median point for supporting services.

Several biomes (estuaries, salt marshes/wetlands, reefs and sand/beach/dunes) are also travel destinations, so their value in RESA was sometimes approximated by using the travel cost method. This method estimates economic values associated with ecosystems or sites that are used for recreation, and its use assumes that the value of a site is reflected in how much people are willing to pay to travel to the site (other methods are also defined in the Glossary and discussed in Appendix 1). The travel costs are highly variable, ranging from $1.30 to $3,190 (the travel costs and their referenced sources are included in Appendix 4). The studies reflecting travel costs have been excluded from Table 4 to avoid causing confusion by using multiple metrics; however, this has led to the complete omission of values for sand/beach/dunes, and underscores the sensitivity and limitation of the RESA method in adequately reflecting values.

3. RESA results

The following description of RESA results is organised hierarchically, starting with the largest case-study area and progressing to the smaller ones. Figure 2 shows the location of the case-study MPAs. In the sections that follow, additional information about the spatial data, area estimates of the ES biomes and estimates of the various components of ES value are presented for each case-study site.

3.1 New Zealand's Exclusive Economic Zone (EEZ)

New Zealand's EEZ was established in 1982 and covers an area that is nearly 15 times the size of New Zealand's terrestrial land mass (268 021 km^2) (Table 5). If the somewhat artificial boundary of the EEZ is extended to become an ecosystems-based boundary that includes the continental shelf, the area of direct relevance to New Zealand becomes 5.7 million km^2, which is approximately 21 times larger than New Zealand's land area and represents almost 1.7% of the world's oceans (MacDiarmid et al. 2013: 238).

Table 5. Estimated areas of the ecosystem goods and services (ES) biomes of the New Zealand Exclusive Economic Zone (EEZ).

ES BIOME	AREA (ha)	AREA (%)
Open sea/ocean	379 405 978	91.3596
Continental shelf	28 889 539	6.9565
Estuary/lagoon/intertidal	3 162 428	0.7615
Salt marshes/wetland	19 087	0.0046
Seagrass/algae beds	68 514	0.0165
Reefs	3 205 575	0.7719
Mangroves	20 843	0.0050
Sand, beach and dunes	516 808	0.1244
Total area	415 288 772	

For the purposes of this study, the total area of the EEZ was constructed from three spatial datasets (i.e. GIS layers) (see Table 3). The overall EEZ boundary shapefile was sourced from the Koordinates[11] GIS website, which provided the outer geographical boundary of the EEZ and was used to depict the open ocean biome; the New Zealand Region Bathymetry and the New Zealand 250m Bathymetry Rainbow layers created by NIWA (2008), and also available from the Koordinates website, were used to interpret the continental shelf biome; and the New Zealand Gaps[12] Marine Biological Habitat layer supplied by DOC, Wellington (DOC & MFish 2011), was used to classify and depict the nearshore biomes. The layers depicting the continental shelf and nearshore biomes needed to be clipped so that their combined areas equalled that defined by the EEZ boundary shapefile. The agreement between the combined area and the EEZ shapefile area has an error of 1.56%, which can be explained by the boundary geometry on the coastline side of the New Zealand Gaps Biological Habitats layer (DOC & MFish 2011). This GIS layer includes some terrestrial/coastal features, such as Lake Ellesmere (Te Waihora) in the South Island, and so we assume that this discrepancy would be reduced if the area of these terrestrial features was added to the combined EEZ area estimate.

A spatial depiction of the ES biomes associated with the New Zealand EEZ is provided in Fig. 3 and estimates of the area of each ES biome are listed in Table 5. Estimates of the value of direct and indirect ES benefit flows produced annually by the biomes of this managed area ($\$NZ_{2010}$/yr) are summarised in Table 6, with ES grouped into the four standard categories: supporting, regulating, provisioning and cultural services. Appendix 3 provides additional

[11] http://koordinates.com/ (viewed 30 July 2013).

[12] A habitat classification was developed to underpin planning for the protection of biodiversity (DOC & MFish 2008), and a report on a gap analysis of coastal marine habitats and MPAs in the New Zealand Territorial Sea was completed in 2011 (DOC & MFish 2011).

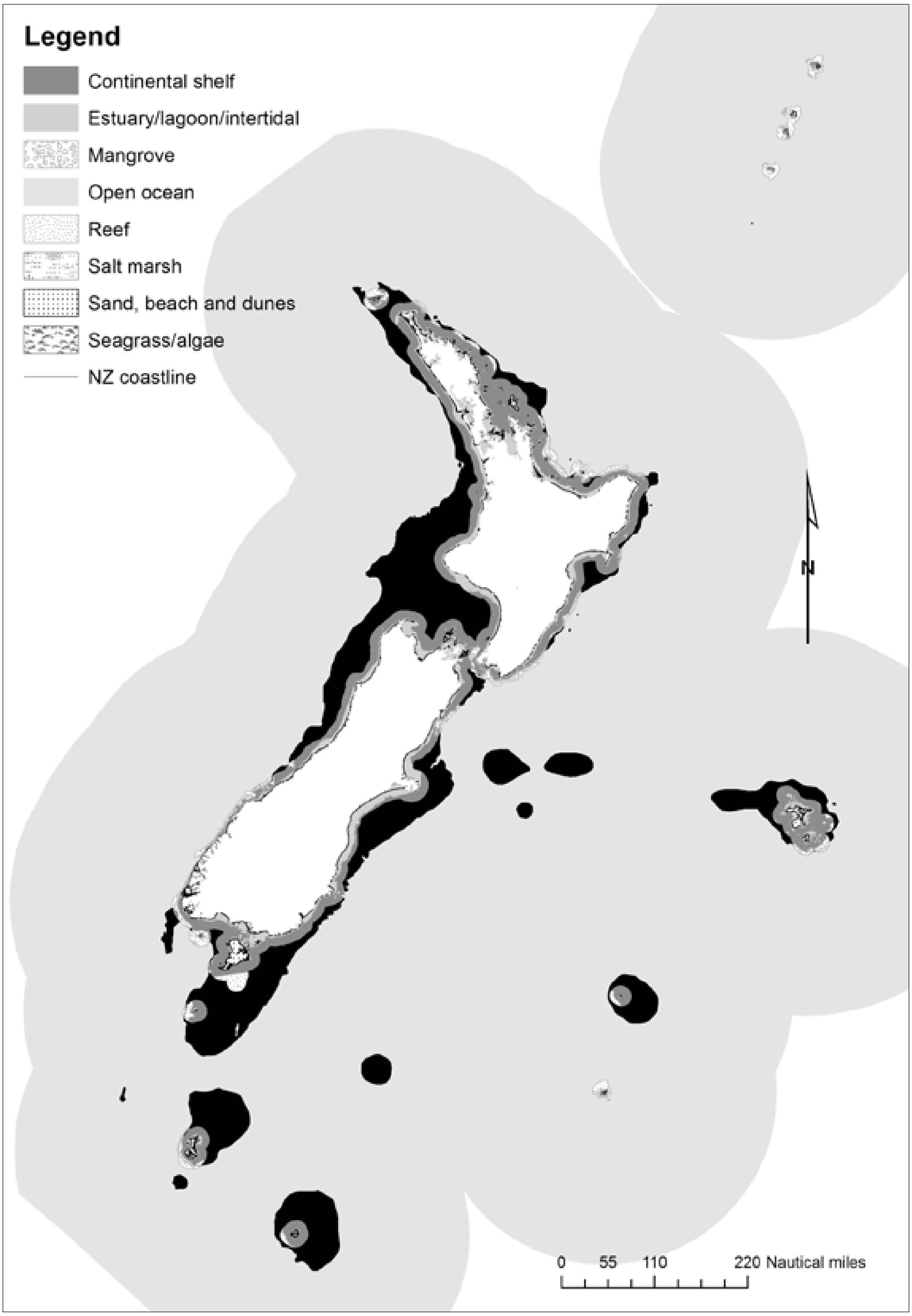

Figure 3. Map of the ecosystem goods and services (ES) biomes associated with the New Zealand Exclusive Economic Zone (EEZ).

sub-categories of ES. Collectively, they generate a mean ES value of $403B/yr[13] (with lower- and upper-range estimates of c. $215B/yr and c. $634B/yr, respectively), which is about 2.07 times GDP for that same year ($194B). Dividing the average ES value estimate by the human population estimate for 2010 (4 370 000) yields a mean per capita ES value of $92,245/yr.[14]

Table 7 provides percentage estimates of the contribution made by each ES biome in the EEZ toward the four ES categories. Three biomes (open sea/ocean, continental shelf and estuary/lagoon/intertidal) collectively account for 98.5% of the value contributed by supporting services, 69% of the value contributed by regulating services, 99.9% of the value contributed by provisioning services and 99.7% of the value contributed by cultural services. These results mostly reflect the proportional size of each biome (Table 5), the data available for each and the relatively high dollar-per-hectare values for these particular biomes, illustrating that when data are available and appropriate valuation methods are applied, it is easier to make ES value more visible. Unfortunately, when ES value is not available or made visible, it is quickly assumed to be zero—even though, in reality, it is the scarce biomes that are among the more valuable. Therefore, by increasing the spatial resolution and carrying out localised valuation studies, the perceived value of these biomes may increase.

Table 6. Mean estimates of ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for biomes in the New Zealand Exclusive Economic Zone (EEZ).

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Open sea/ocean	$94,472,088,651	$24,661,388,604	$12,216,872,508	$5,691,089,678	$137,041,439,441	34.00
Continental shelf	$87,333,077,697	$2,368,942,233	$4,275,651,836	$4,275,651,836	$98,253,323,601	24.37
Estuary/lagoon/intertidal	$142,565,454,085	$4,310,390,495	$366,841,744	$1,467,366,977	$148,710,053,302	36.89
Salt marshes/wetland	$846,580,988	$284,208,718	$2,103,496	$137,434	$1,133,030,637	0.28
Seagrass/algae beds	$2,750,109,536	N/A	$287,762	N/A	$2,750,397,298	0.68
Reefs	$1,121,502,777	$13,261,467,416	$3,526,133	$23,721,262	$14,410,217,588	3.57
Mangroves	$210,953,622	$587,777,112	$1,271,433	$12,568,425	$812,570,593	0.20
Sand, beach and dunes*	N/A	N/A	N/A	N/A	N/A	N/A
Total	$329,299,767,358	$45,474,174,578	$16,866,554,913	$11,470,535,611	$403,111,032,460	100.00

* This biome is included for completeness; however, no values were available (see section 2.1.4).

Table 7. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the total value for the ES categories in New Zealand's Exclusive Economic Zone (EEZ) (based on average estimates).

BIOME	ES CATEGORY				TOTAL	% AREA
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Open sea/ocean	28.69	54.23	72.43	49.61	34.00	91.3596
Continental shelf	26.52	5.21	25.35	37.28	24.37	6.9565
Estuary/lagoon/intertidal	43.29	9.48	2.18	12.79	36.89	0.7615
Salt marshes/wetland	0.26	0.62	0.01	0.00	0.28	0.0046
Seagrass/algae beds	0.84	–	0.00	–	0.68	0.0165
Reefs	0.34	29.16	0.02	0.21	3.58	0.7719
Mangroves	0.06	1.30	0.01	0.11	0.20	0.0050
Sand, beach and dunes*	–	–	–	–	–	0.1244
Total	100.00	100.00	100.00	100.00	100.00	100.0000

* This biome is included for completeness; however, no values were available (see section 2.1.4).

[13] MacDiarmid et al. (2013) arrived at an approximate value of US$357B per year, equivalent to NZ$435B, for New Zealand's marine area.

[14] The per capita value is only provided to give the reader a sense of the magnitude of a conservatively estimated ES value.

3.2 Banks Peninsula Marine Mammal Sanctuary

The Banks Peninsula Marine Mammal Sanctuary includes 389 km of coastline, from the Rakaia River in the north to the Waipara River in the south, and extends c. 12 nautical miles (n.m.) out to sea (Fig. 4). The present-day sanctuary is an extension of New Zealand's first marine mammal sanctuary, which was created around Banks Peninsula in 1988. The aim of the sanctuary was to protect the endangered Hector's dolphin/upokohue (*Cephalorhynchus hectori*) from by-catch in set nets. The many bays and harbours along the Banks Peninsula coastline make it an ideal habitat for Hector's dolphins and many other marine animals (DOC 2012a).

Table 8. Estimated areas of the ecosystem goods and services (ES) biomes of the Banks Peninsula Marine Mammal Sanctuary.

ES BIOME	AREA (ha)	AREA (%)
Continental shelf	392 147	96.63
Estuary/lagoon/intertidal	910	0.22
Reefs	5 910	1.46
Sand, beach and dunes	6 853	1.69
Total area	405 820	100.00

A spatial depiction of the ES biomes associated with the Banks Peninsula Marine Mammal Sanctuary is provided in Fig. 4 and estimates of the area of each ES biome are listed in Table 8. The map was constructed from the Gaps Marine Biological Habitat GIS layer for the South Island (see Tables 2 & A2.3 (Appendix 2)). The total biome area of 405 820 ha provided in Table 8 is based on the area defined by the GIS shapefile supplied by DOC. However, this figure underestimates the size of the Sanctuary by 7179 ha according to the figures quoted on the DOC website[15] for this marine managed area (MMA). Estimates of the value of direct and indirect ES benefit flows produced annually by this MMA (NZ$_{2010}$/yr) are summarised in Table 9, with ES grouped into the four standard categories. Collectively, they generate an average ES value of $1.4B/yr (with lower- and upper-range ES values of c. $799M/yr and c. $2B/yr, respectively), which is about 0.35% of the corresponding value for New Zealand's entire EEZ and 0.72% of total GDP for that same year. Dividing the average ES value estimate by the human population estimate for 2010 yields a per capita average ES value of $321/yr.

Table 10 provides percentage estimates of the contribution made by each of the ES biomes in the Banks Peninsula Marine Mammal Sanctuary towards the four ES categories. One biome (continental shelf) accounts for 96.49% of the value contributed by supporting services, 55.59% of the value contributed by regulating services, 99.81% of the value contributed by provisioning services and 99.2% of the value contributed by cultural services. These results are a consequence of a number of different factors, the foremost being the relative size of this biome (96% of total area) (Table 8).

[15] www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-mammal-sanctuaries/banks-peninsula/ (viewed 30 July 2013).

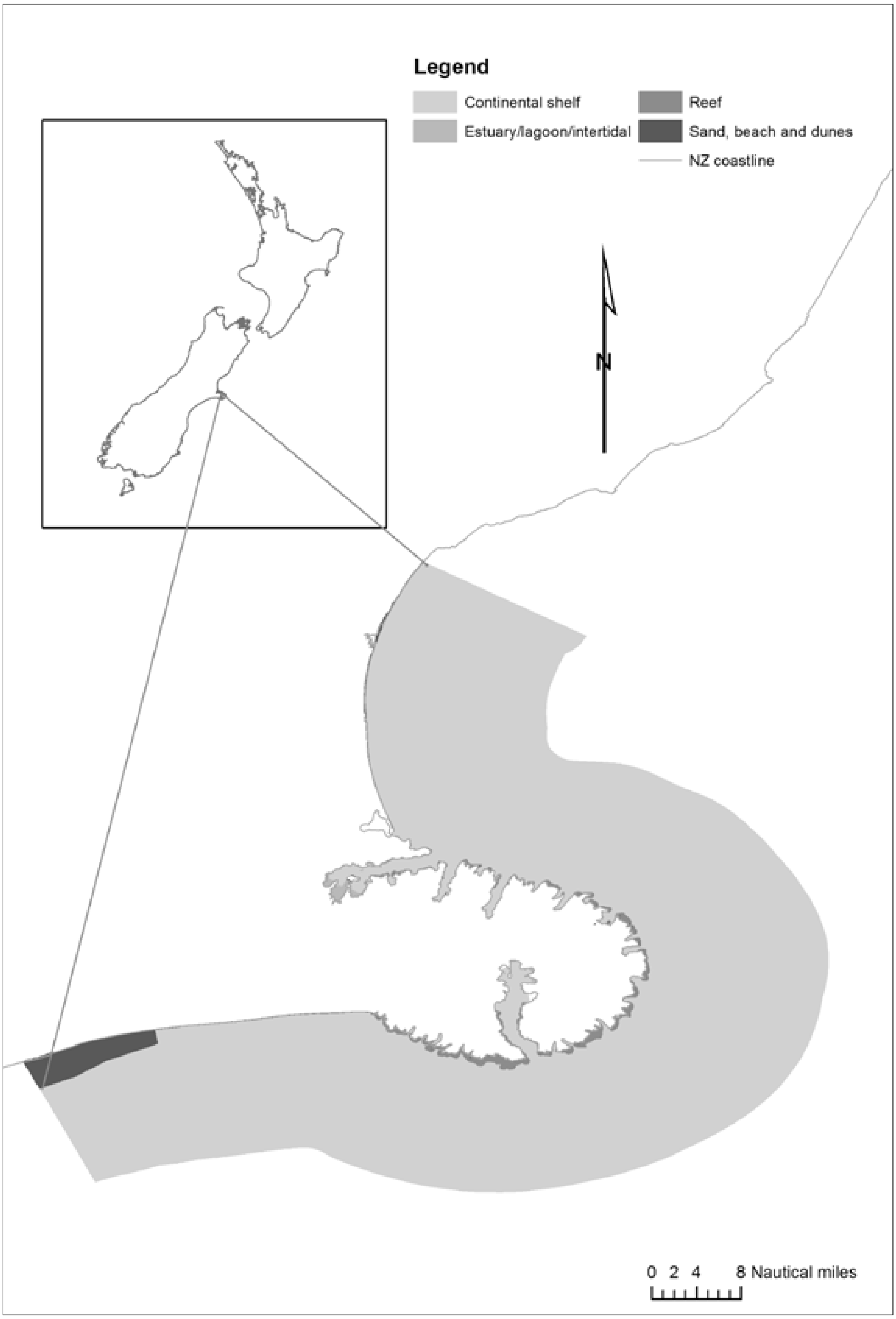

Figure 4. Map of the ecosystem goods and services (ES) biomes associated with the Banks Peninsula Marine Mammal Sanctuary.

Table 9. Average estimates of ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for biomes in the Banks Peninsula Marine Mammal Sanctuary.

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Continental shelf	$1,185,461,439	$32,156,083	$58,037,808	$58,037,808	$1,333,693,137	95.06
Estuary/lagoon/intertidal	$41,039,939	$1,240,821	$105,602	$422,407	$42,808,769	3.05
Reefs	$2,067,540	$24,448,098	$6,501	$43,731	$26,565,869	1.89
Sand, beach and dunes*	–	–	–	–	–	–
Total	$1,228,568,918	$57,845,001	$58,149,910	$58,503,946	$1,403,067,775	100.00

* This biome is included for completeness; however, no values were available (see section 2.1.4).

Table 10. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the total value of the ES categories in the Banks Peninsula Marine Mammal Sanctuary (based on average estimates).

BIOME	ES CATEGORY				TOTAL	% AREA
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Continental shelf	96.49	55.59	99.81	99.20	95.06	96.63
Estuary/lagoon/intertidal	3.34	2.15	0.18	0.72	3.05	0.22
Reefs	0.17	42.26	0.01	0.08	1.89	1.46
Sand, beach and dunes*	–	–	–	–	–	1.49
Total	100.00	100.00	100.00	100.00	100.00	100.00

* This biome is included for completeness; however, no values were available (see section 2.1.4).

3.3 Poor Knights Islands Marine Reserve

The Poor Knights Islands Marine Reserve is located c. 24 km from the nearest coastal settlement of New Zealand (Whangarei Harbour), and includes the open ocean and seabed within 800 m of the Poor Knights Islands (Tawhiti Rahi Island and Aorangi Island) and their associated islets. The Reserve also includes the waters and seabed within 800 m of the High Peak Rocks (Pinnacles or Poor Knights Rocks) and Sugarloaf Rock, which lies approximately 8 km south of the Poor Knights Islands (DOC 2012c).

The Poor Knights Islands were designated a marine reserve on 18 February 1981 to protect the unique and unusually diverse assemblage of marine flora and fauna that occurs there as a result of the East Auckland Current, which transports subtropical larvae to the Reserve; the steep, rocky, subtidal topography of the islands; local oceanic salinity levels; and the high water clarity. These environmental factors also mean that there is a strong subtropical component to the marine life here (DOC 2012c).

Table 11. Estimated areas of the ecosystem goods and services (ES) biomes in the Poor Knights Islands Marine Reserve.

ES BIOMES	AREA (ha)	AREA (%)
Continental shelf	1101	57.29
Estuary/lagoon/intertidal	10	0.52
Reefs	804	41.83
Sand, beach and dunes	7	0.36
Total area	1922	100.00

A spatial depiction of the ES biomes associated with the Poor Knights Islands Marine Reserve is provided in Fig. 5 and estimates of the area of each ES biome are listed in Table 11. The map was constructed from the Northland Marine Biological Habitat GIS layer for the North Island (see Tables 3 & A2.1 (Appendix 2)). The GIS shapefile supplied by DOC yielded a total biome area of 1922 ha (Table 11), which is

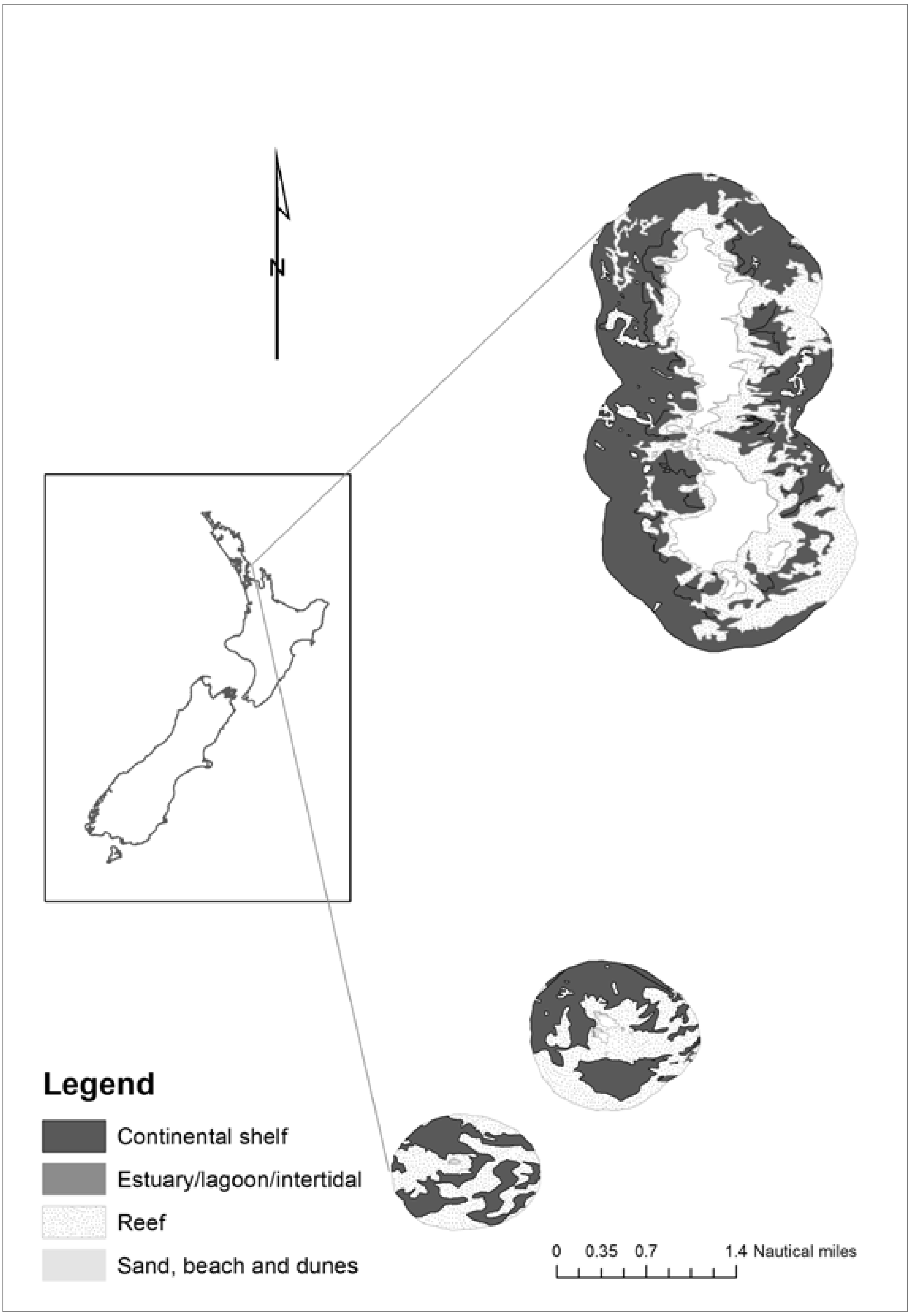

Figure 5. Map of the ecosystem goods and services (ES) biomes associated with the Poor Knights Islands Marine Reserve.

32 ha more than the area quoted on the DOC website[16] for this MPA (DOC 2012c). Estimates of the value of direct and indirect ES benefit flows produced annually by this MPA (NZ$$_{2010}$/yr) are summarised in Table 12, with ES grouped into the four standard categories. Collectively, they generate an average ES value of $7.8M/yr (with lower- and upper–range ES values of c. $3M/yr and c. $15.9M/yr, respectively), which is 0.0019% of the same average ES value for New Zealand's entire EEZ and c. 0.004% of total GDP for that same year. Dividing the average ES value estimate by the human population estimate for 2010 yields a per capita average ES value of $1.79/yr.

Table 13 provides percentage estimates of the contribution made by each of the ES biomes in the Poor Knights Islands Marine Reserve towards the four ES categories. One biome (continental shelf) accounts for 81.86% of the value contributed by supporting services, 2.63% of the value contributed by regulating services, 98.75% of the value contributed by provisioning services and 93.87% of the value contributed by cultural services. These results are a consequence of a number of different factors, the foremost being the relative size of this biome (Table 11).

Table 12. Average estimates of the ecosystem service value ($$_{2010}$/yr) by four ecosystem goods and services (ES) categories for biomes in the Poor Knights Islands Marine Reserve.

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Continental shelf	$3,328,498	$90,287	$162,957	$162,957	$3,744,699	47.81
Estuary/lagoon/intertidal	$456,355	$13,798	$1,174	$4,697	$476,024	6.08
Reefs	$281,117	$3,324,128	$884	$5,946	$3,612,075	46.11
Sand, beach and dunes*	–	–	–	–	–	–
Total	$4,065,970	$3,428,213	$165,015	$173,600	$7,832,798	100.00

* This biome is included for completeness; however, no values were available (see section 2.1.4).

Table 13. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the total value of the ES categories in the Poor Knights Islands Marine Reserve (based on average estimates).

BIOME	ES CATEGORY				TOTAL	% AREA
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Continental shelf	81.86	2.63	98.75	93.87	47.81	57.29
Estuary/lagoon/intertidal	11.22	0.40	0.71	2.71	6.08	0.52
Reefs	6.92	96.97	0.54	3.42	46.11	41.83
Sand, beach and dunes*	–	–	–	–	–	0.36
Total	100.00	100.00	100.00	100.00	100.00	100.00

* This biome is included for completeness; however, no values were available (see section 2.1.4).

16 www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/poor-knights-islands/facts/ (viewed 30 July 2013).

3.4 Whangarei Harbour Marine Reserve

The Whangarei Harbour Marine Reserve comprises two sites—Waikaraka and Motukaroro/Passage Island at Reotahi. The combined area of both sites is approximately 2.54% of the total marine area of Whangarei Harbour (see Fig. 2).

The main goals when creating a marine reserve in Whangarei Harbour was to preserve marine biodiversity, increase public awareness, and create spaces for both study and recreational enjoyment. On 2 December 2004, the then Minister of Conservation Chris Carter approved two of the original three proposed areas being accorded marine reserve status. Further consultation resulted in the Minister removing one area (Motumatakohe) from the proposal due to strong opposition from fishers and local iwi. The Minister of Fisheries approved the remaining two areas in 2005. These MPAs were formally opened by DOC on 18 October 2006.

A spatial depiction of the ES biomes associated with both protected areas in Whangarei Harbour Marine Reserve is shown in Fig. 6. The source shapefiles gave a combined area of 237.63 ha, which is slightly less than the figure quoted on the DOC website (253.7 ha). The Motukaroro area has been depicted using two different GIS spatial resolutions (Fig. 6A & B), which enabled the effect of spatial resolution on ES value estimates to be compared and quantified. As can be seen, the higher resolution map (Fig. 6B) includes continental shelf and seagrass/algae beds, both of which add value. Consequently, we found that a higher spatial resolution had an influence on total value estimates using RESA.

3.4.1 Motukaroro

The diversity of marine life in the waters around Motukaroro/Passage Island makes the island an important zone ecologically. Species at Motukaroro range from colourful anemones to sponges, maomao (*Scorpis violacea*), unusual Spanish lobster (*Arctides antipodarum*) and giant kingfish (*Seriola lalandi*). A strong tidal influence associated with the mouth of Whangarei Harbour supports communities of sessile filter-feeders, which, in turn, attract other mobile marine species (DOC 2012f). In addition, the southern shore of Motukaroro/Passage Island is characterised by a striking rocky shore zonation.

The two GIS depictions of Motukaroro (Fig. 6A & B) were constructed from the Northland Marine Biological Habitat GIS layer for the island (Kerr 2009; see Table 2) and a local site-specific Marine Biological Habitat GIS layer of higher spatial resolution, which was provided by DOC (unpublished spatial data held by National Office, DOC, Wellington). The GIS shapefile supplied by DOC yielded a total biome area of 26.4 ha (site-specific area estimates for Motukaroro are not provided on the DOC website).[17] Estimates of the ES biome areas derived from each GIS layer are listed in Table 14. The differences in spatial resolution between the layers resulted in the site-specific data providing area estimates for four biomes, whereas the Northland data provided estimates for only two biomes. In addition, it should be noted that it was assumed that the continental

Table 14. Estimated areas of the ecosystem goods and services (ES) biomes in the Whangarei Harbour (Motukaroro) Marine Reserve based on data from two GIS layers: Northland Biological Habitat GIS data (NBioH) and site-specific biological habitat data (SSBioH).

ES BIOME	NBIOH		SSBIOH	
	AREA (ha)	AREA (%)	AREA (ha)	AREA (%)
Continental shelf	–	–	1.64	6.21
Estuary/lagoon/intertidal	20.35	77.00	21.31	80.72
Seagrass/algae beds	–	–	3.10	11.74
Reefs	6.07	23.00	0.35	1.33
Total area	26.42	100.00	26.40	100.00

17 www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/whangarei-harbour/ (viewed 30 July 2013).

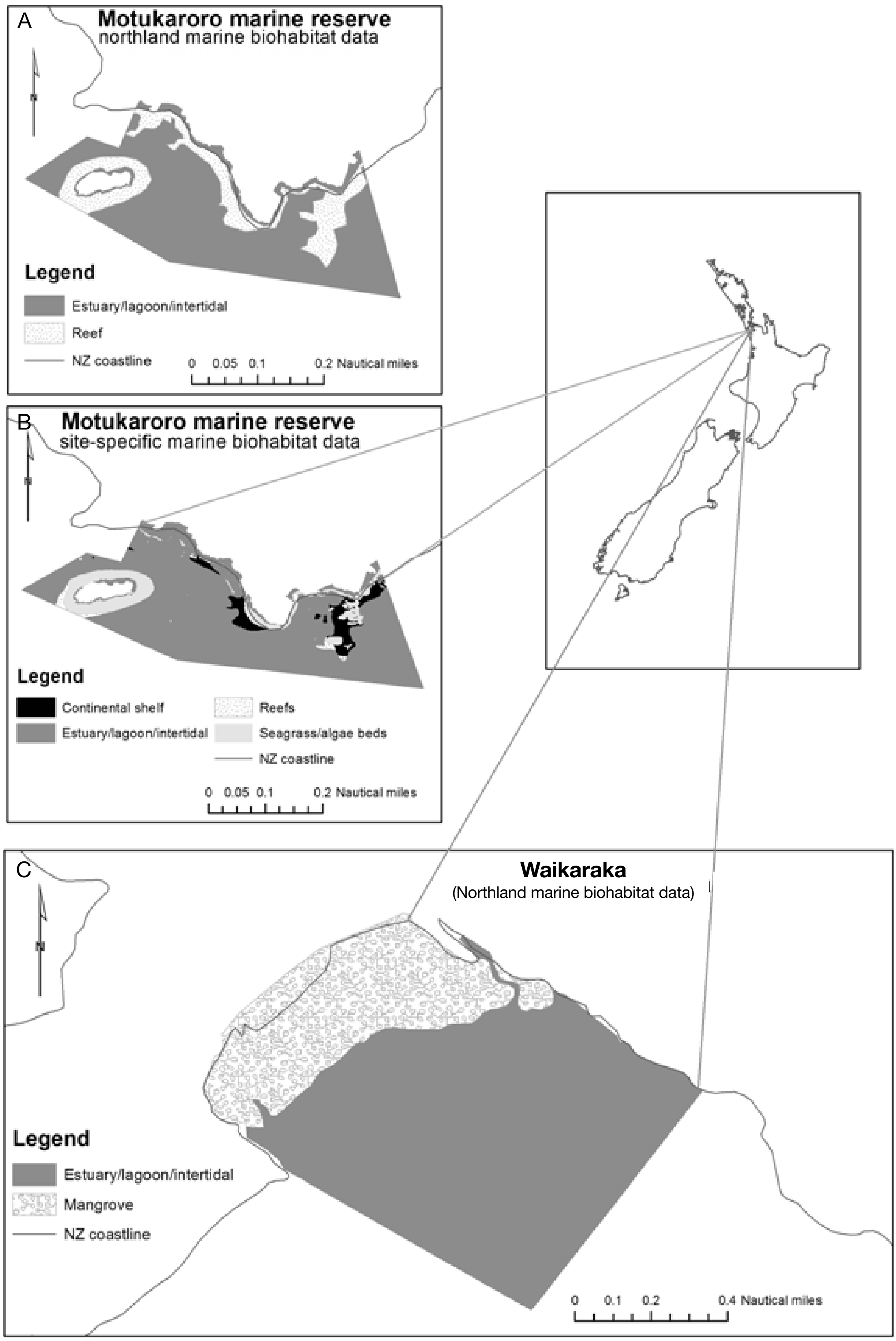

Figure 6. Map of the ecosystem goods and services (ES) biomes associated with the Whangarei Harbour Marine Reserve. A. Motukaroro using Northland marine biohabitat data; B. Motukaroro using site-specific marine biohabitat data; and C. Waikaraka using Northland marine biohabitat data.

shelf extends from the intertidal/estuarine zones to the drop-off zone, as all nearshore open water is mapped as estuarine in the GIS layers.

Estimates of the value of direct and indirect ES benefit flows produced annually by this MPA (NZ$$_{2010}$/yr) are summarised in Tables 15 & 16, which are based on the Northland Marine Biological Habitat ES dataset (see Tables 2 & A2.1 (Appendix 2)) and the site-specific Marine Biological Habitat dataset (see Tables 3 & A2.2 (Appendix 2)), respectively. Comparison of these two datasets reveals that the mean ES estimate derived from the Northland dataset ($984,225/yr; with lower- and upper-range values of c. $531,711/yr and c. $1.5M/yr, respectively) is $149,543/yr less than (or c. 13% of) the ES value derived from the site-specific dataset ($1.13M/yr; with lower- and upper-range values of c. $620,965/yr and c. $1.7M/yr, respectively).

These results clearly demonstrate that a change in the spatial resolution of biome data is associated with a marked change in ES value, even though the total area of the two different spatial datasets was the same. Due to the assumptions associated with the use of benefit-transfer methods, RESA and similar assessments provide conservative estimates of ES value. Therefore, improvements in representation and the acquisition of local market and non-market values along with higher-resolution biome data will increase the ES value estimates. The average ES value estimate based on site-specific spatial data ($1.13M/yr) is 0.00028% of the same average ES value for New Zealand's entire EEZ and c. 0.00058% of total GDP for that same year. Dividing that average ES value estimate by the human population estimate for 2010 yields a per capita ES value of $0.26/yr.

Table 17 provides percentage estimates of the contribution made by each ES biome, using the site-specific data reported in Table 15. One biome (estuary/lagoon/intertidal) accounts for 88.12% of the value contributed by supporting services, 94.9% of the value contributed by regulating services, 90.61% of the value contributed by provisioning services and 97.58% of the value contributed by cultural services. These results are a consequence of a number of different factors, the foremost being that this biome makes up 80.72% of the total area (Table 14).

Table 15. Average estimates of ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for biomes in the Whangarei Harbour (Motukaroro) Marine Reserve (Northland Marine Biological Habitat ES dataset).

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Estuary/lagoon/intertidal	$917,398	$27,737	$2,361	$9,442	$956,938	97.23
Reefs	$2,124	$25,112	$7	$45	$27,288	2.77
Total	$919,522	$52,849	$2,368	$9,487	$984,226	100.00

Table 16. Average estimates of ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for biomes in the Whangarei Harbour (Motukaroro) Marine Reserve (site-specific Marine Biological Habitat ES dataset).

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Continental shelf	$4,961	$135	$243	$243	$5,582	0.49
Estuary/lagoon/intertidal	$960,789	$29,049	$2,472	$9,889	$1,002,199	88.40
Seagrass/algae beds	$124,423	–	$13	–	$124,436	10.97
Reefs	$121	$1,428	$0	$3	$1,552	0.14
Total	$1,090,294	$30,612	$2,728	$10,135	$1,133,769	100.00

Table 17. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the ES categories in the Whangarei Harbour (Motukaroro) Marine Reserve (site-specific Marine Biological Habitat ES dataset).

BIOME	ES CATEGORY				TOTAL
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL	
Continental shelf	0.46	0.44	8.90	2.40	0.49
Estuary/lagoon/intertidal	88.12	94.90	90.61	97.57	88.40
Seagrass/algae beds	11.41	–	0.48	–	10.97
Reefs	0.01	4.66	0.01	0.03	0.14
Total	100.00	100.00	100.00	100.00	100.00

3.4.2 Waikaraka

Waikaraka supports a population of highly productive mangroves (*Avicennia marina*) that provide shelter and food to many marine organisms, and also play an important role in stabilising banks and trapping silt runoff from the land (DOC 2012f). A spatial depiction of the ES biomes associated with Waikaraka is provided in Fig. 6C and estimates of the area of each ES biome are listed in Table 18.

Table 18. Estimated areas of the ecosystem goods and services (ES) biomes of the Whangarei Harbour (Waikaraka) Marine Reserve.

ES BIOME	AREA (ha)	AREA (%)
Estuary/lagoon/intertidal	152.15	72.00
Mangroves	59.07	28.00
Total area	211.22	100.00

The GIS depiction shown in Fig. 6C was constructed from the Northland Marine Biological Habitat GIS layer (Kerr 2009) (see Tables 2 & A2.1 (Appendix 2)). The GIS shapefile supplied by DOC yielded a total biome area of 211.22 ha (comparable area estimates were not available on the DOC website[18]). Estimates of the value of direct and indirect ES benefit flows produced annually by this MPA (NZ$$_{2010}$/yr) are summarised in Table 19, with ES grouped into the four standard categories. Collectively, they generate an average ES value of $9.46M/yr (with lower- and upper-range ES estimates of c. $6.1M/yr and c. $13.9M/yr, respectively), which is 0.0023% of the same average ES value for New Zealand's entire EEZ and c. 0.005% of total GDP for that same year. Dividing the average ES value estimate by the human population estimate for 2010 yields a per capita ES value of $2.16/yr.

Table 20 provides percentage estimates of the contribution made by each of the ES biomes towards the four ES categories. One biome (estuary/lagoon/intertidal) accounts for 91.98% of the value contributed by supporting services, 11.07% of the value contributed by regulating services, 83.05% of the value contributed by provisioning services and 66.46% of the value contributed by cultural services. However, although most of the annual economic value generated by this reserve area comes from the various ES associated with this biome, 88.93% of the value of regulating services is associated with the mangrove biome. These results reflect the fact that the reserve comprises only two ES biomes (mangroves—27.97% of total area; and estuary/lagoon/intertidal—72.03% of total area), with monetary value being associated with biome area (Table 18).

[18] www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/whangarei-harbour/ (viewed 30 July 2013).

Table 19. Average estimates of the ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for biomes in the Whangarei Harbour (Waikaraka) Marine Reserve.

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Estuary/lagoon/intertidal	$6,858,965	$207,377	$17,649	$70,596	$7,154,588	75.65
Mangroves	$597,859	$1,665,806	$3,603	$35,620	$2,302,888	24.35
Total	$7,456,824	$1,873,183	$21,252	$106,216	$9,457,476	100.00

Table 20. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the ES categories for the Whangarei Harbour (Waikaraka) Marine Reserve (based on average estimates).

BIOME	ES CATEGORY				TOTAL	% AREA
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Estuary/lagoon/intertidal	91.98	11.07	83.05	66.46	75.65	72.00
Mangroves	8.02	88.93	16.95	33.54	24.35	28.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

3.5 Te Angiangi Marine Reserve

The Te Angiangi Marine Reserve was established in August 1997 and is located on the Central Hawke's Bay coast, approximately 30 km east of the inland settlements of Waipukurau and Waipawa.

The Reserve covers an area of c. 1.3 square n.m. (Fig. 2) and extends 1 n.m. offshore from the local mean high water mark. At low tide, a broad rock platform is exposed, providing access to a diverse array of marine life, including golden limpets (*Cellana flava*), large beds of Neptune's necklace (*Hormosira banksii*), pink coralline seaweed and eelgrass (*Zostera* spp.). Small fish, crabs, juvenile paua (*Haliotis* spp.) and kina (*Evechinus chloroticus*) inhabit the rock pools. There is c. 138 ha of subtidal reef, which is covered in *Ecklonia* kelp forest and broken in places by long sandy guts (DOC 2012d). Common reef animals include paua, opal top shells (*Cantharidus opalus*), rock lobsters (*Jasus edwardsii*), and fish such as red and blue moki (*Cheilodactylus spectabilis* and *Latridopsis ciliaris*, respectively), butterfish (*Odax pullus*), banded wrasse (*Notolabrus fucicola*), marblefish (*Aplodactylus arctidens*), and sweep (*Scorpis lineolatus*). The most spectacular underwater scenery is found at depths of 9–15 m south of Aramoana (DOC 2012d). Colourful nudibranchs (sea slugs) and large schools of butterfly perch (*Caesioperca lepidoptera*) and tarakihi (*Nemadactylus macropterus*) are found at depths of 24–36 m on the Boulder Bank or Sponge Garden. This community is dominated by finger sponges and red seaweeds. Several types of fish, including sea perch (*Helicolenus percoides*), scarlet wrasse (*Pseudolabrus miles*), large blue cod (*Parapercis colias*) and common roughy (*Paratrachichthys trailli*), are more abundant here than anywhere else in the Reserve.

Table 21. Estimated areas of the ecosystem goods and services (ES) biomes in the Te Angiangi Marine Reserve.

ES BIOME	AREA (ha)	AREA (%)
Continental shelf	2.88	0.65
Estuary/lagoon/intertidal	184.28	41.56
Seagrass/algae beds	0.22	0.05
Reefs	238.01	53.69
Sand, beach and dunes	17.95	4.05
Total area	443.34	100.00

A spatial depiction of the ES biomes associated with the Te Angiangi Marine Reserve is provided in Fig. 7 and estimates of the area of each ES biome are listed in Table 21. DOC provided two spatial datasets for the Te Angiangi Marine Reserve, one of which was based on the results of a recent

Figure 7. Map of the ES biomes associated with the Te Angiangi Marine Reserve.

mapping study by NIWA of marine habitats either side of and including the Reserve (see Funnell et al. 2005) and the other consisting of Blackhead GIS map layers. Unfortunately, however, the resolution of the Blackhead mapping was not as high as that provided in the Gaps Marine Biological Habitat layers, so the Blackhead study and associated spatial datasets were not used.

Figure 7 was constructed from the Gaps Marine Biological Habitat GIS layer for the North Island (see Tables 3 & A2.3 (Appendix 2)). The GIS shapefile supplied by DOC yielded a total biome area of 443.34 ha, which is 3 ha less than the figure quoted on the DOC website[19] for this MPA. Estimates of the value of direct and indirect ES benefit flows produced annually (NZ$$_{2010}$/yr) are summarised in Table 22, with ES grouped into the four standard categories. Collectively, they generate an average ES value of $9.8M/yr (with lower- and upper-range estimates of c. $4.9M/yr and c. $16M/yr, respectively), which is 0.0024% of the same average ES value for New Zealand's entire EEZ and c. 0.01% of total GDP for that same year. Dividing the average ES value estimate by the human population estimate for 2010 yields a per capita ES value of $2.23/yr.

Table 23 provides percentage estimates of the contribution made by each of the ES biomes in the Te Angiangi Marine Reserve towards the four ES categories. One biome (estuary/lagoon/intertidal) accounts for 98.9% of the value contributed by supporting services, 20.32% of the value contributed by regulating services, 96.87% of the value contributed by provisioning services and 97.5% of the value contributed by cultural services. By contrast, the reef biome accounts for 79.66% of the value contributed by regulating services (Table 22). These results are a consequence of a number of different factors, the foremost being the relative area of these biomes (41.56% and 53.69% of the total area for the estuary/lagoon/intertidal biome and the reefs biome, respectively) (Table 21).

Table 22. Average estimates of the ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for the ES biomes in the Te Angiangi Marine Reserve.

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Continental shelf	$8,718	$236	$427	$427	$9,808	0.10
Estuary/lagoon/intertidal	$8,307,617	$251,176	$21,377	$85,507	$8,665,677	89.57
Seagrass/algae beds	$4,692	–	$1	–	$4,693	0.05
Reefs	$8,269	$984,639	$262	$1,761	$944,931	10.28
Sand, beach and dunes*	–	–	–	–	–	–
Total	$8,329,296	$1,236,052	$22,066	$87,695	$9,750,110	100.00

* This biome is included for completeness; however, no values were available (see section 2.1.4).

Table 23. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the ES categories for the Te Angiangi Marine Reserve (based on average estimates).

BIOME	ES CATEGORY				TOTAL	% AREA
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Continental shelf	0.10	0.02	1.94	0.49	0.10	0.65
Estuary/lagoon/intertidal	99.74	20.32	96.87	97.50	89.57	41.56
Seagrass/algae beds	0.06	–	0.00	–	0.05	0.05
Reefs	0.10	79.66	1.19	2.01	10.28	53.69
Sand, beach and dunes*	–	–	–	–	–	4.05
Total	100.00	100.00	100.00	100.00	100.00	100.00

* This biome is included for completeness; however, no values were available (see section 2.4.1).

[19] www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/te-angiangi/ (viewed 30 July 2013).

3.6 Westhaven (Te Tai Tapu) Marine Reserve

The Westhaven (Te Tai Tapu) Marine Reserve was established in 1994 along with the terrestrial Westhaven (Whanganui Inlet) Wildlife Management Reserve. This reserve network was designed to offer protection for plant and animal life within its boundaries, benefitting not only fish and shellfish, but birds as well. The Westhaven estuary is an enclosed, drowned river valley that is c. 13 km long and 2–3 km wide. The sea entrance to it is 19 km southwest of Farewell Spit, on the West Coast. As the tide enters the inlet, it divides into northeast and southwest channels before spilling out onto expansive intertidal flats, which dominate the estuary. Much of the inlet is bordered by coastal forest of kahikatea (*Dacrycarpus dacrydioides*), pukatea (*Laurelia novae-zelandiae*), rātā (*Metrosideros* spp.), beech (*Fuscospora* spp. and *Lophozonia menziesii*), rimu (*Dacrydium cupressinum*) and nīkau (*Rhopalostylis sapida*). Eelgrass beds, salt marshes, tidal wetlands, dunes, cliffs, islands, rock platforms and underwater reefs provide important habitat for a variety of species (DOC 2012e).

Approximately 30 species of marine fish use the inlet at some stage of their life history, and it is an important breeding and nursery area for snapper (*Pagrus auratus*), flatfish, kahawai (*Arripis trutta*) and whitebait (*Galaxias* spp.). Many fish enter the estuary to take advantage of the rich food supply found in the eelgrass beds and intertidal sand flats. More species of invertebrate are known from this estuary than any other South Island estuary and it is the second most important tidal area in the Nelson/Marlborough region for wading birds, including godwits, knots and oystercatchers. It is also the only site on the West Coast where the threatened banded rail (*Gallirallus philippensis*) is found. An uninterrupted sequence of plant life from forest to salt marsh helps to maintain the estuary's overall health and diversity (DOC 2012e).

Table 24. Estimated areas of the ecosystem goods and services (ES) biomes in the Westhaven (Te Tai Tapu) Marine Reserve.

ES BIOMES	AREA (ha)	AREA (%)
Estuary/lagoon/intertidal	510.99	97.17
Salt marshes/wetland	0.07	0.01
Seagrass/algae beds	14.84	2.82
Total area	525.90	100.00

A spatial depiction of the ES biomes associated with the Westhaven (Te Tai Tapu) Marine Reserve is provided in Fig. 8 and estimates of the area of each ES biome are listed in Table 24.

Figure 8 was constructed from the Gaps Marine Biological Habitat GIS layer for the South Island (see Tables 2 & A2.3 (Appendix 2)). The GIS shapefile supplied by DOC yielded a total biome area of 525.9 ha, which is c. 10 ha less than the figures quoted on the DOC website[20] for this MPA. Estimates of the value of direct and indirect ES benefit flows produced annually (NZ$_{2010}$/yr) are summarised in Table 25, with ES value grouped into the four standard categories. Collectively, they generate an average ES value of $24.6M/yr (with lower- and upper-range ES estimates of c. $13.5M/yr and c. $37M/yr, respectively), which is 0.01% of the same average ES value for New Zealand's entire EEZ and c. 0.01% of total GDP for that same year. Dividing the average ES value estimate by the human population estimate for 2010 yields a per capita ES value of $5.64/yr.

Table 26 provides percentage estimates of the contribution made by each of the biomes toward the four ES categories. One biome (estuary/lagoon/intertidal) accounts for 97.47% of the value contributed by supporting services, 99.85% of the value contributed by regulating services, 99.88% of the value contributed by provisioning services and 100% of the value contributed by cultural services. These results are a consequence of a number of different factors, the foremost being the relative size of this biome (97.17% of the total area; Table 24).

[20] www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/westhaven-te-tai-tapu/ (viewed 30 July 2013).

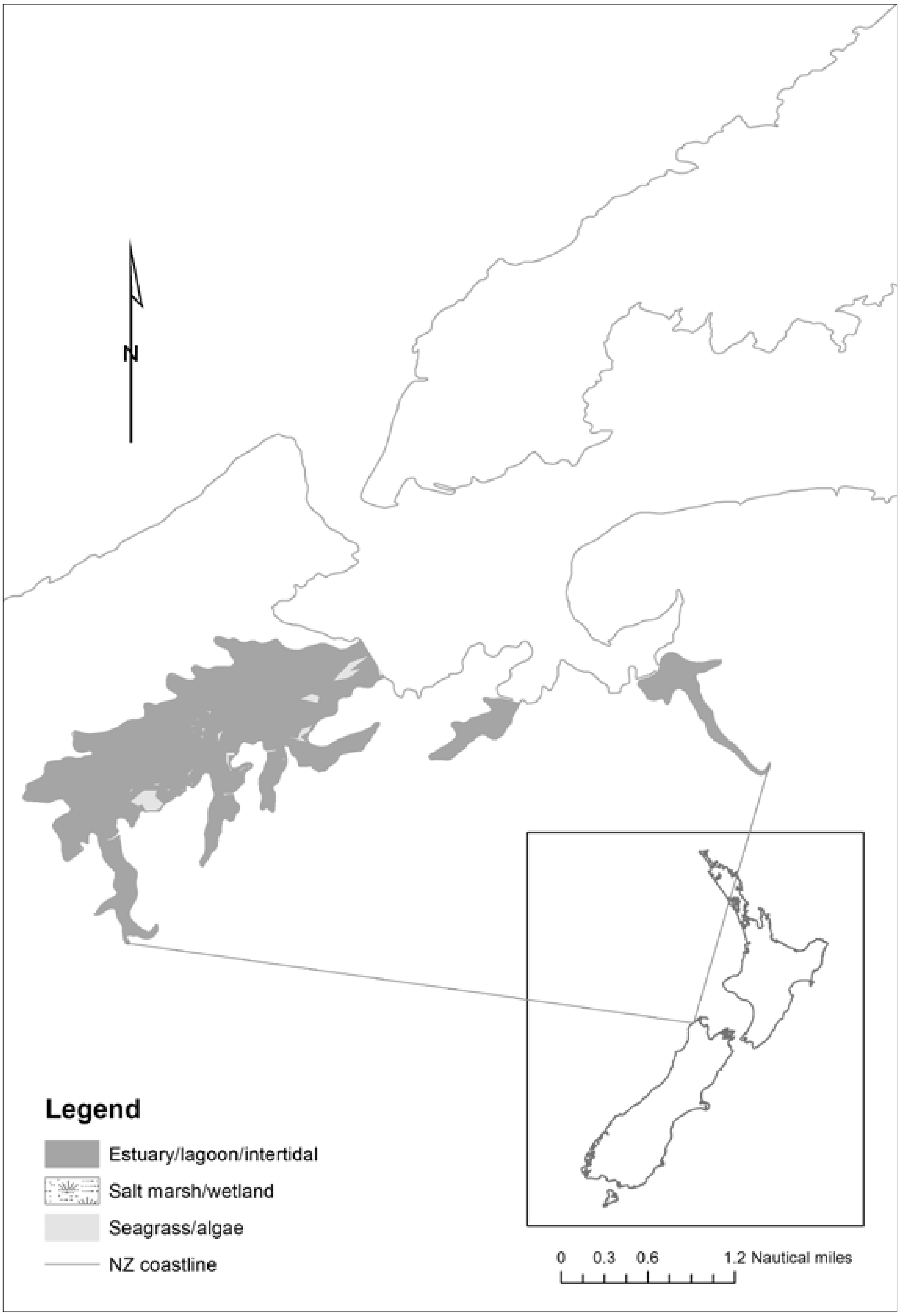

Figure 8. Map of the ecosystem goods and services (ES) biomes associated with the Westhaven (Te Tai Tapu) Marine Reserve.

Table 25. Average estimates of ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for biomes in the Westhaven (Te Tai Tapu) Marine Reserve.

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Estuary/lagoon/intertidal	$23,035,940	$696,479	$59,275	$237,099	$24,028,793	97.56
Salt marshes/wetland	$3,105	$1,042	$8	$1	$4,156	0.02
Seagrass/algae beds	$595,663	N/A	$62	N/A	$595,725	2.42
Total	$23,634,708	$697,522	$59,345	$237,100	$24,628,674	100.00

Table 26. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the ES categories for the Westhaven (Te Tai Tapu) Marine Reserve (based on average estimates).

BIOME	ES CATEGORY				TOTAL	% AREA
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Estuary/lagoon/intertidal	97.47	99.85	99.88	100.00	97.56	97.17
Salt marshes/wetland	0.01	0.15	0.01	0.00	0.02	0.01
Seagrass/algae beds	2.52	N/A	0.11	N/A	2.42	2.82
Total	100.00	100.00	100.00	100.00	100.00	100.00

3.7 Piopiotahi Marine Reserve

The Piopiotahi Marine Reserve in Milford Sound was first established in 1993. This Reserve is a deep fiord basin that contains muddy underwater habitats, a large section of deep reef, and various sections of shallow and deeper rock wall along its northern shore. The rock wall on the inner northern side of Milford Sound is dominated by delicate deep-water sessile invertebrates, including encrusting tubeworms, sponges, soft corals, colonial sea squirts, black coral (*Antipathella fiordensis*) and anemones. The Reserve is a popular recreation spot, especially for diving around world-famous black corals. While overfishing of blue cod and rock lobster has been a problem in the past, research now suggests that the area's reserve status is contributing to the recovery of these species (DOC 2012b).

Table 27. Estimated areas of the ecosystem goods and services (ES) biomes in the Piopiotahi Marine Reserve.

ES BIOME	AREA (ha)	AREA (%)
Estuary/lagoon/intertidal	650.03	90.10
Reefs	71.40	9.90
Total area	721.43	100.00

A spatial depiction of the ES biomes associated with the Piopiotahi Marine Reserve is provided in Fig. 9 and estimates of the area of each ES biome are listed in Table 27.

Figure 9 was constructed from the Gaps Marine Biological Habitat GIS layer (DOC & MFish 2011) for the South Island (see Tables 2 & A2.3 (Appendix 2)). The GIS shapefile supplied by DOC yielded a total biome area of 721.43 ha, which is 31.43 ha less than the figures quoted on the DOC website[21] for this MPA. Estimates of the value of direct and indirect ES benefit flows produced annually by this MPA (NZ$$_{2010}$/yr) are summarised in Table 28, with ES grouped into the four standard categories. Collectively, they generate an average ES value of $30.9M/yr (with lower- and upper-range estimates of c. $16.8M/yr and c. $46.9M/yr, respectively), which is 0.01% of the same average ES value for New Zealand's entire EEZ and c. 0.02% of total

[21] www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/fiordlands-marine-reserves/facts/fiordland-marine-reserves-a-z/piopiotahi-milford-sound/ (viewed 30 July 2013).

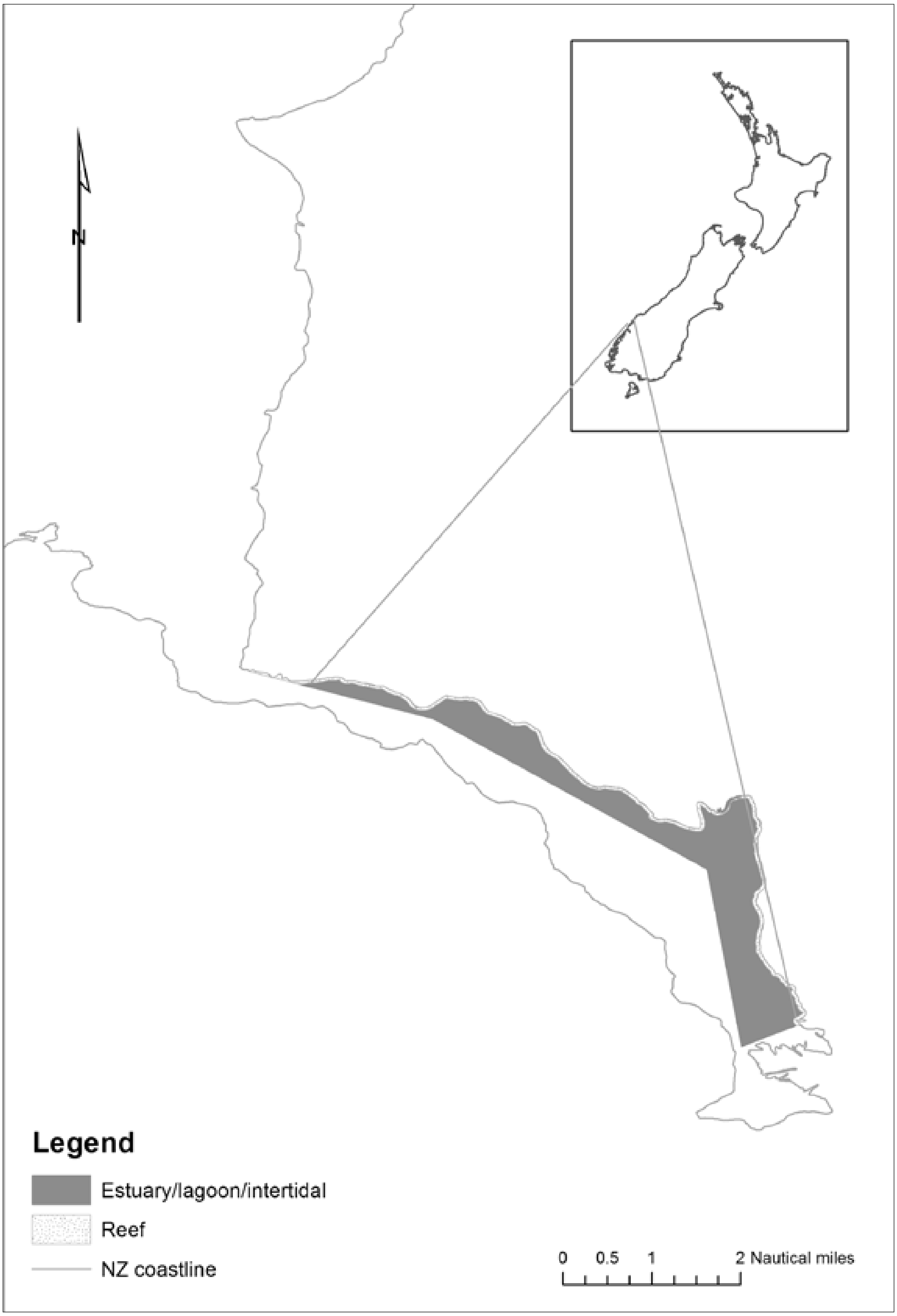

Figure 9. Map of the ecosystem goods and services (ES) biomes associated with the Piopiotahi Marine Reserve.

GDP for that same year. Dividing the average ES value estimate by the human population estimate for 2010 yields a per capita ES value of $7.07/yr.

Table 29 provides percentage estimates of the contribution made by each of the ES biomes in the Piopiotahi Marine Reserve towards the four ES categories. One biome (estuary/lagoon/intertidal) accounts for 99.91% of the value contributed by supporting services, 75% of the value contributed by regulating services, 99.9% of the value contributed by provisioning services and 99.83% of the value contributed by cultural services. These results are a consequence of a number of different factors, the foremost being the relative size of this biome (90.1% of the total area; Table 27).

Table 28. Average estimates of ecosystem service value (NZ$$_{2010}$/yr) by four ecosystem goods and services (ES) categories for the biomes in the Piopiotahi Marine Reserve.

BIOME	ES CATEGORY				TOTAL	% VALUE
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Estuary/lagoon/intertidal	$29,304,002	$885,991	$75,403	$301,614	$30,567,011	98.96
Reefs	$24,980	$295,382	$79	$528	$320,969	1.04
Total	$29,328,982	$1,181,373	$75,482	$302,142	$30,887,980	100.00

Table 29. Percentage estimates of the economic contribution of each ecosystem goods and services (ES) biome to the ES categories for the Piopiotahi Marine Reserve (based on average estimates).

BIOME	ES CATEGORY				TOTAL	% AREA
	SUPPORTING	REGULATING	PROVISIONING	CULTURAL		
Estuary/lagoon/intertidal	99.91	75.00	99.90	99.83	98.96	90.10
Reefs	0.09	25.00	0.10	0.17	1.04	9.90
Total	100.00	100.00	100.00	100.00	100.00	100.00

3.8 Summary

A summary of the estimated values of each of the case-study sites is provided in Table 30.

Table 30. Summary of the estimated average values for each case-study site shown as a percentage of the Exclusive Economic Zone (EEZ), percentage of gross domestic product (GDP) and value per capita (NZ$$_{2010}$/yr).

CASE STUDY	% EEZ	% GDP	VALUE PER CAPITA
Exclusive Economic Zone (EEZ)	100	207	$92,245
Banks Peninsula Marine Mammal Sanctuary	0.35	0.72	$321
Poor Knights Islands Marine Reserve	0.0019	0.004	$1.79
Whangarei Harbour Marine Reserve			
Motukaroro	0.00028	0.00058	$0.26
Waikaraka	0.0023	0.005	$2.16
Te Angiangi Marine Reserve	0.0024	0.01	$2.23
Westhaven (Te Tai Tapu) Marine Reserve	0.01	0.01	$5.64
Piopiotahi Marine Reserve	0.01	0.02	$7.07

4. Supply, demand and value of ES provided at each of the case-study sites

The RESA method provides a snapshot of benefit-transferred values of ES at a single point in time and is consequently considered a static approach. RESA emphasises the supply of ES and then extrapolates these to rapidly and crudely produce benefit-transferred values. However, these values are limited in terms of their availability and transferability, as discussed in section 2.3.1. The RESA method is useful for providing a conversation starter, however, where the main message is that the invisible values quickly add up, even when data gaps exist.

Several approaches can be used to understand, capture and manage these invisible values. This section introduces the notion that both the biophysical supply of ES as well as the socially, economically and culturally driven demand for ES are important for understanding the value of ES beyond benefit-transferred values. In this section, we introduce the concept of *value* in terms of the *gap between the supply of and demand for ecosystem goods and services* that are provided in New Zealand's current MPA network. We also highlight that an understanding of both the supply of and demand for ES allows us to more fully appreciate changes that occur over time, which will require a trans-disciplinary collaboration between natural and social scientists, alongside policy makers and other stakeholders. Finally, we emphasise that the value of ES depends on whether the supply and demand of ES is perceived, and by whom.

We acknowledge that DOC decision-makers and staff are likely to be particularly interested in how RESA values change over time following the implementation of MPA status. This is a crucial question that will require the sophisticated use of ES as an organising principle (including system dynamic modelling tools), preferably with stakeholder involvement, to answer it—which is at the opposite end of the valuation tool continuum from RESA (see section 5). Therefore, the application of these methods is unfortunately beyond the scope of this report. We do, however, provide an overview of the various approaches that are available internationally for deepening our understanding of changes in ES value through time in section 5. The remainder of section 4 provides a simple conceptual example of transitioning from a RESA method to various valuation methods.

4.1 Creating the supply, demand and value tables for ES

We explored the question of supply of and demand for ES by using a simple matrix, which expands the static RESA approach in the direction of 'changes in value of ES' for each of the case studies. Unfortunately, we did not have the resources to make an integrated assessment by developing a supply profile of ES or by involving stakeholders in the development of demand profiles for ES for each of the case studies. Therefore, instead, we used our expert opinion to exemplify simple supply and demand tables to scope for possible changes over time that are likely to be associated with MPA status.

To introduce the notion of change over time in the most rudimentary way, we set up three worksheet tables in Microsoft Excel, with the eight case studies as columns and relevant marine ES as rows. The four broad ES categories of the MEA (2005) (supporting, regulating, provisioning and cultural services) were subdivided into the 24 subcategories that are generally, but not always consistently, applied in the ES literature—and these categories were interpreted for all ES that are specifically relevant to the case studies. This transition from an 'ecosystem service' to specific benefits is often referred to as an 'ecosystem benefit'. Translation of the ES for specific benefits from the case studies highlights the need for both consistency at an international and national level as well as local stakeholder driven flexibility in defining and using the

ES terminology, so that the findings can be effectively scaled and studies can be carried out to make comparative value assessments. This research theme has developed rapidly since this study was initiated.

For each case-study site, each ES was assigned a score from 1 to 5 (1 = low, 5 = high) for the likelihood of changes in the supply of and demand for ES (Tables 31 & 32, respectively). The value of ES was then calculated based on the gap between their supply and demand (Table 33).

The implementation of MPA status is predicted to enhance ES supply in case-study sites that already have a high habitat diversity. Initial changes in ES are likely to be related to perceptual and/or passive values, while supporting and regulating services are likely to respond more slowly. The enhancement of fisheries may benefit from paying attention to ecosystem habitat reconstruction and may be constrained by the slow recovery of benthic habitat productivity. However, the benefits of fish population recovery may not necessarily be realised locally. A hindrance to assessing the influence of MPA status on the case-study ecosystems is our poor understanding of how close each system is from threshold conditions that could change the system irreversibly, and what role disturbance plays in maintaining optimal levels of local marine biodiversity, habitat diversity and ecosystem productivity.

In creating each of the tables, some specific assumptions were made. The table of likely changes in ES supply (Table 31) addressed the question 'Has the protection offered by MPA status resulted in an increase in the supply of ES?' Decline was not considered in this exercise, as the relationship between the case-study area and the wider region was not taken into account. The basic assumption was that an increase in the area of an ES biome that is responsible for the flow of goods and services constituted evidence for an increase in the supply of supporting, regulating and provisioning ES. We also assumed that the extent of the influence of implementation of MPA status would depend on the initial habitat structure of a case study's ecosystems. To do this exercise properly in an ideal world, an integrated assessment of all biophysical information would provide the supply profile for each case study. Again, substantial advances have recently been achieved in this research area.

For the table depicting the likelihood of changes in ES demand (i.e. the likelihood of changes in local customer requests for ES) (Table 32), we assumed that more members of the public wanting or using ES constituted evidence of an increased demand (again, decline was not considered).

Table 33 was created by determining the gap between the supply (Table 31) and demand (Table 32) for each cell in turn. While the values presented cannot be used for decision-making at this point, this approach highlights the need to consider the gap between the (biophysical) supply of ES and the (social, cultural and economic) demand for ES. While the rhetoric is borrowed from neo-classical economic market-based language, the implications of moving beyond 'perceived' and visible values opens a window of opportunity for communication to include market and non-market based values, preferably with stakeholder involvement, as further discussed in section 5.

Instead of using scores for 'likelihood of change', other measures such as 'relative importance' could be used to develop future scenarios and prioritisations. The RESA could also have been extended by converting the qualitative scores into monetary scores by setting a price point in each table. Such a move towards monetary values brings both advantages and disadvantages, depending on one's perspective. The use of monetary values provides a common metric, and may also lead some to conclude that markets for ES are appropriate. However, there are severe limitations to including the full costs and benefits (see Appendix 1).

The use of matrices to link supply and demand of ES in general terms is a first step towards demonstrating the potential for interlinking multiple databases in a similar manner to create highly sophisticated decision support tools (section 5). Other methods can also be used to explore how ES values change following the implementation of MPA legal status, including participatory approaches, more complex system dynamic model building or a combination of both. Since the scoring method used here is qualitative and arbitrary (and has been introduced by way of an example only), ideally it should be used in a model-building context in which stakeholders and/or participants allocate scores and then together discuss the results[22]. 'Meaning' that is attached to qualitative scores of this kind, and indeed to the empirical results of any system dynamic model, is socially mediated (Purdon 2003; van den Belt 2004). Thus, in interpreting the score results, it is not our intention to concentrate on their numerical value, but rather to focus on their meaning. It must also be remembered that the numbers that are presented are merely symbols being used to communicate concepts (change, in this case)—indeed, a similar result could have been achieved by using arrows, where a high likelihood of change is represented by an upward-pointing arrow, a medium likelihood by a horizontal arrow and a low likelihood by a downward-pointing arrow; and if other scientists, stakeholders or participants scored the same tables, the numerical results would be different. Unfortunately, numbers are prone to taking on a life (or meaning) of their own, which can lead to a fallacy of misplaced concreteness (i.e. mistaking an abstract for a physical reality; Daly 1980).

While this tool is not precise, its merit lies in its ability to allow us to gain a quick insight into the supply and demand of ES, and the gap between these, to establish a proxy of value beyond the limitations of monetary values derived from a RESA. In addition, if this format was used efficiently with multiple groups, a pattern may emerge. Our use of this tool is only an illustration, in a format that would connect well toward decision-support frameworks that use integrated, spatially dynamic models.

4.2 Likelihood of change in ES supply following MPA implementation

Table 31 shows the scores for the likelihood of an increase in ES supply following the implementation of MPA status for the case-study sites. The abiotic supporting and regulating ES have the lowest scores as it was predicted that they would be the slowest to respond to MPA status in terms of increased supply benefits. This is mainly because these services are related to habitat structure (which does not change quickly unless they were dramatically disturbed before the area received MPA status) and linkages with external systems that are not necessarily influenced by local conservation management and/or protection decisions. Similarly, climate regulation as a regulating service is also slow to be affected (Micheli et al. 2008; Ling et al. 2009) and therefore was scored lower than provisioning services such as food provision. The supply of cultural ES were scored highly.

The locations of these case-study sites to some extent determined the likelihood of increased provisioning services, particularly local fish stocks, following the implementation of MPA status. Since these marine habitats are typically diverse and likely to play a role in nurturing fish stocks that are exported to local fisheries, this indirect benefit of MPA status will not necessarily be evident locally. Therefore, research into both ecosystem functioning and socio-economic factors would be required to measure this change empirically and/or qualitatively for each case-study site.

Table 31 raises interesting questions about the role of disturbance (Claudet et al. 2010) in optimising the supply of ES benefits and the impact that shifts in human management regimes might have on something as simple as species diversity. These questions are important because the loss of species diversity (and functional roles) in a marine ecosystem can potentially constrain critical ecosystem processes (Clemente et al. 2010). Although MPA status affords some overall control of these effects, research into depleted fisheries suggests that recovery may depend substantially on the parallel recovery of marine habitat and benthic productivity (Fogarty 2005).

[22] Unfortunately, stakeholder involvement was beyond the scope of this study.

Table 31. Scores for the likelihood of an increase in ecosystem goods and services (ES) supply following the implementation of marine protected area (MPA) status for the case-study sites. 1 = low likelihood, 5 = high likelihood. (Year of implementation in parentheses.)

MEA = Millenium Ecosystem Assessment (2005); PKI = Poor Knights Islands Marine Reserve; EEZ = New Zealand Economic Exclusive Zone; BP = Banks Peninsula Marine Mammal Reserve; Piop = Piopiotahi Marine Reserve; West = Westhaven (Te Tai Tapu) Marine Reserve; Te Angi = Te Angiangi Marine Reserve; Whang = Whangarei Harbour Marine Reserve.

MEA ES CATEGORY	ES CATEGORY	ES EXAMPLE	PKI (1981)	EEZ (1982)	BP (1988)	PIOP (1993)	WEST (1994)	TE ANGI (1997)	WHANG (2006)	TOTAL
Provisioning	Water supply	Purification	2	2	2	1	3	2	3	**15**
	Medicinal resources	Fish oil	3	2	3	2	2	2	1	**15**
	Ornamental resources	Crustacean diversity	3	2	2	3	3	3	3	**19**
	Raw materials	Shellfish	4	2	3	2	3	3	4	**21**
	Food	Productivity	3	3	3	3	3	3	4	**22**
	Genetic resources	Biodiversity	4	3	3	3	3	3	4	**23**
Cultural	Recreation	Diving	3	2	2	3	2	2	1	**15**
	Aesthetic	Ecosystem integrity	3	2	3	4	3	3	4	**22**
	Science and education	Research	4	3	4	3	4	4	4	**26**
	Spiritual and historic	Mauri	4	4	4	3	4	3	5	**27**
Supporting	Hydrological cycle	Evaporation	1	1	1	1	1	1	1	**7**
	Pollination	Mangrove	1	1	1	1	2	1	1	**8**
	Nutrient cycling	Plankton growth	2	2	2	1	1	1	2	**11**
	Habitat	Reef construction	3	2	2	2	3	2	1	**15**
	Net primary production	Fish stocks	4	4	3	3	3	3	3	**23**
Regulating	Climate regulation	DNS (cloud) seeding	1	1	1	1	1	1	1	**7**
	Soil retention	Sedimentation	1	1	1	1	2	1	3	**10**
	Soil formation	Wetland recovery	1	1	1	1	2	1	3	**10**
	Disturbance regulation	Kelp recovery	3	2	2	1	2	3	2	**15**
	Gas regulation	C sequestration	3	3	2	1	2	2	3	**16**
	Waste regulation	Nutrient uptake	3	2	2	2	2	2	3	**16**
	Nutrient regulation	Biological mediation	3	2	2	2	3	3	3	**18**
	Biological regulation	Biol pop regulation*	3	3	3	3	3	3	3	**21**
	Water regulation	Purification	3	3	3	2	3	3	4	**21**
Site total			**65**	**53**	**55**	**49**	**60**	**55**	**66**	**403**

* Biological population regulation.

4.3 Likelihood of changes in ES demand following MPA implementation

The implementation of MPA status is likely to create additional demand for some ES that are related to the enhancement of the marine ecosystem and its role as a provider of highly valued ecological processes, such as carbon sequestration (i.e. habitat formation, biological productivity; Herr & Galland 2009; Rickels et al. 2010), water purification (Alvarez-Vazquez et al. 2006) and regulation. In general, the research theme regarding the demand for ecosystem services remains complex and divided in its approaches.

Table 32 shows the scores for the likelihood of an increase in ES demand following the implementation of MPA status for the case-study sites. As for ES supply, we anticipated that the greatest increase in ES demand would likely be in the cultural area (Ressurreicao et al. 2012), associated with more passive values such as enhanced mauri, research interest, the perceived

Table 32. Scores for the likelihood of an increase in ecosystem goods and sercices (ES) demand following the implementation of marine protected area (MPA) status for the case-study sites. 1 = low likelihood, 5 = high likelihood. (Year of implementation in parentheses.)

MEA = Millenium Ecosystem Assessment (2005); PKI = Poor Knights Islands Marine Reserve; EEZ = New Zealand Economic Exclusive Zone; BP = Banks Peninsula Marine Mammal Reserve; Piop = Piopiotahi Marine Reserve; West = Westhaven (Te Tai Tapu) Marine Reserve; Te Angi = Te Angiangi Marine Reserve; Whang = Whangarei Harbour Marine Reserve.

MEA ES CATEGORY	ES CATEGORY	ES EXAMPLE	PKI (1981)	EEZ (1982)	BP (1988)	PIOP (1993)	WEST (1994)	TE ANGI (1997)	WHANG (2006)	TOTAL
Provisioning	Water supply	Purification	1	1	1	1	3	1	3	**11**
	Medicinal resources	Fish oil	1	1	1	1	1	1	1	**7**
	Ornamental resources	Crustacean diversity	1	1	1	1	1	1	1	**7**
	Raw materials	Shellfish	4	3	2	1	4	2	2	**18**
	Food	Productivity	1	1	1	1	1	1	1	**7**
	Genetic resources	Biodiversity	5	5	5	5	5	5	5	**35**
Cultural	Recreation	Diving	4	1	2	2	2	3	3	**17**
	Aesthetic	Ecosystem integrity	4	3	4	3	4	4	4	**26**
	Science and education	Research	4	4	4	4	4	4	4	**28**
	Spiritual and historic	Mauri	4	4	4	4	4	4	4	**28**
Supporting	Hydrological cycle	Evaporation	1	1	1	1	1	1	1	**7**
	Pollination	Mangrove	1	1	1	1	1	1	3	**9**
	Nutrient cycling	Plankton growth	1	1	1	1	1	1	1	**7**
	Habitat	Reef construction	3	3	3	3	1	3	3	**19**
	Net primary production	Fish stocks	3	5	3	1	1	1	1	**15**
Regulating	Climate regulation	DNS (cloud) seeding	1	1	1	1	1	1	1	**7**
	Soil retention	Sedimentation	1	1	1	1	3	1	3	**11**
	Soil formation	Wetland recovery	1	1	1	1	4	1	2	**11**
	Disturbance regulation	Kelp recovery	4	2	3	1	1	3	4	**18**
	Gas regulation	C sequestration	5	5	5	5	5	5	5	**35**
	Waste regulation	Nutrient uptake	2	1	1	1	3	1	1	**10**
	Nutrient regulation	Biological mediation	3	3	2	3	1	1	3	**16**
	Biological regulation	Biol pop regulation*	1	1	1	1	1	1	1	**7**
	Water regulation	Purification	2	2	2	2	1	2	1	**12**
Site total			**58**	**52**	**51**	**46**	**54**	**49**	**58**	**368**

* Biological population regulation.

role of an MPA in enhancing ecosystem integrity and opportunities for recreational fulfilment associated with diving, snorkelling, etc. Local demand of this kind may also be strongly correlated with the methods used by DOC to implement MPAs and the extent to which there is opportunity for creating partnerships with local communities (Cinner 2007; Christie et al. 2009). Habitat diversity influences the likelihood of increased demand and so, as for ES supply, initial habitat diversity is probably a more important determinant of a change in ES demand than time since MPA implementation. Demand for supporting ES was scored low, in a similar way to supply of supporting ES, due to their invisibility; however, this remains a researchable point. Also, the demand for provisioning services was scored low, as provisioning is generally not the goal of MPAs.

4.4 Likelihood of changes in ES value following MPA implementation

Table 33 presents the calculated difference between the supply of and demand for ES, which provides a qualitative indicator of where the shift in ES value likely occurred once MPA status was implemented at each of the case-study sites. A positive value indicates that supply exceeds demand for an ES, while a negative value indicates that demand exceeds the supply and so a shortage is experienced.

The scoring is only used by way of an example. A much better way to understand shifts in value associated with ES change over time is to explicitly model the marine ecosystem, preferably supported by a process of engaged stakeholders, as explored in section 5.

Table 33. Scores for the likelihood of an increase in ecosystem goods and services (ES) value following the implementation of MPA status for the case-study sites. 1 = low likelihood, 5 = high likelihood. (Year of implementation in parentheses.)

MEA = Millenium Ecosystem Assessment (2005); PKI = Poor Knights Islands Marine Reserve; EEZ = New Zealand Economic Exclusive Zone; BP = Banks Peninsula Marine Mammal Reserve; Piop = Piopiotahi Marine Reserve; West = Westhaven (Te Tai Tapu) Marine Reserve; Te Angi = Te Angiangi Marine Reserve; Whang = Whangarei Harbour Marine Reserve.

MEA ES CATEGORY	ES CATEGORY	ES EXAMPLE	PKI (1981)	EEZ (1982)	BP (1988)	PIOP (1993)	WEST (1994)	TE ANGI (1997)	WHANG (2006)	TOTAL
Provisioning	Water supply	Purification	1	1	1	0	0	1	0	**4**
	Medicinal resources	Fish oil	2	1	2	1	1	1	0	**8**
	Ornamental resources	Crustacean diversity	2	1	1	2	2	2	2	**12**
	Raw materials	Shellfish	0	–1	1	1	–1	1	2	**3**
	Food	Productivity	2	2	2	2	2	2	3	**15**
	Genetic resources	Biodiversity	–1	–2	–2	–2	–2	–2	–1	**–12**
Cultural	Recreation	Diving	–1	1	0	1	0	–1	–2	**–2**
	Aesthetic	Ecosystem integrity	–1	–1	–1	1	–1	–1	0	**–4**
	Science and education	Research	0	–1	0	–1	0	0	0	**–2**
	Spiritual and historic	Mauri	0	0	0	–1	0	–1	1	**–1**
Supporting	Hydrological cycle	Evaporation	0	0	0	0	0	0	0	**0**
	Pollination	Mangrove	0	0	0	0	1	0	–2	**–1**
	Nutrient cycling	Plankton growth	1	1	1	0	0	0	1	**4**
	Habitat	Reef construction	0	–1	–1	–1	2	–1	–2	**–4**
	Net primary production	Fish stocks	1	–1	0	2	2	2	2	**8**
Regulating	Climate regulation	DNS (cloud) seeding	0	0	0	0	0	0	0	**0**
	Soil retention	Sedimentation	0	0	0	0	–1	0	0	**–1**
	Soil formation	Wetland recovery	0	0	0	0	–2	0	1	**–1**
	Disturbance regulation	Kelp recovery	–1	0	–1	0	1	0	–2	**–3**
	Gas regulation	C sequestration	–2	–2	–3	–4	–3	–3	–2	**–19**
	Waste regulation	Nutrient uptake	1	1	1	1	–1	1	2	**6**
	Nutrient regulation	Biological mediation	0	–1	0	–1	2	2	0	**2**
	Biological regulation	Biol pop regulation	2	2	2	2	2	2	2	**14**
	Water regulation	Purification	1	1	1	0	2	1	3	**9**
Site total			**7**	**1**	**4**	**3**	**6**	**6**	**8**	**35**

* Biological population regulation.

5. Valuation tools

Many tools are currently available to assist in value assessment. In this section, we discuss monetary valuation tools when the benefits of ES are perceived and tools that generally emphasise non-monetary benefits, which are often not perceived.

5.1 When ES benefits are perceived

Where people are aware of the existence of ES and the activities that affect them (i.e. the ES are characterised by risk rather than uncertainty[23]), several neo-classical approaches are available for valuing them (or non-market goods in general) (Mitchell & Carson 1989; Bateman et al. 2002). These methods attempt to estimate the economic value of an ecosystem or ecosystem component by summing the use value (direct and indirect) and non-use or passive value (Pearce et al. 1989; Pearce & Turner 1990; Perrings et al. 1995). Direct value can be measured by using the United Nations System of National Accounts (SNA), as it records transactions associated with commodities that are traded on commercial markets. Indirect value is the value derived from ES that support or protect direct-use activities (Perry 2010); for example, the pollination services of insects and bees to produce crops. Non-use value is where people derive value not from the exploitation of nature, but from its existence (Krutilla 1967). For a more detailed discussion of economic concepts of externalities, price and value, see Appendix 1.

The standard valuation approach is based on marginal analysis (i.e. the analysis of changes at the margin of defined constraints and assuming that all else is equal). This often leads to considering incremental changes in the quantity or quality of ES as a result of their use by humans (Mitchell & Carson 1989) and assumes that the substitution of human-made capital for natural capital is always possible. In neo-classical economics, individuals are regarded as insatiable, rational, use-maximisers, who take into account the benefits, costs and risks associated with their actions. The neo-classical subject derives utility from consumption, and producers deliver such utility for profits; and driven by the individual pursuit of self-interest, markets allocate resources efficiently by bringing supply and demand into equilibrium via pricing. Strictly speaking, economic efficiency, which is also termed 'Pareto optimality', is defined as an allocation of resources such that no further reallocation is possible that would provide gains in production or consumer satisfaction to some firms or individuals without simultaneously imposing losses on others. Inherent in this concept are a number of assumptions (Wills 1997), including:

- Individual preferences count and are assumed to be good for the individual
- The economic welfare of society is based on the aggregated economic welfare of its individual citizens
- A change that makes everyone better off and no individual worse off constitutes a positive change in total welfare

Most ES are essential, non-rival (i.e. the enjoyment one person derives does not subtract from the enjoyment of another person) and non-substitutable, and frequently have thresholds beyond which the ecosystems that provide them cannot regenerate. Therefore, Costanza et al. (1997) suggested that the demand curve is like that represented in Fig. 10, where each point on the curve represents the sum of marginal benefits for all beneficiaries. For ES, the demand curve is almost vertical where supply ('critical natural capital stocks') is the minimum necessary to meet human needs. This can be for survival or alternatively can be the minimum required for the ES to regenerate or avoid destructive positive feedback loops, such as in run-away climate change.

[23] Appendix 1 includes a discussion on risk and uncertainty.

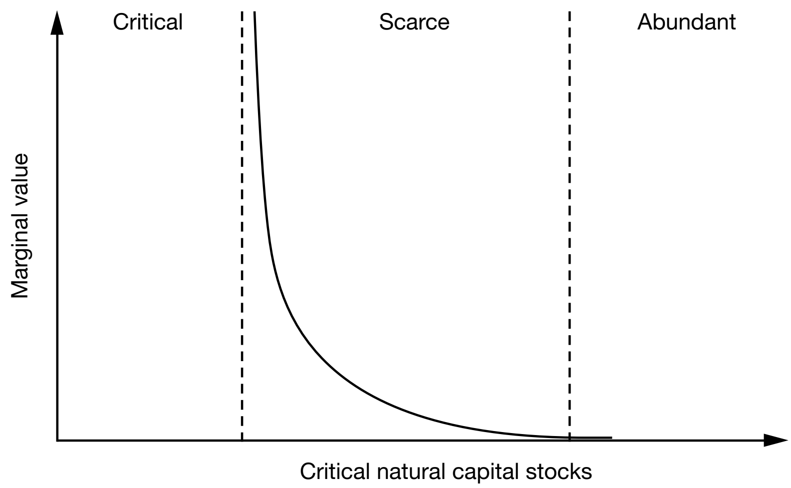

Figure 10. Estimation of the consumers' surplus for an essential, non-rival and non-substitutable ecosystem service. (Adapted from Costanza et al. 1997.)

At this level of 'critical survival' consumption, the ES are priceless, invaluable and their value approaches infinity. At the other end of the scale, ES are so abundant and can provide for all uses, and so have zero marginal value. In today's world, very few ES are so sufficiently abundant that this is the case, however; rather, most are either in the scarce or the critical zone of the demand curve, with values ranging from very invaluable to valuable.

5.1.1 Neo-classical ES valuation methods

Neo-classical methods can be classed as either stated or revealed preference methods. The former include contingent valuation, conjoint analysis, choice experiments, choice ranking and contingent rating, which simulate market conditions using questionnaires/surveys and hypothetical scenarios. The supply side is represented by the interviewer, who offers to provide a certain amount of goods and services at a given price, and the respondent simulates demand by expressing a willingness either to accept or reject the offer. By contrast, revealed preference methods, such as travel cost, hedonic pricing and avoidance cost methods, create demand and supply data from actual, observable, market-based information that is based on individuals' purchases linked to the ES being valued.

Stated preference methods

The contingent valuation method is the most frequently used stated preference method. It works best when the simulated good or service is similar in nature to a marketed good or service. Once the researcher has constructed and presented a range of hypothetical scenarios, a willingness-to-pay and/or -accept question is posed, specifically asking respondents to state their maximum/minimum willingness to pay/accept money in return for the given change in the quantity or quality of the environmental good, service or resource. The values reported by participants depend on the simulation conditions created by the researcher, and the design and administration of the questionnaire (Mitchell & Carson 1989; Arrow et al. 1993; Hanemann 1994; Venkatachalam 2004). A mean 'willingness' is then extrapolated from the survey sample to the wider population to obtain the environmental value (Mitchell & Carson 1989). The popularity of this and other stated preference methods is attributed to its ability to include non-use values of a resource and to accommodate environmental changes that have not yet occurred.

Choice experiment methods utilise carefully designed tasks or alternatives to reveal factors that influence choice (Birol et al. 2006). Of these methods, conjoint analysis involves respondents rating or ranking choices consisting of different levels of different attributes and predetermined price levels (Hanley et al. 2001), while choice analysis involves respondents making specific choices between alternatives with different levels of the same attributes or with different attributes (Hensher et al. 2005). The primary difference between choice experiment and contingent valuation methods is that the former involve trade-offs among choices, whereas in the latter respondents express their willingness-to-pay based on a proposed environmental change. The advantages of choice experiments for valuation include the fact that the marginal values of goods and services are easy to measure; respondents are more familiar with making defined choices than the abstract/hypothetical contingent value payment approach; they are more informative, as they offer individuals multiple choices; and they reduce some of the response problems and biases associated with contingent valuation methods (Louviere et al. 2000; Birol et al. 2006). Both of these approaches can be used to value any environmental resource and also to estimate non-use values. However, choice experiment methods have the additional benefit of being able to estimate specific attributes of a resource rather than just the resource as a whole.

Revealed preference methods

Revealed preference methods assume that the values an individual holds about an ES can be reflected in his/her purchase of a market good to which the environmental good is related. Therefore, the ES itself is not traded, but it can be linked in some way to goods and services that are traded and have market prices. Revealed preference methods can only estimate the value of a resource *in situ* or on site; they cannot measure non-use or passive values.

The travel cost method, which is one of the oldest non-market valuation techniques, is predominantly used to put an economic value on recreational sites, using the travel costs of visiting these sites as a proxy (Seller et al. 1985; Smith et al. 1986; Bockstael et al. 1991). This method is based on actual behaviour and choices, and is relatively inexpensive to carry out. Beyond entry fees for recreational sites, the cost (associated with the trip) incurred in the private goods and services market is used to infer the per-trip value for the site visited. The rationale is that an individual undertakes a visit to a recreational site if the recreational benefits or utility from such a visit are at least equal to the cost of the visit to that site (Ndebele 2009). The visit to the site is treated as a single transaction and travel cost as the price for that transaction (Wilson & Carpenter 1999); and the valuation is based on a demand curve derived from travel costs and number of trips. This method can be used to estimate the economic benefits and costs resulting from changes in access cost for a recreational site, elimination of an existing recreational site, addition of a new recreational site and changes in the environmental quality of a site (Birol et al. 2006). Limitations associated with the method include the difficulty of defining and measuring the opportunity cost of travel time, sample selection, and the fact that analysis is limited to the assessment of an existing situation (Kahneman & Knetsch 1992; Birol et al. 2006).

There are several variants of the travel cost method: the individual travel cost demand method; the zonal travel cost method; the hedonic travel cost method; and the random utility model. The hedonic pricing method is 'based on the hedonic hypothesis that goods are valued for their utility bearing attributes or characteristics' (Rosen 1974: 34) and that consumers view commodities as bundles of attributes that they take into account when determining the price they are willing to pay (Lancaster 1966). This method is often used to estimate the value of a non-market amenity that influences property price (Colby 1989). For example, an estimate of the value of a coastal view can be determined by studying the relationship between similar houses in the same location with and without a coastal view. Statistical data, which are often readily available from official sources, are used to estimate the hedonic price of the individual attributes by regressing observed price of differentiated goods against the attributes of the good (Rosen 1974; Wilson & Carpenter 1999).

Combined stated and revealed preference methods

Combined stated and revealed preference methods unite the desirable features of both approaches: a valuation is based on actual behaviour, as in revealed preference models, and is then extended beyond the current observed state (Hanley et al. 2003). Methods such as contingent behaviour models combine the observation of the current behaviour (e.g. current number of trips to a beach) with behaviour that would occur in a contingent market (e.g. the number of intended trips to the beach if the water quality was suitable for swimming at all times). Stated preference and revealed preference methods have also been combined with deliberative practices to improve validity (Spash et al. 2005).

Benefit-transfer and RESA

The valuation methods discussed above are time consuming and expensive to apply. Consequently, valuation techniques that rely on existing knowledge rather than empirical research are gaining acceptance (Brouwer et al. 2003; Liu et al. 2011). Benefit-transfer uses existing non-market valuation studies from other areas—the 'study sites'—and applies them to the area of interest—the 'policy site'—avoiding the need to carry out empirical studies (Bateman et al. 2000, 2002; Champ & Boyle 2003; Freeman 2003; Alves et al. 2009). Value transfer and function transfer are the two main types of benefit-transfer: value transfers can be a single-point estimate transfer, an average value (or measure of central tendency) transfer, or an agreed-on estimate transfer; by contrast, function transfers can be either a demand function transfer or a meta-analysis regression benefit function transfer.

The process of benefit-transfer is complex and more research is needed to evaluate the extent to which these estimates are transferable across societies where preferences, constraints and institutions differ (Bateman et al. 2000; Champ & Boyle 2003). A number of problems associated with benefit-transfer have been documented, such as difficulty in finding good quality studies of similar situations; insufficient allowance for characteristics to change over space and time; the inability to measure new impacts as measures are based on previous studies (Turner et al. 2003); and the existence of substantial transfer errors (Brouwer 1998; Bateman et al. 2000).

These issues have led to recommendations for the use of benefit-transfer being developed (Loomis & Rosenberger 2006). Since the landmark study by Costanza et al. (1997), several RESAs have been completed, many of which have been based on a simplistic benefit-transfer of the Costanza et al. (1997) unit value for ES.

Although the information generated from a RESA may be approximate, it can provide an indication of magnitude—for example, the relative contribution of ES values compared with gross domestic and/or regional products. This information can signal that substantial value is currently invisible and improved decision-support systems are needed. Loomis & Rosenberger (2006: 344) found 'that qualitative descriptions of benefits rarely offset monetary estimates of costs in a cost benefit comparison … Even a simple benefit-transfer, in this case, may provide an indication of whether the benefits and costs are in the same order of magnitude.' It is important to consider whether a RESA is worth the effort if it cannot be precise—and the answer from a neo-classical perspective may well be 'no'. However, from an ecological economics perspective, the answer may well be 'yes' if RESA is regarded as one of many sources of relevant information for decision-making, and one step in a desired direction. The monetary values generated can contribute to a participatory, stakeholder-involved dialogue to broaden the scope of issues under consideration; and the incorporation of such values can be a small step towards including social fairness as well as ecological sustainability in the debate.

5.1.2 Limitations of neo-classical ES valuation techniques

Neo-classical ES valuation techniques contribute to our awareness of the importance of ecosystems to human wellbeing. However, there are a number of valid criticisms associated with their use (based on van den Belt et al. 2011):

- Methods tend to value a single service, whereas ecosystems generate a bundle of services, many of which are unacknowledged.
- It is not possible to value what we do not understand—and there is a lack of information on the roles and functions of many ecosystems and the ES they provide.
- Once a valuation study is completed, the results are provided to decision-makers who then (ideally) somehow integrate them into market prices or management decisions. However, by that time, it is quite possible that the prices on which the study was based have changed.
- Valuation of ES requires determining the marginal value of ecosystems and the ES they provide. However, marginal analysis is difficult, as working out the cost of loss is dependent on many factors interacting at a number of scales. For example, the loss of 100 km^2 of Amazon forest disrupts the hydrological cycle, soil retention and species habitat at a local scale, and climate regulation at a more global scale (Daily 1997).
- The rights of future generations and the under-privileged are overlooked. Markets at best reflect scarcity for the current generation, and measures of marginal value are appropriate only for the current generation (Georgescu-Roegen 1975; Bromley 1989; Gowdy & O'Hara 1995). Scarcity is likely to mean that future generations will assign different values for all types of goods and services compared with current generations.
- The use of discount rates as used in neo-classical valuations of ES is contentious because environmental quality needs to be measured in a broader way than that expressed by standard financial transactions. Costs and benefits that occur in the future are typically exponentially discounted over time to attain their net present value today. Although many economists argue that a discount rate needs to be included to allow for opportunity costs and future generations being wealthier (Portney & Weyant 1999; Nordhaus 2007), environmental impacts such as climate change are heavily skewed toward the future (Neumayer 2003).
- Complexity and interdependencies mean that deriving valuations is fraught with uncertainty. Valuations often do not include careful analysis, nor do they always communicate the level of uncertainty and ignorance that exists.
- Valuations focus on the ecological effects that are easiest to value because of data availability or available studies, rather than on the full range of ecological values that are essential to maintain ES.
- There are many difficulties associated with the measurement of flows from or toward the environment, and/or the measurement or estimation of changes in these flows and attributing them to a time period (O'Connor & Schoer 2009).
- Aggregation across methods can be problematic. If value estimates are in different units, combining them is not possible without making assumptions. If the methods used have quite different (or unclear) underlying concepts of value or overlaps, aggregation is not possible (EPA 2009). In addition, aggregation over different scales (temporal, geographic or political) also requires clearly communicated assumptions.

5.2 When ES benefits are not perceived

The previous sections introduced the concept of valuing ES using RESA, and considered the neo-classical economic valuation approaches that are frequently used when ES benefits are perceived. This sections is based on the premises that RESA indicates large information gaps and neo-classical economic valuation methods have severe limitations, and discusses how we should proceed when ES benefits are not readily perceived.

An ecological economic approach to valuation highlights the need for synthesis as well as analysis, and an ability to consider trade-offs associated with economic efficiency, equity and fairness, ecological sustainability, stewardship, and cultural and ethical values. In this report, we have chosen to focus on the evaluation of gaps or trade-offs, rather than the precise measurement of value (i.e. valuation) as, to quote Einstein, 'It is better to be roughly right than precisely wrong'—and this is especially true when it is possible to simulate the potential outcomes (i.e. through modelling) and rectify any mistakes (i.e. through collaborative governance and adaptive management) before making any actual changes to a system. We make this distinction between understanding versus predicting value because ecosystems can cross irreversible thresholds into altered states, which affects the ES or benefits that people derive from such ecosystems. Furthermore, ecosystems are complex, nested, dynamic and adaptable systems that do not always lend themselves well to predictions regarding time, scale and the direction of perturbations. Finally, irreversible changes and their consequences for ES provision may occur at different scales (i.e. a local challenge may not be perceived as a challenge from a national or global perspective, and vice versa). Consequently, where ES can be measured through the market, we have placed importance on economic benefits (i.e. monetary values), but where the market is not an efficient mechanism for the allocation of resources, we have placed more importance on the contribution of ES to society in general. This approach requires the incorporation of social science, to reflect the values that people hold and would express *if* they were well informed about the relevant ecological and human wellbeing factors, and *if* these values were then also understood in the context of everything else that may be going on in people's lives.

What follows is a general outline of the range of tools and approaches used in ecological economic evaluation. The specific case studies of section 3 are not considered, but a more detailed discussion of how these methods might be applied to marine spatial planning, management and protection in New Zealand is provided in section 5.3.1. This section is based on a more detailed review of integrated ES modelling by Videira et al. (2011).

5.2.1 Ecological indicators

Ecological indicators are measures of key ecosystem properties that reflect changes in ES by providing information on the direction and possible magnitude of an impact or of an ecosystem's response to stress (Eiswerth & Haney 2001). An important first step to using ecological indicators is selecting appropriate predictive variables—a task that is arguably less complex than defining and implementing an ecological production function (EPA 2009), which needs to reflect how individual indicators are interlinked. Well-selected indicators can capture spiritual, cultural and aesthetic values, which it is often not appropriate to express in monetary terms (Granek et al. 2010). Furthermore, a well-defined indicator that is correlated with a specific ES can be used to rapidly detect and/or predict change in the ES even if it is not quantified—which contrasts with large, complex ecological models, which in the past have been difficult to use for rapid evaluations (Hoagland & Jin 2006). Indicators can be used in situations where no single evaluation scheme would work well over all circumstances, scales and locations (Videira et al. 2011).

5.2.2 Participation and stakeholder involvement

Stakeholder involvement, through group deliberation, facilitation, mediation and negotiation, enhances ES evaluation. As de Groot et al. (2002: 404) explained, '[With its roots in] social and political theory, this valuation approach is based on democratic principles and the assumption that values should not be aggregated from individual preferences but as a result of open public debate'. As mentioned earlier in this report, 'meaning' is socially mediated (Purdon 2003), and participatory approaches enables social influence and consensus to define the value of ES (Cowling et al. 2008). Although science can help make informed judgments, basing evaluations on the personal preferences of scientists or experts, rather than the general public, undermines the usual presumptions that public involvement is central to democratic governance (Berelson 1952; EPA 2009).

We make a distinction between public participation and stakeholder participation, even though members of the public are stakeholders, because public involvement requires a different method from stakeholder involvement. For example, regardless of incentives, publicity and effort, many citizens are excluded either by choice or by the selection process so that such involvement is frequently not inclusive of all relevant interests. Also, value conflicts can make deliberation intractable, so it is not feasible to solely rely on consensus outcomes (Dietz et al. 2005: 363). However, having acknowledged these limitations, virtual environments are increasingly opening up new ways to involve the wider community, new engagement processes are constantly emerging (Margerum 2008) and government by consensus (Costanza & Folke 1997) is currently a priority area for research funding (Videira et al. 2011).

5.2.3 Scientific and cultural knowledge

There will always be trade-offs when managing human-ecological systems. Decision-making around the preferred management option requires factual information that allows clear communication of the potential consequences that each alternative has had and could have on ES. Credible scientific information 'can provide a common set of facts on which to base political negotiations' (Granek et al. 2010: 209). However, the climate change debate is teaching us that science and education can in fact also serve to increase the divide between opposite world views (Bleda & Shackley 2008; Hamilton 2011), with 'facts' being gathered and interpreted through different lenses to arrive at increasingly different conclusions.

The role of science in ES evaluation is not limited to the natural sciences—other types of science are also needed. Integration science (Costanza 2003) plays an important role in understanding co-evolving (human–ecological) systems, and providing input into political and participatory processes (Pienkowski 2009; Murtaza 2011). Political science can identify and build appropriate institutional structures that play a leading role in the governance of ecological systems that are responsible for ES benefits (van den Belt 2004). Social science is increasingly important for understanding the 'demand for ES'; and economics is similarly important, by providing cost-benefit analyses associated with various management options, within appropriate boundaries (see also Appendix 1). In its broadest sense, scientific knowledge associated with evaluating ES represents a continuum of world views.

Māori in New Zealand—and indigenous people in general—also bring cultural knowledge to our understanding of ES, which partly explains why we are interested in ES as the paradigm that is able to create a common language for science and policy.

5.2.4 Multi-criteria analysis (MCA)

Multi-criteria analysis (MCA) is an alternative or complementary approach to evaluation that does not rely on monetary units (Proctor 2001) and is ideally suited to decision-making involving multiple goals or valuation problems (Costanza & Folke 1997). MCA helps to frame a problem in a multidimensional way to achieve a political compromise (Munda et al. 1994; Martinez-Alier et al. 1998). According to Proctor & Drechsler (2006: 72–73):

> *Multi-criteria analysis (MCA) is a means of simplifying complex decision-making tasks that may involve many stakeholders, a diversity of possible outcomes and many and sometimes intangible criteria by which to assess the outcomes. Multi-criteria analysis is an effective technique to identify trade-offs in the decision-making process with the ultimate goal of achieving a most favoured outcome for the stakeholders involved.*

The need to incorporate the perspectives of multiple decision-makers into MCA has led to the development of a process known as deliberative multi-criteria evaluation (Proctor & Drechsler 2006), which combines the MCA decision-making process with a deliberative procedure (the Citizens' Jury) (Yeh et al. 1999). An example of MCA software is 1000Minds[24]. One of the disadvantages of MCA is that it is a static (i.e. snapshot) approach that does not allow for systemic changes and uncertainty. In addition, stakeholders may mistrust it if it is regarded as a technocratic instrument that can be manipulated (Janssen et al. 2001).

5.2.5 Scenarios

Limburg et al. (2002: 409) argued that as 'the force of humanity increases on the planet, ecosystem service valuation may need to switch from choosing among resources to valuing the avoidance of catastrophic ecosystem change'. Decision-making associated with future states requires the use of scenario modelling and planning to understand pressures on ecosystems, particularly since the loss and degradation of ES may limit future options and thus predetermine choices. Scenario planning has been used to good effect in the natural resource sector (Cowling et al. 2008) and was used extensively to explore potential changes in ES by the MEA (2005). Scenario analysis provides a method of valuing alternative pathways into sustainable and desirable futures, and as such forms an essential basis for ecological economic research (Bockstael et al. 1995).

5.2.6 Mapping and modelling

Computer-based modelling assists in thinking about complex integrated datasets and system dynamics (Costanza & Gottlieb 1998; Costanza et al. 1998). Data in the form of maps (Cole 2007) or other modelling formats can describe many aspects of ES, and these tools facilitate dialogues and support decision-making (van den Belt 2004). One of the key strengths of integrated models in particular is that, instead of focusing on a single ES, they can incorporate the best available scientific knowledge of how entire ecosystems function, how they are spatially and hierarchically connected, and how they respond to perturbations over large temporal and spatial scales. Modelling allows us to take into account how ecosystem interconnectedness, system structure and spatial extent change over time (Boumans et al. 2002). However, with all mapping and modelling, there is a trade-off between the capacity to answer broad questions (Costanza & Maxwell 1991; Fitz et al. 1996), where the purpose of the model is to understand an underlying system (Costanza et al. 1993), and the capacity to answer narrow and specific questions (Wackernagel et al. 2002), where the purpose tends to be prediction. During model design, the use and context of the model (i.e. scoping, research or management) are considered (Costanza & Ruth 1997; van den Belt 2004). ES valuations have typically been driven by short-term, locally focused human preferences (Limburg et al. 2002).

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[24] www.1000minds.com/about/about-us (viewed 22 November 2013).

As with all tools and participatory processes, models have their limitations, however. Their technical complexity makes them expensive to build, and their outputs are generally only as reliable as the data they use and the structure imposed by the modellers. Furthermore, the output can be difficult for decision-makers and the public to interpret (although the spatial and visual representation of change in the supply and demand for ES using GIS can provide a helpful indication of economic value and community values; Boumans & Costanza 2007). In addition, it must also be remembered that models are only useful for answering the questions that they are designed to answer. For these reasons, their use in democratic consensus building and decision-making must be carefully considered (van den Belt et al. 1998, 2006; van den Belt 2004). The ability to quickly and flexibly assemble and re-assemble models from existing databases to answer timely questions is increasingly important.

It is also relevant to make a distinction between models that have been developed through inductive reasoning (i.e. where observed data points or initial information are generalised) and deductive reasoning (i.e. a generalised understanding is synthesised to reach a conclusion) for decision support. In essence, inductive models extrapolate data to arrive at a meaningful pattern and are more appropriate for use in a narrowly defined area of investigation. By contrast, deductive models are more appropriate when the integration of a wide set of information is required (such as stakeholder perceptions of demand for ES) and where an understanding of patterns is the starting point for follow-up action. These assessment approaches can be combined to create a toolkit that includes both case studies (benefit-transfer or original) and 'big data' for understanding ES and their values.

In ES research, it is becoming increasingly important to develop the capacity to assemble and re-assemble various forms of data and information to answer complex questions through the use of multiple models, especially when following deductive reasoning. Three frameworks that currently allow this are Multi-scale Integrated Models of Ecosystem Services (MIMES), Integrated Valuation of Environmental Services and Trade-offs (InVEST), and SeaSketch.

Multi-scale Integrated Models of Ecosystem Services (MIMES)

The MIMES framework facilitates case-study analysis through participatory model building, data collection and valuation. It primarily builds on GUMBO—the Global Unified Metamodel of the Biosphere (Boumans et al. 2002)—but is also based on a broad range of earlier multi-scale ES modelling work, including MEA reports (MEA 2005), IMAGE (Integrated Model to Assess the Global Environment) 2.4 (Bouwman et al. 2006) and GLOBIO (Global Biodiversity Model) (Leemans et al. 2007).

MIMES is an ecological economic assessment modelling framework that can be applied at global, regional and local scales over various timeframes. Rather than being 'another model', MIMES can be viewed as an ES-based organising principle or framework. Using an expanding library of databases, models, evolving definitions and conventions, simulation models can be developed with relative flexibility to understand the gap between the supply of and demand for ES. The agility of model construction allows for timely configuring and re-configuring of information, in dialogue with multiple scientific disciplines and stakeholders. Mediated Modelling, i.e. model building *with* rather than *for* people (van den Belt 2004), is the first step and usually results in dynamic but non-spatial integrated models, which can be qualitative or quantitative (van den Belt et al. 2011). This can then be expanded to create spatially dynamic models from which maps of areas that illustrate where 'hotspots' for management opportunities emerge over time can be produced (Crossman & Bryan 2009).

Figure 11 provides a generic overview of how the supply and demand for ES can be interconnected in a causal loop diagram. Natural capital (1) is represented by the biomes included in this report and these biomes supply ES (2), as described in section 3. However, it should be noted that a higher spatial resolution than was used in the RESA in this report can be accommodated through MIMES. More importantly, Fig. 11 illustrates that economic sectors are the beneficiaries of ES supply (3) (see Appendix 3 for an example of ecosystem demand from economic sectors). Through delivering economic services (4), economic sectors increasingly put pressure on natural capital (5) and also require/demand ecosystem services (6) to continue these market-based activities. When the demand for ES (6) is compared to the supply of ES (2), there is a gap (7) (either plenty or too little). This is what we refer to as 'value', as outlined in section 4 of this report. Depending on the size and the direction of this ES gap (7), actions (8) can be taken to maintain or enhance natural capital (1) in its ability to supply ES (2). The demand for ES (6) is greater when the non-market demand for ES (9) is also included—this was only partially achieved by calculating a RESA in this report. Where benefits from ES are perceived, non-market values (9) can be revealed, stated or calculated through 'total economic valuation' case studies (see Appendix 1). Currently, we have a better understanding of natural capital (1) and ES supply (2) than ES demand (6), which is in part determined by people's perceptions. The ES demand is likely to be much larger than is currently perceived or can be perceived through non-market assessments—indeed, we have an inclination (through RESA and other assessments) that the full magnitude of ES demand through non-market demand is huge and many would argue that consequently the value is unquantifiable (see Appendix 1). Therefore, MIMES proposes an integrated framework that is flexible enough to use existing data without ignoring common sense to address knowledge gaps. The perception of the gap between supply and demand of ES (7) should ideally become the focus of participatory processes and governance through adaptive management.

Figure 12 illustrates the relative gap between ES supply and demand over time. Whether we perceive the benefits of ES and therefore the demand for ES or not matters in relation to the supply of ES. Neo-classical economic theory assumes that there would be a static equilibrium through the clearing of market-based supply and demand of goods and services. However, in the case of ES, there are presumed changes over time (i.e. a system dynamic approach to ES supply and demand). Figure 13A and B illustrate the dynamic gap between supply and demand of ES in response to actions taken.

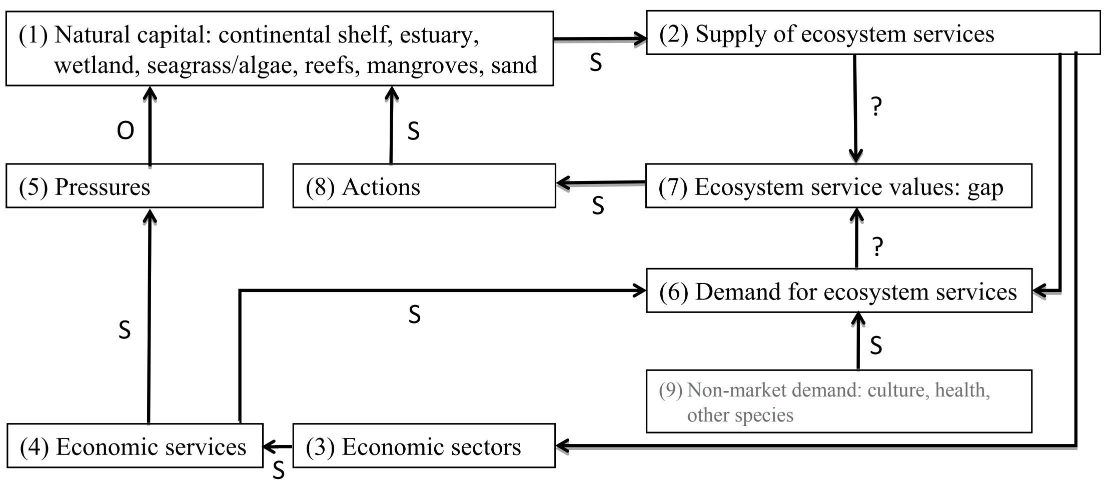

Figure 11. Overview of a MIMES structure as a causal loop diagram. S = same, i.e. the connection moves in the same direction. O = opposite, i.e. the connection moves in the opposite direction. ? = unknown, where the direction depends on a relative direction.

The MIMES framework provides an opportunity to think about value in a multi-scale context. Managers and stakeholders can develop the capacity to flexibly develop models and explore different scenarios, revealing assumptions (including differing world views), and apply valuation methods and concepts for examining local trade-offs in services. Currently, the strength of MIMES modelling (as a deductive approach) is not in the precision of its scenarios but rather in the transparency of the assembly process—equally important to the resulting model is the process and transparency of the assumptions behind such models, as this is where the opportunities for collaborative learning lie. Specifically, MIMES can treat ecosystem conservation as a form of economic development, where outcomes in alternative value systems affect environmental decision-making (de Groot et al. 2002). For example, MIMES can estimate the trade-offs in biodiversity and ecological integrity or the effects of management decisions on the social equity of stakeholders. Confidence in this type of multi-scale simulation model is established by calibrating the results of the simulations (i.e. testing them against observed data) (Boumans et al. 2001) over time and therefore supporting adaptive management.

In MIMES, the economic system harvests large amounts of material and energy from the larger ecological system and discards waste at each phase of a production chain. The state of the human population, knowledge and social institutions (rules and norms) drives the rate of this material and energy flux. In this example, the impacts of human activities on the numerous elements that affect human wellbeing are assessed Three distinct types of value are estimated: the contribution of these elements, activities and impacts to the production of conventional economic goods and services; the contribution of these elements, activities and impacts to our sustainable social welfare system or quality of life; and the difference between service demands and availability to actors involved in different economic sectors across various cultural perspectives and time scales (social equity). These three distinctions are also reflected in a rudimentary format in section 3. MIMES elaborates and interconnects these distinctions through a particular form of production functions (Fig. 14).

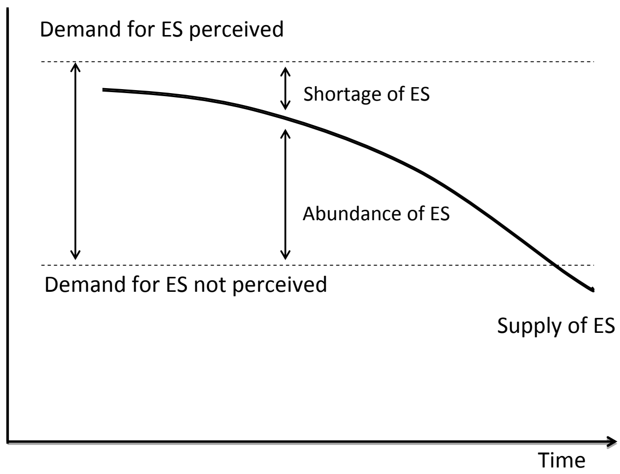

Figure 12. Relative supply and demand of ecosystem goods and services (ES) projected over time.

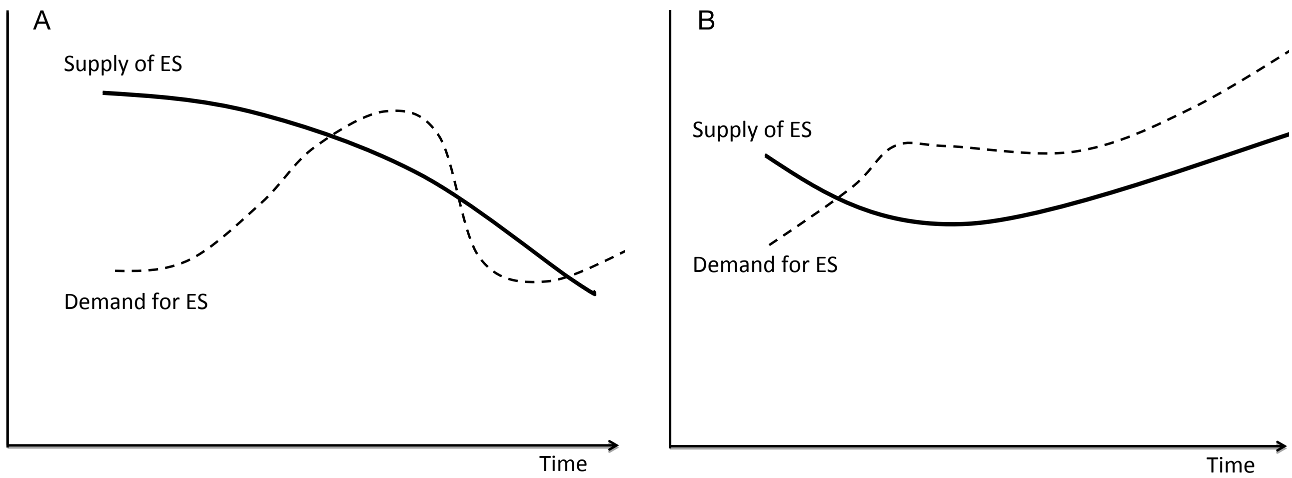

Figure 13. Demand for ecosystem goods and services (ES) shown as A. not influencing and B. influencing the supply of ES.

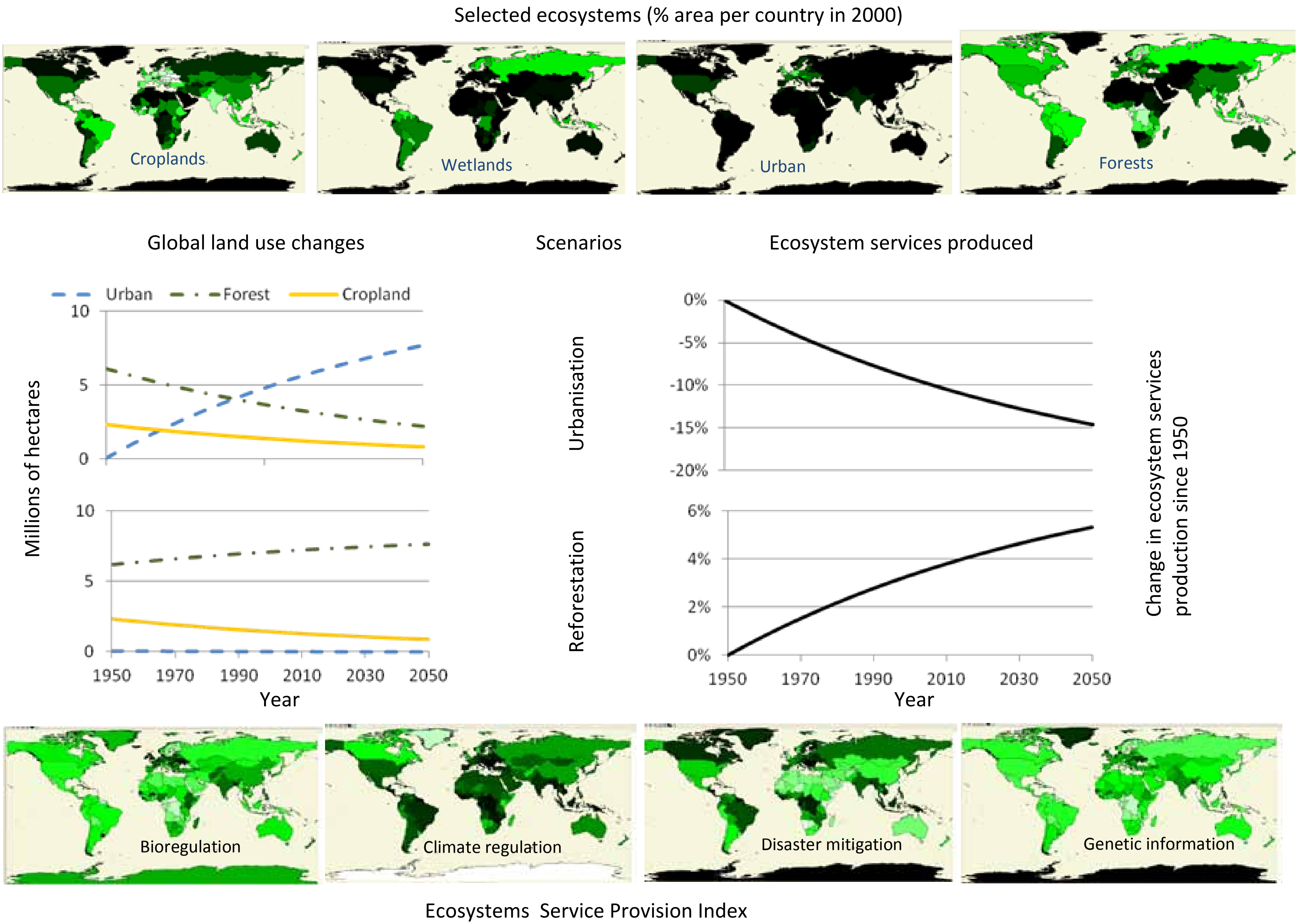

Figure 14. A simulation of a selection of the MIMES variables visually represented in time and space. (Source: Dr Roelof Boumans.)

Integrated Valuation of Environmental Services and Trade-offs (InVEST)

InVEST (Tallis et al. 2012) is a static approach to the integrated valuation of ES, which is less complex and better marketed than MIMES. Decision-makers map ES in a spatially explicit modelling framework that can then be used to assess the trade-offs associated with alternative management choices, and to identify areas where investment in natural capital can enhance social, economic and cultural outcomes of conservation in terrestrial, freshwater and marine ecosystems (Fig. 15). Conservation organisations can use InVEST to align their efforts to protect biodiversity with activities that improve human livelihoods.

InVEST models run as script tools in the ArcGIS 'ArcToolBox' environment (Tallis et al. 2012) and, like all tools, are most effective if decision-making starts with stakeholder consultation. Stakeholders develop spatial 'scenarios' (Goldstein et al. 2010; BernHardt et al. 2012; Dean et al. 2012), which typically include maps of potential future land use and/or land cover, and/or marine habitats and ocean uses. Scenario maps are critical inputs in all InVEST models. InVEST can then estimate how the current location, amount, delivery and value of relevant ES are likely to change in a future development scenario (Kareiva et al. 2011). InVEST not only uses maps as information sources but also produces maps as outputs (Goldstein et al. 2010; BernHardt et al. 2012; Dean et al. 2012).

As in the other models, the spatial resolution of analyses is flexible. Using InVEST iteratively, stakeholders can create new scenarios based on the information revealed by the models until suitable solutions are identified (Tallis & Polasky 2009; Daily et al. 2012). InVEST models are based on simple (RESA-like) production functions that define how an ecosystem's structure and function affects the flows and values of ES. Even though the output is static, InVEST models integrate both the supply and demand aspects (through stakeholder involvement) of ES value (Nelson et al. 2009).

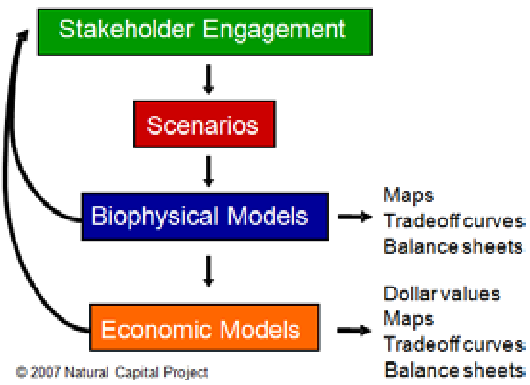

Figure 15. Overview of the InVEST structure. (Source: Daily et al. 2012.)

SeaSketch

SeaSketch (Fig. 16) is a relatively new Google-based tool for collaborative ocean planning and management through scenario development, and includes MPAs, transportation zones, renewable energy sites and more. The advantage of SeaSketch is its ability to allow the online sharing of datasets. However, due to its limited modelling and analytical capability, it cannot yet explicitly model and/or explore changes in marine ES beyond the provision of different datasets from areas of interest. The McClintock Lab (University of California Santa Barbara, http://mcclintock.msi.ucsb.edu/) is creating SeaSketch for worldwide, online use. Users will be able to initiate a project by defining a study region; upload map layers from existing web services; define 'sketch classes', such as prospective MPAs, transportation zones or renewable energy sites; sketch and receive automated feedback on those designs, such as the ecological value or the potential economic impacts of an MPA; and share sketches and discuss them with other users in a map-based chat forum (McClintock et al. 2012).

SeaSketch - Better decisions through global participation

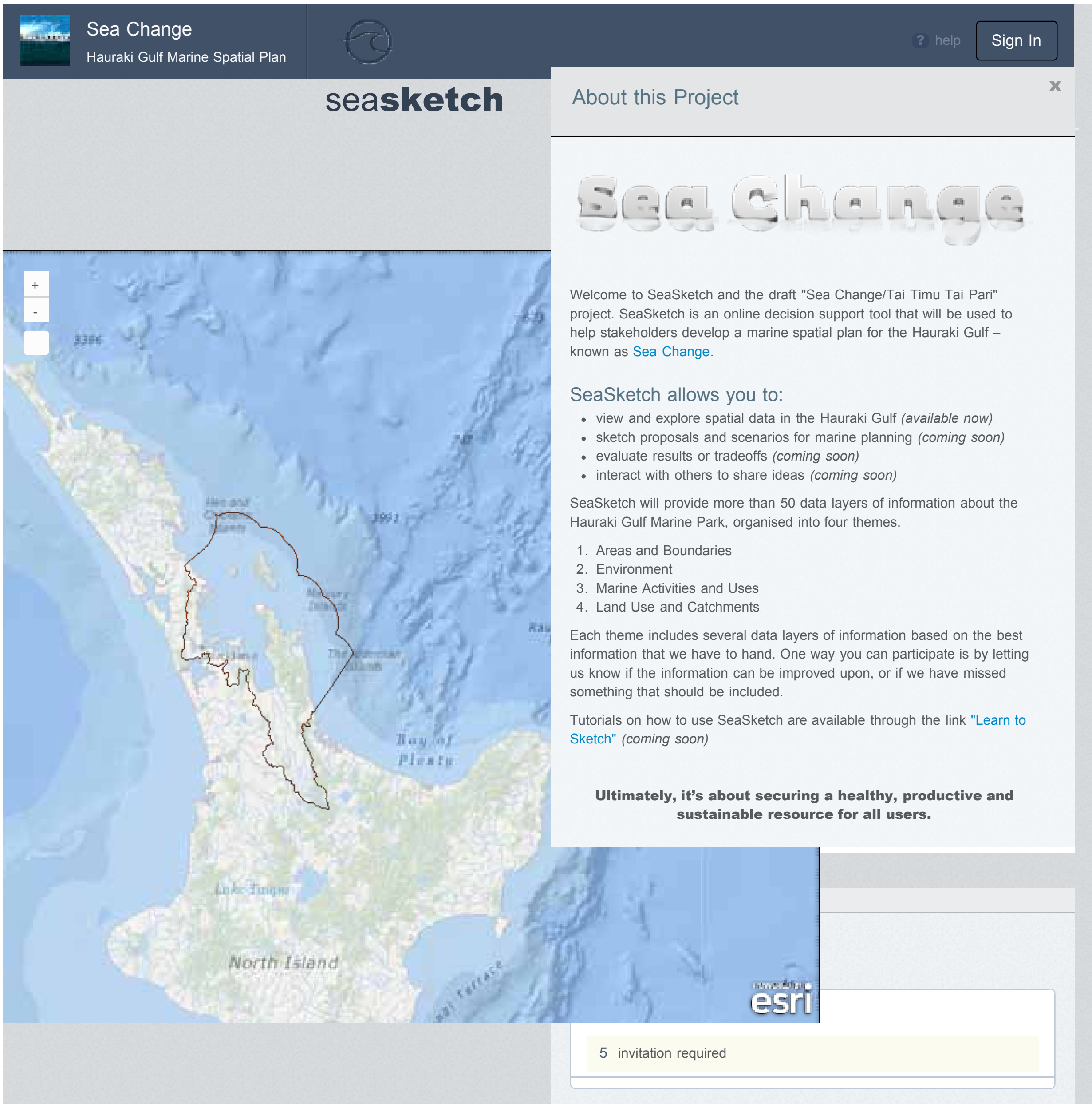

Figure 16. Example of SeaSketch output. (Source: McClintock et al. 2012.)

5.2.7 Payments for Ecosystem Services (PES)

Payments for Ecosystem Services (PES) is a fairly new policy tool requiring those who benefit from ES to pay for their provision and restoration. Wunder (2005: 3) defined PES as a 'voluntary transaction where a well-defined environmental service (or a land use likely to secure that service) is being "bought" by a (minimum one) environmental service buyer from a (minimum one) environmental service provider if and only if the environmental service provider secures environmental service provision (conditionality)'. This tool has received considerable attention in academic literature (Nelson et al. 2010; Arriagada & Perrings 2011) and in on-ground applications (Engel & Palmer 2008; Engel et al. 2008; Clements et al. 2010).

Since ES themselves are often difficult to measure, payments are usually made for adopting land uses associated with the provision of ES. PES can be economically efficient whenever the additional value of services generated by an alternative land use is greater than the costs of adopting that use, including the actual costs of implementation, opportunity costs and the transaction costs of negotiating an agreement. This last point is particularly important because the transaction costs associated with PES can be relatively high. Therefore, in practice, payments are generally based on the costs of implementation rather than the estimated values of the services generated (Wunder 2005, 2007). PES can be implemented either by integrating ES into markets or by institutional arrangements (Engel et al. 2008).

5.3 Applying ES valuation tools to marine management and protection

5.3.1 ES valuation method continuum and decision-making

We propose that the decision-making that occurs as part of the management and protection of marine areas is influenced by two different variables—the relative magnitude of the decision stakes and the uncertainty of the system (i.e. the relative level of uncertainty about which ES trade-offs must be assessed and which decisions made). The ES valuation methods outlined in sections 5.1 and 5.2 sit along a continuum, making them appropriate for different combinations of these two variables (Fig. 17):

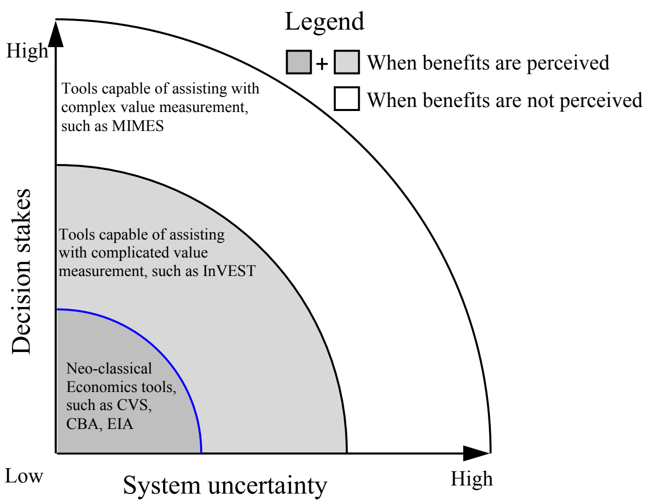

Figure 17. An illustration depicting the continuum of ecosystem services valuation methods as a function of system uncertainty and decision stakes. (Adapted from Funtowicz & Ravetz 1993.)

- **When decision stakes and system uncertainty are low**, it is safe to assume that ES benefits are perceived and so the valuation problem may be characterised as purely a measurement challenge. In a decision-making context of this kind, neo-classical economic tools such as contingent valuation, cost-benefit analysis, economic impact analysis and RESA can provide indicative, albeit incomplete, estimates of perceived value.
- **When decision stakes and system uncertainty are both intermediate in size**, fewer essential ES benefits are perceived and hence the ES valuation method will no longer be solely addressing a measurement problem. Therefore, this combination requires valuation methods such as InVEST and SeaSketch, as these are capable of helping us to organise and interpret

complicated whole-of-system value information, while reducing uncertainty (about value) to lie within upper- and lower-value estimates, for a range of scenarios. Such tools are primarily communication tools that illustrate trade-offs between generality and ease of use versus specificity and flexibility of development. They are relatively easy to implement and communicate but, by virtue of this, are somewhat limited in what they can do (e.g. they do not model dynamic changes over time well).

- **When decision stakes and system uncertainty are both high**, and essential ES benefits are not perceived, a different set of ES valuation modelling tools are needed, which are geared towards efficiently organising data availability (both small and big data) as well as data gaps. In this instance, where ill-informed decisions will have costly consequences, ES valuation is no longer just a measurement problem, but nor is it a complicated problem that can be confidently addressed with low-level scenarios and highly generalised modelling frameworks. Therefore, multi-scale, spatially explicit, integrated modelling frameworks such as MIMES are more appropriate. ES valuation tools of this kind are not only able to deal with system complexity across many spatial and temporal scales, but are also flexible enough to model areas of certainty and uncertainty explicitly by drawing on state-of-the-art theory and computing capabilities, incorporating soft and hard variables that make extensive scenario testing possible. Because such modelling frameworks require more diverse technical expertise than pure GIS-based approaches, model development must be strongly linked with stakeholder and/or participant consensus building—although a MIMES model is surprisingly intuitive for the complexity it offers.

5.3.2 The characteristics of a conservation ES valuation toolkit

A final way to think about the various valuation methods and tools discussed in this report is to match their characteristics with the different management and protection value needs. The important characteristics that should be considered fall into the following dimensions:

- **Economic dimension**—While this report began by discussing monetary valuation, it was our aim to provide a wider concept of 'valuation' beyond 'direct, market-based prices'. Neo-classical economic valuation may include indirect, non-market-based monetary values or an equivalent expression of values that is required for ES valuations. However, Ecological Economics valuation aims to develop integrated tools for decision support, connecting the biophysical supply of ES with the socio-economic-cultural demand for these services. From an Ecological Economics perspective, values are not necessarily stated or revealed, but rather constructed through collaborative learning and development of adaptive capacity to address complex challenges.
- **Social dimension**—All tools are designed to interact with stakeholders or end-users sooner or later, and end-user type is relevant. The inclusion of more end-users in the development of tools is not necessarily better, however, so the trade-off between an increased level of understanding and communication needs to be explicitly considered. The appropriate level of public, stakeholder or end-user involvement is important.
- **Spatial dimension**—Geographic information is increasingly important, and its inclusion is feasible with modern computing and remote-sensing capabilities. With a multitude of GIS layers available, the question soon becomes one of compatibility and comparability. Other key questions include 'Who uses such information in end-user processes, and at what resolution?' and 'How do spatial data link with increasingly advanced analytical and synthesis-oriented tools?'
- **Dynamic dimension**—Understanding changes over time is increasingly relevant. Interlinkages and trade-offs in spatial and social dimensions may need to be made, and syntheses undertaken, to gain insight in the functioning of ecological, economic and social systems.

- **Process dimension**—Adaptive management theoretically includes vision, assessment, planning, implementation and monitoring stages (see Fig. 18) that feed back to allow re-alignment of the vision. The tools presented in this report fall into the assessment phase and may be thought of as being capable of progressively developing from scoping to research to management tools (Costanza & Ruth 1997; van den Belt 2009).

The tools outlined in this report each have their strengths and weaknesses (Table 34), and so selection requires careful consideration. An ES valuation tool's characteristics should be matched with the context, content and process, and the social, spatial, dynamic, economic and adaptive (process) dimensions of a given management and/or protection problem. As Figs 16 & 17 also show, the preferred choice of ES valuation method ultimately involves careful consideration of the trade-offs associated with decision stakes, uncertainty, model capabilities and the need for adaptive management, coupled with collaborative learning and consensus building.

On a final note, the intensity at which a coastal/marine area is used may also determine the appropriate tool or approach. The mix of 'value' propositions for an intensely used area yields different trade-offs than an area with a light human presence or pressures. Therefore, ultimately, valuation requires goal-setting at a societal level.

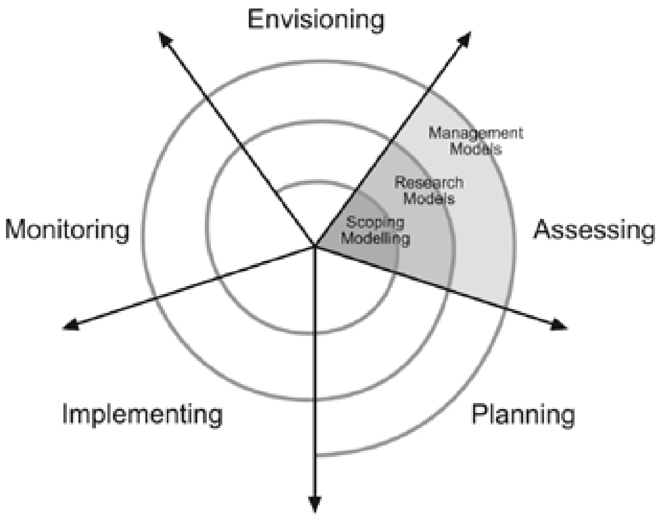

Figure 18. Adaptive management cycle and assessment tools. (Source: van den Belt 2009.)

Table 34. A conservation ecosystem goods and services (ES) valuation 'toolbox'.

PARAMETER	DIMENSION	TOOL			
		RESA	SEASKETCH	INVEST	MIMES
Context	Social	Possible	Yes	Yes	Yes
Content	Spatial	Limited	Yes	Yes	Yes
	Dynamic	No	No	No	Yes
	Economic	Yes	Limited	Yes, where benefits are perceived	Yes, where benefits are not perceived
Process	Adaptive	Scoping	Scoping	Research	Management

6. Conclusions

Valuations of ecosystems in coastal and marine areas are required for different management and protection purposes to ensure that these ecosystems continue to contribute to the wellbeing of New Zealanders. These include capturing the attention of the public and policy makers, contemplating trade-offs, setting priorities, identifying critical ecosystems or ecological resources, and making decisions about protection, remediation, restoration and redevelopment. An ES approach increasingly provides an organising principle for understanding and managing the benefits that people derive from ecosystems. ES valuation can assist in determining and monitoring how to best protect coastal and marine ecosystems and resources, and how to communicate optimal management approaches and services. However, care needs to be taken that monetary valuation outputs are not used as an exchange to determine what (from a narrow economic viewpoint) should be preserved or used as input for consumptive, economic purposes. The complexity of coastal ES means that valuations are subject to high levels of uncertainty and high stakes. The type of valuation tool or approach to use and whether it should be based on monetary value or some other unit of measure is best determined on a case-by-case basis. For example, if the time scale is short, the benefits are well understood, the ecosystem is far removed from a threshold beyond which it will irreversibly change and public involvement is not required, then the neo-classical economic methods, including RESA, may provide a relevant starting point. By contrast, if there are large-scale and long-term implications, including a risk of irreversible changes of the ecosystem, which involve both high levels of uncertainty and multiple stakeholders with varying value positions, a more dynamic multi-attribute approach, such as MIMES, is preferable. Furthermore, the weighing up and balancing of competing interests might require a collaborative, adaptive management, decision-aiding process that is bolstered by relevant science.

Despite its shortcomings, the RESA in this study indicated that marine ecosystems have much value. For example, based on a conservative estimate, the EEZ generates a virtual NZ$403B per year or roughly NZ$92,245 per New Zealander per year. However, this is not a price that should be paid by the highest bidder in the market for use of this ecosystem. RESAs for eight marine protected areas and reserves have also been calculated, indicating the strengths and weaknesses of the available and evolving toolkit for ES. The case studies provide a reference point that can be used to highlight what can be achieved with more advanced ecological economic valuation tools. Rather than claiming a precise dollar value for MPAs, we argue that the value of ES depends on the supply of and demand for ES, which is not always mediated through markets, and we exemplified this notion using high-level matrices. Such matrices can be refined with the aid of modelling tools and socialised through participatory processes.

Given DOC's interest in understanding the implications (in ES terms) of changing an area from management to protection, we suggest that informed decisions will require primary studies (which was beyond the scope of this study) rather than benefit-transfer studies. Ideally, such primary studies will be set in a multi-scale, adaptive management framework following ES-based organising principles.

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9. Glossary

Note: In the following list, the biome definitions are drawn from a variety of published and online sources (e.g. Allen 2005; Holzman 2008; Kuennecke 2008; Quinn 2008; Woodward 2008a, b, 2009).

Algae beds Marine algae are a large and diverse group of unicellular to multicellular organisms, ranging from more simple seaweeds to giant kelp that have been known to grow up to 65 m in length. Algae are morphologically different from terrestrial plants (even though they still use photosynthesis) and complete their life cycles (with the aid of pollination) below water.

Benefit-transfer A valuation method in which the goal is to estimate benefits for one study by adapting an estimate of benefits from another study. This method is often used when it is too expensive and/or there is insufficient time available to conduct an original valuation study (Plummer 2009; Boyle et al. 2010).

Choice experiment This valuation method is based on Lancasterian consumer theory, which proposes that consumers make choices based not on the simple marginal rate of substitution between goods, but on preferences for the attributes of these goods. Choice experiments predict consumers' choice by determining the relative importance of various attributes in consumers' choice processes (Brazell 1998; Garber-Yonts 2000).

Continental shelf This extension of the terrestrial land mass includes the coastal plain that is usually hidden beneath marine waters. These land masses are usually exposed only during glacial periods, when the mean high tide mark moves oceanward due to falling sea levels as a result of the formation of terrestrial ice masses. During the present 'interglacial' period, continental shelves are submerged under relatively shallow seas known as shelf seas and gulfs.

Contingent valuation A valuation method in which people are directly asked their willingness to pay or accept compensation for some change in ecological service.

Damage Cost Avoidance (DCA or DC) This method estimates the costs of ecosystem services based on avoiding damages due to lost services.

Delphi panel This is a structured communication technique in which a forecasting method relies on a panel of experts. This method is based on the idea that group judgments are more legitimate than individual judgments.

Direct use value / direct value Values attributed to the direct utilisation of ecosystem services.

Ecosystem services (ES) The benefits people derive from ecosystems.

Energy analysis This valuation method uses the total biological productivity of ecosystems as a measure of their total contributory value. Primary plant production is the basis for the food chain that supports the production of economically valuable products such as fish and wildlife. This production is converted into an equivalent economic value based on the cost to society to replace this energy source with fossil fuel, as measured by the overall energy efficiency of economic production.

Estuary This biome is a body of coastal water that is supplied by one or more terrestrial rivers or streams and is open to nearby coastal waters. Estuaries are transition zones between freshwater and marine ecosystems, and are thus influenced by marine tides, waves and the influx of saline water, as well as freshwater/sedimentary processes. Due to their high levels of nutrients both in the standing water column and the sedimentary deposits, estuaries rank among the most biologically productive natural habitats on Earth.

Exchange value / value in exchange The quantified worth of one good or service expressed in terms of the worth of another.

Externality In economics, an externality is a consequence of an industrial or commercial activity that affects other parties without this being reflected in market prices, e.g. the pollination of surrounding crops by bees kept for honey.

Full-cost accounting This generally refers to the process of collecting and presenting information about environmental, social and economic costs and benefits/advantages for each proposed alternative. It is equivalent to 'cost effectiveness analysis'. Concrete alternatives for a decision are required. It is a conventional method of cost accounting that traces direct costs and allocates indirect costs, which is sometimes referred to as the 'triple bottom line'.

Gross domestic product (GDP) The value of all final goods and services within the geographic boundaries of a country, uncorrected for non-residents or citizens located abroad.

Gross national product (GNP) The total value of all final goods and services produced within a country in a particular year, plus the income earned by its citizens (including the income of those located abroad), minus the income of non-residents located in that country. GNP measures the value of goods and services that the country's citizens produced regardless of their location. GNP is one measure of the economic condition of a country, under the assumption that a higher GNP leads to a higher quality of living, all other things being equal.

Hedonic price method This valuation method is used to value ecosystems or ecosystem goods and services that directly affect market prices. It is commonly used in analysing variations in house prices that reflect the home owner's willingness to pay for environmental attributes; it can be used to estimate the benefits associated with environmental amenities, such as aesthetics and proximity to recreational locations.

Ignorance Lacking knowledge or information.

Indirect use value / indirect value The value attributed to the indirect utilisation of ecosystem services, through the positive externalities that ecosystems provide.

Intertidal zone This nearshore marine ecosystem, also known as the foreshore, seashore or littoral zone, is the area that lies above water at low tide and under water at high tide (i.e. the area between tide marks). The marine habitat found in this area varies greatly, with its substrate ranging from estuarine mud and sand, to boulders, cobblestones and calcareous material, to rock platform. The biological diversity also varies, from low to very high.

Latent class model A model that is used to evaluate choice behaviour as a function of the visible features of the choices and the hidden heterogeneity in respondent characteristics.

Mangroves This biome is named after its mangrove trees, which are small to medium-sized, and grow in coastal sedimentary habitats from the tropics to some warmer temperate regions. Mangrove forests can be zonal or mixed in species composition. They tend to be sensitive to small adjustments in tidal range and will thus respond to sedimentation by seaward migration. Consequently, mangroves are associated with land-building geomorphological processes. This also means that this biome has a clearly defined plant age structure, with older, buttressed mangrove trees to the rear, and smaller, aerial-rooted trees and shrubs in the intertidal zone. Mangroves can also grow in and along the margins of brackish lagoons that receive saltwater inundation periodically as a result of high tide and/or severe storms.

Marginal analysis The benefit of doing/receiving a little bit more of an activity versus the cost of doing/receiving a little bit more. Marginal analysis tends to focus on incremental rather than step changes because the context of the activity needs to be narrow to reduce influences beyond the analysis.

Market price valuation This valuation method estimates the economic value of ecosystem products or services that are bought and sold in commercial markets. It uses standard economic techniques for measuring the economic benefits from marketed goods, based on the quantity people purchase and the quantity supplied at different prices.

Meta-analysis The process or technique of synthesising research results by using various statistical methods (including regression) to retrieve, select and combine results from previous studies.

Meta-regression A statistical method that is often used to perform a meta-analysis, which tests the relationship between values of *x* (a dependent variable) given the observed values of *y* (the independent variable(s)).

Multi-criteria analysis (MCA) A tool for choosing between alternatives that involve a number of often conflicting goals. It examines how significant aspects of choices are assessed and traded-off by decision-makers.

Multinomial logit model A model that is used to represent choice between two exclusive options; for example, whether a person chooses to drive to work or take a bus. The weakness of this model is that it implies that the choice between any two alternatives depends only on the characteristics of the alternatives being compared, rather than the characteristics of any other group of alternatives.

Neo-classical valuation methods Valuation methods that assume that people display rational and utility-optimising behaviour, and that a scarcity of resources is signalled through markets.

Non-use value Experience of value without the utilisation of an ecosystem. Examples include existence value, which is attributed to the pure existence of an ecosystem; altruistic value, which is based on the welfare that ecosystems may provide for other people; and bequest value, which is based on the welfare that ecosystems may provide for future generations.

Open ocean This biome (which is more technically known as the 'pelagic zone') consists of the theoretical water column extending from the ocean's floor to its surface. It begins at the coastal waters of any terrestrial land mass and its adjacent continental shelf.

Opportunity cost The loss of potential gain from other alternatives when one alternative is chosen.

Passive value Similar to non-use value.

Productivity method This valuation method estimates economic values for ecosystem products or ecosystem goods and services that are bought and sold in commercial markets.

Random utility model This model is used in travel cost, recreation-demand analysis to value features of recreational sites, such as the benefits of improved access to beaches or improved water quality for recreational purposes. The travel cost random utility model analyses a person's choice of one recreation site over other sites, and assumes that the choice depends on the site's features and reveals the person's preferences for those features.

Reef This biome is usually associated with submerged rock structures that are present in marine ecosystems. However, in nautical terminology, the definition of reef is quite broad and can include a rock structure, sandbar or other feature lying 10–12 m or less beneath the surface of marine water.

Regression analysis This statistical method describes the nature of the relationship between two or more variables (a dependent variable and independent variable(s)). The regression equation can then be used to estimate a value based on one or more independent variables.

Replacement costs This valuation method evaluates the loss of a natural system's service in terms of what it would cost to replace that service.

Revealed preference methods These valuation methods are based on the idea that the preferences of consumers can be revealed by their purchasing habits. Two such methods are travel cost method and hedonic price.

Risk The probability or threat of an undesirable or negative occurrence caused by a known vulnerability that may be avoided through pre-emptive action.

Salt marshes / coastal wetland Much like estuaries, these biomes also play an important role in the aquatic food web by facilitating the movement of terrestrial nutrients into coastal waters. Salt marshes are found in the upper intertidal zone between terrestrial land (or sandy beaches) and salty or brackish water. They are dominated by stands of terrestrial, salt-tolerant plants that play an essential role in stabilising and trapping terrestrial sediments. They also assist in buffering and dissipating coastal wave energy. A wetland is a terrestrial area that is permanently or seasonally inundated with water, thus creating a habitat that supports aquatic vegetation. Coastal wetlands form when physical barriers dam water but allow salt-water inundation during abnormally high tide or storm events; for example, sedimentation and the establishment of plants can turn a lagoon into a coastal wetland.

Sand dunes A dune is a hill of sand built either by wind or water flow. Sand dunes generally form in stages and are eventually stabilised by the establishment of plant cover, usually following distinct successional stages. They provide habitat to plants and living organisms. Inland dunes of older age gradually form a distinct topsoil that supports the growth of grassland, shrubland and eventually mature forest. It is difficult to specify the exact location of dunes because they are capable of moving inland, especially during storm events that disturb the stabilising surface vegetation. When sand dune movement results in terrestrial water being dammed, dune lakes, lagoons, coastal wetlands and mangrove swamps form. In this report, dunes are included in the 'sand, beach and dunes' biome.

Seagrass Flowering plants from one of four plant families (Posidoniaceae, Zosteraceae, Hydrocharitaceae or Cymodoceaceae) that grow in marine ecosystems surrounded by saline water. 'Grass' reflects the plants' long and narrow leaves, and their associations, which resemble terrestrial meadows.

Shadow price (SP) This refers to the opportunity cost of an activity or project to a society, and is calculated where the actual price is not known or, if known, does not reflect the real loss made.

Stated preference methods These are market research tools that allow researchers to understand how consumers value different ecosystem goods and services. They involve asking consumers to rate, rank or assess how much they would be willing to pay or accept for a certain product or service. The choices made by consumers then help to determine how they value the particular product or service. Examples of these methods include contingent valuation, conjoint analysis and choice experiment.

Travel cost method This method estimates economic values associated with ecosystems or sites that are used for recreation. Its use assumes that the value of a site is reflected in how much people are willing to pay to travel to the site.

Uncertainty A state of limited knowledge where it is impossible to exactly describe the existing state or one or more future outcomes.

Value in use / use value Values attributed to the direct utilisation of ecosystem services. See also 'Direct use value / direct value'.

Willingness-to-pay In this valuation method, people are asked to state their willingness to pay for specific environmental services, based on a hypothetical scenario.

Appendix 1

A background to neo-classical ecosystem services valuation methods, when value is perceived

Valuation is an anthropocentric process that may, in fact, be pointless when ecosystems are essential and non-substitutable—indeed, some have gone so far as to argue that, because humans cannot exist without ecosystem goods and services (ES), their value approximates infinity (Costanza et al. 1997; Farley 2012). Valuation measures are meaningful only within established boundaries, which, in turn, can be established only by moral and ethical values, rather than by economics alone. There are many valid reasons why we should not place any monetary values on ecosystems and their services (Sagoff 1988; Bockstael et al. 2000; Heal 2000), including the fact that it suggests that money serves as a substitute for value and there is an inherent risk that 'price' will be associated with an exchange value, implying that ES are 'up for sale to the highest bidder'. Moreover, moral values cannot be reduced to cost-benefit analysis or elicited by a contingent valuation survey (see Glossary for definitions of these and other economic terms). Socially fair distribution also enters the debate on monetary 'price' values; for example, future generations are unable to express their preferences in today's market transactions, which means that the determination of today's market 'prices' is biased against their (unknown) needs and circumstances. However, these limitations of monetary valuation should not be used as justification for its total abolition.

The complexities of ES make any scientific and economic estimates of their contribution to human wellbeing highly uncertain. Food is an essential ES that humans cannot do without, yet few would argue against its monetary valuation in the supermarket. Non-monetary valuation also has its limitations. However, it is no longer an option to avoid undertaking explicit valuation or using the results of such valuation when making decisions about ecosystems and ES, due to the rapid, global-scale ecosystem degradation, irreversible transformation and loss that is currently taking place (Vitousek et al. 1986). As Farber et al. (2006: 18) argued, 'Ecosystem management decisions inevitably involve trade-offs across services and between time periods, and weighing those trade-offs requires valuation of some form'. Furthermore, any choice of one valuation method over another involves a value statement because we are expressing a preference, and so 'we cannot avoid the valuation issue because as long as we are forced to make choices, we are doing valuation' (Costanza & Folke 1997: 50). Indeed, assigning monetary value allows comparisons of hard-to-compare entities, with no explicit or implicit commitment to bring ecosystem services to market.

The complex choices that are involved in decision-making need to be made more explicit by engaging in adequate dialogue, and using scientific data and expert opinion where available. The process must allow a decision to be reached whilst also adapting to new information. To date, most decisions concerning resource allocation, and hence the current state of ES, have been driven by market forces and narrow market-based assumptions—a consequence of heavy reliance on market-based valuation methods.

A1.1 Price versus value

To better understand the limitations of monetary valuation, we first consider the role of pricing and, in particular, the distinction between price and value. Most people assume that market prices measure value; however, they do not fully appreciate what is behind a price statement. Economists have long recognised that prices do not necessarily measure the actual contributions of commodities to our welfare. As Adam Smith (1776) pointed out, diamonds contribute little to human welfare, but are very expensive, whereas water is essential to life but is generally quite cheap. This has led economists to distinguish between value in use and value in exchange (or simply exchange value): for example, while the in use value of diamonds is low, their exchange value is high. The value in use of something is a measure of the contribution to our welfare that results from consuming all units, as opposed to the value of consuming the last unit, which is the marginal value.

Arising from these concepts is 'diminishing marginal utility' (Daly & Farley 2004), which, for water, would be applied thus: having achieved the goal of human survival, each additional unit of water consumed has uses that are less and less important (to human wellbeing), with correspondingly lower and lower marginal value (i.e. the benefit of doing/receiving a *little* bit more of an activity versus the cost of doing/receiving a *little* bit more of that activity). Diminishing marginal utility is the marginal value of a commodity that determines its exchange value, or market price, based on the simple question 'How much of one good or service (e.g. diamonds) does one have to give up in exchange for an additional unit of another good or service (e.g. water)?' Neo-classical economists focus almost entirely on marginal values, or prices, which should not be confused with total value in the use of a good or service.

This market model allows for the efficient allocation of resources; however, this is not the only, or even the most important, goal on which human and ecological wellbeing depends (Costanza & Folke 1997). If the achievement of other goals, such as social fairness, ecological sustainability and cultural integrity, are also desired, then determining the best allocation of resources is less straightforward. Efficient allocation is not necessarily fair or sustainable (Daly 1992). Therefore, what is needed is a new definition of the notion of 'utility' that is applicable across all scales, from the individual to the global ecosystem level. To understand value in a broader, whole-of-system and intergenerational context of this kind, it is necessary to move beyond valuation methods that are based solely on market pricing (Limburg et al. 2002) and, where possible, make appropriate accounting adjustments when the use of price-based valuation methods cannot be avoided (Saez & Requena 2007).

A further problem with the market-price model is that the full spectrum of the costs of economic activity may not be revealed or fully taken into account in producer or consumer decisions. When this situation exists, it results in less-than-optimal outcomes for society due to what economists call externalities (Bithas 2011).

A1.2 Externalities

All economic activities involve externalities (Bartolini & Bonatti 2002), which are the costs or benefits of an economic activity (typically production, consumption) that impact on others who are not involved in the activity and who receive no compensation (Martinet & Blanchard 2009). Externalities can be positive or negative.

Economic production requires the physical transformation of ES provided by nature. Many of these same ES also serve as the structural building blocks of ecosystems across local, regional and global levels of scale (Gustafsson 1998). Thus, ES are degraded or lost when natural resources are converted to economic products, and their loss is an externality that is not accounted for. Likewise, energy is required for economic production, and a major source of energy is fossil fuels. The burning of fossil fuels to power production and consumption processes creates pollutants that may negatively degrade the ecosystems from which we derive ES (Soderholm & Sundqvist

2003). Even non-consumptive energy production, such as hydroelectricity generation, impacts (both positively and negatively) on ES such as recreation, habitat provision and water quality as a result of eutrophication from reduced water flows and temperature increases.

It is important that the full costs associated with economic activities are understood and quantified when calculating market prices. However, there are challenges with full-cost accounting when seeking to internalise external costs, as the tools that are currently available are limited. Furthermore, the full range of behaviours of ecosystems may not yet be fully understood (Costanza et al. 1992) and, as for any quantification, there will be varying degrees of uncertainty (Cook & Heinen 2005). More 'cost' detail is not necessarily the only solution to the externality problem—however, understanding system structure and interconnections may well be of greater benefit.

A1.3 Uncertainty

Uncertainty exists when the possible outcomes of an activity are known but the probabilities of those outcomes are not (Knight 1921). Uncertainty hinders our ability to accurately estimate monetary values (Winkler 2006) and to communicate the quality of scientific data that exist (Costanza et al. 1992). Uncertainty is different from risk—with risk, both the outcomes of an activity and the probability of those outcomes are known, allowing economists to convert risk into a certainty equivalent (i.e. a minimum willingness to pay for or accept compensation for risk is used by the insurance industry). By definition, uncertainty cannot be converted into certainty equivalents and there are no clear methods for incorporating it into quantitative value estimates (Costanza & Cornwell 1992). At the greatest extreme, ignorance exists when not even the possible outcomes of an activity are known (Hueting & Reijnders 1999).

Evolutionary processes are inherently unpredictable, as is major technological change (Faber et al. 1998). For example, if we seriously degrade coastal ecosystems, leading to the loss of biodiversity, can they adapt over time? Or, if we wipe out critical ecosystem functions, can new technologies replace them (Stern 1997)? Even the best-informed scientists struggle to understand what ES ecosystems generate, how they generate them, how they are affected by economic activities and how the various services interact. All too often we only learn about these once the capacity to generate an ES has been seriously degraded or destroyed (Vatn & Bromley 1994; Farley 2008).

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Appendix 2

GIS feature-class categories for ecosystem goods and services biomes

Table A2.1. Ecosystem goods and services (ES) biomes used in this report aligned with GIS feature classes from the Northland Marine Biological Habitat GIS layer. MHT = mean high tide.

ES BIOME	DEPTH	HABITAT TYPE	EXPOSURE
Continental shelf	Deep	Gravel	Exposed
			High current
		Mud	Moderate
			High current
		Sand	Exposed
			High current
		Volcanic	Exposed
Estuary/lagoon/intertidal	Intertidal	Beach	Exposed
			Moderate
			Sheltered
			Estuarine env.
			High current
		Rocky shore	Exposed
			Moderate
			Sheltered
			Estuarine env.
			High current
		Mudflat	Moderate
	Shallow	Gravel	Exposed
			Moderate
			Sheltered
			Estuarine env.
			High current
		Mud	Sheltered
			Estuarine env.
			High current
		Estuarine	Estuarine env.
		Reef	Estuarine env.
		Sand	Exposed
			Moderate
			Sheltered
			Estuarine env.
			High current
		Volcanic	Exposed
Mangrove	Above MHT	Biogenic	Exposed
	Intertidal	Biogenic	Moderate
Open ocean	>1000 m	Mud	Exposed

Continued on next page

Table A2.1 continued

ES BIOME	DEPTH	HABITAT TYPE	EXPOSURE
Reef	Deep	Reef	Exposed
			High current
	Shallow	Reef	Exposed
			Moderate
			Sheltered
			High current
	500–1000 m	Reef	High current
	200–500 m	Reef	Exposed
Salt marsh	Biogenic > MHT	Biogenic salt marsh	Estuarine env.
	Estuarine > MHT	Biogenic salt marsh	Estuarine env.
Seagrass/algae bed	Shallow	Biogenic rhodoliths	Moderate
	Biogenic > MHT	Biogenic seagrass > MHT	Estuarine env.
	Intertidal	Biogenic seagrass	Estuarine env.
Sand, beach and dunes	Above MHT	Sand, beach and dunes	Exposed

Table A2.2. Ecosystem goods and services (ES) biomes used in this report aligned with GIS feature classes from the Motukaroro Marine Biological Habitat GIS layer.

ES BIOME	FEATURE CLASS	HABITAT TYPE	DEPTH
Seagrass/algae bed	smw	Shallow mixed weed	Subtidal
	rcf	Tangleweed forest	Subtidal
	re	Ecklonia forest	Subtidal
	ct	Coralline turf	Subtidal
Estuary/lagoon/intertidal	si	Sand	Intertidal
	sri	Mixed sand rock	Inter/subtidal
	ri	Rock	Intertidal
	s	Sand and cobble	Inter/subtidal
Continental shelf	sr	Mixed rock and sand	Subtidal
	cob	Cobble	Subtidal
	ru	Urchin barrens	Subtidal
Reefs	rd	Reef deep	Subtidal
	srd	Mixed sand rock deep reef	Subtidal

Table A2.3. Ecosystem goods and services (ES) biomes used in this report aligned with GIS feature classes from the Gaps Marine Biological Habitat GIS layer. MHT = mean high tide.

ES BIOME	DEPTH	HABITAT TYPE	EXPOSURE
Continental shelf	Deep	Mud	Exposed
			Moderate
			High current
		Sand	Exposed
			Moderate
			High current
		Gravel	Exposed
			High current
	Shallow	Sand	Exposed
			Moderate
			Sheltered
			Estuarine env.
			High current
		Mud	Moderate
			Sheltered
			Estuarine env.
			High current
		Reef	Estuarine env.
Estuary/lagoon/intertidal	Intertidal	Mudflat	Sheltered
			Estuarine env.
		Rocky shore	Exposed
			Estuarine env.
			High current
		Beach	Estuarine env.
		Shingle	Sheltered
Reef	Shallow	Reef	Exposed
			Moderate
			Sheltered
			Estuarine env.
			High current
	Deep	Reef	Exposed
		Mud	High current
Sand, beach and dunes	Intertidal	Beach	Exposed
			Moderate
			Sheltered
	> MHT	Sand, beach and dunes	Exposed

Appendix 3

Classification of ecosystem goods and services

Ecosystem goods and services (ES) disaggregated to show the difference in detail between conventional ES categories and values (MEA 2005) and ES supply based on economic sectors. Alignment between ES supply and United Nations System of National Accounts (SNA) sectors was provided by Dr Garry McDonald, Market Economics Ltd, Auckland.

ES CATEGORY	MEA VALUE	ES SUPPLY	ES DEMAND FROM SNA SECTORS
Supporting	Nutrient cycling	In/organic—Carbon	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
		In/organic—Oxygen	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
		In/organic—Nitrogen	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
		In/organic—Hydrogen	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
		In/organic—Sulphur	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
		In/organic—Phosphorus	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
	Net primary production	Phytoplankton	Fishing
		Fish stocks	Fishing
		Marine mammals	Fishing
		Decomposers and filter feeders	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
	Pollination and seed dispersal	Mangrove	N/A
		Marine species (sexual reproduction)	Fishing
		Marine species (asexual reproduction)	Fishing
		Intertidal urchin dispersal	Fishing
	Habitat	Sand dune	N/A
		Intertidal	N/A
		Estuarine	N/A
		Lagoon	N/A
		Shallow sand	N/A
		Shallow mud	N/A
		Shallow stone/rock	N/A
		Shallow reef	N/A
		Deep sand	N/A
		Deep mud	N/A
		Deep stone/rock	N/A
		Deep reef	N/A
		Drop-off zone	N/A

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Appendix 3 continued

ES CATEGORY	MEA VALUE	ES SUPPLY	ES DEMAND FROM SNA SECTORS
[Supporting contd.]	[Habitat contd.]	Continental shelf	Fishing
		Open ocean	Fishing
		Infrared absorption	N/A
	Hydrological cycle	Rainfall	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing; industry
		Buffering (wetlands, dune lakes, lagoons)	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging
		Mixing fresh and salt water	
		Water storage	All sectors using water
		Sediment trapping	Mining; quarrying
Regulating	Gas regulation	Carbon dioxide (photosynthesis)	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing; industry; households
		Methane gas	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing; industry; households
		Ozone	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing; industry; households
		Nitrous oxide	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing; industry; households
	Climate regulation	Ocean temperature	All climate-dependent sectors
		Heat transfer (ocean to atmosphere)	All climate-dependent sectors
		Water evaporation	
		DNS seeding	
	Disturbance regulation	High energy wave protection	All sectors located near coastline
		Sediment trapping	All sectors located near coastline
		Dune vegetation cover	All sectors located near coastline
		Sand dune building	All sectors located near coastline
		Abiotic/biotic habitat structure	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming; forestry and logging; fishing
		Exotic marine animal species invasions	Fishing
	Biological regulation	Predators—marine birds	Fishing
		Predators—marine mammals	Fishing
		Predators—marine fish	Fishing
		Physical disturbance (including temperature, salinity)	Fishing
		Density feedback	Fishing
		Biological compensation	Fishing
		Spatial effects	
		Migration	

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ES CATEGORY	MEA VALUE	ES SUPPLY	ES DEMAND FROM SNA SECTORS
[Regulating contd.]	Water regulation	Tidal ebb and flow (water circulation)	Fishing
		Dissipation of wave energy	Fishing
		Mixing of fresh and salt water	Fishing
		Water purification (filter feeders)	Fishing
	Soil retention	Estuarine sediment de-acceleration	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		Coastal wetland filtering	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
	Soil formation	Estuarine sediment	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		Lagoon sediment	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		Shallow/deep mud formation	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		River plume formation	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		Bioturbation	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
	Waste regulation	Effluent dilution	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		Effluent biological remediation	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		Filter feeding extraction of nutrients	Horticulture and fruit growing; livestock and cropping farming; dairy cattle farming; other farming
		Storage of heavy metal content	Mining; quarrying
		Pollution detoxification	All sectors indirectly
	Nutrient regulation	Ocean salinity buffering	All sectors indirectly
		Ocean PH adjustment	All sectors indirectly
		Macro-nutrient buffering	All sectors indirectly
		Micro-nutrient buffering	All sectors indirectly
Provisioning	Water supply	Fresh water	Water supply
		Saline water	Petroleum and industrial chemical manufacturing
		Water storage	Water supply
		Transportation	Water and rail transport
		UV filtering (surface water)	All sectors indirectly
	Food	Plankton	Fishing
		Kelp	Fishing
		Sea urchin	Fishing
		Pāua (*Haliotis* spp.)	Fishing
		Mussels	Fishing
		Pipi (*Paphies australis*)	Fishing

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Appendix 3 continued

ES CATEGORY	MEA VALUE	ES SUPPLY	ES DEMAND FROM SNA SECTORS
[Provisioning contd.]	[Food contd.]	Toheroa (*Paphies ventricosa*)	Fishing
		Lobster	Fishing
		Snapper (*Pagrus auratus*)	Fishing
		Blue cod (*Parapercis colias*)	Fishing
		Kingfish (*Seriola lalandi*)	Fishing
		Pigfish (*Bodianus unimaculatus*)	Fishing
		Sandager's wrasse (*Coris sandayeri*)	Fishing
		Scorpion fish	Fishing
		Trevally (*Caranx ignobilis*)	Fishing
		Flounder	Fishing
		Pōrae (*Nemadactylus douglasii*)	Fishing
		Crabs	Fishing
		Algae, microalgae	Fishing
	Raw materials	Polysaccharides	Fishing
		Agricultural feedstock (seaweeds)	Fishing
		Compost (seaweed)	Services to agriculture, hunting and trapping
		Chitin (crab shells)	
		Sand, gravel and crushed rock	Mining; quarrying
		Dissolved minerals	Mining; quarrying
		Feathers	Textile and apparel manufacturing; cultural and recreational services
		Microalgae	Petroleum and industrial chemical manufacturing
	Genetic resources	Flavours	Other food manufacturing
		Fragrances	Petroleum and industrial chemical manufacturing
		Enzymes and reagents	Petroleum and industrial chemical manufacturing
		Genetic libraries	Business services; education
		Molecular libraries	Business services; education
		Biodiversity	Business services; education
		Agriculture and aquaculture	Fishing
		Food	Fishing
		Cosmetics	Petroleum and industrial chemical manufacturing
		Ecotoxicology	Business services
		Bioremediation	Business services
		Biofuel production	Petroleum and industrial chemical manufacturing
		Genetic engineering	Business services; education
	Medicinal resources	Pharmacology and human health	Health and community services; petroleum and industrial chemical manufacturing
		Fish oils (Omega 3)	Health and community services; petroleum and industrial chemical manufacturing
		Urchins	Health and community services; petroleum and industrial chemical manufacturing
		Phytoplankton	Health and community services; petroleum and industrial chemical manufacturing
		Kelp	Health and community services; petroleum and industrial chemical manufacturing

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Appendix 3 continued

ES CATEGORY	MEA VALUE	ES SUPPLY	ES DEMAND FROM SNA SECTORS
[Provisioning contd.]	Ornamental resources	Shells	Furniture and other manufacturing
		Drift wood	Furniture and other manufacturing
		Dried kelp	Furniture and other manufacturing
Cultural	Recreation	Sea kayaks	Cultural and recreational services
		Pleasure boating	Cultural and recreational services
		Dive boats	Cultural and recreational services
		Divers	Cultural and recreational services
		Swimming	Cultural and recreational services
		Wading	Cultural and recreational services
		Snorkelling	Cultural and recreational services
		Swimming/wading	Cultural and recreational services
	Aesthetic	Underwater film making	Cultural and recreational services
		Reef and rock pool exploration	Cultural and recreational services
		Observing mammals (e.g. whale watching)	Cultural and recreational services
		Observing marine birds	Cultural and recreational services
	Science and education	Marine surveys	Business services; education
		Eco-tours	Cultural and recreational services
		Local school projects	Education
		Map making and spatial depiction	Business services
		Experiments	Business services; education
	Spiritual and historic	Mauri	N/A
		Atua domains	N/A
		Meditation/reflection	N/A
		Source of inspiration	N/A
		Object lessons	N/A
		Kaitiaki	Cultural and recreational services

References

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Appendix 4

Full data providing the value estimates in NZ$$_{2010}$

Table A4.1. Acronyms used in the benefit-transfer data table (Table A4.2).

ACRONYM	EXPLANATION	ACRONYM	EXPLANATION
AE	Accounting estimate	MA	Meta-analysis
AM	Assessment model	MCA	Multi-model criteria analysis
AU	Area unit	MCE	Multiple choice experiment
BT	Benefit transfer	MCV	Mean compensating variation
CBA	Cost benefit analysis	MNL	Multinomial logit model
CE	Choice experiment	MP	Market price
CL	Conditional logit model	MR	Meta-regression
CNV	Conservation value	MV	Marginal value
CS	Consumer surplus	NLM	Nested logit model
CV	Contingent valuation	NMNL	Nested multinomial logit model
Dn	Donation	NPV	Net present value
DCA	Damage cost avoidance	NRUM	Nested random utility model
DCV	Dichotomous contingent valuation	OECV	Open-ended contingent valuation
DCVM	Demand and contingent valuation models	OV	Option value
DE	Damage estimate	PF	Production function
DFM	Discrete factor method	PM	Productivity method
DP	Delphi panel	PSN	Person
DV	Direct value	R	Regression
EA	Energy analysis	RA	Regression analysis
EC	External costs	RC	Replacement costs
EDF	Expected damage function approach	RM	Referendum model
EP	Export price	RPT	Revealed preference technique
EV	Existence value	RUM	Random utility method
FR	Fishery rent	RUTCM	Random utility travel cost method
FSA	Fisheries Statistical Area	SC	Substitution cost
HH	Household	SP	Shadow price
HP	Hedonic price methods	SPT	Stated preference technique
HPF	Household production function	TC	Travel cost method
IV	Indirect value	TLA	Territorial local authority
JM	Joint model	UV	Use value
LCM	Latent class model	WTP	Willingness-to-pay

Table A4.2. Estimated value for each ecosystem good and service (ES) for each biome of relevance to the case studies. See Table 1 for the full names of the ES and Table A4.1 for the full names of the methods used (abbreviated here for space). A= average, L = lowest value, H = highest value.

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
Open ocean		Median	AE	US$252 (90–415)	/ha/yr	Global	Costanza et al. 1997	US$$_{1994}$
	Supporting	Nutri. cycl.	RC	US$118 (62–174)	/ha/yr	Global	Costanza et al. 1997	US$$_{1994}$
	Regulating	Gas regul.	DV	US$38 (0.61–76)	/ha/yr	Global	Costanza et al. 1997	Marine CO_2 uptake (US$$_{1994}$)
				US$0.03	/ha/yr	Global	Costanza et al. 1997	Methanogenesis (US$$_{1994}$)
		Bio-regul.	RC	US$5	/ha/yr	Global	Costanza et al. 1997	Biological control (US$$_{1994}$)
	Provisioning	Food	MP	US$15	/ha/yr	Global	Costanza et al. 1997	Food production (US$$_{1994}$)
		Raw mat.	DV	US$0.08	/ha/yr	Global	Costanza et al. 1997	Limestone formation (US$$_{1994}$)
	Cultural	Aesthetic	DV	US$76 (7–145)	/ha/yr	Global	Costanza et al. 1997	US$$_{1994}$
Continental shelf		Median	AE	AU$2,895	/ha/yr	Australia	Blackwell 2005	AU$$_{2005}$
				US$1,610 (931–2,289)	/ha/yr	Global	Costanza et al. 1997	US$$_{1994}$
	Supporting	Nutri. cycl.	RC	US$1,431 (752–2,110)	/ha/yr	Global	Costanza et al. 1997	US$$_{1994}$
	Regulating	Bio-regul.	MP	US$39	/ha/yr	Global	Costanza et al. 1997	Biological control (NZ$$_{1994}$)
	Provisioning	Food	MP	US$68	/ha/yr	Global	Costanza et al. 1997	Food production (NZ$$_{1994}$)
		Raw mat.		US$2	/ha/yr	Global	Costanza et al. 1997	NZ$$_{1994}$
	Cultural	Cultural		US$70	/ha/yr	Global	Costanza et al. 1997	NZ$$_{1994}$
Estuary/lagoon/ intertidal		Median	AE	AU$41,055	/ha/yr	Australia	Blackwell 2005	AU$$_{2005}$
				US$22,832 (12,150–33,833)	/ha/yr	Global	Costanza et al. 1997	NZ$$_{1994}$
	Supporting	Habitat	SPT	US$64	CS/trip	USA	Whitehead et al. 2000	Current quality (US$$_{1995}$)
			MP	US$131	/ha/yr	Netherlands	Costanza et al. 1997	Habitat (NZ$$_{1994}$)
		Nutri. cycl.	RC	US$21,100 (11,100–31,100)	/ha/yr	Global	Costanza et al. 1997	NZ$$_{1994}$
		NPP	EA	US$141.70	/ha/yr	USA	Costanza et al. 1997	Primary production (NZ$$_{1994}$)

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Estuary/lagoon/ intertidal contd.]	Regulating	Water regul.	CV	FF 215	/HH/yr	Brest, France	Legoffe 1995	Improved water salubrity (1993 data)
		Nutrient regul.	CV	FF 160	/HH/yr	Brest, France	Legoffe 1995	Eutrophication avoidance (1993 data)
		Gas regul.	PM	US$2.56M	FR/yr	USA	Smith & Crowder 2011	30% N reduction for blue crab (*Callinectes sapidus*) (US$$_{1994}$)
		Disturb. regul.	DCA	US$567	/ha/yr	Netherlands	Costanza et al. 1997	Damage prevention (US$$_{1994}$)
				US$78	/ha/yr	Global	Costanza et al. 1997	Biological control (US$$_{1994}$)
		Bio-regul.	CE	NZ$4.8M	/yr	New Zealand	Bell et al. 2008	Invasive crab predation (NZ$$_{2007}$)
	Provisioning	Food	MP, DV	US$521 (30–1,331)	/ha/yr	Global	Costanza et al. 1997	Mussel culture (US$$_{1994}$)
		Raw mat.	MP	US$25	/ha/yr	Netherlands	Costanza et al. 1997	Sand shells (US$$_{1994}$)
	Cultural	Recreation	MP	US$567	/ha/yr	Netherlands	Costanza et al. 1997	Non-consumptive (US$$_{1994}$)
		Reg. inc.		US$195	/ha/yr	Italy	Costanza et al. 1997	Hunting/fishing (US$$_{1994}$)
			CE	NZ$3.2M	/yr	New Zealand	Bell et al. 2008	Invasive alien crab (NZ$$_{2007}$)
		Sci. & educ.	WTP	US$34.02	/ha/yr	Netherlands	Costanza et al. 1997	Scientific use (US$$_{1994}$)
		.	MP	US$24.57	/ha/yr	Netherlands	Costanza et al. 1997	Scientific use (NZ$$_{1994}$)
Salt marsh/ wetland		Median		US$16,854	/ha/yr	USA	Costanza et al. 1997	NZ$$_{1994}$
	Supporting	Maint. fish.	PM	US$6,471	/acre	USA	Bell 1997	Capitalised value (US$$_{1984}$)
				US$981	/acre	USA	Bell 1997	Capitalised value (US$$_{1984}$)
			MP	US$1.04 (0.19–1.89)	/acre	USA	Freeman 1991	
		Habitat	MCA, DP	AU$43.42	/ha/yr	Australia	Curtis 2004	Wetland biodiversity support
			MP	US$195.64	/ha/yr	Netherlands	Costanza et al. 1997	Marine habitat (US$$_{1994}$)
		Nutri. cycl.	MCA, DP	AU$9.16	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Pollination	MCA, DP	AU$8.45	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Biodiversity	MCA, DP	AU$17.13	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		NPP	EA	US$43,772	/ha/yr	USA	Costanza et al. 1997	Primary production (US$$_{1994}$)
				US$1,753	/ha/yr	USA	Costanza et al. 1997	Primary production (US$$_{1994}$)
				US$36,467	/ha/yr	USA	Costanza et al. 1997	Primary production (US$$_{1994}$)
				US$1,499	/ha/yr	USA	Costanza et al. 1997	Primary production (US$$_{1994}$)

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Salt marsh/ wetland contd.]	Regulating	Coast. protect.	DCA, R	US$8,263	/ha/yr	USA	Costanza et al. 2008	Reduced hurricane damages (US$$_{2004}$)
		Water purific.	RC	US$1,142 (785–1,500)	/acre	USA	Breaux et al. 1995	Waste treatment alternatives
		Climate regul.	MCA, DP	AU$15.96	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands (US$$_{1994}$)
		Disturb. regul.	DE	US$1.49	/ha/yr	USA	Costanza et al. 1997	Storm protection (AU$$_{1994}$)
			DE	US$2.98	/ha/yr	USA	Costanza et al. 1997	Storm protection (US$$_{1994}$)
			WTP	US$566.51	/ha/yr	USA	Costanza et al. 1997	Storm protection (US$$_{1994}$)
			RC	US$7,336	/ha/yr	UK	Costanza et al. 1997	Shoreline protection (US$$_{1994}$)
		C-sequest.	MP	US$30.50	/ha/yr	Global	Barbier et al. 2011	2009 C-sequestration (US$$_{2000}$)
		Gas regul.	MCA, DP	AU$16.20	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Coast. protect.	MCA, DP	AU$12.91	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
				AU$10.09	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Erosion cont.	MCA, DP	AU$17.14	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Bio-regul.	MCA, DP	AU$14.79	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Soil form.	MCA, DP	AU$2.35	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Waste	MCA, DP	AU$25.58	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
			RC	US$6,695	/ha/yr	Netherlands	Costanza et al. 1997	Waste treatment, total (org+N+P) (US$$_{1994}$)
	Provisioning	Water	MCA, DP	AU$2.58	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
		Raw mat.	MCA, DP	AU$5.64	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
				AU$6.81	/ha/yr	Australia	Curtis 2004	Fresh and saltwater wetlands
			CV or WTP	£15.27	/ha/yr	UK	King & Lester 1995	Net income from livestock grazing
			WTP	US$95 (43.57–145.86)	/ha/yr	USA	Costanza et al. 1997	Trapping furbearer (US$$_{1994}$)
		Food		US$20.04	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)
			WTP	US$85.84	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)
			MP	US$137.91	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)
				US$94.02	/ha/yr	USA	Costanza et al. 1997	Shell fishery (US$$_{1994}$)
				US$1,416	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)
				US$122.08	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)
			DV	US$242.95	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)
				US$0.72	/ha/yr	USA	Costanza et al. 1997	Blue crab (US$$_{1994}$)
				US$25.77	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Salt marsh/ wetland contd.]	[Provisioning contd.]	[Food contd.]	[DV contd.]	US$1,426	/ha/yr	USA	Costanza et al. 1997	Commercial fishing (US$$_{1994}$)
				US$16.03	/ha/yr	USA	Costanza et al. 1997	Non-commercial fishing (US$$_{1994}$)
				US$58.12	/ha/yr	USA	Costanza et al. 1997	Trapping/hunting (US$$_{1994}$)
			MV	US$192.40	/ha/yr	USA	Costanza et al. 1997	Aquaculture/oysters (US$$_{1994}$)
	Cultural	Recreation	CE	£31.60	/PSN	UK	Birol & Cox 2007	Otter habitat creation (£$_{1994}$)
				£1.20	/PSN	UK	Birol & Cox 2007	Protecting birds (£$_{1994}$)
			MCA, DP	AU$5.87	/ha/yr	Australia	Curtis 2004	Wetlands (AU$$_{1994}$)
			TC	US$8.59	CS/trip	USA	Johnston et al. 2002	Swimming (US$$_{1995}$)
				US$19.23	CS/trip	USA	Johnston et al. 2002	Boating (US$$_{1995}$)
				US$40.25	CS/trip	USA	Johnston et al. 2002	Recreational fishing (US$$_{1995}$)
				US$49.83	CS/trip	USA	Johnston et al. 2002	Bird & wildlife observation (US$$_{1995}$)
			HP	US$26	CS/trip	USA	Hoagland & Meeks 2000	Whale watching (US$$_{1996}$)
			RPT	US$922.84	/ha/yr	USA	Costanza et al. 1997	No growth (US$$_{1994}$)
				US$772.82	/ha/yr	USA	Costanza et al. 1997	
			TC	US$20.66	/ha/yr	USA	Costanza et al. 1997	No growth (US$$_{1994}$)
			WTP	US$882.02	/ha/yr	Sweden	Costanza et al. 1997	No growth (US$$_{1994}$)
			MP	US$894.31	/ha/yr	USA	Costanza et al. 1997	No growth (US$$_{1994}$)
				US$1,507	/ha/yr	USA	Costanza et al. 1997	Rec. land price (US$$_{1994}$)
				US$1,784	/ha/yr	USA	Costanza et al. 1997	Hunting & fishing (US$$_{1994}$)
			WTP	US$448.80	/ha/yr	USA	Costanza et al. 1997	Hunting & fishing (US$$_{1994}$)
			WTP, RPT	US$144.61	/ha/yr	Mexico	Costanza et al. 1997	WTP for rec. land use (US$$_{1994}$)
		Aesth./spirit.	MCA, DP	AU$12.68	/ha/yr	Australia	Curtis 2004	Wetlands
Seagrass/ algae beds		Median		AU$34,172	/ha/yr	Australia	Blackwell 2005	US$$_{1994}$
				US$19,002	/ha/yr	Global	Costanza et al. 1997	NZ$$_{1994}$
	Supporting	2nd prod.	PM	AU$114M	/yr	Australia	McArthur & Boland 2006	Seagrass contrib. to GDP
				AU$133M	/yr	Australia	McArthur & Boland 2006	Seagrass contrib. to GDP
		NPP	CE	AU$ 41.5 (39–44) (5% inc.)	/yr	Australia	McCartney 2009	Increase in seagrass pop. (5%)
				(AU$41–62) (10% inc.)	/yr	Australia	McCartney 2009	Increase in seagrass pop. (10%)

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Seagrass/algae beds contd.]	[Supporting contd.]	[NPP contd.]	[CE contd.]	(AU$36–53) (5% inc.)	/yr	Australia	McCartney 2009	Increase in fish pop. (5%)
				(AU$37–54) (10% inc.)	/yr	Australia	McCartney 2009	Increase in fish pop. (10%)
				(AU$17–24) (5% inc.)	/yr	Australia	McCartney 2009	Increase in abalone pop. (5%)
				(AU$20–28) (10% inc.)	/yr	Australia	McCartney 2009	Increase in abalone pop. (10%)
		Habitat	PM	AU$1,415	/ha/yr	Australia	Watson et al. 1993	Seagrass beds in Cairns Harbour
				AU$1.2M (0.6–2.2M)	/yr	Australia	Watson et al. 1993	Prawn and seagrass interdependency
		Nutri. cycl.	RC	US$19,000 (10k–28k)	/ha/yr	Global	Costanza et al. 1997	$US\$_{1994}$
	Regulating	Maint. fish.	PM	AU$235,000	/yr	Australia	McArthur & Boland 2006	Fish stock and seagrass decline
		Bio-regul.	CE	AU$36.5 (31–42) (25% dec.)	/yr	Australia	McCartney 2009	Decrease in whale conditions (25%)
				AU$54.5 (47–62) (50% dec.)	/yr	Australia	McCartney 2009	Decrease in whale conditions (50%)
	Provisioning	Raw mat.	MP	US$2.00	/ha/yr	Global	Costanza et al. 1997	$US\$_{1994}$
Reefs		Median		US$6,075 (613–11,537)	/ha/yr	Global	Costanza et al. 1997	$US\$_{1994}$
	Supporting	NPP	CE	AU$70 (58–82) (5% inc.)	/yr	Australia	McCartney 2009	Increase in coral pop. (5%)
				(AU$68–96) (10% inc.)	/yr	Australia	McCartney 2009	Increase in coral pop. (10%)
				(AU$40–65) (5% inc.)	/yr	Australia	McCartney 2009	Increase in fish pop. (5%)
				(AU$55–69) (10% inc.)	/yr	Australia	McCartney 2009	Increase in fish pop. (10%)
				(AU$30–63) (5% inc.)	/yr	Australia	McCartney 2009	Increase in turtle pop. (5%)
				(AU$48–68) (10% inc.)	/yr	Australia	McCartney 2009	Increase in turtle pop. (10%)
		Habitat	CNV	US$7	/ha/yr	Galapagos	Costanza et al. 1997	Habitat/refugia ($US\$_{1994}$)
		Coast. protect.	DC or EDF	US$174	/ha/yr	Indian Ocean	Wilkinson et al. 1999	House prices & coral
		Maint. fish.	PM	US$30,000 (15,000–45,000)	$/km^2/yr$	Philippines	White et al. 2000	Local sustainable fishing
				(US$5,000–10,000)	$/km^2/yr$	Philippines	White et al. 2000	Reef-fish export (US$10/kg)
		Bio-regul.	CE	(AU$31–42) (2% inc.)	/yr	Australia	McCartney 2009	Whale/shark pop. inc. (2%)
				(AU$47–62) (5% inc.)	/yr	Australia	McCartney 2009	Whale/shark pop. inc. (5%)
		Disturb. regul.	RC	US$500	/ha/yr	Philippines	Costanza et al. 1997	$NZ\$_{1994}$
				US$5,000	/ha/yr	Global	Costanza et al. 1997	$NZ\$_{1994}$

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Reefs contd.]	[Supporting contd.]	Waste regul.	RC	US$58	/ha/yr	Galapagos	Costanza et al. 1997	Waste treatment (US$$_{1994}$)
		Bio-regul.	SP	US$4.9	/ha/yr	Galapagos	Costanza et al. 1997	Biological control (US$$_{1994}$)
		Food	RPT	US$0.10	/ha/yr	Philippines	Costanza et al. 1997	Food production (US$$_{1994}$)
			CBA, RPT	US$440	/ha/yr	Philippines	Costanza et al. 1997	Fish & lobster production (US$$_{1994}$)
			MP	US$0.70	/ha/yr	Galapagos	Costanza et al. 1997	Fish & lobster production (US$$_{1994}$)
		Raw mat.	MP	US$5.20	/ha/yr	Galapagos	Costanza et al. 1997	Construction (US$$_{1994}$)
				US$0.40	/ha/yr	Galapagos	Costanza et al. 1997	Ornaments (US$$_{1994}$)
				US$2.90	/ha/yr	Philippines	Costanza et al. 1997	Aquarium trade (US$$_{1994}$)
			EC	US$18.20	/ha/yr	Philippines	Costanza et al. 1997	Harvest (US$$_{1994}$)
			Summed values	US$27	/ha/yr	Global	Costanza et al. 1997	Total (US$$_{1994}$)
	Cultural	Recreation	CV, WTP	US$88,000	/40k tourists	Seychelles	Mathieu et al. 2003	Marine park revenue
			TC	US$110	/PSN/day	USA	Pendleton 2005	Ship diving on the Yukon
			RPT, CV	US$169 (131–207)	CS/PSN/day	USA	Park et al. 2002	Snorkelling (Florida Keyes)
				US$481.15	/PSN/yr	USA	Park et al. 2002	Snorkelling
			CV	US$2.97	/PSN/day	USA	Johns et al. 2001	Artificial reef use/PSN/day
				US$8.49	/PSN/day	USA	Johns et al. 2001	Natural reef use/PSN/day
				US$14.26	/PSN/day	USA	Johns et al. 2001	Artificial reef use/PSN/day
				US$16.85	/PSN/day	USA	Johns et al. 2001	Artificial reef use/PSN/day
			RPT	US$1,287	/ha/yr	USA	Costanza et al. 1997	Parks (US$$_{1994}$)
			NPV	US$46.30	/ha/yr	Australia	Costanza et al. 1997	NZ$$_{1994}$
			CS	US$509	/ha/yr	Australia	Costanza et al. 1997	NZ$$_{1994}$
			RPT	US$6,000	/ha/yr	Tahiti	Costanza et al. 1997	Expenditures (US$$_{1994}$)
				US$1,251	/ha/yr	Bonaire	Costanza et al. 1997	Diving (US$$_{1994}$)
				US$15	/ha/yr	Galapagos	Costanza et al. 1997	Sustainable rec. (US$$_{1994}$)
		Books & films	DV	US$0.02	/ha/yr	Galapagos	Costanza et al. 1997	NZ$$_{1994}$
		Spirit./histor.	Dn	US$0.15	/ha/yr	Galapagos	Costanza et al. 1997	Spiritual (US$$_{1994}$)
		Sci. & educ.		US$0.70	/ha/yr	Galapagos	Costanza et al. 1997	Spiritual (US$$_{1994}$)

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
Mangroves		Median		AU$17,963	/ha/yr	Australia	Blackwell 2005	
				US$721.50 (713–730)	/ha/yr	Trinidad Tobago	Costanza et al. 1997	$NZ\$_{1994}$
				US$2,242 (2,210–2,273)	/ha/yr	Puerto Rico	Costanza et al. 1997	$NZ\$_{1994}$
				US$1,355	/ha/yr	Fiji	Costanza et al. 1997	$NZ\$_{1994}$
	Supporting	Maint. fish.	PF	US$848 (708–987)	/ha	Thailand	Barbier 2007	Offshore fishery production inc.
			PM	US$5,846	/ha/yr	Australia	Morton 1990	Mangrove (*Avicennia marina*) nursery
		Habitat	MP	US$142	/ha/yr	Thailand	Costanza et al. 1997	Habitat ($US\$_{1994}$)
		NPP	EA	US$4,648	/ha/yr	USA	Costanza et al. 1997	Primary production ($US\$_{1994}$)
	Regulating	Coast. protect.	EDF	US$9,894 (8,966–10,821)	/ha	Thailand	Barbier 2007	Storm protection
		Disturb. regul.	SC	US$1,701	/ha/yr	Malaysia	Costanza et al. 1997	Storm protection ($US\$_{1994}$)
		Erosion cont.	RC	US$3,679	/ha/yr	Thailand	Sathirathai & Barbier 2001	Coastline protection costs
		C-sequest.	MP	US$30.50	/ha/yr	Global	Barbier et al. 2011	2009 C-sequestration ($US\$_{2000}$)
	Provisioning	Raw mat.	MP	US$534 (484–584)	/ha/yr	Thailand	Barbier 2007	Net income (forest products) ($US\$_{1996}$)
		Food	MP	US$66.09	/ha/yr	Thailand	Costanza et al. 1997	Food production and fishing ($US\$_{1994}$)
				US$123.87	/ha/yr	Indonesia	Costanza et al. 1997	Commercial fishing ($US\$_{1994}$)
				US$174.78	/ha/yr	Trinidad Tobago	Costanza et al. 1997	Commercial fishing ($US\$_{1994}$)
				US$894.88	/ha/yr	Fiji	Costanza et al. 1997	Commercial fishing ($US\$_{1994}$)
				US$69.91	/ha/yr	Indonesia	Costanza et al. 1997	Commercial fishing ($US\$_{1994}$)
				US$4,761	/ha/yr	Australia	Costanza et al. 1997	Commercial fishing ($US\$_{1994}$)
				US$15.88	/ha/yr	Indonesia	Costanza et al. 1997	Trap/hunt/gather ($US\$_{1994}$)
				US$586	/ha/yr	Thailand	Costanza et al. 1997	Food production ($US\$_{1994}$)
				US$280	/ha/yr	Thailand	Costanza et al. 1997	Food production ($US\$_{1994}$)
				US$1,961	/ha/yr	Nicaragua	Costanza et al. 1997	Food production ($US\$_{1994}$)
			IV	US$70.67	/ha/yr	Indonesia	Costanza et al. 1997	Commercial fishing ($US\$_{1994}$)
		Raw mat.	MP	US$222.83	/ha/yr	Thailand	Costanza et al. 1997	Aquaculture ($US\$_{1994}$)
				US$1,142	/ha/yr	Thailand	Costanza et al. 1997	Charcoal ($US\$_{1994}$)
				US$90.76	/ha/yr	Trinidad Tobago	Costanza et al. 1997	Woodchips ($US\$_{1994}$)
				US$12.97	/ha/yr	Indonesia	Costanza et al. 1997	Woodchips ($US\$_{1994}$)
				US$32.41	/ha/yr	Malaysia	Costanza et al. 1997	Woodchips ($US\$_{1994}$)
				US$233.19	/ha/yr	Malaysia	Costanza et al. 1997	Timber ($US\$_{1994}$)

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Mangroves contd.]	[Provisioning contd.]	[Raw mat. contd.]	IV	US$17.30	/ha/yr	Indonesia	Costanza et al. 1997	Woodchips (US$$_{1994}$)
			EP	US$89.83	/ha/yr	Indonesia	Costanza et al. 1997	Forest products (US$$_{1994}$)
	Cultural	Recreation		US$285	/ha/yr	Trinidad Tobago	Costanza et al. 1997	Recreation/tourism (US$$_{1994}$)
				US$909	/ha/yr	Puerto Rico	Costanza et al. 1997	US$$_{1994}$
Sand, beach and dunes	Regulating	Recreation	CE	US$4.45	/HH	USA	Huang et al. 2007	Coastal erosion control
	Cultural	Recreation	DFM	US$166	/trip	USA	Landry & Liu 2009	Beach access loss
				US$1,547	/HH/yr	USA	Landry & Liu 2009	Beach access loss
			TC	US$34	/PSN/day	USA	Bell & Leeworthy 1990	Beach recreation (US$$_{1984}$)
				US$24B	/asset	USA	Bell & Leeworthy 1990	Est. asset value (Florida beaches) (US$$_{1984}$)
			TC, RUM	US$45.50 (11–80)	/PSN/day	USA	Bin et al. 2005	CS/day, North Carolina beach (US$$_{2003}$)
				US$25.50 (11–41)	/PSN/day	USA	Bin et al. 2005	Night stay, North Carolina beach (US$$_{2003}$)
			CV	US$7.29	/HH/trip	USA	Binkley & Hanemann 1978	CS/beach activity day
			HP	US$1,229	/PSN/yr	USA	Edwards & Gable 1991	Beaches rec. value, Rhode Island (US$$_{1980}$)
			TC	US$29.75 (25.78–33.72)	/HH/day	USA	King 2001	Beaches rec. value, San Clemente
			TC, RUM	US$11.13	/trip	USA	Lew & Larson 2005	Beaches rec. value, San Diego County
			TC	US$55	/PSN/yr	Netherlands	Nunes et al. 2009	Rec. benefits/day (US$$_{2001}$)
			WTP	US$6	/family visit	USA	Hall et al. 2002	WTP for reduction in habitat decline
			CV, DCA	US$2.86 (1.53–4.18)	/PSN/day	USA	Kline & Swallow 1998	US$$_{1995}$
			SPT	£5.81	/PSN/yr	Scotland	Hanley et al. 2003	CS (improved water quality)
				£0.48	/trip	Scotland	Hanley et al. 2003	CS (improved water quality)
			CV	£17.50 (10–25)	/HH/yr	England	Georgiou et al. 2000	CV on beach improvement
			CV	US$76	/PSN/yr	Netherlands	Nunes et al. 2009	Marine ES benefits/day (US$$_{2001}$)
			CE	NZ$50.94	/HH/yr	New Zealand	Batstone & Sinner 2010	WTP for improved track (NZ$$_{2010}$)
Unspecified	Regulating	Waste regul.	HP	US$8,500 (7,000–10,000)	/property	Massachusetts, USA	Mendelsohn et al. 1992	Effects of PCB pollution (US$$_{1989}$)
	Provisioning	Food	MP	AU$125.5M (1M–250M)	/yr	Western Australia	Allen et al. 2009	Commercial fisheries

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Unspecified contd.]	[Provisioning contd.]	[Food contd.]	DP	NZ$3.6B		New Zealand Exclusive Economic Zone (EEZ)	Allen et al. 2009	Commercial fisheries value at risk
				(NZ$0–300M)	FSA[i]	New Zealand EEZ	Batstone et al. 2009	Finfish/shellfish species value at risk
				(NZ$0–2.7M)	FSA[ii]	New Zealand EEZ	Batstone et al. 2009	Eel species value at risk
				(NZ$0–72M)	FSA[iii]	New Zealand EEZ	Batstone et al. 2009	Rock lobster species value at risk
	Cultural	Aesthetic	HP	Ocean view (add 59%)	/property	Auckland, New Zealand	Bourassa et al. 2004	Auckland ocean view property prices
				Ocean view (add 23.6%)	/property	Washington, USA	Benson et al. 1998	1984–94 data
		Rec. fishing	RUTCM	US$119	/trip	Alaska, USA	Hausman et al. 1995	Sport fishing
				US$148	/trip	Alaska, USA	Hausman et al. 1995	Sport fishing
			RUTCM	(US$1.68–3.66)	welfare losses/ angler/trip	Tampa Bay, Florida, USA	Green et al. 1997	1989–90 data
			RUM, TC	(US$5.91–35.02)	/angler/trip	Oahu, Hawaii, USA	Haab et al. 2008	WTP to prevent closure of coastal HDARs
			CV	(US$38.12–258.20)	/PSN/trip	Texas, USA	Downing & Ozuna 1996	Eight bays ($US\$_{1989}$)
			NRUM	(US$0.81–7.94)	/trip	East Florida, USA	Bockstael et al. 1989	1987–88 data
			CV & TC	US$3,451	/yr	Mexico and USA	Cameron 1992	CVM question on fishing preferences (1987 data)
			TC, CV & JM	US$9.85 (TC)	/angler	Gulf of Mexico, USA	Gillig et al. 2003	Rec. value of red snapper (*Lutjanus campechanus*) fishing (1991 data)
				US$85.70 (CV)	/angler	Gulf of Mexico, USA	Gillig et al. 2003	Rec. value of red snapper fishing (1991 data)
				US$14.50 (joint)	/angler	Gulf of Mexico, USA	Gillig et al. 2003	Rec. value of red snapper fishing (1991 data)
			RUM	(US$0.85–42.33)	loss/trip	Northeastern states, USA	Hicks et al. 1999	WTP for fishery access (1994 data)
			HPF	US$515	/yr	Rhode Island, USA	McConnell 1979	Flounder
			TC	US$233	/yr	Rhode Island, USA	McConnell 1979	Flounder

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Unspecified contd.]	[Cultural contd.]	[Rec. fishing contd.]	CV	(US$3–31)	/trip	Mid and South Atlantic, USA	McConnell et al. 1994	WTP 1 yr access to the entire east coast
			RUM, TC	(US$11.02–80.37)	/trip	Mid and South Atlantic, USA	McConnell et al. 1994	WTP 1 yr access to individual states
			RUM, TC	(US$0.18–7.72)	access/ fisher/day	Southeastern states, USA	Whitehead & Haab 1999	1997 data
				(US$9.10–175.02)	/yr	Clatsop, Oregon, USA	Morey et al. 1991	Yearly compensating variation (1981 data)
				(AU$1.91–14.46)	loss/trip	Western Australia	Raguragavan et al. 2010	Access to 48 individual sites (2000–01 data)
			DCVM	(US$52–135)	/yr	North Carolina, USA	Whitehead et al. 2001	WTP for the annual license (1998 data)
				(AU$0.15–11.52)	/trip	Western Australia	Zhang et al. 2003	Shore-based fishing access (2000–01 data)
			CV	(US$56.46–139.79)	/yr	Denmark, Finland, Iceland, Norway and Sweden	Toivonen et al. 2004	Recreational fishing (US$$_{1999}$)
			CV	US$14.47	/fish/trip	British Columbia, Canada	Cameron & James 1987	Chinook salmon (*Oncorhynchus tshawytscha*) WTP (1984 data)
			HP	(US$0.39–2.58)	/trip	North Carolina, USA	Smith et al. 1991	CS per trip (US$$_{1982}$)
			NRUM	(US$0.38–1.87)	CV	East coast of Florida, USA	Bockstael et al. 1989	Welfare effect on increased catch
			CV & TC	US$98.05	MCV/day	Alaska, USA	Hamel et al. 2001	Halibut (*Hippoglossus stenolepis*) and salmon (*Oncorhynchus* spp.)
			CE, WTP	(AU$4M–14M)	/yr	Western Australia	Allen et al. 2009	Maintain access to fishing (1997 data)
			SPT, CV	(NZ$1.61–19.76)	/fish	New Zealand	Wheeler & Damania 2001	Value of fish species (1998/99 data)
			DCVM	(AU$18.72–44.82)	/fish	Southern Queensland, Australia	Campbell & Reid 2000	Boat and shore anglers (1996 data)
			CV	(NZ$58M–101M)	/yr	New Zealand	Kerr et al. 2003	Annual marine rec. fishery benefits (2002 data)
			SPT, CV	NZ$220M	/yr	New Zealand	Wheeler & Damania 2001	Net benefit from fishing
			CV	(NZ$52–65)	/trip	Whangamata, New Zealand	Schischka & Marsch 2008	WTP for last fishing trip (NZ$$_{2010}$)
			WTP	(NZ$106–249)	/yr	New Zealand	Kerr et al. 2003	Marine rec. fishing license (NZ$$_{2010}$)

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Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Unspecified contd.]	[Cultural contd.]	Rec. boating	NLM, RUM, TC	(US$353.23–423.94)	/boater/yr	Southwest Florida, USA	Thomas & Stratis 2002	Recreational boating (Florida) (1998 data)
		Seaside rec.	RUM	(SEK 240M–540M)	/yr	Sweden	Sandström 1996	Reduce marine nutrient load 50% (1990–94 data)
				NZ$59	/PSN/day	New Zealand	Kaval & Yao 2007	Summary
	Other	Oil spill protect.	CV, WTP, AM, RM	US$48	/HH	Alaska, USA	Carson et al. 2003	WTP to prevent an Exxon Valdez type oil spill
		Sp. protect.	CV	US$26.63	/PSN	Maine, USA	Kotchen & Reiling 2000	Measure environmental attitudes
			CV, BT	(US$2.32–5.81)	/HH	California, USA	Loomis 2006	WTP for additional 196 (7.58%) sea otters (*Enhydra lutris*)
			CV	US$40.41	/HH/yr	Alaska, USA	Giraud et al. 2002	WTP for marine benefits (2000 data)
				US$61.13	/HH/yr	Alaska, USA	Giraud et al 2002	Steller sea lion (*Eumetopias jubatus*) habitat (2000 data)
				162 drachmas	UV/PSN	Aegean sea, Greece	Langford et al. 1998	Protect monk seal (*Monachus monachus*) (1995 data)
				838 drachmas	OV/PSN	Aegean sea, Greece	Langford et al. 1998	Protect monk seal (1995 data)
				2,321 drachmas	EV/PSN	Aegean sea, Greece	Langford et al. 1998	Protect monk seal (1995 data)
Coast. ind.		Water transp.	MP, DP	(NZ$0–1,620,000)	AU[i]/yr	New Zealand	Batstone et al. 2009	Marine transport
				(NZ$0–1,600,000)	AU[ii]/yr	North Island, New Zealand	Batstone et al. 2009	Economic value added by stevedoring
		Oil and gas extract.	MP, DP	(NZ$0–2,920,000)	AU[iii]/yr	Taranaki, New Zealand	Batstone et al. 2009	Oil and gas extraction industry
		Exploration ind.	MP, DP	(NZ$0–270,000)	AU[iv]/yr	Taranaki, New Zealand	Batstone et al. 2009	Marine fishing industry
		Marine fishing ind.	MP, DP	(NZ$0–2,249,000)	AU[v]/yr	New Zealand	Samarasinghe et al. 2009	Marine fishing industry
				(NZ$0–1,700,000)	/district/yr	New Zealand	Batstone et al. 2009	Marine fishing industry
		Rock lobster ind.	MP, DP	(NZ$0–1,131,000)	/TLA/yr	New Zealand	Samarasinghe et al. 2009	Marine fishing industry
		Line fishing ind.	MP, DP	(NZ$0–1,410,000)	/TLA/yr	New Zealand	Samarasinghe et al. 2009	Marine fishing industry
		Finfish trawling ind.	MP, DP	(NZ$0–6,747,000)	/TLA/yr	New Zealand	Samarasinghe et al. 2009	Marine fishing industry
		Aquaculture ind.	MP, DP	(NZ$0–9,000,000)	/district/yr	New Zealand	Batstone et al. 2009	Marine farming industry

Continued on next page

Table A4.2 continued

ES BIOME	MA CATEGORIES	ES	METHOD	VALUE [A (L–H)]	UNIT	AREA	REFERENCE	ADDITIONAL INFORMATION
[Unspecified contd.]	[Other contd.]	Fish wholesale ind.	MP, DP	(NZ$0–3,126,000)	/TLA/yr	New Zealand	Samarasinghe et al. 2009	Fish wholesale industry
		Boat building ind.	MP, DP	(NZ$0–11,991,819)	/district/yr	New Zealand	Batstone et al. 2009	Boat building industry
		Ship building ind.	MP, DP	(NZ$0–2,439,000)	/TLA/yr	New Zealand	Samarasinghe et al. 2009	Ship building industry
		Marine equip. retail	MP, DP	(NZ$0–2,214,000)	/TLA/yr	New Zealand	Samarasinghe et al. 2009	Marine equipment retailing
		Water quality	OECV	(US$30.25–93.26)	/PSN	Chesapeake Bay, USA	Lipton 2004	2000 data
			CE	(£1.10–2.00)	/HH/yr	England & Wales, UK	EFTEC 2010	Marine disease reduction (1997 data)
			CV	US$14.26	/PSN	Coast of Estoril, Portugal	Machado & Mourato 2002	1997 data
			HP	1.55% price reduction	/property	Chesapeake Bay, USA	Leggett & Bockstael 2000	Change faecal coliform count
			CE	NZ$58.18	/HH/yr	Auckland, New Zealand	Batstone & Sinner 2010	WTP for water quality improvement
		Ecological health	CE	NZ$135.64	/HH/yr	Auckland, New Zealand	Batstone & Sinner 2010	WTP for ecological health

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