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Towards a 'total economic value' of coastal marine ecosystem services in Nelson Bays, Nelson Tasman region, New Zealand

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Executive summary

Ecosystem services underpin all market economic activity and yet their contribution to human welfare often goes unnoticed because of the difficulties associated with measurement in monetary units of account. Over the last two and half decades, efforts have been made to address this problem. The emergence of the 'ecosystem services' metaphor as a tool for aiding markets and local communities to reconnect with their 'primal' dependency on ecosystems has been linked with rapid developments in valuation method. Since the ground-breaking publication of Costanza *et al.,* (1997) that attempted to value (in monetary terms) the annual contribution of global ecosystems to global GDP, the same valuation methods have been applied and enhanced in studies around the globe. The emergence of the 'Millennium Ecosystem Assessment' (MEA) of global ecosystem wellbeing and more recently 'The Economics of Ecosystems and Biodiversity' (TEEB) study have succeeded in drawing the attention of the international community to global ecosystem wellbeing and extending the theory and methods employed in earlier ecosystem services valuation activities. Despite all of these contributions, scientists continue to hold and express grave concerns about the wellbeing of global ecosystems. Furthermore, while much has been achieved in the development of ecosystem services valuation method, this area of research remains an imprecise science, challenged by: computational problems, issues of method dependency, scarcity of critically important non-market valuation data and uncertainty.

This report outlines the results of a rapid ecosystem services assessment (RESA) of marine ecosystem services within the Nelson Bays located adjacent the Nelson Tasman regions of New Zealand. This study is based on the use of 23 different supporting, regulating, provisioning and non-material ecosystem services that are valued in terms of their role in 8 different coastal marine ecosystems (i.e. continental shelf, estuary, intertidal, lagoon, saltmarsh, seagrass, reefs and sand, beach and dunes). Rapid ecosystem services assessment of this marine study area is based on the use of a total economic value taxonomy for which only use-values have been estimated at this stage. Passive or non-use values have not been estimated at this time. Market and non-market valuation data for this study has been drawn from a range of sources including: regional economic accounts and the transfer of benefits from suitable published international and national studies. Spatial databases for coastal marine ecosystems in our study area have been used with GIS software to provide estimates of coastal marine ecosystem cover in hectares. As such, this valuation study mainly represents a supply-side assessment of ecosystem services value. Some adjustments have been made for demand-side estimates of value. However these corrections typically involve assumptions that are as yet unsubstantiated with field data.

In this investigation, an effort has been made, where ever possible to comply with recent theoretical and methodological developments in ecosystem services valuation and benefits transfer methods. However, as a pilot study, this research has been limited in terms of what can be accomplished in terms of method improvements. Therefore, the ecosystem services value estimates outlined in this study should be interpreted with care and an understanding of the limiting assumptions, sparse

data, computational challenges and uncertainties on which this study is based. Efforts have been made in writing this report to provide transparency in these areas. One important improvement adopted by this study has involved the adoption of recently published accounting conventions for the estimation of net and gross estimates of total economic value. The main difference between these two TEV indicators is that supporting services are not included in the estimation of net total economic value. This accounting convention thus avoids previous problems in TEV estimation associated with the 'double counting' of supporting ecosystem services with regulating, provisioning and non-material ecosystem services. In this study we also provide guidance on the accounting adjustment of what we refer to as a 'valuation Table representation' problem that is a direct result of our use of the MEA framework as a means to avoid 'double counting'. By worked example we seek to show that this new accounting adjustment produces superior TEV estimates that we report on below as outcomes of this study. This study has thus attempted to estimate total net and gross value for both individual coastal marine ecosystems and all coastal marine ecosystems combined. All estimates of monetary value have been CPI adjusted to quarter 4, year 2012 and are expressed in New Zealand dollars.

This study found that in the year 2012, coastal marine ecosystems within the Tasman-Golden Bays study area made a net total economic value contribution to human welfare of $4,797M/yr., approximately 131% of Nelson Tasman GDP for the same year. Removal of market value estimates from this net total associated with coastal fisheries harvest results in a slightly lower net total economic value estimate of $4,795M/yr., an estimate that is currently absent from regional economic accounts used to estimate GDP. Total net value estimates were also made for individual ecosystems: continental shelf $1,493M/yr., estuaries $438M/yr., lagoons $19M/yr., intertidal $1,431M/yr., saltmarsh $71M/yr., seagrass at $922M/yr., rocky reefs $5M/yr., sand, beach and dunes $418M/yr.

An effort has also been made within this study to position ecosystem services value estimates for coastal marine ecosystems within local regional terrestrial ecosystems. This was done for a couple of reasons. First, the Nelson Tasman region is home to 3 national parks (Abel Tasman 225.41 km^2; Nelson Lakes 1,017.53 km^2; and Kahurangi 4,520 km^2) and a wildlife sanctuary (i.e. Farewell Spit) that has international Ramsar status. These ecological assets contribute immense recreational value to the coastal marine ecosystems in our study area. Second, the wellbeing of coastal marine and terrestrial ecosystems are inextricably interlinked, in particular through coastal catchments, rivers (i.e. aquatic ecosystems), vegetation cover, wildlife habitat and the role of coastal marine ecosystems in supporting the regional economy.

This study found that in the year 2012, terrestrial ecosystems adjacent the Tasman-Golden Bays study area made a net total economic value contribution to human welfare of $3,859M/yr., approximately 105% of Nelson Tasman GDP for the same year. Removal of market value estimates from this net total associated with coastal primary industries (i.e. horticulture, agriculture and forestry) results in a lower net total economic value estimate of $1,725M/yr., approximately 47% of Nelson Tasman GDP; a total value estimate that is currently absent from regional economic accounts used to estimate GDP. When combined, in the year 2012 marine and terrestrial ecosystems contributed a net total economic value (estimate) to human welfare of $8,656M/yr. If this combined total is adjusted by the removal of market-based marine and terrestrial value estimates it results in a combined NTEV of $6,520M/yr., approximately 179% of the Nelson Tasman GDP for 2012. These net total economic value estimates highlight the economic importance of terrestrial-aquatic-marine ecosystems to the Nelson Tasman regional economy. Another interesting finding of this study is that the NTEV estimate for coastal marine ecosystems (i.e. $4,797M/yr.) in our study area is larger than the NTEV estimate for terrestrial ecosystems (i.e. $3,859M/yr.). These results highlight the importance of coastal marine ecosystems to the New Zealand market economy.

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Appendix A

List of acronyms and symbols

ES	Ecosystem service
ESV	Ecosystem service valuation
MESV	Marine ecosystem service valuation/value
TESV	Terrestrial ecosystem service valuation/value
TEV	Total economic value
MBI	Ministry of Business, Innovation and Employment
PCE	Parliamentary Commissioner for the Environment
GDP	Gross domestic product
SNA	System of National Accounts
RESA	Rapid ES assessment
BT	Benefits transfer
CPI	Consumer price index
PPP	Purchasing power parity
GIS	Geographical information system
CME	Coastal marine ecosystem
MEA	Millennium Ecosystem Assessment
M	Millions
SR	The sum of supporting and regulating service value estimates
GHG	Greenhouse gas
NPP	Net primary production
%	Percentage
EEZ	Exclusive Economic Zone
CD	CD-ROM or compact disc
DOC	Department of Conservation
NIWA	National Institute of Water and Atmospheric Research
MFish	Ministry of Fisheries
m^2	Metres squared or square metres (a unit of area measurement)
NOAA	National Oceanic and Atmospheric Administration
EVRI	Environmental valuation reference inventory
TEEB	The economics of ecosystems and biodiversity
GeoServ	A Java-based network server used in managing spatial data
OECD	The Organisation for Economic Cooperation and Development
CMEA	Coastal marine ecosystem area
GV	Gross value
NV	Net value
SESV	Supporting ES value
RESV	Regulating ES value
NESV	Non-material ES value

PESV	Provisioning ES value
UV	Use value
PV	Passive value
LCDB	Landcover Database
FC	Feature class
Dom	Dominant
MLWS	Mean low water spring
MHWS	Mean high water spring
EMP	Earth Microbiome Project
ROV	Remotely operated vehicle
TDC	Tasman District Council
NCC	Nelson City Council
µm	Micrometre
mm	Millimetre
DBH	Diameter at breast height
$/ha./yr.	Dollars per hectare per year
$/yr.	Dollars per year
MEAF	Millennium Ecosystem Assessment Framework
MES	Marine ecosystem services
TES	Terrestrial ecosystem services
GTEV	Gross total economic value
NTEV	Net total economic value

List of abbreviations

ha.	Hectares
Supp.	Supporting services
Reg.	Regulating services
Prov.	Provisioning services
Non-mat.	Non-material services
$\$NZ_{2012}M/yr.$	Millions of New Zealand dollars per year, CPI adjusted to quarter 4, 2012
Gross	Gross value estimates
Net	Net value estimates
Approx.	Approximately
spp.	Species
Seq.	Sequestration
Mar.	Marine
Terr.	Terrestrial
Hort.	Horticulture
Int.	International
Agric.	Agriculture
Gt C $yr.^{-1}$	Giga tones of carbon per year
Q4	The 4^{th} quarter of a calendar year
Excl.	Excluding
AbelTas.	Abel Tasman
m	Metre

1. Introduction

This paper outlines the results of a scoping[1] (Baskaran *et al.,* 2010), ES valuation of CMEs within a Tasman and Golden Bays study area. Results from this study will be used to more clearly define future research priorities and identify key knowledge gaps while providing initial proximate estimates of gross and net ES value. This study is part of an MBI funded research programme[2] (MBIE, 2012) that aims to: (i) build tools to achieve more effective inclusion of marine ecosystem values in economic tradeoffs, and (ii) to bring analysis of this kind into mainstream policy, planning and business decision-making (Patterson, 2012). This initial scoping study, based on the use of a TEV accounting taxonomy provides an important, but incomplete step towards the achievement of these goals. The findings of this valuation study will need to be supported by the use of a broader range of valuation assessment methods. Combined, these various research efforts represent a first step towards the future development of a spatially explicit, bicultural, *coastal marine* ES accounting framework. The coastal marine ESV research outlined in this report is the result of a 1–year investigation and has been documented to help build a case for long-term research funding in this area.

1.1 ESV research in New Zealand

An incentive for the use of an ES approach in this study follows from its political support and past uptake in New Zealand policy science. Both 'The Treasury' (Binning, 2000) and Parliamentary Commissioner for the Environment (PCE, 2002) have signalled that markets for ES is a likely means of incentivising the restoration of biodiversity on private land in New Zealand. The emergence of markets for ES over the last decade has so far only focused on Kyoto-compliant carbon credits[3] and various water trading schemes. The potential to use a broader range of ES credits to incentivise natural ecosystem restoration still exists (Lau, 2013), but has been slow to emerge. This approach has partly been hindered by the lower-than-expected international market price for carbon. However, as a step towards more complete environmental market adoption, considerable progress has been made in depicting, valuing and modelling ES in both Māori and non-Māori cultural contexts.

An ESV was first applied in New Zealand following the international publication of the Costanza *et al.,* (1997) *Nature* paper that attempted to estimate the annual monetary contribution of ES to global GDP. The same valuation method and BT data was combined with an assessment of passive ES values to estimate the total economic value contribution of biodiversity in New Zealand to annual GDP (Patterson and Cole, 1999a). Variations of ESV method were then applied across a range of different regional case studies (Patterson and Cole, 1999c; Cole and Patterson, 2003;

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[1] The design of ESV method is determined by a research project goal (e.g. scoping, theoretical research, policy, litigation etc)

[2] The short title of this research programme is 'Marine ES Valuation'. The MBIE investment process name is '2012 Environment – Smart Ideas. The research proposal reference is 'Prop-29905-ESI-MAU'. The MBIE research contract reference number is MAUX1208.

[3] http://www.ebex21.co.nz/

McDonald and Patterson, 2003), implemented in regional economy-environment accounting (Patterson *et al.,* 2011; Cole and Patterson, 2013), systems dynamic modelling frameworks (McDonald, 2005) and catchment scale participatory modelling (Cole *et al.,* 2006). ES valuation has also been supported by the growth, in New Zealand of a specific, non-market valuation literature (eg. Baskaran *et al.,* 2009; Ndebele, 2009; Takatsuka *et al.,* 2009; Creagh, 2010; Tait *et al.,* 2011; Kerr and Swaffield, 2012) and more recently the spatial depiction of ES along with estimates of their $/ha./yr. market and non-market values (Dymond *et al.,* 2012) at national scale (Ausseil *et al.,* 2013).

The establishment of ES research in New Zealand has also involved investigation into the possible use of ES theory and valuation methods in a Māori cultural context (Awatere, 2003; Cole and Patterson, 2005; Cole and Patterson, 2008; Smith, 2008). This has included the potential roles of: (i) the TEV taxonomy (Crystall *et al.,* 2008), (ii) the spatial depiction of ES (Cole, 2007; Golubiewski, 2008a; Golubiewski, 2008b) as an aid to the expression of kaitiakitanga[4] (Cole, 2008) and (iii) the depiction of ES in mediated modelling (Van den Belt, 2012). This cultural-specific application of ES theory and practice in New Zealand provides an important and valuable theoretical foundation for this present research programme. While terrestrial ES have been well studied in New Zealand, relatively little work has been done in the area of coastal marine ES. This research programme aims to address this current imbalance while using this study as an opportunity to better adapt the current ESV toolkit[5] to a New Zealand coastal marine research and management context.

1.2 Rationale for this valuation study

Underpinning theory and methods associated with the valuation of ES may be described as an imprecise (Kumar, 2010a), post-normal science that is unlikely to ever meet the rigorous empirical and/or logic requirements needed for experimental replication (Kumar, 2010b). Perhaps, not surprisingly, despite a clear policy science goal orientation, the international uptake of ESV results in policy, planning and management contexts has been poor (Laurans *et al.,* 2013). While acknowledging these limitations, there are compelling and pragmatic reasons for being explicit about the value of ecosystems.

Perrings (1996) and Costanza *et al.,* (1997) argue that we implicitly place value on ecosystems and biodiversity in terms of our daily behaviour and decisions. In the highly interconnected world we live in, simple daily activities like buying and consuming food; driving a car; switching lights on and/or running a hot shower are based on implicit values that we use to choose between ‘use’, ‘non-use’ and ‘preferred options’. By choosing to ‘use’, our actions daily contribute to the depletion, modification and in some cases decline and/or extinction of species and natural

[4] Kaitiakitanga is a Māori name for human behaviour that involves caring and/or acting as a guardian for ones own whānau/hapū/iwi or the natural world. In Māori cosmology the wellbeing of people (He Tangata) and the natural world (Taiao) are inextricably interrelated.

[5] Described in sub-section 1.3 of this introduction section

ecosystems - locally, nationally and globally. Making choices that tradeoff our personal welfare against ecosystem wellbeing is an integral part of modern daily life and human decision-making. As noted by Costanza (2003) "... as long as we are forced to make choices, we are doing valuation".

Valuation method helps us to consciously account for the existence and/or absence of the values that 'are' or 'could' or arguably 'should' be associated with the tradeoffs we are daily making. Arresting ecosystem and species decline can only be achieved by informed choice and this requires explicit statement of the values involved in the decisions we make. If further progress is to be made in arresting current national and/or international trends in ecosystem (World Resources, 2005) and biodiversity decline (Sukhdev, 2010), then more studies of the kind outlined in this paper are urgently needed. Serious efforts must also be made to bridge the science/policy gap that currently prevents the use of ESV information in planning and business management contexts (Wainger *et al.,* 2010).

Valuation method can be used to measure and sum the value of ecosystem goods and services, based on an examination of peoples revealed and/or stated preferences. While this measurement goal seems simple, valuation is a complex problem that rests on numerous operational assumptions that are required to approximate the measurement of variables (i.e. value estimates) that change with respect to time, spatial scale (Hein *et al.,* 2006) and subtle differences in worldview (i.e. fundamental measurement reference points), (Kumar and Kumar, 2008). Furthermore, not all value is 'visible' and/or 'accessible' given the current state of scientific knowledge.

Economic markets are an incomplete and imprecise means of measuring human values. Unfortunately, the creation of alternative valuation methods (Costanza and Folke, 1997) needed to elicit values associated with broader societal goals like social fairness, ecological sustainability and cultural wellbeing (Chan *et al.,* 2012), has proved difficult. Most ecosystem valuation research is still based on the estimation of market and/or non-market values as a theoretical extension of standard neo-classical market valuation method. Blamey and Common (1994) show that there are significant operational problems in validly and reliably measuring human preferences in this way. Standard neo-classical economic valuation, here alluded to, is fundamentally anthropocentric and as such has a number of significant limitations. Neo-classical valuation method is predicated on the use of a narrow 'efficiency' goal used to elicit short-term perceptions of instrumental[6] value (Farber *et al.,* 2002) that are typically based on incomplete ecological knowledge. For example, Costanza (1991) points out that humans generally assign higher value to species of direct commercial value and/or species that are easy to empathise with, whereas less visible species such as invertebrates are often ignored.

[6] Value associated with the role of an entity in providing system-wide influence and/or contributing to system-wide benefits. Instrumental, extrinsic or contributory value may be contrasted with intrinsic value or worth not related in any way to the functional role of an entity in a wider network or system.

A further challenge associated with valuation method is the calculation of ecosystem and biodiversity value in a way that is commensurate with other market-based yardsticks of progress like GDP and our system of national accounts (SNA). Comparison of this kind makes ecosystem values both visible and more easily accessible to policy makers. Environmental Accounting exercises such as this have been very successful in other countries in highlighting the contribution of natural resources and the environment - to economic indicators in the United States (Daly *et al.,* 1989) and Australia (Hamilton, 1997). The most influential publication in this area of research was that of Costanza *et al.,* (1997). These co-authors showed that annual global ES value was, surprisingly, more than double the global GDP in terms of their contribution to human welfare.

This present study is based on the use of a standard neo-classical valuation approach. However, our approach to valuation (overall) is based on methodological pluralism (Niraj *et al.,* 2010; Lo, 2011). Thus, we consider this study as applying only one of a wide range of valid ESV tools. In order to capture a broader range of values, other valuation methods in addition to the anthropocentric neo-classical approach are really needed. Recent developments in alternate ecosystem valuation methods include: contributory value (Patterson, 1998; Patterson, 2002; Patterson, 2008), emergy analysis (Siche *et al.,* 2008; Chen *et al.,* 2011), embodied energy analysis (Brown and Herendeen, 1996), discourse (Wilson and Howarth, 2002), multiple criteria analysis (Zhang and Lu, 2010), cultural ES assessment (Satterfield *et al.,* 2013) and spatially explicit ecological-economic modelling (Boumans *et al.,* 2002; Boumans and McNally, 2012; Daily *et al.,* 2012). While the pragmatics of research funding and stakeholder engagement can strongly bias valuation studies in the direction of using neo-classical valuation method, we feel that it is unwise to rely on only one approach or perspective.

1.3 Rapid ES Assessment (RESA)

The research findings outlined in this report may be considered as an example of rapid ES assessment (RESA), (O'Farrell *et al.,* 2012; Peh *et al.,* 2013). RESA provides an extension of well-established neo-classical valuation methods into the realm of both TES and MES. RESA is not the only way of accounting for market and non-market values of ES (cf. Costanza and Hannon, 1989; Odum, 1996; Weber and Crew, 2000; Patterson *et al.,* 2006). However, alternative methods of economy-ecosystem valuation/accounting tend to be more costly, complex, theoretically oriented and data intensive.

RESA can be thought of as a simplified version of BT method - an attempt to avoid the high 'method' compliance costs (Cole, 2014) typically associated with point estimate and meta analysis approaches typically used in formal BT studies. While RESA involves the transfer of benefits from either (i) previously published 'RESA' studies and/or (ii) published primary/secondary valuation research (Bagstad, 2009) … the details of BT method compliance as 'used', 'partly used' and/or 'not used' in RESA studies are rarely published in detail (Loomis and Rosenberger, 2006). While this practice maybe consistent with the constraints imposed by limited research budgets and the primary goal of a 'rapid' assessment, it means that questions of 'valuation data' *quality*[7] and *interpretation* are difficult to answer. This is a very real limitation *for* the use of RESA in a policy context. For this reason, RESA is generally justified on the grounds that the results of such valuation studies should be limited to scoping, awareness raising, future research prioritising, and stakeholder engagement (O'Farrell *et al.,* 2012) research contexts.

Generating high quality valuation data that can be transferred from survey to policy site (i.e. BT) is a task that requires meticulous effort, appropriate method, careful reporting and large amounts of time. The additional need for collective stakeholder validation and ownership of valuation data adds another layer of complexity to this research task. Thus, there is high research cost associated with ESV based on point estimate BT (Barton, 2002; Bagstad, 2009) and/or meta-analysis (Shrestha and Loomis, 2001; Lindhjem and Navrud, 2008; Londono and Johnston, 2012). These high research costs really 'limit' the application of BT method to 'high stakes' policy, economic and/or legal problem contexts for which scientifically defensible data and/or legal compliance is required (Bingham *et al.,* 1992). While RESA provides the luxury of a low cost valuation method that is relatively easy to use, it is still dependent on valuation data availability (Pendleton *et al.,* 2007) and quality. The use of RESA can make data quality questions difficult to answer and does not change the fact that benefit transfer is *simply not feasible when there are no original benefit studies or the original studies are poorly designed and reported* (Wilson and Hoehn, 2006 p. 340).

Despite its limitations, one of the reasons RESA has been so widely adopted internationally reflects the current lack of a viable alternative neo-classical valuation method that connects with real-world policy, economy, planning and business contexts. A neo-classical valuation method 'gap' currently exists between the extremes of (i) RESA as a low cost, accessible but imprecise scoping tool and (ii) the comparatively high compliance costs (Cole, 2014) associated with the appropriate use of BT method to produce transparent and defensible valuation data suited to policy, planning, economic and business contexts (Laurans *et al.,* 2013). This 'gap' is also evident in current ESV practice. There exists a very real 'cost' disincentive in moving from ESV studies based initially on RESA, followed by more expensive BT method. A well-rehearsed justification for using RESA has been to scope-out a problem and generate rough value estimates that can be used to prioritise the future investment of research funds in more detailed BT studies and/or modelling research. Thus, we might think of RESA as a first step and BT as a third step. However, ESV practice is currently missing a second step and this second step is needed because the jump between step 1 (i.e. RESA) and step 3 (i.e. BT) is too great in research cost terms.

While the use of RESA is based on a seemingly logical argument, it is very difficult to find examples of where the jump between step 1 and step 3 has worked in practice. For example, RESA was initially used in New Zealand in both national and regional scale assessments of TESV (Patterson and Cole, 1999a; Patterson and Cole, 1999c; Cole and Patterson, 2003; McDonald and

[7] The word 'quality' is used in the context of this study and report to refer to the assessment of method, computational accuracy and valuation uncertainty

Patterson, 2003; Crystall *et al.,* 2008). However, none of this early scoping research was ever followed by more detailed BT research that directly connected with policy development. A similar trend is evident in the international literature (Laurans *et al.,* 2013). This situation exists despite the arguably 'urgent need' that exists for the more effective inclusion of social fairness, ecological sustainability and cultural survival values in current market economic decision-making.

A RESA approach is used in this study because it provides a widely adopted (World Resources, 2005; Costanza and Kubiszewski, 2012), low cost and relatively simple method for measuring benefits-to-humans from ES in monetary terms. However, as a research team, we are very aware of the limitations of a RESA approach (on the one hand) and the problems associated with justifying detailed BT research in financial terms (on the other hand). We feel that the use of a RESA method provides an important, but *incomplete* entry point towards understanding the benefits to local communities that flow from MES within our study area. As noted earlier in this introduction, we consider this study as applying one of a wide range of valid ESV tools that could ideally be used. In order to capture a broader range of values, other valuation methods in addition to well-established anthropocentric, neo-classical approaches are really needed. It is our hope that continued funding of this research programme beyond its initial 1–year term will make exploration of these other methods possible.

The remainder of this report is organised around well-established scientific report format with one exception. We have moved a detailed explanation of our research method into the appendix of this report (Appendix A). This was done to make what we feel are the important findings of this report more accessible to readers. Thus, beyond this introductory context, section two outlines the results of this study, section 3 provides a discussion of results and method while section 4 draws the report to a close with conclusions.

2. Gross and net value estimates of ES in our study area

In this report section we present the results of an ESV of the Tasman and Golden Bays study area (Figure A1) by individual CME and then TEV estimates for both TES and MES. We also provide an introduction to the interpretation of these results. Each result sub-section begins with a brief outline of each CME, consideration of the GV and NV and then seeks to interpret these results with a focus on data quality. In calculating GV and NV estimates for each CME we were only able to gather enough BT data to support a mid-range value estimate. The calculation and layout of all results Tables is explained in sub-section 2.5.

2.1 The problem of interpreting ESV and TEV estimates

Interpretation of the valuation information presented in Tables 1–8 requires two types of information. First, the estimation of ESV for a given CME and/or all CMEs combined (i.e. TEV) involves the use of limiting assumptions associated with the rapid assessment valuation methods used in this study. To assist the reader, an outline of key assumptions is provided (Appendix B). Limiting assumptions can alter the estimation of value by making it larger or smaller than it should actually be. Thus, the results outlined in this report section need to be viewed with these limiting assumptions in mind. It is important to note that these limiting assumptions are not an indication of error in the measurement process. They simply indicate that the rapid assessment valuation method we have used is limited by our either understanding and/or the resources we have available for conducting a more detailed or comprehensive study.

Second, TEV estimates for individual ecosystems reflect individual ecosystem service values that are an indication, either directly or indirectly of perceived value. Thus, the fact that for a given CME, regulating ES have a higher total monetary value than supporting ES may not necessarily reflect an underlying marine ecological 'value' rationale. This difference may simply be the result of relative differences in human perception of what is important in welfare terms and what is not. In theory, human perception of value should be based on current ecological knowledge and a reasoned response to market supply and demand pressures. However, consumers are not always in possession of this information and have been shown to give value preference to more iconic, empathetic and visible entities over other less visible and ecologically more important entities.

2.2 A guide to interpreting ES (monetary) value estimates

While numerous RESA studies have now been published both nationally and internationally, the question of how to appropriately interpret RESA value estimates has not been clearly articulated in the published literature to date. This is surprising because monetary valuation is an imprecise science and the interpretation of valuation/RESA results should not be assumed to be a strait forward matter. The interpretation of RESA results involves a conscious shift in thinking. This is because when we see cardinal values in a report Table, there is a tendency to assume that the figures quoted represent an effort to measure size or extent and that these measurements will be correct, subject to the limitations of our measurement devices/method. For example, in laboratory science, measurement using laboratory glassware can be influenced by parallax error. Also, the measurement of very small elemental quantities must be conducted inside sealed glass cabinets to prevent air movement from disturbing the measurement apparatus. Generally speaking, we have become adapted to a modern scientific world in which we have control of measurement devices and measurement error.

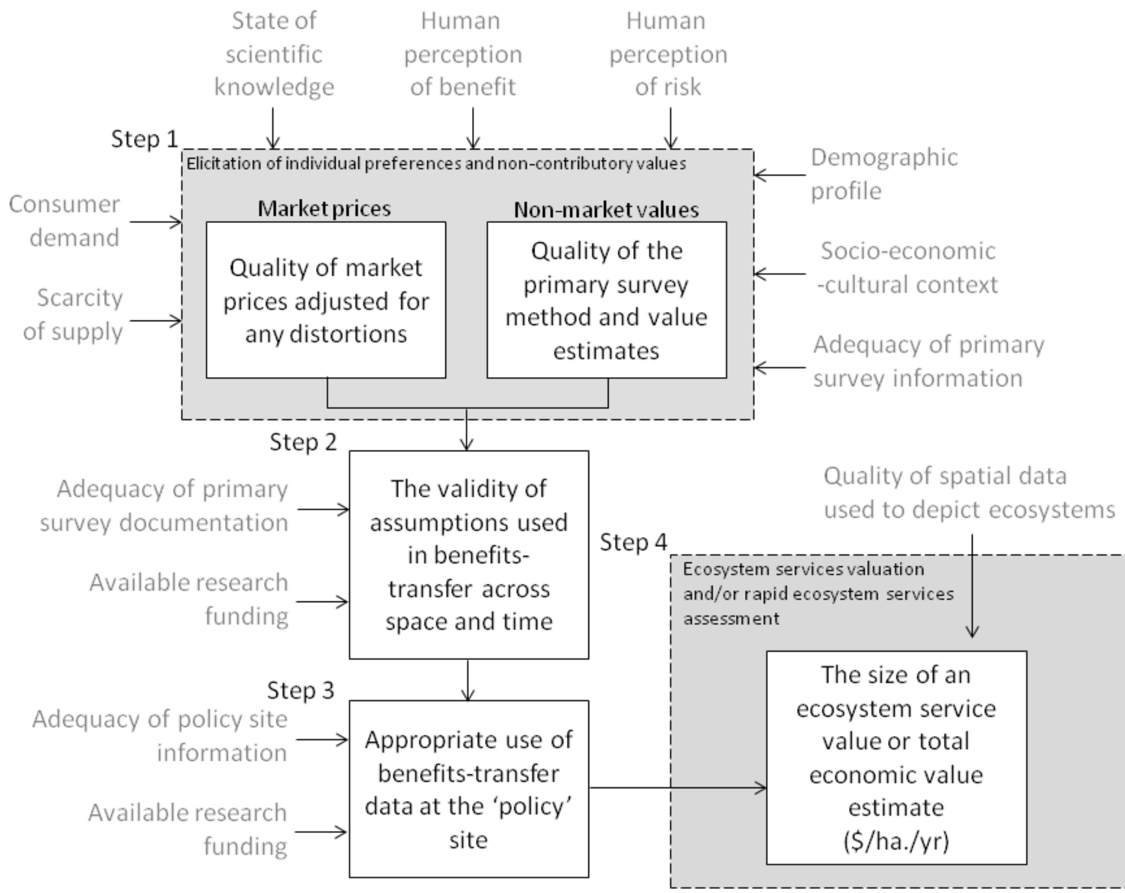

Figure 1 *An illustration that depicts the RESA method as a stepwise process along with the contributory factors that play a role in influencing the size of an ecosystem service value or TEV estimate*

Unfortunately, this way of 'laboratory science' thinking about measurement is an unhelpful basis for interpreting RESA results. This is because RESA value estimates are influenced by both (i) measurement problems over which we have *partial* control and (ii) measurement uncertainties over which we have no control at all. Interpretation of RESA value estimates ideally requires an understanding of data quality issues across the entire valuation and/or rapid assessment process. However, conventions for reporting on this information have been slow to emerge (Rosenberger and Stanley, 2006). Given this situation, we are pretty sure that most RESA value and TEV estimates are incomplete, have wide margins of computational error associated with them and may even indicate orders of magnitude that are incorrect. Because of the complex nature of the method used to create ES value estimates, we also think there is a strong correlation between valuation data quality and available research funding. The more funding and time we have to spend on ES valuation data collection and calculations, the greater confidence we can have in the quality of our value estimates.

In Figure 1, we have attempted to portray the ES valuation/assessment process in a way that highlights the many potential contributory factors that influence what we refer to in the lower right hand corner of Figure 1 as 'the size of an ESV or TEV estimate'. This illustration seeks to correct the oft-mistaken idea that the assignment of a monetary value in RESA implies an indication of size or extent for which we have control over measurement error and certainty. The RESA method is here depicted as involving 4 main steps, the contributory influence of which, on the final size of an ES value or TEV estimate is described below.

2.2.1 An explanation of step 1 in Figure 1

The valuation process begins (i.e. step 1) with the elicitation of individual preferences and non-contributory values. Value estimates can be drawn from market prices and/or non-market surveys and neither of these sources of value estimates is necessarily accurate. Market prices can be influenced by distortions at the time of measurement. Non-market value estimates are obtained using (i) stated preference methods that simulate markets in a survey activity and (ii) revealed preference methods that seek to infer value estimates from consumer behaviour. Non-market value estimates are clearly *method dependent* and therefore an ongoing area of research.

The elicitation of individual preferences using either market prices or non-market value estimates is highly sensitive to a range of external influences including: (i) shifts in supply and demand that temporarily influence price, (ii) the state and/or lack of scientific knowledge that guides the expression of consumer preferences, (iii) human perception of risk that influences decisions about spending behaviour in markets and the statement of preferences in non-market survey methods, (iv) the influence of demographic profile (esp. income distribution) on consumption and stated preferences, (v) socio-economic-cultural context and (vi) the adequacy of primary survey information in stated preference surveys. Thus, both market and non-market values *are at best* 'estimates' that are subject to market distortions and non-market survey influences over which we do not yet have full measurement control. Also, the state of current scientific knowledge (i.e. uncertainty) means that even the most accurate measurement of market prices and non-market stated preferences maybe misleading. Generally, what science continues to discover about the value of ES to human wellbeing will *continue to place upward pressure* on market prices and/or stated/revealed preference estimate.

2.2.2 An explanation of step 2 in Figure 1

RESA is dependent upon the transfer of benefits from original survey sites to a policy site[8]. This means that policy site estimates of data are strongly dependent upon the current state of primary ESV data in the published literature. Where there are gaps in international data available for transfer, estimates of TEV at the policy site will be accordingly lower than they should be. BT is also influenced by the adequacy of primary survey documentation. This documentation is all we have for assessing the similarity of survey and policy site similarity and for making appropriate accounting adjustments where there is a perceived lack of similarity. The amount of research funding we have access to will determine the amount of time we have to spend assessing and making corrections for 'between site' dissimilarity.

Furthermore, the transfer of benefits across time is method dependent; the computational adjustment method used determines the ultimate size of the value estimate and this includes adjustments for PPP, CPI and exchange rates across time. CPI and PPP themselves are calculated from data (i.e. GDP estimates) supplied from SNAs that are themselves created (bottom up) from industry survey estimates of market transactions that can have significant margins of error associated with them.

2.2.3 An explanation of step 3 in Figure 1

BT data must be appropriately used at the policy site. This accounting goal is strongly dependent upon the adequacy of policy site information that can be used to (i) assess 'survey/policy site similarity' and (ii) make appropriate accounting corrections for dissimilarity. Clearly, the extent to which it is possible to make detailed assessments of similarity and corrections for dissimilarity is strongly dependent upon available research funding and suitable data.

2.2.4 An explanation of step 4 in Figure 1

The size of an ESV or TEV estimate ($/ha./yr.) is the result of multiplying together estimates of ecosystem area (ha.) by a given ecosystem service value estimate ($/yr.). It is important to note that the resultant value reported in $/ha./yr. is weighted by an estimation of relevant area (ha.). Thus, the quality and accuracy of spatial data will also influence the size of an ESV or TEV estimate. There are numerous potential sources of estimation error in spatial data associated with: (i) the method of area estimation, (ii) the aggregation of GIS feature classes and (iii) availability of spatial data that measures *landuse* rather than *landcover.*

2.2.5 The rationale behind ESV

Figure 1 provides a useful visual overview of key sources of potential measurement and/or computational error and uncertainty associated with the creation of RESA value estimates. Given this illustration and written explanation, it should now be clear that the interpretation of RESA

[8] This includes the movement of benefits across both space (i.e. between regions or between countries) and time (i.e. value estimates initially measured in the past may need to be applied at a future time).

results needs to be undertaken with care, caution and adequate information. Monetary valuation is not a precise science and this raises an oft-asked question i.e. ‘if the monetary value of ES is so difficult to estimate then why bother’? There are a number of important reasons for valuation exercises of this kind.

First, there has been a tendency in the past, not to attempt to value the contribution to human welfare made by ES. This resulted in a situation in which ES effectively had a value of zero. Scientists are now in general agreement that a value of zero is far more problematic than an imprecise estimate of monetary value. Second, attempts to avoid the monetary valuation of ES contributed to a situation in which consumers simply assumed that ecosystems made no contributions of value to human welfare.

Although imprecise, RESA have played an important role in raising public and policy awareness about the fact that even by conservative estimation, ES can make an annual contribution to human welfare that typically exceeds estimates of annual GDP in local market economies. Finally, we actually have no choice. As the human population and levels of economic consumption increase, ecosystem goods and services are gradually becoming scarce and it is essential that these changes are associated with appropriate price signals. Thus, the monetary valuation of ES provides an incomplete, but valuable foundation for making tradeoffs with the aid of cost-benefit analysis.

2.3 Value of ES derived from the continental shelf CME

The continental shelf ecosystem covers approximately 92% (368,705 ha.) of our study area (Table A2) and may be described as areas always inundated by seawater (i.e. sub-tidal) covering the continental shelf. Rocky reef, seagrass and macroalgae are not included in this CME. The benthic sediment type for this CME can range from mud to boulders. Coastal waters includes areas with bryozoan mounds, 75% of the artificial structures in the case study area (excluding ramps, sea and rock walls), with the other 25% being assigned to the ‘rocky reef’ CME. The GIS depiction of this CME includes the following structural feature classes: mud (excluding estuarine mud); mud/sand (excluding estuarine mud/sand), sand (excluding estuarine sand), gravel (excluding estuarine gravel), cobble/boulder/rock (excluding estuarine cobble, estuarine boulder, estuarine rock) and 75% of artificial structures, excluding ramp & seawall/rock wall features.

The results of rapid valuation assessment suggest that the continental shelf CME produces an annual GV of ES estimated at $1,440M/yr. (Table 1) in $\$NZ_{2012}$. Most of this GV is created by supporting ($1,354M/yr.), non-material ($46M/yr.), and regulating ($37M/yr.) ecosystem services. A small portion of this value is derived from commercial food production ($1.45M/yr.) meaning that approximately 1.6% of this ESV is captured by the regional SNA. Once contributions made by supporting ES have been removed, then this CME has a NV estimate of $87M/yr.

Table 1 *Value estimate of ES derived from continental shelf CME (NZ_{2012}$M/yr.)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Nutrient cycling	1,354.22	-	-	-	-	1,354.22	-
Biological regulation	-	36.91	-	-	-	36.91	36.91
Food	-	-	1.45	-	1.45	1.45	1.45
Raw materials	-	-	1.89	-	-	1.89	1.89
Aesthetic	-	-	-	22.08	-	22.08	22.08
Research & education	-	-	-	2.21	-	2.21	2.21
Spiritual & historic	-	-	-	22.08	-	22.08	22.08
Column totals	1,354.22	36.91	3.35	46.37	1.45	1,440.84	86.62

The estimate of NV ($87M/yr.) for continental shelf represents 8% of net TEV (Table 12a). However, of all CMEs valued in this study, continental shelf has the highest level of spatial extent at 92% (i.e. 368,705 ha.) of the study area (Table A2). Thus, it's GV and NV estimates are partly a consequence of spatial extent and in addition - a relatively high (average) gross '$/ha.' multiplier of $3,908/ha. (Table 2).

Table 2 *GV (NZ_{2012}$/yr.), area (ha.) and '$/ha.' value estimates (NZ_{2012}$) for all 8 CMEs in this study*

CME	Gross ($/yr.)	Area (ha.)	Gross ($/ha.)
Continental shelf	1,440,841,710	368,705	3,908
Estuary	440,606,866	7,628	57,760
Intertidal	798,633,058	10,353	77,140
Lagoon	20,110,464	260	77,140
Saltmarsh	115,031,548	1,491	77,140
Seagrass	890,532,329	7,404	120,269
Rocky reefs	6,004,221	1,270	4,724
Sand beach/dunes	417,521,436	3,008	138,804

As can be seen from Table 1, the rapid valuation assessment of continental shelf is based on 7 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material[9]) are underrepresented by value estimates (i.e. a total of 7 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented approximately 30% of the values needed to completely fill Table 1 with all 23 ES indicators used in this study.

Nutrient cycling makes the largest monetary contribution to the value of continental shelf in comparison to any other ecosystem service including food production (i.e. fish harvest within the study area). This result is surprising. While the cycling of nutrients in the coastal zone at the

[9] The name 'non-material' has been used in this study in preference to 'cultural' services, as used in the international MEA research programme.

interface between terrestrial aquatic and marine ecosystems is important for marine primary production, most nutrients, terrestrial organic materials and sediments are eventually stored in marine sediments that are only made available to the human economy over geological time scales. Therefore, the high values for this ecosystem service seem to represent an anthropocentric rather than ecological perception of value.

Non-material (i.e. aesthetic, research, educational, historic and spiritual) ES make the next largest monetary contribution ($46.37M/yr.) to Table 1. This total contribution is even larger than the combined total of provisioning services (which includes food harvest) and the monetary value linked with the regulation of marine populations and biodiversity ($37M/yr.). These results highlight just how important such non-material values are to human wellbeing.

Overall, there are more empty cells in Table 1 than those with values, a fact that reflects on the paucity of national and/or international value data for this important CME. There also appears to be no value data available (i.e. internationally and/or nationally) for some important ES that we would expect to find in the open ocean/continental shelf ecosystem. For example, the surface waters of this ecosystem capture light that is used directly by phytoplankton and indirectly by zooplankton as the basis of marine primary production. This critical ecosystem service is completing missing. Likewise, while the terrestrial/marine sediment of the continental shelf is an important storage site for terrestrial carbon, we have been unable to find any estimates for carbon sequestration associated with this ecosystem. Recreation benefits (i.e. boating, diving, sailing, pleasure fishing), habitat provisioning, gas and waste regulation values should also be included in total value estimates of this CME. We must therefore consider the gross and net total estimates for continental shelf value to be an underestimate of annual economic value.

2.4 Value of ES derived from estuarine CME

The estuarine CME covers approximately 1.9% (7,628 ha.) of our study area (Table A2) and may be described as partially enclosed coastal embayment's where freshwater and seawater meet and mix. The estuarine CME does not include saltmarsh/wetland, seagrass or macroalgae, although these habitats may be present in some places. The GIS depiction of this CME includes the following structural feature classes: estuarine mud, estuarine mud/sand, estuarine sand, estuarine gravel, estuarine cobble, estuarine boulder, estuarine rock, estuarine beach, estuarine rocky shore, shellfish bed and worm beds.

The results of rapid valuation assessment suggest that estuarine CMEs produce an annual GV of ES estimated at $441M/yr. in NZ_{2012} (Table 3). Most of this estimated GV is contributed by supporting ($416M/yr.) and regulating ($13M/yr.) ecosystem services. A small portion of this value is derived from an international estimate[10] of the contribution made by estuaries to commercial food production (i.e. $10M/yr.) meaning that approximately 1% of NV belonging to

[10] Due to a lack of local data we have used averaged international market data

this CME could be captured by the SNA. Once contributions made by supporting ES have been removed, this CME yields an annual NV estimate of $25M/yr.

Table 3 *Value estimate of ES derived from estuarine CME (NZ_{2012}$M/yr.)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Nutrient cycling	413.12	-	-	-	-	413.12	-
Habitat	2.56	-	-	-	-	2.56	-
Disturbance regulation	-	11.10	-	-	-	11.10	11.10
Biological regulation	-	1.53	-	-	-	1.53	1.53
Food	-	-	10.2	-	10.2	10.20	10.20
Raw materials	-	-	0.49[1]	-	-	0.49	0.49
Recreation	-	-	-	1.61	-	1.61	1.61
Column totals	415.68	12.63	10.69	1.61	10.2	440.61	24.92

[1] International average

The estimate of NV ($25M/yr.) for estuarine ecosystems represents 2% of net TEV (Table 12a). Estuarine CME have a spatial extent of 1.9% (i.e. 7,628 ha.) of the study area (Table A2). In contrast to continental shelf, estuarine ecosystem services have a much larger (average) gross '$/ha.' multiplier of $57,760/ha. (Table 2) applied to a comparatively small spatial area (Table A2). As can be seen from Table 3, the rapid assessment of estuarine ES is based on 7 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material) are underrepresented by value estimates (i.e. a total of 7 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented 30% of the values needed to completely fill Table 3 with all 23 ES indicators used in this study.

The mixing of fresh and saline water in estuaries plays an important role in the deceleration and deposition of terrestrial sediments and organic materials in estuaries. The inflow of both freshwater and coastal waters into an estuary thus results in high levels of nutrients in both the water column and sediments. This means that estuaries are among the most productive natural ecosystems in the world. Not surprisingly, nutrient cycling makes the largest monetary contribution to the monetary value of estuaries in comparison to any other ecosystem service including food production (i.e. fish harvest). While estuaries play an important role in coastal marine productivity, their non-material (i.e. recreational) benefits are relatively small ($1.6M/yr.) when compared with supporting, regulating and provisioning service categories. The estimates of value for PES (i.e. food production and raw materials) are based on the transfer of international average value estimates. While recreational fishing is permitted within estuaries, we have no local estimates of the indicative monetary value of fish catch and/or local raw materials harvest. While a market for these provisioning services may exist in New Zealand, further research is needed in this area to better understand how to appropriately apply these value estimates. Given that estuaries sustain high levels of marine and terrestrial biodiversity, it seems likely that the monetary estimates provided in this RESA for supporting habitat and biological regulation should be substantially higher and possibly similar to nutrient cycling. While this may differ from one estuary to another, one of New Zealand's estuaries is actually protected under the International Ramsar convention[11]. Thus, it seems likely that the estuaries of our study area should also have a moderate to high biodiversity status given their proximity to the expansive mudflats, sand spit and high bird diversity of Farewell Spit[12], Kahurangi National Park and Abel Tasman National Park.

Overall, there are more empty cells in Table 3 than those with values, a fact that reflects on the paucity of national and/or international value data for this important CME. There also appears to be no value data available (i.e. internationally and/or nationally) for some important ES that we would expect to find in an estuarine CME. For example, the nutrient rich surface waters of this ecosystem capture light that is used directly by phytoplankton and indirectly by zooplankton as the basis of marine primary production. This critical ecosystem service is completely missing. The terrestrial/marine sediment of estuaries is an important storage site for terrestrial and marine carbon. However we have been unable to find any estimates for carbon sequestration associated with this ecosystem. Gamete/seed dispersal, erosion control, waste regulation, genetic resources (i.e. high biodiversity), aesthetic, research and spiritual values should also be included in total value estimates of this CME. We must therefore consider the GV and NV estimates for estuarine value to be an underestimate of annual economic value.

2.5 Value of ES derived from the lagoon CME

The lagoon CME covers approximately 0.01% (261 ha.) of our study area (Table A2) and may be described as a shallow stretch of water separated from the ocean by a coastal land barrier. In our case study area, small lagoons are located along Farewell Spit. The GIS depiction of this CME includes only one structural feature class: water.

The results of rapid valuation assessment suggest that the lagoon CME produces an annual GV of ES estimated at \$19.33M/yr. in $\$NZ_{2012}$ (Table 4). Most of this GV is contributed by supporting (\$8.26M/yr.) and regulating (\$6.25M/yr.) ecosystem services. A small portion of this value is derived from provisioning services (i.e. \$5M/yr.), although they are not related to market activity given the Ramsar and Wildlife Reserve status of Farewell Spit where lagoon ecosystems are located. Once contributions made by supporting ES have been removed, then this CME yields an annual NV estimate of \$11M/yr.

Unfortunately, international RESA studies tend to group estuarine, lagoon and intertidal together as one ecosystem indicator. A likely reason for this aggregation is a lack of available market and/or non-market values for intertidal and lagoon ecosystems. We have not been able to find a unifying

11 http://sciblogs.co.nz/waiology/2013/02/05/ramsar-wetlands-in-nz-why-are-they-important-and-where-are-we-going/

12 Farewell Spit is also protected under the international Ramsar convention

ecological rationale for this aggregation in the previously published reports and papers we have reviewed. For this reason we have applied 'saltmarsh' ecosystem value estimates to intertidal and lagoon ecosystems rather than estuarine ESV estimates. We have done this because we feel that there is a higher *functional* similarity between intertidal/lagoon and saltmarsh ecosystems (i.e. they are all tidal or semi-tidal). Also, estuarine ecosystems perform a distinct (daily) biophysical function in the mixing of fresh and marine waters. Thus, the sizable estuarine value estimates for nutrient cycling, habitat, disturbance regulation and food production don't easily apply to lagoon and intertidal ecosystems. Having said this, the '$/ha.' value estimates for saltmarsh (i.e. $77,140) are actually higher than those of estuarine ecosystems (i.e. $57,760). Neither of these valuation and/or classification/approaches is ideal. An urgent need for more primary valuation research related to these ecosystems exists. Therefore, in the absence of more suitable valuation data, we report the following rapid assessment findings (Table 4).

Table 4 *Value estimate of ES derived from lagoon CME (NZ_{2012}$M/yr.)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Nutrient cycling	0.003	-	-	-	-	0.003	-
NPP	8.19	-	-	-	-	8.19	-
Gamete/seed dispersal	0.003	-	-	-	-	0.003	-
Habitat	0.06	-	-	-	-	0.06	-
Gas regulation	-	0.006	-	-	-	0.006	0.006
Climate regulation	-	0.40	-	-	-	0.40	0.40
Disturbance regulation	-	0.31	-	-	-	0.31	0.31
Biological regulation	-	0.005	-	-	-	0.005	0.005
Water regulation	-	4.18	-	-	-	4.18	4.18
Erosion control	-	0.004	-	-	-	0.004	0.004
Sediment formation	-	0.0008	-	-	-	0.0008	0.0008
Waste regulation	-	1.35	-	-	-	1.35	1.35
Water supply	-	-	0.04	-	-	0.04	0.04
Genetic resources	-	-	4.71	-	-	4.71	4.71
Recreation	-	-	-	0.07	-	0.07	0.07
Research & education	-	-	-	0.00000021	-	0.00000021	0.00000021
Spiritual & historic	-	-	-	0.0045	-	0.0045	0.0045
Column totals	8.26	6.25	4.75	0.08	-	19.33	11.07

The estimate of NV ($11.07M/yr.) for the Farewell Spit lagoon ecosystems represents 1% of net TEV (Table 12a). Estuarine CME have a spatial extent of 0.01% (261 ha.) of the study area (Table A2). In contrast to continental shelf and estuarine, the lagoon ecosystem (along with intertidal and saltmarsh) share a much larger (average) gross '$/ha.' multiplier of $77,140/ha. (Table 2) applied to comparatively small ecosystem areas (Table A2). As can be seen from Table 4, the rapid assessment of lagoon ES is based on 17 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material) are underrepresented by value estimates (i.e. a total of 17 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented 73% of the values needed to completely fill Table 4 with all 23 ES indicators used in this study.

Although still incomplete, Table 4 contains a much greater representation of ES than Table 3 (i.e. estuarine) and Table 1 (i.e. continental shelf). This means that important ES that apply to lagoon ecosystems like NPP, waster regulation; genetic resources; water regulation and habitat are now more effectively represented. The non-material recreational, research, educational and aesthetic importance of lagoons is also valued in recognition of the location of these ecosystems in a wildlife sanctuary with international Ramsar status. Finally, the contribution made to nutrient cycling is comparatively small as we would expect for a lagoon along with other supporting and regulating services more specifically relevant to saltmarsh ecosystems.

Averaged international value estimates have been included for the provisioning of water supply and genetic resources. These values would be relevant as supporting services given the vital contribution made by Farewell Spit to local biodiversity. For this reason we have left these value estimates in this rapid assessment. However, these same provisioning values would be an overestimate for a New Zealand cultural context in which these things have little or no commercial value (assuming harvest from these lagoons were legally permissible). None of these values are captured by GDP as consistent with the legal status of Farewell Spit as a Ramsar site and wildlife sanctuary.

Overall, there are still more empty cells in Table 5 than those with values, a fact that reflects on the paucity of national and/or international value data for this important CME. There also appears to be no value data available (i.e. internationally and/or nationally) for some important ES that we would expect to find in the lagoon ecosystem. For example, lagoons perform a function in the storage of carbon related to organic sediments formed as a consequence of primary production (i.e. marine phytoplankton and zooplankton). This CME is also a likely candidate for food provisioning as a supporting ecosystem service to local birdlife. Overall, we must therefore consider the gross and net total estimates for estuarine value to be a likely underestimate of annual economic value.

2.6 Value of ES derived from intertidal coastal marine ecosystems

The intertidal CME covers approximately 2.6% (10,353 ha.) of our study area (Table A2) and may be described as benthic area lying between the extremes of high and low tides. In this case, only rocky intertidal areas are included while sandy intertidal areas are captured in the 'sand, beach and dunes' category (below). This CME does not include intertidal areas within estuaries. Boat ramps, sea and rock walls are also included in this CME. The GIS depiction of this CME includes the following structural feature classes: shoreline rocky sediment (excluding estuarine rocky shore), ramps, coastal water and rock walls.

Economic values for rapid assessment of the intertidal CME have been derived from the saltmarsh ecosystem (ref. sub-section 2.5). The results of rapid valuation assessment suggest that the intertidal CME produces an annual GV of ES estimated at $799M/yr. in NZ_{2012} (Table 6). This GV estimate is contributed to by supporting ($328M/yr.), regulating ($248M/yr.) and provisioning ($219M/yr.) ecosystem services. None of the estimates for provisioning services have been derived from local estimates of regional GDP. Once contributions made by supporting ES have been removed, this CME yields an annual NV estimate of $441M/yr. (Table 5).

Table 5 *Value estimate of ES derived from intertidal CME (NZ_{2012}M/yr.)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Nutrient cycling	0.12	-	-	-	-	0.12	-
NPP	325.36	-	-	-	-	325.36	-
Gamete/seed dispersal	0.11	-	-	-	-	0.11	-
Habitat	2.55	-	-	-	-	2.55	-
Gas regulation	-	0.23	-	-	-	0.23	0.23
Climate regulation	-	15.70	-	-	-	15.70	15.70
Disturbance regulation	-	12.18	-	-	-	12.18	12.18
Biological regulation	-	0.21	-	-	-	0.21	0.21
Water regulation	-	165.83	-	-	-	165.83	165.83
Erosion control	-	0.18	-	-	-	0.18	0.18
Sediment formation	-	0.03	-	-	-	0.03	0.03
Waste regulation	-	53.69	-	-	-	53.69	53.69
Water supply	-	-	1.50	-	-	1.50	1.50
Food	-	-	29.09	-	-	29.09	29.09
Raw materials	-	-	1.79	-	-	1.79	1.79
Genetic resources	-	-	186.97	-	-	186.97	186.97
Recreation	-	-	-	2.92	-	2.92	2.92
Research & education	-	-	-	0.0000082	-	0.0000082	0.0000082
Spiritual & historic	-	-	-	0.18	-	0.18	0.18
Column totals	328.15	248.04	219.35	3.10	-	798.63	441.39

The estimate of NV ($441M/yr.) for the intertidal CME represents 43% of net TEV (Table 12a). Intertidal CME have a spatial extent of 2.6% (10,353 ha.) of the study area (Table A2). Intertidal is thus the second largest ecosystem type in our study area next to continental shelf in terms of spatial extent.

In this rapid assessment, the intertidal CME shares a GV '$/ha.' multiplier of $77,140/ha. Along with saltmarsh and intertidal (ref. Table 2) when this multiplier is applied to an equally large ecosystem area (i.e. 10,353 ha.) it produces the 3rd largest CME value estimate in this study. As can be seen from Table 5, the rapid assessment of intertidal services is based on 19 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material) are underrepresented by value estimates (i.e. a total of 19 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented 82% of the values needed to completely fill Table 5 with all 23 ES indicators used in this study.

Although still incomplete, Table 5 contains a much greater representation of ES than Table 3 (i.e. estuarine) and Table 1 (i.e. continental shelf). This means that important ES that apply to intertidal ecosystems like NPP, waste regulation; genetic resources; water regulation and habitat are now more effectively represented. The non-material recreational, research, educational and aesthetic importance of intertidal are also valued in recognition of the role this CME plays in providing non-material benefits to human welfare. The contribution made to nutrient cycling is comparatively small as we would expect for an intertidal ecosystem when compared with estuarine. The role of the intertidal ecosystems in disturbance regulation and erosion may well be undervalued with these value estimates that we have applied from saltmarsh ecosystems. Finally, the combination of a large '$/ha.' multiplier for recreational ES and the spatial extent of intertidal ecosystems (i.e. 10,353 ha.) results in a value estimate of $2.9M/yr. This is probably an overestimate when compared with sand, beach and dune ecosystems, which have a comparative value estimate of $5M/yr. It's unlikely that intertidal ecosystems would receive a comparative level of recreational use as sand, beach and dunes.

Averaged international values have been included for the provisioning of water, food, raw materials and genetic resources. These values are probably an overestimate in a New Zealand cultural context for where these things would have little or no commercial value. Further research is needed to better understand the validity of these value estimates. None of these provisioning values are captured by current regional estimates of GDP.

Overall, there are still more empty cells in Table 5 than those with values, a fact that reflects on the paucity of national and/or international value data for this important CME. There also appears to be no monetary value data available (i.e. internationally and/or nationally) for some important ES that we would expect to find in the rocky intertidal ecosystem. For example, intertidal ecosystems perform a function in the storage of carbon related to benthic species and mussel beds. This CME is also a likely candidate for food provisioning as a supporting ecosystem service to local birdlife and fish species. Overall, we must therefore consider the gross and net total estimates for estuarine value to be a likely underestimate of annual economic value.

2.7 Value of ES derived from saltmarsh CME

The saltmarsh CME covers approximately 0.4% (1,491 ha.) of our study area (Table A2) and may be described as a community of halophytic (salt-tolerant) emergent vegetation rooted in soils alternately inundated and drained by tidal action. The GIS depiction of this CME includes the following structural feature classes: estuarine shrubland, tussockland, grassland, sedgeland, rushland, reedland and herbfield.

The results of rapid valuation assessment suggest that the saltmarsh produces an annual GV of ES estimated at \$115M/yr. in $\$NZ_{2012}$ (Table 6). Most of this GV is contributed by supporting (\$47M/yr.), regulating (\$35M/yr.) and provisioning (\$32M/yr.) ecosystem services. None of the estimates for provisioning services have been derived from local estimates of regional GDP. Once contributions made by supporting ES have been removed then this CME yields an annual NV estimate of \$64M/yr. (Table 6).

Table 6 *Value estimate of ES derived from saltmarsh CME (*$\$NZ_{2012}$*M/yr.)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Nutrient cycling	0.02	-	-	-	-	0.02	-
NPP	46.86	-	-	-	-	46.86	-
Gamete/seed dispersal	0.02	-	-	-	-	0.02	-
Habitat	0.37	-	-	-	-	0.37	-
Gas regulation	-	0.03	-	-	-	0.03	0.03
Climate regulation	-	2.26	-	-	-	2.26	2.26
Disturbance regulation	-	1.75	-	-	-	1.75	1.75
Biological regulation	-	0.03	-	-	-	0.03	0.03
Water regulation	-	23.89	-	-	-	23.89	23.89
Erosion control	-	0.03	-	-	-	0.03	0.03
Sediment formation	-	0.00	-	-	-	0.00	0.00
Waste regulation	-	7.73	-	-	-	7.73	7.73
Water supply	-	-	0.22	-	-	0.22	0.22
Food	-	-	4.19	-	-	4.19	4.19
Raw materials	-	-	0.26	-	-	0.26	0.26
Genetic resources	-	-	26.93	-	-	26.93	26.93
Recreation	-	-	-	0.42	-	0.42	0.42
Research & education	-	-	-	0.0000012	-	0.0000012	0.0000012
Spiritual & historic	-	-	-	0.03	-	0.03	0.03
Column totals	47.27	35.73	31.59	0.45	-	115.03	63.58

The estimate of NV (\$64M/yr.) for the saltmarsh ecosystems represents 6% of net TEV (Table 12a). Saltmarsh CME has a spatial extent of 0.4% (1,491.20 ha.) of the study area (Table A2). Saltmarsh is thus one of the smallest ecosystems in our study area in terms of spatial extent. In this rapid assessment, the saltmarsh ecosystem type shares a gross '\$/ha.' multiplier of \$77,140/ha. with lagoon and intertidal ecosystems (Table 2), however its GV estimate is one of the smallest for our study area. As can be seen from Table 6, the rapid assessment of saltmarsh services is based on 19 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material) are underrepresented by value estimates (i.e. a total of 19 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented 82% of the values needed to completely fill Table 6 with all 23 ES indicators used in this study.

The saltmarsh ecosystem value estimates have also been applied to the lagoon and intertidal ecosystems. Consistent with the results for these 2 ecosystems, Table 6 contains a much greater representation of ES than Table 3 (i.e. estuarine) and Table 1 (i.e. continental shelf). This means that important ES that apply to saltmarsh ecosystems like NPP; waste regulation; genetic resources; water regulation and habitat are represented. The non-material recreational, research, educational and aesthetic importance of intertidal is also valued in recognition of the role this ecosystem plays in providing non-material benefits to human welfare. Given the lack of iconic status that this ecosystem has, the non-material service estimate is small and we would expect this. Finally, the contribution made to nutrient cycling is comparatively small as we would expect for a saltmarsh ecosystem when compared with estuarine.

Averaged international values have been included for the provisioning of water, food, raw materials and genetic resources. These are likely to be an overestimate for New Zealand conditions because the saltmarsh ecosystem type is not used as a basis for harvesting food and materials of commercial value as may be the case in other cultures. By contrast, the role of food, raw materials, water supply and genetic resources as supporting services has no value at all and this is likely to be a critical omission of value. For this reason, we have left these value estimates in this rapid assessment. Further research is needed in this area to better understand the applicability of these values to a New Zealand cultural context.

Overall, there are still more empty cells in Table 7 than those with values, a fact that reflects on the paucity of national and/or international value data for this important CME. There also appears to be no value data available (i.e. internationally and/or nationally) for some important ES that we would expect to find in the saltmarsh ecosystem. For example, saltmarsh ecosystems perform a function in the storage of carbon related to the presence of halophytic plants and organic rich sediments. Overall, we must therefore consider the gross and net total estimates for saltmarsh value to be a likely underestimate of annual economic value.

2.8 Value of CME derived from the seagrass CME

The seagrass CME covers approximately 1.9% (7,404 ha.) of our study area (Table A2) and contains seagrass (sometimes called eelgrass) that are the sole marine representatives of the class Angiospermae[13]. *Zostera muelleri* is the most common species of seagrass in New Zealand. It primarily grows in the intertidal zone with limited populations growing in sheltered sub-tidal areas

[13] *Zostera muelleri* is the most common species of seagrass in New Zealand. It primarily grows in the intertidal zone with limited populations growing in sheltered sub-tidal areas with clear water.

with clear water. The GIS depiction of this CME includes only one structural feature class (i.e. seagrass).

The results of rapid valuation assessment suggest that the seagrass CME produces an annual GV of ES estimated at $890M/yr. in NZ_{2012} (Table 8). In Table 8, this GV is contributed fully by supporting services. This fact reflects a lack of suitable international and/or local BT data for valuing seagrass regulating, provisioning and non-material services. Unfortunately, this means that it is currently not possible to calculate a separate estimate of NV for this CME from the published literature.

Table 7 *Value of ES derived from seagrass CME (NZ_{2012}M/yr.)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Nutrient cycling	523.49	-	-	-	-	523.49	-
Habitat	360.82	-	-	-	-	360.82	-
Carbon sequestration	6.22	-	-	-	-	6.22	-
Column totals	890.53	-	-	-	-	890.53	-

In Table 8 we have attempted to generate a crude estimate of GV and NV for seagrass based on what we know about its ecology and comparative values of saltmarsh ecosystems within our study area. In the case of seagrass, it would not have been appropriate to just apply saltmarsh values as we have done in the case of lagoon and intertidal ecosystems. This is because the supporting values alone that are shown in Table 7 are based on a '$/ha.' (GV) multiplier of $120,269/ha. The size of this multiplier is second only to sand, beach and dunes at $138,804/ha. (i.e. the largest for our entire study area). By comparison, the GV multiplier for saltmarsh (supporting, regulating, provisioning and non-material services combined) is only $77,140/ha. Thus, the '$/ha.' multiplier value of supporting services for seagrass is very high. Therefore, the use of all saltmarsh values in this case would likely result in a significant underestimate of GV and NV for seagrass.

In Table 8 we have supplemented the supporting values of Table 7 (seagrass) with the regulating, provisioning and non-material values of saltmarsh, applied to the spatial extent of seagrass in our study area. Table 8 thus provides what is likely to be a *crude assessment* of NV ($32M/yr.) and GV ($922M/yr.) for seagrass. Given the high value estimates for nutrient cycling, habitat and carbon sequestration/storage, in ecological terms we would expect the contributions of atmospheric gas, climate, disturbance and biological regulation along with erosion control, sediment formation and waste regulation (Table 8) to be higher. This assumption is based on the understanding that supporting services contribute value to regulating and provisioning services.

Table 8 *A crude value estimates of ES derived from seagrass CME (NZ_{2012}$M/yr.) based on regulating, provisioning and non-material value estimates transferred from the saltmarsh ecosystem values used in this study*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Nutrient cycling	523	-	-	-	-	523	-
Habitat	360	-	-	-	-	360	-
Carbon seq./storage	6.2	-	-	-	-	6.2	-
Gas regulation	-	0.028	-	-	-	0.028	0.028
Climate regulation	-	0.188	-	-	-	0.188	0.188
Disturbance regulation	-	0.140	-	-	-	0.140	0.140
Biological regulation	-	0.025	-	-	-	0.025	0.025
Water regulation	-	0.617	-	-	-	0.617	0.617
Erosion control	-	0.018	-	-	-	0.018	0.018
Sediment formation	-	0.004	-	-	-	0.004	0.004
Waste regulation	-	3.5	-	-	-	3.5	3.5
Water supply	-	-	0.184	-	-	0.184	0.184
Food	-	-	3.5	-	-	3.5	3.5
Raw materials	-	-	0.220	-	-	0.220	0.220
Genetic resources	-	-	22.9	-	-	22.9	22.9
Recreation	-	-	-	0.358	-	0.358	0.358
Spiritual & historic	-	-	-	0.004	-	0.004	0.004
Column totals	891	5	27	0	-	922	32

The validity of provisioning and non-material ES is difficult to assess for the seagrass ecosystem in a New Zealand cultural context. This really needs more research to assess the validity of these averaged international values. Table 8 suffers from the under representation problems evident in all other results (i.e. Tables 1, 2–7 presented so far in this report). As can be seen from Table 8, this crude assessment of seagrass services is based on 17 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material) are underrepresented by value estimates (i.e. a total of 17 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented 73% of the values needed to completely fill Table 9 with all 23 ES indicators used in this study.

The GV estimate of $922M/yr. in Table 8 is second only in size to the GV estimate for continental shelf at $1,441M/yr. (Table 1). Thus, while relatively small in spatial extent (i.e. 1.9% of the study area), seagrass contributes ES that are highly valued in monetary terms. Our crude assessment of seagrass ES is still missing some ES that we would expect to be included in a valuation assessment. Most species of seagrass undergo submarine pollination and for this reason the 'gamete/seed dispersal' ES should be included in Tables 7 and 8. Like all autotrophic plants, seagrass' photosynthesize and thus contribute to NPP – another ES that is missing from this rapid and crude assessment. Thus, given the high values associated with supporting services for seagrass ecosystems, a total absence of pollination and NPP; as well as questions over the adequacy of transferring saltmarsh value estimates for regulating, provisioning and non-material services, our rapid and crude estimates of GV and NV must be considered as underestimates of the total value of this ecosystem.

2.9 Value of ES derived from rocky reef CME

The rocky reef CME covers approximately 0.3% (1,270 ha.) of our study area (Table A2) and may be described as being composed of sub-tidal rock larger than a boulder (> 200 mm diameter, often solid slab of rock). Biogenic reefs (*e.g.* those made of bryozoans or sabellid worms) are not included in this CME. This CME also includes 25% of the total area of artificial structures (excluding ramps, rock and seawalls) to account for the artificial reef function provided by these structures. The GIS depiction of this CME includes the following structural feature classes: rocky reef, 25% of artificial structures excluding ramps, sea and rock walls.

The results of rapid valuation assessment suggest that the rocky reef CME produces an annual GV of ES estimated at \$6M/yr. in NZ_{2012} (Table 10). Most of this GV is contributed by regulating (\$5M/yr.) and non-material (\$0.75M/yr.) services. In the case of this CME we currently have no assessment of the market value of food or other resources it provides or could provide. This fact reflects a gap in both international and local valuation literature. Once contributions made by supporting ES have been removed then this CME yields an annual NV estimate of \$5M/yr. (Table 9).

Table 9 *Value of ES derived from rocky reef CME ($\$NZ_{2012}M/yr.$)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
NPP	0.57	-	-	-	-	0.57	-
Habitat	0.02	-	-	-	-	0.02	-
Disturbance regulation	-	4.48	-	-	-	4.48	4.48
Biological regulation	-	0.01	-	-	-	0.01	0.01
Waste regulation	-	0.15	-	-	-	0.15	0.15
Raw materials	-	-	0.02	-	-	0.02	0.02
Recreation	-	-	-	0.75	-	0.75	0.75
Research & education	-	-	-	0.0000010	-	0.0000010	0.0000010
Column totals	0.59	4.65	0.02	0.75	-	6.00	5.41

The estimate of NV (\$5M/yr.) for rocky reef represents 0.4% of net TEV (Table 12a). Rocky reefs also have a relatively small level of spatial extent at 0.3% (i.e. 1,271 ha.) of the study area (Table A2). Thus, their GV and NV estimates are partly a consequence of this small spatial extent and small (average) gross '\$/ha.' multiplier of \$4,724/ha. (Table 2).

As can be seen from Table 9, the rapid assessment of rocky reef is based on 8 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material) are underrepresented by value estimates (i.e. a total of 8 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented 34% of the values needed to completely fill Table 9 with all 23 ES indicators used in this study.

Disturbance regulation makes the largest monetary contribution to the value of rocky reef in comparison to any other ecosystem service including NPP. This result probably reflects a couple of contextual factors. First, value estimates for ES associated with rocky reef ecosystems are scarce in the published literature. Research in this area has focused primarily on the urgent survival needs of the world's coral reef systems that are threatened by climate change and known to be in decline. Unfortunately, it is not easy to transfer coral reef benefits to a rocky reef ecosystem types. While some functional similarities can exist, these two reef systems represent two very different marine ecologies.

Second, published valuation research that has been conducted on rocky reefs in general has primarily come out of North America where coastal protection against severe storm events is a high priority. Thus, the disturbance regulation value estimates (Table 10) are probably an over-estimate for New Zealand marine conditions. By contrast, the value of rocky reef ecosystems in supporting higher levels of localised NPP, habitat and biological regulation have probably been under-estimated for New Zealand marine ecosystems. Non-material (i.e. recreation, research and educational) services make a small contribution ($0.75M/yr.) to Table 10 which is probably consistent with our study area given that rocky reef does not receive high recreational use.

Overall, there are more empty cells in Table 10 than those with values, a fact that reflects on the paucity of local/national and/or international value data for this important CME. There also appears to be no value data available (i.e. internationally and/or nationally) for some important ES that we would expect to find in the open ocean/continental shelf ecosystem. For example, marine biodiversity associated with rocky reefs provides a sink for the storage of carbon, yet we have no value estimates for carbon sequestration. Rocky reefs can also play a role in erosion control. Because of the role that rocky reefs play in providing habitat for marine organisms, they are known to increase local marine biodiversity and thus contribute towards increase in fish populations (i.e. potential fish harvest). Given these omissions, we must therefore consider the gross and net total estimates for rocky reef value to be an underestimate of annual economic value.

2.10 Value of ES derived from sand, beach and dune CME

The sand, beach and dune CME covers approximately 0.8% (3,008 ha.) of our study area (Table A2) and may be described as: (i) a sandy area lying between the extremes of high/low tides and (ii) vegetated sand dunes in which the cover of vegetation in the canopy (commonly *Spinifex* spp., *Ammophila arenaria* or *Desmoschoenus spiralis*) is at least 20% and in which the vegetation cover exceeds that of any other growth form or bare ground. The GIS depiction of this CME includes the following structural feature classes: shoreline soft sediment (excluding estuarine beach), boulder bank and duneland.

The results of rapid valuation assessment suggest that the sand, beach and dune CME produces an annual GV of ES estimated at $417M/yr. in $\$NZ_{2012}$ (Table 10). This GV is contributed by regulating ($198M/yr.) and non-material ($219M/yr.) ecosystem services. An absence of value from supporting services simply reflects an absence of suitable national and/or international valuation data. Given these limitations, an assessment of GV is not possible while an assessment of NV is devoid of provisioning services. Of these two valuation representation problems, the former is likely to more problematic. In a New Zealand context, apart from iron sand mining in Taharoa on the West coast of the North Island, there is currently no commercial market for provisioning services (i.e. raw materials and/or food) harvested from the sand, beach and dunes ecosystem. There is likely to be some cultural harvest by local Māori communities. However, we can probably assume this would be small. Further research would be needed to verify this assumption.

Table 10 *Value of ES derived from sand, beach & dune CME ($\$NZ_{2012}M/yr.$)*

MES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Climate regulation	-	0.84	-	-	-	-	0.84
Disturbance regulation	-	197.12	-	-	-	-	197.12
Recreation	-	-	-	4.97	-	-	4.97
Research & education	-	-	-	0.000024	-	-	0.0000024
Spiritual & historic	-	-	-	214.59	-	-	214.59
Column totals	-	197.96	-	219.56	-	-	417.52

The estimate of NV ($417M/yr.) for sand, beach and dunes represents 38% of net TEV (Table 12a), second only to intertidal at 43% of net TEV. Sand, beach and dunes also have a relatively small level of spatial extent at 0.8% (i.e. 3,008 ha.) of the study area (Table A2). Thus, its NV estimate is partly a consequence of this small spatial extent multiplied by the largest (average) gross '$/ha.' multiplier of $138,804/ha. for our entire study area (ref. Table 2).

As can be seen from Table 10, the rapid assessment of sand, beach and dunes is based on 5 out of 23 ES indicators used in this study. This means that overall, the MEA service groupings (i.e. supporting, regulating, provisioning and non-material) are underrepresented by value estimates (i.e. a total of 5 value estimates out of 23 possible value estimates that could be used). Thus, we may have successfully represented 21% of the values needed to completely fill Table 10.

Value estimates for regulating and non-material services in Table 10 are quite similar. This fact highlights the important role that sand, beach and dunes play in human welfare, especially in the areas of recreation, spiritual and historic ES. It is important to note that with the exception of research and education, the non-material value estimates for recreation and spiritual/historic are based on international value averages. However, we have only applied these multipliers to 20% of the total sand, beach and dune area captured within our study area. 20% represents a conservative estimate of actual sand, beach and dune *use* within our study area as opposed to an assessment of sand, beach and dune cover as estimated by GIS. The use of land cover estimates with the very high recreational (i.e. $138,749) and spiritual/historic (i.e. $71,339) '$/ha.' multipliers would result in an excessive over-estimate of non-material value. For this reason, we have attempted to estimate actual ecosystem use in this case.

By comparison, the multipliers used for regulating services (i.e. climate and disturbance regulation) have been applied to the full spatial extent of the sand, beach and dune CME. The resultant value estimates are indicative of the ecological and/or biophysical role of this CME in protecting human coastal settlement, productive land and National Parks. In the case of Nelson City, there might well be a case for increasing these international value estimates given that much of the city is vulnerable to localized flooding during high tide events that coincide with heavy rainstorms.

Overall, there are more empty cells in Table 10 than those with values, a fact that reflects on the paucity of local/national and/or international value data for this important CME. There also appears to be no value data available (i.e. internationally and/or nationally) for some important ES that we would expect to find in the sand, beach and dune ecosystem. We would expect that the sand, beach and dune ecosystem provide an important habitat function, especially for coastal seabirds. In places where sand dunes are draped in successional vegetation, this ecosystem type performs an important role in carbon sequestration, soil formation, waste regulation, nutrient cycling and erosion control. While food for human consumption is not harvested from sand, beach and dunes we would expect that food and raw materials play an important role in supporting services. Given the diverse range of marine creatures that inhabit the sand, beach and dune CME, we would expect value estimates for biological regulation and genetic resources. Finally, most people draw immense aesthetic pleasure from sand, beach and dune ecosystems. Given these omissions, we must therefore consider the gross and net total estimates for sand, beach and dune value to be an underestimate of annual economic value.

3.0 TEV estimates described and evaluated

The rapid valuation assessment results presented in section 2 of this report can be aggregated and summed to create estimates of GTEV and NTEV. These GTEV and NTEV results are outlined in this report section along with an interpretation of these results and analysis of valuation data quality. Because our MES study area is adjacent a terrestrial landmass, we attempted to present and evaluate GTEV and NTEV estimates for both MES and TES. This data is presented in individual results Tables and then a composite results Table. The composite results Table outlined in this report section provide an opportunity to give written consideration to those ES (i.e. the basic interrelationships) that link marine and terrestrial ecosystems.

3.1 GTEV and NTEV estimates for marine CME

Table 11 suggests that our study area (entire) annually produces a GTEV of ES estimated at \$4,129M/yr. in $\$NZ_{2012}$ (Table 11). This estimate of GTEV is contributed to (in descending order) by supporting (\$3,045M/yr.), regulating (\$542M/yr.), non-material (\$272M/yr.) and provisioning (\$271M/yr.) ecosystem services. Once contributions made by supporting ES have been removed then this entire study area yields a NTEV estimate of \$1,085M/yr. (Table 11). The rapid assessment of provisioning services (\$271M/yr.) here quoted in both GTEV and NTEV estimates includes (i) a small portion of value derived from local food production as estimated by GDP (\$1.45M/yr.) and (ii) an additional estimate of various other provisioning services (i.e. \$27M/yr.) based on international market and non-market data. Local food production (i.e. fish harvest) as estimated by the regional SNAs is approximately 0.1% of total NTEV for this study area. By comparison, provisioning services minus the local food production component (i.e. 0.1% of NTEV) is approximately 25% of total NTEV for this study area. These rapid assessment results suggest that based on international averages, these marine ecosystems potentially provide much higher levels of provisioning services than is currently being measured by New Zealand's national and regional SNAs. However, as indicated in the narrative associated with results section 2 of this report, more detailed research is really needed to be able to apply these international, non-material ecosystem service estimates with confidence in a New Zealand socio-economic-cultural context.

Table 11 *NTEV and GTEV estimates of coastal marine ES in our study area ($\$NZ_{2012}M/yr.$)*

CME	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Continental shelf	1,354	37	3	46	1	1,441	87
Estuary	416	13	11	2	10	441	25
Intertidal	328	248	219	3	29	799	470
Lagoon	8	6	6	0	1	20	12
Saltmarsh	47	36	32	0	4	115	68
Seagrass	891	-	-	-	-	891	-
Rocky reefs	1	5	0	1	-	6	5
Sand, beach/dunes	-	198	-	220	-	418	418
Total	3,045	542	271	272	46	4,129	1,085

In Table 11, the absence of value estimates for the seagrass and sand, beach and dune ecosystems are now more visually evident. In sub-section 2.8 we attempted to address this under representation problem with seagrass by creating crude value estimates for regulating, provisioning and non-material services. This added an additional \$31M/yr. to seagrass in terms of additional regulating (i.e. \$5M/yr.), provisioning (\$27M/yr.) and non-material (\$0.36M/yr.) ecosystem services. This crude estimate was created by applying value estimates from saltmarsh to the total area of seagrass for these 3 additional MEA service categories. The addition of this crude estimate to Table 11 would not make a substantial difference as it accounts for only 0.77% of the gross estimate reported in Table 11.

Table 12 *GTEV and NTEV of coastal marine ES in our study area (% of column totals)*

CME	% Supp.	% Reg.	% Prov.	% Non-mat.	% GDP	% Gross	% Net	% Area
Intertidal	11	46	81	1.14	64	19	43	2.6
Sand, beach & dunes	-	37	-	81	-	10	38	0.8
Continental shelf	44	7	1	17	3	35	8	92.1
Seagrass	29	-	-	-	-	22	-	1.9
Saltmarsh	2	7	12	0.16	9	3	6	0.4
Estuary	14	2	4	0.59	22	11	2	1.9
Lagoon	0.271	1	2	0.03	2	0.487	1	0.1
Rocky reefs	0.019	1	0.0056	0.28	-	0.145	0.499	0.3
Total	100	100	100	100	100	100	100	100

An analysis of the percentage distribution of GTEV and NTEV by column total is provided in Table 12. This Table has been organised into descending rank order based on the relative percentage contributions of the various NTEV estimates (i.e. intertidal 43%, sand, beach and dunes 38%, continental shelf 8%, seagrass, saltmarsh 6%, estuary 2%, lagoon 1% and rocky reefs 0.5%). When the percentage contribution of the various ecosystems in rank order is compared with the percentage contribution of each ecosystem to total area (i.e. Column 9, Table 12), it is clearly evident that spatial extent is not the main determinant of estimated CME value. If area were a key determinant of estimated CME value, then we would expect to see a direct correlation between % area (column 9) and NTEV (column 8). Therefore, these NTEV results mainly reflect human preferences and the influence of what modern science has contributed in terms of knowledge about the importance of these CMEs to human wellbeing.

3.1.1 Interpretation of GTEV and NTEV estimates for CME

The assessment of results presented in this report section can be best interpreted by drawing attention to a number of limitations of this rapid assessment of TEV. First, it is likely that we have only captured approximately 25-80% of value estimates that would be needed to completely fill all of the supporting, regulating, provisioning and non-material columns of the results tables for the various CME. Second, it is also evident that some important ES have been completely omitted due to an absence of national and/or international BT data. Third, the application of international value estimates for PES needs more research to appropriately apply these estimates in a New Zealand socio-economic-cultural context[14]. Finally, we have questioned the validity of some value estimates in the context of our study area. Combined, these limitations suggest that the GTEV and NTEV estimates reported in Table 11 and 12 are likely to be underestimates of value. It is difficult to accurately assess the extent of this underestimation. Furthermore, it is unlikely that such underestimate scaling could be applied equally across all CME and all MES. Individual MES can differ greatly in their relative value contributions. This is why we need valuation accounting approaches like TEV.

3.2 GTEV and NTEV estimates of Nelson Tasman regional TES

As noted earlier in the method section of this report (Appendix A), inter-linkages between coastal marine and terrestrial ecosystems can extend inland as far as 100km. For this reason, it's not ideal to consider an assessment of CME TEV in isolation from a comparative assessment of TES TEV. While we are not yet able to provide detailed valuation information on specific coastal marine/terrestrial ES inter-linkages, with currently available terrestrial TEV estimates it is at least possible to comment on key ES that currently interlink TES and MES.

The terrestrial landmass that interfaces with our Nelson Bays CME study area maybe broadly defined by the Nelson Tasman regional authority boundary. We have used this boundary for the valuation of terrestrial ecosystems that directly and/or indirectly influence the wellbeing of CME in Nelson Bays. For example, this terrestrial study area includes a number of large catchments with rivers (i.e. the Buller, Motueka, Aorere, Takaka and Wairoa) that empty into Nelson Bays. This group of catchments includes the Motueka, the southern boundary of which reaches approximately 100km inland. Key terrestrial/marine inter-linkages associated with the Motueka catchment and river that empty into Tasman Bay have been extensively studied as part of a 6–year cross-disciplinary research programme[15].

The Tasman region is also home to 3 national parks: Abel Tasman (225.41 km^2); Nelson Lakes (1,017.53 km^2) and Kahurangi (4,520 km^2) and a bird sanctuary located along the 40 km long sands of Farewell Spit. The Nelson Tasman regions are also home to popular beaches and fishing locations which means that our coastal marine study area, linked with terrestrial national parks, rivers and abundant bird life is a favoured tourist location.

The Nelson Tasman terrestrial ecosystems used in this study cover an estimated 1,003,580 ha. and have been spatially depicted for the purposes of ESV using the 2001 Landcover Database (LCDB2). The GIS depiction of this terrestrial study area includes the following structural feature classes: horticulture and cropping, agriculture, intermediate agriculture scrub, native scrub, intermediate agriculture forest, forest scrub, forest, wetlands, swamps and floodplains, lakes and

[14] This statement assumes that we can subsume Pākehā and Māori into one market-based cultural context – an assumption that is highly questionable.
[15] The Motueka Integrated Catchment Management Research Programme http://icm.landcareresearch.co.nz/

rivers. Our rapid valuation assessment of this regional-scale terrestrial ecosystem suggests that our terrestrial study area (entire) annually produces a GTEV of ES estimated at \$6,277M/yr. in $\$NZ_{2012}$ (Table13). This economic estimate of GTEV is contributed to (in descending order) by supporting (\$2,356M/yr.), provisioning (\$2,338M/yr.), regulating (\$1,544M/yr.) and non-material (\$39M/yr.) ecosystem services. The assessment of provisioning services (\$2,338M/yr.) here quoted includes a significant estimate of value derived from (i) primary food production as captured by commercial markets (i.e. \$1,919M/yr.) and (ii) timber harvest as captured by commercial markets (i.e. \$200M/yr.) meaning that 54% of NTEV belonging to this terrestrial study area (entire) has been captured by the SNA. Once contributions made by supporting ES have been removed, this regional-scale Terrestrial ecosystem yields a NTEV estimate of \$3,921M/yr. (Table13).

Table13 *GTEV and NTEV estimates of TES related to our CME study area ($\$NZ_{2012}M/yr.$)*

TES	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net
Horticulture & Cropping	1	1	156	-	156	158	157
Agriculture	16	63	1,763	-	1,763	1,842	1,826
Int. Agriculture Scrub	-	8	-	-	-	8	8
Native Scrub	19	24	9	5	-	57	38
Int. Agriculture Forest	38	13	-	-	-	51	13
Forest Scrub	33	10	6	2	-	51	18
Forest	2,202	951	200	-	200	3,353	1,151
Wetlands	40	53	26	4	-	123	83
Swamp/floodplain	7	58	50	15	-	130	123
Lakes	-	59	21	2	-	82	82
Rivers	-	304	107	11	-	422	422
Total (TESV)	2,356	1,544	2,338	39	2,119	6,277	3,921

3.2.1 Interpretation of GTEV and NTEV estimates for TES

The rapid assessment of regional-scale TES suffers from the same types of limitations that are documented in this report as applying to CME. First, the problem of value representation still exists. In the case of terrestrial ecosystems our rapid assessment matrix (entire) has 253 cells (23 TES x 11 terrestrial ecosystems). Of this total 253 possible value estimates, we have managed to find 105 value estimates. Thus, we have captured approximately 41% of value estimates that would be needed to completely fill all of the supporting, regulating, provisioning and non-material columns of the TESV matrix for all terrestrial ecosystem types. This level of representation is better than marine ecosystems, a fact that reflects the existence of a more comprehensive (national and/or international) terrestrial valuation literature.

Second, as with CME it is also evident that some important TES have been completely omitted due to an absence of national and/or international BT data. For example, in the cases of lakes, rivers and intermediate agriculture scrub we have no estimates for supporting values. Third, the application of international value estimates for PES needs more research to appropriately apply these estimates in a New Zealand socio-economic-cultural context. Fourth, like marine ecosystems, our estimates of area for TES are based on Landcover rather than landuse. This implies an element of overestimation in spatial extent that will differ from one TES to another. Also, we have only focused attention on rural landscapes and ecological assets like national Parks and wildlife sanctuaries. The contribution of urban TES has not been assessed and this is an important omission because, much like productive rural landscapes, urban landscapes produce high levels of disservices. Disservices or disutility, if accounted for would theoretically lower current TEV estimates for TES. Overall, we have questions about the validity of some TESV estimates used in our TES study area. Combined together, these limitations suggest that the GTEV and NTEV estimates reported in Table 13 are likely to be underestimates of value. It is difficult to accurately assess the extent of this underestimation.

3.3 GTEV and NTEV estimates of CME and TES combined

By combining TES and CME TEV results into one composite Table it is possible to gain a more effective overview of terrestrial/marine ecosystem inter-linkages.

Table14 *GTEV and NTEV estimates of CME and TES (NZ_{2012}$M/yr.) combined*

TES	Type	Supp.	Reg.	Prov.	Non-mat.	GDP	Gross	Net	SR
Hort. & Cropping	TESV	1	1	156	-	156	158	157	2
Agriculture	TESV	16	63	1,763	-	1,763	1,842	1,826	79
Int. Agric. Scrub	TESV	-	8	-	-	-	8	8	8
Native Scrub	TESV	19	24	9	5	-	57	38	43
Int. Agric. Forest	TESV	38	13	-	-	-	51	13	51
Forest Scrub	TESV	33	10	6	2	-	51	18	43
Forest	TESV	2,202	951	200	-	200	3,353	1,151	3,153
Wetlands	TESV	40	53	26	4	-	123	83	93
Swamp/floodplain	TESV	7	58	50	15	-	130	123	65
Lakes	TESV	-	59	21	2	-	82	82	59
Rivers	TESV	-	304	107	11	-	422	422	304
Continental shelf	MESV	1,354	37	3	46	1	1,441	87	1,391
Estuary	MESV	416	13	11	2	10	441	25	428
Intertidal	MESV	328	248	219	3	29	799	470	576
Lagoon	MESV	8	6	6	0	1	20	12	15
Saltmarsh	MESV	47	36	32	0	4	115	68	83
Seagrass	MESV	891	-	-	-	-	891	-	891
Rocky reefs	MESV	1	5	0	1	-	6	5	5
Sand, beach/dunes	MESV	-	198	-	220	-	418	418	198
Total (MESV)	Mar.	3,045	542	271	272	46	4,129	1,085	-
Total (TESV)	Terr.	2,356	1,544	2,338	39	2,119	6,277	3,921	-
Final total		5,401	2,086	2,609	311	2,165	10,406	5,006	7,487

This combined rapid valuation assessment data suggests that combined, CME and TES annually produce a GTEV of ES estimated at $10,406M/yr. in NZ_{2012} (Table 14). This economic estimate of GTEV is contributed to (in descending order) by: supporting ($5,401M/yr.), provisioning ($2,609M/yr.), regulating ($2,086M/yr.) and non-material ($311M/yr.) ecosystem services. Once contributions made by supporting ES have been removed then TES and CME combined yields a NTEV estimate of $5,006M/yr. (Table 14).

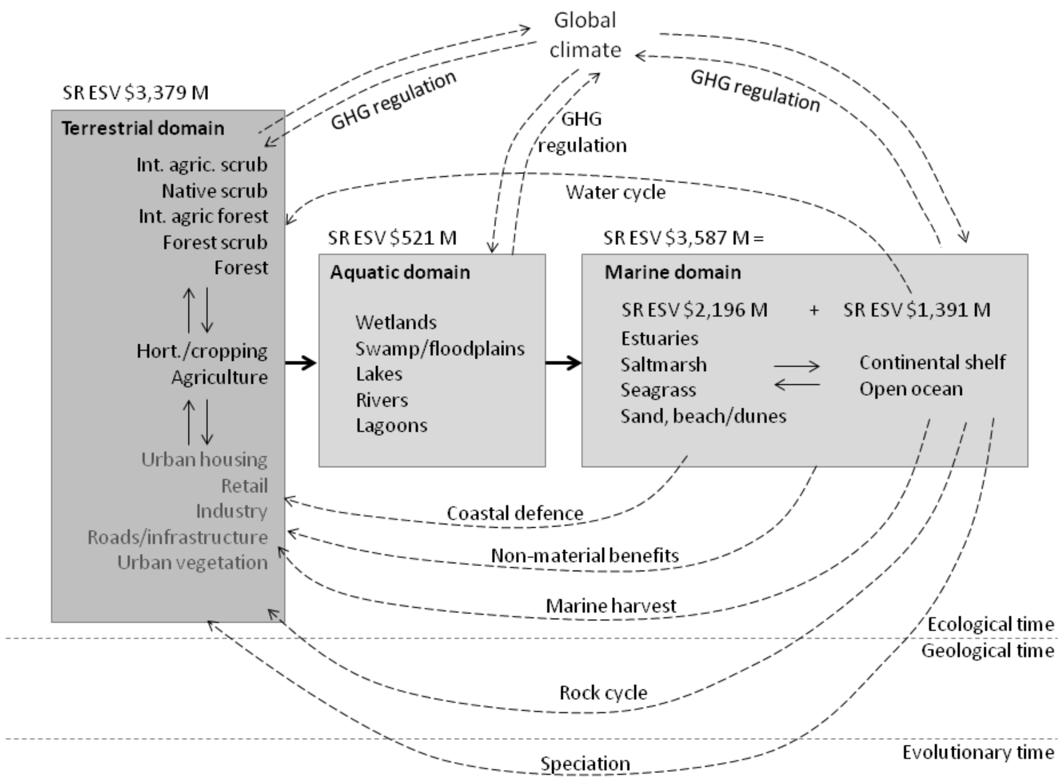

Figure 2 *A visual depiction of the interrelationships between terrestrial, aquatic and marine ecosystems that is numerically implied in Table 14.*

There is a lot of information in Table 14 and this can make it difficult to see important relationships between TES and CME. Such interrelationships will be of particular interest to policy makers and planners because they help us to start thinking about terrestrial, aquatic and marine ecosystems (as depicted in Table 14) as parts of a much larger interconnected land/ocean system. To help illustrate this point we have attempted to visually depict key interrelationships of Table 14 in Figure 2. Figure 2 introduces a new unit of ES value estimate created by adding together supporting and regulating ES for similar terrestrial and marine ecosystem types. SR estimates have been calculated using data listed in column 10 of Table 14. To assist in better understanding this new unit of measurement, SR value estimates are analysed in Tables 15 and 16.

3.4 Describing the visual depiction of Table 14 in Figure 2

Figure 2 is based on the terrestrial and marine ecosystem listed in column 1 of Table 14 with one exception. Our current RESA of TES does not include urban ecosystems like: urban housing, retail, industry, roads/infrastructure and urban vegetation. In Figure 2 we have included urban ecosystems in the grey box titled 'Terrestrial ecosystems' to acknowledge that they are important, but currently not valued. To help differentiate urban ecosystems from all other terrestrial ecosystems we have portrayed them in light grey text.

Figure 2 attempts to show just how terrestrial, aquatic and marine ecosystems in Table 14 are interrelated. Two different types of interrelationship are implied based on flows of ES value. First, terrestrial vegetation contributes to soil development and protects productive soils from erosion that would result in a net loss of soil to aquatic and marine ecosystems. Aquatic ecosystems are inextricably interrelated with landcover vegetation, primarily at a catchment scale. With the aid of aquatic ecosystems, catchment ecosystems export nutrients and organic matter to marine ecosystems. We have attempted to quantify the value contributed across terrestrial, aquatic and marine ecosystems by adding together supporting and regulating (SR) value estimates from Table 14. SR value provides an estimate of the monetary value of supporting and regulating ecosystem functions from which provisioning and non-material services are derived. SR ESV is therefore a monetary estimate of the annual value of ecosystem function *to human welfare*. These supporting and regulating functions sustain ecosystems in a way that makes possible the continued flow of benefits from these same ecosystems to humans in the form of provisioning and non-material ES.

Ecosystems listed in the terrestrial domain of Figure 2 annually contribute SR ESV of $3,379M/yr. (Figure 2) that enhances human welfare while contributing to the functioning of ecosystems in the aquatic and marine domains. Inextricably interrelated with terrestrial ecosystems, aquatic ecosystems annually contribute SR ESV of $521M/yr. (Figure 2) that enhances human welfare while contributing towards the successful functioning of ecosystems in the aquatic and marine domains. Likewise, marine ecosystems, annually contribute SR ESV of $3,587M/yr. (Figure 2) that enhances human welfare while contributing[16] towards the successful functioning of ecosystems in the marine and terrestrial domains.

3.4.1 Explaining the derivation of SR ESV as a unit of measurement

Figure 2 shows that there is a net flow of SR ESV from terrestrial to marine ecosystems via aquatic ecosystems. The ecology, biodiversity and biophysical functioning of terrestrial, aquatic and marine ecosystems are inextricably interrelated in complex ways. What Figure 2 seeks to show in very simplistic terms are the existence of a flow of benefits from one domain to the next and then back via feedbacks that operate over differing time scales. We have estimated value contributions across this interlinked terrestrial-aquatic-marine ecosystem by adding together CME and TES value estimates for supporting and regulating services. We have done this because these two MEA

[16] Over ecological, geological and evolutionary time scales

categories contribute towards: (i) supporting services essential for the production of all other ES and (ii) regulating services responsible for the regulation of ecosystem processes. By contrast, the MEA categories we call provisioning and non-material[17] services refer specifically to flows of benefits to human welfare. We have removed these two MEA services from the calculation of SR so that we can estimate flows of benefits to ecosystems and their component processes. Thus, Figure 2 is an attempt to show how TESV is shared downstream by aquatic and marine ecosystems. Likewise, aquatic ESV is shared downstream by marine ecosystems and feedback to terrestrial ecosystems. SR ESV estimates provide a starting point for assessing the community values (in monetary terms) associated with this interlinked terrestrial-aquatic-marine ecosystem.

3.4.2 Describing feedback interrelationships in Figure 2

Figure 2 also depicts essential feedbacks between marine and terrestrial domains over differing temporal scales. At an evolutionary time scale, flows of benefits come from marine ecosystems based on the emergence of new species (i.e. speciation). Raw materials, minerals and fossil fuels linked with the rock cycle create a flow of benefits back to the terrestrial environment over geological time scales. The capitalist market economy has rapidly grown over the last 200 years, largely as a result of technology that provides to access energy in the form of fossil fuels etc. Over ecological time scales, the market economy benefits from the harvest of marine species, non-material services, coastal defense, water cycling and greenhouse gas (GHG) regulation - intimately linked to global climate. GV and NV estimates for these feedback interrelationships are outlined in the various results Tables in this report section.

3.5 Independent verification of SR ESV estimates used in Figure 2

The creation of SR ESV as a unit of measurement provides a monetary estimate of ES that support and regulate ecological processes. This raises an interesting question. Is SR ESV a valid value estimate for assessing the interrelationship between terrestrial and marine ecosystems? One way of answering this question could be to compare our terrestrial and marine SR ESV estimates with an empirically established 'proxy' for ecological processes in both of these ecosystems. We decided to further explore this idea by comparing our SR ESV value estimates (column 10, Table 14) with empirical estimates of global NPP as published in the international journal 'Science' (Field *et al.,* 1998). We then repeated the same analysis for NTEV estimates (column 9, Table 14). The results of this analysis are presented in Tables 15 and 16 and described below. Tables 15 and 16 were created so that our use of SR ESV estimates in preference to NTEV estimates could be compared and evaluated against an empirically established proxy for ecosystem function in the terrestrial and marine ecosystems depicted in Figure 2.

[17] In the MEA, what we have referred to as non-material services is called cultural services.

Table 15 *A comparison of SR ESV estimates (column 10, Table 14) with global NPP estimates from Field et al. (1998).*

Domain	$\$NZ_{2012}$M/yr.	% SR ESV	Subtotal % SR ESV	Global NPP	% NPP
Terrestrial ecosystems	3,379	45.1	52.1	56.4	53.8
Aquatic ecosystems	521	7.0			
CME – Cont. shelf	2,196	29.3	47.9	48.5	46.2
Continental shelf	1,391	18.6			
Column total	7,487	100.0	100.0	104.9	100.0

In Tables 15 and 16, column 1 contains a list of the component ecosystems that make up the terrestrial, aquatic and marine domains depicted in Figure 2. Column 3 of Tables 15 and 16 contains value estimates of SR ESV (Table 15) and NTEV (Table 16) respectively. In column 4 of Tables 15 and 16, value estimates for SR ESV and NTEV have been converted to percentages. In column 5 of Tables 15 and 16, percentage calculations for; (i) terrestrial and aquatic ecosystems and (ii) costal marine and continental shelf ecosystems have been subtotaled. This has been done to create percentage estimates of the value contributions made by *all* terrestrial and *all* marine ecosystems in both Tables.

Table 16 *A comparison of NTEV estimates (column 9, Table 14) with global NPP estimates from Field et al. (1998).*

Domain	$\$NZ_{2012}$M/yr.	% NTEV	Subtotal % NTEV	Global NPP	% NPP
Terrestrial ecosystems	3,211	64.1	78.3	56.4	53.8
Aquatic ecosystems	710	14.2			
CME – Cont. shelf	998	19.9	21.7	48.5	46.2
Continental shelf	87	1.7			
Total	5,006	100.0	100.0	104.9	100.0

In column 5 of Tables 15 and 16 we have provided empirical estimates of global NPP for all terrestrial and all marine ecosystems. Measured in Giga tonnes of Carbon per year (Gt C $yr.^{-1}$), this data suggests that annual global NPP (i.e. 104.9 Gt C $yr.^{-1}$) is created from (i) global terrestrial ecosystem NPP that annually produces 56.4 Gt C $yr.^{-1}$ and (ii) global marine ecosystem NPP that annually produces 48.5 Gt C $yr.^{-1}$. These same estimates of global NPP for terrestrial and marine domains are converted into percentage estimates in column 6 of Tables 15 and 16. The global NPP data is identical in both Tables 15 and 16. We use global NPP data as a proxy of the relative contributions (in percentage terms) of terrestrial and marine domains (Figure 2) to ecosystem function.

3.5.1 The contribution of marine ecosystems assessed using global NPP

Global NPP data suggests that the level of NPP in global terrestrial and marine ecosystems is very similar in percentage terms (i.e. terrestrial 53.8% and marine 46.2%). The similarity of percentage estimates for global terrestrial and marine NPP is somewhat counter intuitive because over 70% of the Earth's surface is covered in water. While these percentage estimates for global terrestrial and marine area/cover will vary on geological and ecological time scales (i.e. as global ice stores melt and then return), these estimates of relative spatial extent show just how productive terrestrial ecosystems are in terms of NPP. However, what must also not be missed is that 46% of all NPP on Earth occurs in marine ecosystems. In ecological terms, these figures highlight the importance of marine ecosystems to human and planetary survival and wellbeing. This fact implies that the interrelationships depicted in Figure 2 are very important.

3.5.2 Terrestrial and marine SR ESV and NTEV estimates evaluated using global NPP

A comparison of SR ESV and NTEV percentage estimates shown in column 3 of Tables 15 and 16 with percentage estimates of terrestrial and marine NPP draws attention to an interesting pattern in our RESA results. If we measure ecosystem function using monetary estimates of supporting and regulating services (i.e. SR ESV) for terrestrial and marine ecosystems related to our study area, the percentage estimates of SR ESV (column 4, Table 15) are very similar to percentage estimates for global terrestrial and marine NPP (column 6, Table 15). However, by share coincidence, the spatial extent of the terrestrial and marine ecosystems in our combined terrestrial/marine study area (as expressed in percentage terms) equals 71% terrestrial and 29% marine. These area estimates highlight a possible problem in our estimates of SR that is diagnosed and described below:

Terrestrial SR/NPP - approximately 53.8% of global terrestrial NPP is generated on 30% of the Earth's surface (i.e. continental landmass), while approximately 52.1% of the total SR ESV for the terrestrial ecosystems in our study area is generated on 71% of the combined terrestrial/marine study area. This results in a productivity ratio of 0.73 units of terrestrial area to 1 unit of terrestrial SR ESV; whereas the global terrestrial NPP productivity ratio is 1.79 units of terrestrial area to 1 unit of terrestrial NPP. Thus, the SR ESV productivity ratio is only 40% of what it should be; assuming global NPP is an appropriate comparative proxy of ecosystem function.

Marine SR/NPP - approximately 46.2% of global marine NPP is generated on 70% of the Earth's surface (i.e. marine ecosystems), while approximately 47.9% of the total SR ESV for the marine ecosystems in our study area is generated on 29% of the combined terrestrial/marine study area. This results in a productivity ratio of 1.65 units of marine area to 1 unit of marine SR ESV; whereas the global marine NPP productivity ratio is 0.66 units of marine area to 1 unit of marine NPP. Thus, the marine SR ESV productivity ratio is two-and-a-half times (i.e. 250%) what it should be; assuming global marine NPP is an appropriate comparative proxy.

The above results suggest that our total value estimates for supporting and regulating ES involve underestimation for terrestrial ecosystems and overestimation for marine ecosystems when evaluated in productivity terms against global NPP. If we used NTEV estimates (Table 14) instead of SR ESV estimates (Table 14) as an indicator of marine and terrestrial ecosystem function in our study area, the additional value added from non-material and provisioning services and loss of values from supporting services means that NTEV estimates are closer to global NPP in productivity terms.

Terrestrial NTEV/NPP - approximately 53.8% of global terrestrial NPP is generated on 30% of the Earth's surface (i.e. continental landmass), while approximately 78.3% of the total NTEV for the terrestrial ecosystems in our study area is generated on 71% of the combined terrestrial/marine study area. This results in a productivity ratio of 1.1 units of terrestrial area to 1 unit of terrestrial NTEV; whereas the global terrestrial NPP productivity ratio is 1.79 units of terrestrial area to 1 unit of terrestrial NPP. Thus, the NTEV productivity ratio is only 61% of what it should be; assuming global NPP is an appropriate comparative proxy. By comparison, 39% underestimation is better than the 60% underestimation generated by terrestrial SR ESV as outlined above.

Marine NTEV/NPP - approximately 46.2% of global marine NPP is generated on 70% of the Earth's surface (i.e. marine ecosystems), while approximately 21.7% of the total NTEV for the marine ecosystems in our study area is generated on 29% of the combined terrestrial/marine study area. This results in a productivity ratio of 0.7 units of marine area to 1 unit of marine NTEV; whereas the global marine NPP productivity ratio is 0.66 units of marine area to 1 unit of marine NPP. Thus, the marine NTEV productivity ratio is slightly larger (i.e. 6%) than what it should be; assuming global marine NPP is an appropriate comparative proxy. By comparison, 106% agreement is better than the 250% overestimation generated by terrestrial SR ESV as outlined above.

While the NTEV estimates provided in Table 16 are closer to global NPP in productivity terms, NTEV *is not an appropriate indicator of ecosystem function in theoretical terms.* The adding together of monetary estimates for supporting and regulating services to create SR ESV produces what might be called a non-market indicator of ecosystem function. By contrast, NTEV, as a market and non-market indicator is more strongly influenced by human appropriation of NPP and non-material ES. It is also missing the contribution of value from supporting services. For this reason, it is not a suitable indicator of ecosystem function. This analysis of SR ESV and NTEV indicators against global NPP (in productivity terms) provides a rough, but useful yardstick for assessing our ES rapid valuation assessment results. This analysis suggests that we have problems with under and overestimation of ES value in productivity terms when compared with global NPP as a proxy indicator. While this is not a definitive verification of our RESA, it provides a useful point of comparison and highlights, yet again, the need to interpret RESA results with care, caution and adequate understanding of the potential limitations of this valuation approach.

3.6 A comparison of GTEV and NTEV estimates with regional GDP

In evaluating MESV results it is helpful to be able to compare GTEV and NTEV estimates with the monetary yardstick used to indirectly measure welfare in market economic systems (i.e. GDP). Using CPI adjusted 2001 input-output Tables[18] for the Nelson Tasman regions we have estimated the combined 2012 (Q4) GDP of the Nelson Tasman regions combined to be $3,644M/yr.

Our estimate of NTEV for CME within the Nelson Bays study area is $\$NZ_{2012}$ 1,085M/yr. (Table 14), approximately 30% of Nelson Tasman GDP for the same year. If we removed the portion of this estimated captured by commercial markets as food production (i.e. local fish harvest), then our PES-adjusted NTEV for CME is $1,083M/yr. or 28% of Nelson Tasman GDP for the same year. This remaining portion of CME NTEV (i.e. $1,083M/yr.) represents a PES-adjusted estimate of TES NTEV that is currently not captured in the Nelson Tasman region's economic accounts.

In productivity terms, the estimate of NTEV for CME should be higher. This is because the $1,083M/yr. estimate of NTEV for CME was produced in a study area (i.e. 400,121 ha.) that is only 29% of the total area of Nelson Tasman regions (i.e. 1,003,580 ha.) and the marine study area combined (i.e. 1,403,702 ha.). Thus, it is not entirely appropriate to compare annual marine NTEV with regional GDP for the same year without adjusting it for productivity. If we adjusted marine NTEV for productivity using the above area estimates, then the contribution of MES NTEV is closer to $2,656M/yr. or 72% of regional GDP. This productivity-adjusted estimate of MES NTEV is calculated by assuming that the area of MES is the same in percentage terms as TES area (i.e. 71%). This productivity-adjusted estimate is of course meaningless, except that it shows that a comparison of MES NTEV with terrestrial GDP is partly obscured by differences in ecosystem productivity (i.e. value produced per unit area).

By contrast, our estimate of NTEV for TES (Table 14) within the Nelson Tasman regions is $\$NZ_{2012}$ 3,921M/yr., approximately 107% of Nelson Tasman GDP for the same year. In this case no adjustment for productivity is necessary because the TES NTEV is based on the same area used to generate the regional GDP estimate. However, it is important to note that this NTEV estimate for terrestrial ecosystems contains $2,119M/yr. (Table 14) of PESV (food and raw materials) captured by commercial markets and therefore measured as part of GDP. If this portion of the terrestrial NTEV estimate is removed, then the estimate of TES NTEV is $1,802M/yr. (49% of GDP) for the Nelson Tasman regions. This remaining portion of TES NTEV (i.e. $1,802M/yr.) represents a PES-adjusted estimate of TES NTEV that is currently not captured in the Nelson Tasman region's economic accounts.

[18] These input-output Tables were prepared by Market Economics Limited (MEL), Auckland

There is a sense in which we should not be surprised that 28% of CME NTEV and 49% of TES NTEV is not captured by local regional economic accounts used to estimate industry contributions to regional GDP. The SNA framework used in market economic accounting at both national and regional scales does not attempt to measure the contribution of marine and terrestrial ecosystems towards GDP. Studies of the kind outlined in this report continue to show that marine and terrestrial ecosystems annually make a substantial contribution to regional GDP that can be quantified in monetary terms using non-market valuation method. The fact that this contribution to human welfare is not measured in national and regional scale economic accounts is a problem. However, this problem is not as serious as the fact that by not monetising the value contribution of natural ecosystems to human welfare, it is extremely difficult to include this contribution in market economic decision-making. As a consequence, market economic activity involves substantial tradeoffs in ecosystem wellbeing; tradeoffs that are poorly understood in terms of their efficiency, social fairness, ecological sustainability and cultural survival implications.

4. A further accounting adjustment needed

In the results section of this report (i.e. section 2) is outlined the findings of this RESA study that is based on: (i) the use of the Millennium Ecosystem Assessment service categories (i.e. supporting, regulating, provisioning and non-material) and (ii) calls in the published literature to avoid double counting of ES by differentiating between gross[19] and net[20] estimates of TEV. While the 'double counting' accounting adjustment makes 'good sense' conceptually, we have found that implementing this recommendation has highlighted what seems to be a previously unforeseen problem. In this report section we seek to explain the nature of this problem and then describe the accounting adjustment that we have devised as a 'crude' remedy. As will be explained, there is no simple answer to this problem. Its existence is partly a consequence of limitations associated with the use of the MEA services framework and the methods that are typically employed in RESA/ESV research. A consequence of this problem is that accounting efforts made in the estimation of TEV to avoid double counting have actually created a quite serious underestimation problem. The results presented in this report are affected by this problem. In this report section we will seek to define this problem, outline a crude accounting remedy and then explore what influence this new accounting adjustment has on the results outlined in this report so far. We have included this section in a further effort to improve our own application of the RESA method.

4.1 The Millennium Ecosystem Assessment framework

There are a number of different illustrations used to depict the MEA framework. One of the most simple and easiest to understand is provided in Figure 3. This illustration has been sourced from the MEA *Ecosystems and human wellbeing synthesis report* (MEA, 2005). Figure 3 suggests that all individual ES used in this framework are: (i) essential to human and ecosystem wellbeing and (ii) able to be grouped into 4 high-level service categories (i.e. supporting, regulating, provisioning and cultural). In this study we have avoided the use of the MEA category name called 'cultural' because of the difficulties associated with seeking to define this term. Instead, we use the word 'non-material' to describe the range of benefits that the ES in this MEA category provide humans. Two of the MEA service categories (i.e. provisioning and what we call 'non-material') contain ES associated with the direct human appropriation of benefits from ecosystems like food, raw materials, water and recreation etc.

The MEA framework suggests that continued operation of provisioning and non-material services is made possible by the operation of ecosystem supporting and regulating services. These two groups of MEA services contain ES *primarily* responsible for maintaining the life-supporting capacity of ecosystems and the benefits they provide to human communities. Thus, this framework has two groups of services, one that provides for human wellbeing and the other that provides for ecosystem wellbeing - with one crucial exception. As shown in Figure 3, supporting services provide for and thus make possible the production of *all other services including: provisioning,*

[19] The sum of supporting, regulating, provisioning and non-material services
[20] The sum of regulating + provisioning + non-material services (i.e. excluding supporting services)

regulating and cultural. By contrast, regulating services maintain the functioning of ecosystem processes *only.* This distinction is important. In accounting terms, supporting services thus provide inputs to the three remaining provisioning, regulating and non-material categories. This is why (in this study) supporting service values are included in the estimation of gross TEV but not the estimation of net TEV. The net TEV estimate provides accounting recognition of the fact that supporting services are parts of provisioning, regulating and non-material ecosystem processes. These services have been all grouped together and named supporting for the convenience of human perception and measurement. The gross estimate of TEV thus involves 'double counting' of supporting services.

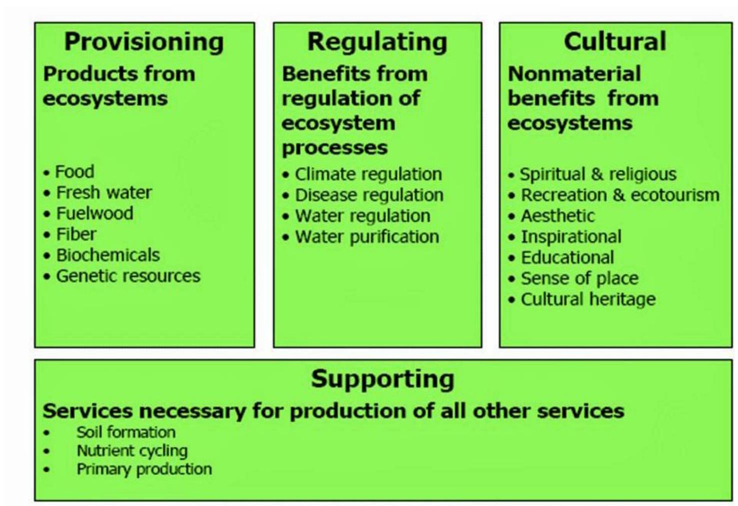

Figure 3 *The Millennium Ecosystem Assessment framework (MEA, 2005).*

4.2 Avoiding the 'double counting' problem

The MEA framework provides 2 key benefits that aid ESV. First, this framework provides a conceptual map for guiding how we think about and classify ES. Second, this framework also provides a way of thinking about ecosystems that can be used to guide a TEV measurement process. This framework has especially aided in the identification of the 'double counting' problem. Unfortunately, the solution to double counting (i.e. removing supporting services value estimates from net TEV) is not quite as straight forward as it might seem. While the idea of removing supporting services value estimates from NTEV is sound, problems have emerged in implementing the accounting needed to accomplish this goal. We found that the implementation process in this study was linked to two different accounting problems.

4.2.1 Problem 1 – the valuation of ES in isolation

The eliciting of stated and revealed preferences using well-known survey and research methods seeks to estimate the non-market value of ES in isolation from their relationship to any other ES values. This approach to value estimation involves the simplification of a more complex contributory valuation problem and is partly a consequence of our systems of ES classification.

For example, the MEA framework is based on the use of exclusive categorical logic; it assumes that ES exist as isolated, discrete entities and we therefore tend to employ accounting procedures that fit with this 'discrete' frame-of-reference. We were first alerted to this problem when trying to value seagrass using the supporting value estimates of Molner *et al.,* (2012). We had found it very difficult to source an adequate collection of international ES value estimates that we could transfer to this study. The collection of ES value estimates used by Molner *et al.,* (2012) only included 3 supporting services (i.e. nutrient cycling, habitat and carbon sequestration). The use of this set of values thus implied that the seagrass CME had a NV of zero (i.e. there were no regulating, provisioning and/or non-material services).

4.2.2 Problem 2 – overlooking the role of MEA 'supporting' and 'regulating' services

When we concentrate on valuation as a process of aggregating individual value estimates, we run the risk of overlooking the fact that our individual value estimates are actually interrelated, even within the highly abstracted MEA framework. Returning to our seagrass example, the existence of 3 supporting services with combined value in excess of $\$NZ_{2012}$ 890M/yr. informs us, by deduction, that there must be corresponding regulating, provisioning and non-material ES that are directly and indirectly related to this 'supporting' value. This deduction can be drawn from the very simple relationships that form the basis of the MEA illustration shown in Figure 3. As already noted, supporting services *are necessary for the production of all other services.*

Once our attention was drawn to this accounting problem, we also became aware that this same problem existed in the value Tables we had created to estimate the NV of CME and TES. Some of these Tables had a lot of relatively small values in them combined with some especially large estimates of value for regulating and/or supporting services. We now realised that these large supporting and/or regulating value estimates do not have corresponding value estimates in other parts of the Table that they were clearly related to. For example, Table 3 for estuarine CME in this report contains a value of $\$NZ_{2012}$ 413M/yr. for nutrient cycling (i.e. a supporting service). However, there is no other corresponding regulating, provisioning and/or non-material value in Table 3 that would (from an accounting perspective) show that this \$413M/yr. had been translated into other regulating, provisioning and/or non-material benefits.

From an accounting perspective, Table 3 is unbalanced (i.e. inputs don't equal outputs). Also, because this $\$NZ_{2012}$ 413M/yr. is a supporting service it is not included in our estimate of NV. Thus, by trying to avoid 'double counting' we have created what we here refer to as a 'valuation Table representation problem'. Our use of individual value estimates needs to be adequately represented in all ES. By overlooking this problem, we can cause quite sizable distortions in our estimates of gross and net TEV.

4.3 The problem of remedying the valuation Table representation problem

There does not seem to be a simple answer to this problem. This problem appears to stem from attempts we have made to apply an empirical assessment to a conceptual model. Our evaluation of this situation has led to the conclusion that a crude accounting adjustment is the most appropriate remedial course of action we can take. This conclusion was influenced by the following understanding.

4.3.1 The problem of identifying ES pathways

While this framework acknowledges that supporting services are needed for the production of all other services, it does not provide us with theory that explains just what these pathways are and how supporting services are coupled with regulating, provisioning and/or non-material services. This is an important limitation of the MEA framework that has accounting implications. The MEA model represents a collection of ES indicators - it was never intended as a theoretically valid representation of an ecosystem. Some of ES interrelationships may be evident through our knowledge of ecosystems. For example, we would expect that nutrient cycling is an essential input to key provisioning services like food, raw materials and genetic resources. However, there are many more regulating and non-material ES for which these causal relationships are unclear. Thus, figuring out how to distribute value around our MEA valuation Tables in order to balance this simplistic accounting model is not straight forward. Another problem concerns the MEA classification. For example, the carbon sequestration service has been located in supporting services. If it was a regulating or provisioning service then we could use it to allocation surplus net primary production too.

4.3.2 The existence of transformation processes

When dealing with ecological processes, the movement of value from one ES to another will involve ecological transformation processes. It would thus be overly simplistic to treat these valuation Tables as a simple input-output or 'double-entry' accounting problem. This means that we cannot assume that the valuation Table will necessarily balance in monetary terms (i.e. the amount of value associated with supporting and regulating services will be fully balanced by the appropriation of ecosystem goods and services in the provisioning and non-material categories).

4.3.3 The allocation of value to different ES

Even if we knew what the most important inter-linkages were, how would we then decide how much value is to be attributed to a given ES in comparison to another? Furthermore, we must also expect that not all supporting services value are distributed to all other parts of the valuation Table. For many if not all supporting and regulating services, we would expect that some value is needed for internal maintenance and regulatory purposes. How to apportion internal feedbacks of this kind is another question.

4.3.4 Time delays

We should not expect that the movement of value from one ES to another is instantaneous and necessarily occurs within the discrete sample interval we are using (i.e. 1 year). Value moves around ecosystems at different rates and in the case of some feedbacks can involve significant delays.

4.3.5 A boundary problem

There is also an implied boundary problem. If we start apportioning value to other parts of the Table while seeking to account for ecosystem inter-linkages then how far do we go? What criteria do we use to decide what is included and what is omitted?

As indicated above, there does not seem to be a neat and tidy closed-form solution to this accounting problem. However, if we do not address this problem it will result in distortions in our gross and net value estimates. In addressing this problem there seems to be little choice other than to apply accounting corrections that seek to 'balance' the valuation Table (i.e. in input-output terms), even though such adjustments will be incomplete and involve uncertainty. The uncertainty part of this problem means that it will be difficult to assess the full consequences of these adjustments in terms of over and/or underestimation of gross and net TEV. However, of the options, a failure to attempt corrections of this kind is likely to result in potentially significant underestimation. To illustrate this point, we have submitted all of the results Tables presented in this report to accounting adjustments of this kind (Tables D1-D8). In the remainder of this section we describe the changes we have made and then evaluate the resultant gross and net TEV estimates.

4.4 The location in this report and layout of results Tables D1-D8

All of the results Tables referred to in this sub-section are contained within Appendix D. These Tables have not been included in this report section because of their size. Each of Tables D1-D8 is based on an identical layout. Each Table is composed of 3 sub-Tables that should be evaluated from left to right. The first sub-Table is identical to the results Tables found in section 2 of this report. This Table thus contains the *original assessment of ESV* for a given CME including estimates of value for supporting, regulating, provisioning, non-material, GDP, GV and NV. The second sub-Table contains accounting adjustments that have been applied to supporting, regulating, provisioning and non-material services in the first Table. It is thus composed of only 4 columns carrying these MEA service category names. The role of this Table is apply accounting adjustments. The third and final sub-Table is the sum of the first (i.e. original assessment) and second (i.e. accounting adjustment) Tables. Thus, the third Table provides a final assessment of ESV that has been corrected for the representation of large ES values present in these valuation Tables.

4.4.1 Accounting adjustments made to results Tables D1-D8

While fully aware of the limitation of any attempts to make accounting adjustments, we have worked to the following guiding principles.

(i). We have only adjusted value estimates in supporting and regulating parts of the Table so as to improve the representation of this value in other parts of the Table.

(ii). We have only adjusted large value estimates that are clearly not balanced (in accounting terms) by the equally sized representation of value in other parts of the Table.

(iii) The main aim of our accounting adjustments has been to improve the representation of value within the Table so as to ensure that a lack of representation does not distort our gross and net TEV estimates.

(iv). The attribution of a large value estimate to other parts of the Table was based on known ecological relationship about which we have some confidence. In cases where there was uncertainty, we have allocated the adjustment to an 'unspecified' ES category that we have added to the Tables as needed. We have adopted the use of footnote numbering and notes below the Table to provide simple interpretative information of apportionment of individual ES.

(v). Where grounds existed for apportioning some of a value estimate to an ES in another part of the Table, we have based this allocation on the percentage contribution made by the target ES value in the Table to NTEV. Any remaining residual value beyond this percentage allocation was place in an 'unspecified' category.

4.4.2 A brief commentary on Tables D1-D8

To assist interpretation of Tables D1-D8, the following narrative has been provided to explain the accounting adjustments made.

Continental shelf CME (Table D1) – Table DI contains a very large value estimate for nutrient cycling of NZ_{2012}$1,354M/yr. While inter-linkages across Table D1 with regulating ES are unclear, nutrient regulation contributes to provisioning services (i.e. food and raw materials). Therefore, 22.7% of Nutrient cycling was allocated to food, 29.5% was allocated to raw material provisioning. The remainder was allocated to an unspecified (regulating) ES category.

Estuarine CME (Table D2) – Table D2 also contains a very large value estimate for nutrient cycling of NZ_{2012}$413M/yr. Similar to Table D1, 40.9% of this value estimate was apportioned to food and 1.9% to raw material provisioning. The remainder was allocated to an unspecified (regulating) ES category.

Lagoon CME (Table D3) – Table D3 contains a large value estimate for net primary production of NZ_{2012}$8M/yr. Because the coastal lagoons of Farewell Spit are located in a wildlife sanctuary, the harvest of food and raw materials is not possible. In the absence of clear inter-linkages with other regulating ES, this value estimate has been attributed to an unspecified (regulating) ES category.

Intertidal CME (Table D4) – Table D4 contains large value estimates for net primary production of NZ_{2012}$325M/yr. and water regulation NZ_{2012}$165M/yr. The likely role of net primary production in regulating services is currently unclear, however we have assumed it does play a role in supporting the provisioning of food (6% in this Table), raw materials (0.38% in this Table) and genetic resources (38% in this Table). The remainder of net primary production has been allocated to an unspecified (provisioning) ES category. The role of water regulation in supporting services is also unclear. However, water regulation does play a role in water supply, for this reason we have apportioned 0.32% to water supply and the remainder to an unspecified (regulating) ES category.

Saltmarsh CME (Table D5) – Table D5 contains large value estimates for net primary production of NZ_{2012}$47M/yr. and water regulation NZ_{2012}$24M/yr. As above in Table D4, the likely role of net primary production in regulating services is currently unclear, however we have assumed it does play a role in supporting the provisioning of food (6% in this Table), raw materials (0.38% in this Table) and genetic resources (40% in this Table). The remainder of net primary production has been allocated to an unspecified (provisioning) ES category. The role of water regulation in supporting services is also unclear. However, water regulation does play a role in water supply, for this reason we have apportioned 0.32% to water supply and the remainder to an unspecified (regulating) ES category.

Seagrass CME (Table D6) – Table D6 contains large value estimates for: nutrient cycling NZ_{2012}$523M/yr., habitat NZ_{2012}$360M/yr. and carbon sequestration NZ_{2012}$6M/yr. The likely role of nutrient cycling in regulating services is currently unclear, however we have assumed it does play a role in supporting the provisioning of food (11% in this Table) and raw materials (0.69% in this Table). The role of habitat is more closely linked with genetic resources (40% in this Table). The remainder of nutrient cycling and habitat value has been allocated to unspecified (provisioning) ES categories. In an absence of any clearly inter-linkages for carbon sequestration we have also allocated it to an unspecified (regulating) ES category.

Rocky reef CME (Table D7) – Table D7 contains a collection of relatively small value estimates. The main unbalanced value estimate in this Table is disturbance regulation at NZ_{2012}$4M/yr. Direct-linkages between disturbance regulation and other provisioning or non-material ecosystem services are unclear. However, supporting services are dependent on the dampening of disturbance for this reason we have allocated this value to an unspecified (supporting) ES category.

Sand, beach and dunes CME (Table D8) – Like Table D7 above, Table D8 contains a collection of relatively small value estimates. The main unbalanced value estimate in this Table is disturbance regulation at NZ_{2012}$197M/yr. Because linkages between disturbance regulation and other provisioning and/or non-material ES are unclear, we have once again allocated this value to an unspecified (supporting) ES category on the assumption that it will contribute to the dampening of disturbance for supporting services.

4.5 Adjusted GTEV and NTEV estimates for marine CME

Table 11[21] suggests that our study area (entire) annually produces a GTEV of ES estimated at $4,129M/yr. in NZ_{2012}$ (Table 11). This estimate of GTEV is contributed to (in descending order) by supporting ($3,045M/yr.), regulating ($542M/yr.), non-material ($272M/yr.) and provisioning ($271M/yr.) ecosystem services. Once contributions made by supporting ES have been removed then this entire study area yields a NTEV estimate of $1,085M/yr. (Table 11). However, this estimate of GTEV and NTEV has not been adjusted to compensate for valuation Table representation.

By contrast, the TEV estimates presented in Table 17 have been adjusted for the valuation Table representation problem outlined in this report section. Table 17 suggests that our study area (entire) annually produces a GTEV of ES estimated at $8,161M/yr. in NZ_{2012}$ (Table 17). This estimate of GTEV is now contributed to (in descending order) by supporting ($3,246M/yr.), regulating ($3,232M/yr.), provisioning ($1,410M/yr.) and non-material ($272M/yr.) ecosystem services. Once contributions made by supporting ES have been removed then this entire study area yields a NTEV estimate of $4,797M/yr. (Table 17). Now that these estimates of GTEV and NTEV have been adjusted to compensate for valuation Table representation, the dramatic difference between adjusted and non-adjusted estimates can be seen. Our adjusted estimates of NTEV and GTEV have undergone approximately 4–fold and 2–fold increases, thus illustrating the ability of this valuation Table representation *problem* to quite dramatically distort aggregate value estimates. The adjustments applied in Tables D1–D8 have gone a long way towards correcting this valuation Table representation problem. An evaluation of the structure of the value estimates now presented in Table 17 indicates that this adjusted TEV Table is much more balanced than its counterpart (c.f. Table 13), as we would expect it to be.

4.5.1 Assessing the adjusted value estimate for provisioning services

The adjusted rapid assessment of provisioning services ($1,410M/yr.) here quoted and used in both GTEV and NTEV estimates includes a small portion of value derived from local food production as estimated by GDP ($1.45M/yr.). However, most of the total value of provisioning services dramatically exceeds the appropriation of food, raw materials, water and genetic resources etc. by humans. This raises an interesting question. Is this an excessive allocation of value to provisioning

[21] Sub-section 3.1

services? Generally, we tend to think of provisioning services as the measurement of the human appropriation of ecosystem goods and services and this is true if our spatial data is based on restricted measurements of land use. This RESA is based on a supply-side assessment of ESV. This means that our estimates of value for individual ES are applied to ecosystem area estimates of maximum spatial extent. Most of our GIS data measures landcover rather than landuse. Landcover provides a theoretical maximum supply of ES delivery. Therefore, we would expect provisioning services to reflect (as they now do) this rather than being confined to just human appropriation.

Also, even a demand-side assessment of value must measure ‘over-production’ of provisioning services to a certain extent. To explain this point it is necessary to draw attention to the existence of non-material services like: spiritual and religious values, knowledge systems, inspirational, aesthetic, recreation and tourism etc. Non-material values are dependent upon the existence of functioning ecosystems at the landscape and local levels of spatial scale. This landscape scale ecosystem structure *is provided by provisioning services* (i.e. the over-abundance of plants, freshwater, fiber, raw materials and genetic resources etc.) as a non-material benefit to human welfare.

Table 17 *Adjusted NTEV and GTEV estimates of coastal marine ES in our study area ($\$NZ_{2012}$M/yr.) based on the aggregation of Tables D1-D8*

CME	**Final adjusted MES TEV summary by CME**						
$\$NZ_{2012}$ M/yr.	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Continental shelf	1,354	1,391	56	46	1	2,847	1,493
Estuary	416	249	188	2	10	854	438
Intertidal	328	717	711	3	29	1,759	1,431
Lagoon	8	14	5	0	0	28	19
Saltmarsh	47	85	102	0	4	235	71
Seagrass	891	573	349	0	0	1,813	922
Rocky reefs	5	5	0	1	0	10	5
Sand beach/dunes	197	198	0	220	0	615	418
Column totals	3,246	3,232	1,410	272	45	8,161	4,797

4.6 Adjusted GTEV and NTEV estimates of Nelson Tasman regional TES

The valuation Table representation problem described in this report section is not isolated to the coastal marine estimate of TEV. Our evaluation of the terrestrial valuation Table revealed the same problem. For this reason, we have also adjusted the TES Table by applying the same accounting guidelines as those use in adjusting the CME Tables. The results from this adjustment process are presented in summary form in Table 18.

Table 18 *Adjusted NTEV and GTEV estimates of TES adjacent our marine study area (NZ_{2012}$M/yr.)*

TES	Final adjusted MES TEV summary						
NZ_{2012}$ M/yr.	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Hort. & Cropping	1	1	-	-	156	2	1
Agric	16	73	-	-	1,763	89	73
Int. Agric Scrub	0	8	4	-	-	12	12
Native Scrub	41	24	29	5	9	98	57
Int. Agri. Forest	38	13	38	-	-	89	51
Forest Scrub	33	10	17	2	6	62	29
Forestry	2,202	2,748	114	-	200	5,064	2,862
Wetlands	40	53	86	4	-	182	143
Swamp/floodplain	54	61	50	15	-	179	125
Lakes	53	59	21	2	-	135	82
Rivers	304	304	107	11	-	728	423
Column totals	2,782	3,355	465	39	2,133	6,640	3,859

Our adjusted rapid valuation assessment of this regional-scale terrestrial ecosystem suggests that our terrestrial study area (entire) annually produces an adjusted GTEV of ES estimated at $6,640M/yr. in NZ_{2012}$ (Table17). This economic estimate of GTEV is contributed to (in descending order) by regulating ($3,355M/yr.), supporting ($2,782M/yr.), provisioning ($465M/yr.), and non-material ($39M/yr.) ecosystem services. The assessment of provisioning services ($2,338M/yr.) here quoted includes an incomplete estimate of value derived from (i) primary food production as captured by commercial markets (i.e. $1,934M/yr.) and (ii) timber harvest as captured by commercial markets (i.e. $200M/yr.) meaning that 55% of NTEV belonging to this terrestrial study area (entire) has been captured by the SNA. Once contributions made by supporting ES have been removed, this regional-scale Terrestrial ecosystem yields a NTEV estimate of $3,859M/yr. (Table17). Overall, Table 17 once again reflects a more balanced allocation of ESV when compared with its pre-adjusted counterpart (i.e. Table 13).

4.7 Adjusted GTEV and NTEV estimates of CME and TES combined

By combining adjusted TES and CME TEV results into one composite Table it is possible to gain a more effective overview of terrestrial/marine ecosystem inter-linkages. This combined rapid valuation assessment data suggests that combined, CME and TES annually produce a GTEV of ES estimated at $14,801M/yr. in NZ_{2012}$ (Table 18). This economic estimate of GTEV is contributed to (in descending order) by: regulating ($6,586M/yr.), supporting ($6,028M/yr.), provisioning ($1,876M/yr.) and non-material ($311M/yr.) ecosystem services. Once contributions made by supporting ES have been removed then TES and CME combined yields a NTEV estimate of $8,656M/yr. (Table 14). Contrary to earlier estimates of TEV, Table 19 indicates that an adjusted GTEV and NTEV for coastal marine ecosystems in now greater than GTEV and NTEV estimates for terrestrial ecosystems. This difference in value now exists despite the fact that in productivity terms, the terrestrial ecosystems in this study cover an area that is roughly twice the size of the marine ecosystem (i.e. 70% TES and 29% CME). This is an important discovery. We don't normally think of marine ecosystems as being more valuable in monetary terms that terrestrial ecosystems. While subject to all of the limiting assumptions of this study, this outcome has only emerged as a result of adjusting our valuation Tables to improve the representation of value estimates – based on the data that we actually have. We normally think about ESV representation in terms of how many ESV we have been able to transfer to a study; this is a different problem.

Table19 *Adjusted GTEV and NTEV estimates of CME and TES ($\$NZ_{2012}M/yr.$) combined*

Combined Table		**Final adjusted MES TEV summary**						
$\$NZ_{2012}M/yr.$		**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Hort. & Crop	T	1	1	-	-	156	2	1
Agric	T	16	73	-	-	1,763	89	73
Int. Agric Scrub	T	0	8	4	-	-	12	12
Native Scrub	T	41	24	29	5	9	98	57
Int. Agri. Forest	T	38	13	38	-	-	89	51
Forest Scrub	T	33	10	17	2	6	62	29
Forestry	T	2,202	2,748	114	-	200	5,064	2,862
Wetlands	T	40	53	86	4	-	182	143
Swamp/floodplain	T	54	61	50	15	-	179	125
Lakes	T	53	59	21	2	-	135	82
Rivers	T	304	304	107	11	-	728	423
Continental shelf	M	1,354	1,391	56	46	1	2,847	1,493
Estuary	M	416	249	188	2	10	854	438
Intertidal	M	328	717	711	3	29	1,759	1,431
Lagoon	M	8	14	5	0	-	28	19
Saltmarsh	M	47	85	102	0	4	235	71
Seagrass	M	891	573	349	0	-	1,813	922
Reefs	M	5	5	0	1	-	10	5
Sand beach/dunes	M	197	198	-	220	-	615	418
Column subtotal	T	2,782	3,355	465	39	2,134	6,640	3,859
Column subtotal	M	3,246	3,232	1,410	272	45	8,161	4,797
Final total	T+M	6,028	6,586	1,876	311	2,178	14,801	8,656

5. Discussion

The aim of this study was to undertake a scoping ESV of CME within a broadly defined Nelson Bays study area. Previous TEV, ESV studies in New Zealand have relied heavily on the legacy of the Costanza *et al.,* (1997) study of global ES as a source of guidance on both valuation method and BT data. In this study we have made a concerted effort to move beyond this important contribution to ESV method. Developments in ESV/BT theory and method over the last two decades now provide a relatively new foundation for continuing this important field of research (Cole, 2014). In particular, the published literature over the last 2 decades has more effectively identified many of the limitations of ESV/BT methods and began the task of searching for solutions. While we do not yet have complete answers to many of the vexing method and theory problems associated with ESV, we have made progress in identifying these issues and documenting the extent to which future research in this area is able to address these many concerns. This is a necessary stage in the growth of ESV research if its early goal of policy relevance (Brookshire, 1992; Costanza *et al.,* 1997) is ever to be fully realised (Laurans *et al.,* 2013).

5.1 Assessment of ESV method used in this study

In the area ESV method, this present study has attempted to respond to a number of published critiques of earlier ESV research and consequent recommendations for improvement. First, we have adopted the MEA classification (MEA, 2003; MEA, 2005; DEFRA, 2007) of ES into provisioning, regulating, supporting and non-material (i.e. MEA cultural) categories which makes it possible to avoid the problem of double counting supporting and regulating ES categories (Haines-Young and Potschin, 2009). We have implemented this accounting recommendation with the use of both gross and net value estimates of marine and terrestrial ES and attempted to adjust for valuation Table representation (i.e. section 4 of this report). Second, we have taken initial steps in seeking to relax the use of a highly abstracted marine study area boundary in favour of an alternative approach that begins to explicitly consider inter-linkages (Jin *et al.,* 2003; Bennett *et al.,* 2009; Leslie *et al.,* 2009; Barbier, 2012; Nystrom *et al.,* 2012) between coastal marine and terrestrial ecosystem and the services they provide.

Third, we have undertaken a critical review (Cole, 2014) of the published literature covering ESV/BT method in order to better understand barriers to the use of ESV in a policy context (Duffield, 1997; Wainger and Mazzotta, 2011; Laurans *et al.,* 2013). Finally, in terms of accounting method we have adopted a number of changes including: (i) where available the use of medium range BT value estimates (Deck and Chestnut, 1992), (ii) the adjustment of BT data for socio-economic similarity using PPP[22] indices (Czajkowski and Scasny, 2010; Kerr and Latham, 2011) and (iii) the reporting of results using a results Table format that includes the disaggregation of ESV data into GV and NV contributions (Deck and Chestnut, 1992). Overall, we feel that these changes in ESV method assist in addressing past problems of over-estimation, the need for more

[22] Czajkowski & Scasny (2010) suggest that their research showed a 50% decline in mean benefits transfer errors and tolerance levels by adopting the use of PPP data to adjust benefits for market currency equivalency.

explicit interlinking of terrestrial, aquatic and marine ES and the more effective communication of likely computational problems and areas of valuation uncertainty.

5.2 Assessment of BT method used in this study

In the area of BT method, this study has also attempted to respond to a number of published critiques of earlier ESV research and consequent recommendations for improvement. First, consistent with calls across the published literature (Brookshire, 1992; Krupnick, 1992; Loomis and Rosenberger, 2006; Plummer, 2009) we have attempted to develop a theoretical and procedural basis for the development of operating guidelines in BT method (Cole, 2014). While there is clearly high monetary cost associated with full BT method compliance, documenting the development of thinking on BT method at least makes it possible to theoretically and methodologically position what we are doing. This is an important first step.

Second, wherever possible, we have attempted to move away from the use of value estimates created in isolation from (Barton, 2002; Bagstad, 2009) any sense of statistical spread or distribution (Deck and Chestnut, 1992; Loomis, 2006). Unfortunately, not all published papers support treatment of data in this manner at this stage. However, in the absence of primary published papers we have attempted to bring together a range of value estimates. Third, as repeatedly advised (Krupnick, 1992; Loomis and Rosenberger, 2006; Rosenberger and Stanley, 2006; Wilson and Hoehn, 2006; Pendleton *et al.,* 2007; Bagstad, 2009; Eigenbrod *et al.,* 2010) in the published literature we have made an effort to locate and assess primary papers as a basis for assessing the suitability of non-market surveys for transfer. Fourth, we aimed to assess potential primary papers for ecological, geographic and socio-economic similarity (Cameron, 1992; Lovett *et al.,* 1997; Barton, 2002; Loomis and Rosenberger, 2006; Morrison and Bergland, 2006; Ready and Navrud, 2006; Bagstad, 2009; Czajkowski and Scasny, 2010). In practice it was extremely difficult to sustain this goal because of the time involved in sourcing and reading primary/secondary papers. Also, not all papers provide the level of information needed to assess similarity across these areas. Thus, our efforts to assess primary papers resulted in a ‘similarity’ verses ‘valuation data’ choice tradeoff. Beyond assessing similarity, we have not had the time or resources needed to individually adjust policy site estimates for socio-economic-cultural dissimilarity. Further work is needed in this area.

Fifth, we employed the use of state-of-the-art GIS technology and available research-based spatial data (Eade and Moran, 1996; Lovett *et al.,* 1997; Bagstad, 2009; Eigenbrod *et al.,* 2010; Cullinan *et al.,* 2011; Martin-Ortega *et al.,* 2012) to minimise error associated with the spatial depiction of ecosystem categories. However, as consistent with the creation of a supply-side assessment of ESV (Bagstad, 2009), our analysis is mostly limited to the use of landcover spatial data. Because of the very high ES multipliers associated with the sand, beach and dunes ecosystem, we made adjustments for landuse by assuming a 20% use of sand, beach and dune ecosystem landcover. This assumption is conservative, but unsubstantiated. More research is needed in this area. Our current spatial database and BT data does not lend itself towards the assessment of a demand-side assessment of ES, even though this is arguably of greater relevance in a policy context.

Sixth, by adjusting survey site value estimates with PPP indices (Ready and Navrud, 2006; Czajkowski and Scasny, 2010) we may have significantly contributed towards a reduction in mean BT error (Czajkowski and Scasny, 2010). However, what appears to have been overlooked in previously published applications of PPP currency conversion adjustment is that the results are influenced by the method of PPP/CPI adjustment (i.e. whether used with the sample or policy site country). Thus the net computational benefit of this important change in BT method is currently unclear.

In summary, we have outlined 6 important changes in our past use of BT method. While this is an important step forward, our review of BT literature (Cole, 2014) identified in excess of 30 key issues that are believed to influence the outcome of BT studies. There is clearly a lot more work that can be done in this area and this includes assessing the tradeoffs associated with the use of research funding in improving BT accuracy in preferred areas at the cost of others potential computational improvement areas. For example, this project involved a tradeoff between (i) efforts to achieve careful filtering of primary studies and (ii) the final availability of papers that could be used to provide ESV for rapid assessment. There have been repeated calls for the international establishment and appropriate design (Villa *et al.,* 2007) of non-market valuation databases and repositories of primary paper supporting data (Loomis and Rosenberger, 2006; Rosenberger and Stanley, 2006; Pendleton *et al.,* 2007; Leon-Gonzalez and Scarpa, 2008). While important progress has been and continues to be made in this area (Sundberg and Söderqvist, 2004; Van der Ploeg and de Groot, 2010; Conservancy, 2012; Economics, 2012; Economy, 2012; Plantier-Santos *et al.,* 2012; EVRI, 2013; Gateway, 2013; Kerr, 2013; Mexico, 2013; NOAA, 2013), the sourcing of primary data for BT is a time consuming and difficult task – one that needs to be carefully considered in terms of the data quality goals of a proposed ESV study.

Consideration of our application of ESV and BT method provides an important foundation for the evaluation of research results and guidance on the domains in which those results can be appropriately used. Our goal in this research project was to undertake a scoping study of the annual flows of ES benefit associated with our interlinked terrestrial-aquatic-marine ecosystem study area. We believe that our use and adjustment of ESV and BT method has made it possible to move towards this goal. While this research process has raised many questions, it has also provided a clearer theoretical and methodological basis on which to move this initial research effort into a future policy relevant context.

6. Conclusions

The estimates of NTEV and adjusted NTEV outlined in this report may be considered as the result of efforts made using RESA to move towards an estimate and understanding of ESV for the Nelson Bays study area. This study and report thus represents an important, but incomplete contribution towards achieving this goal. There is much more that can be done to improve this research effort. Having said this, what we can state with some confidence about these results is that the GTEV and NTEV estimates documented in this report are, on balance - underestimates. This conclusion is drawn partly from the consistent pattern of ESV underrepresentation documented in the results Tables of section 2 of this report and the fact that this assessment of TEV is currently, *only based on an estimate of use value.* Passive or non-use values have not been estimated as part of this study and their absence will contribute towards the underestimation problem. For this reason, it is helpful to think of a study of this kind as an attempt to move *towards* an understanding of ESV, rather than to assume that we can ever make it to the end of such a journey. Hence the title to this report: *Towards a 'total economic value' of coastal marine ecosystem services in Nelson Bays, Nelson Tasman region, New Zealand.*

This study has attempted to position CME NTEV in relation to TES NTEV. Our attempts to estimate SR ESV contributions made by terrestrial, aquatic and marine domains (Figure 2) to collective terrestrial-aquatic-marine ecosystem function have not stood up well to independent validation using global NPP. This analysis has, however, raised a number of important issues. First, it has assisted in providing us with an additional set of empirical reference points (i.e. global NPP) that we can use to assess the quality of our NTEV and GTEV estimates. As has been outlined all through this paper, estimates of GTEV and NTEV are highly sensitive to ESV/BT method, computational accuracy and valuation uncertainties and this analysis reaffirms these issues. Second, this analysis has also helped to draw attention to the need to adjust TEV estimates for ecosystem productivity when seeking to compare GTEV and NTEV estimates and/or other economic indicators like GDP that are derived from ecosystems of differing spatial extent.

Finally, while some uncertainty still remains regarding the use of SR ESV estimates, the efforts we have made to position CME valuation within a frame-of-reference involving a combined terrestrial-aquatic-marine ecosystem model has been beneficial in a number of ways. First, this research process has assisted in creating a conceptual and numerical framework for both visualizing and quantifying this complex land-ocean system. Second, while some uncertainty remains about how to quantify the contributory value of flows of ES to different parts of a combined terrestrial-aquatic-marine ecosystem, the problems associated with achieving this goal are now clearer. Finally, in terms of ESV estimates, what this study has consistently shown is that non-market ESV estimate involves under and overestimation problems that can be addressed from a computational perspective given adequate information and research funding. In an absence of adequate research funding, we have attempted to bring greater transparency to the research process by documenting our assumptions, the limitations of the rapid assessment method used and areas of likely uncertainty in greater detail.

An additional aim of this research project was to improve the quality of our ESV calculations by paying closer attention to recommendations in the published literature. We have experienced mixed success in achieving this goal. It is now evident that efforts made to improve the quality of BT data and ESV method can result in unexpected tradeoffs with other equally important project goals. An outcome of this kind is especially likely in a project that is not adequately resourced in terms of available time and the cross-disciplinary expertise needed to address the now complex web of issues and problems associated with ESV and BT methods. However, what this project has successfully achieved is the building of a solid theoretical grounding in ESV and BT methods that will hopefully assist in guiding future research effort towards a more effective connection between ESV research and policy, planning and business management activities.

Appendix A

A1. RESA method explained

The RESA method used in this study follows a series of sequential steps that are essentially consistent with Costanza *et al.,* (1997) and more recently published RESA research (O'Farrell *et al.,* 2012; Peh *et al.,* 2013). These steps are:

1. *Define a study area boundary*
2. *Map the coverage of ecosystem ecosystems within the study area (in ha.)*
3. *Cross match local coastal marine habitat categories with CME categories*
4. *Locate market and non-market values suited to study area ES*
5. *Calculate value estimates using preferred accounting method*
6. *Table and spatially portray results as relevant*

Where possible, within the scope of available funding and resources we have attempted to take on board a number of important corrections to earlier implementations of the basic RESA steps outlined above. A general description of our rapid assessment method (steps 1-5) is outlined below. To complement the explanation of RESA method here provided in Appendix A, a more detailed analysis of developments in ESV and BT method is available in a separate report (Cole, 2014).

A1.1 Define a study area boundary

The Nelson Bays coastal marine study area used in this project is depicted in Figure A1 and may be defined as follows. The seaward boundary begins at Cape Farewell and follows the MLWS (mean low water spring) line along the northern (Tasman Sea) side of Farewell Spit. At the end of the spit, the seaward boundary runs along the 50m isobath, a natural boundary between Nelson Bays and the Cook Strait, to a meeting point with D'Urville Island at Ragged Point on the southern side of the entrance to Greville Harbour. The boundary then follows the southern coast of D'Urville Island until it reaches Reef Point and then crosses French Pass to join up with the mainland at Channel Point (Figure A1).

This study area is reasonably self-contained with respect to oceanic circulation patterns and allows us to include Farewell Spit, an area with important conservation, recreation and tourism values. The inshore boundary encompasses all coastal features, regardless of their distance inland from the coast. However, terrestrial features are not used for CME valuation purposes. CME features are defined as all parcels of land and aquatic systems that are significantly affected by coastal processes, ecology and biogeochemistry. This, for example, includes saltwater wetlands, estuaries, beaches, dune systems, brackish parts of rivers, islands and the Boulder Bank. Farewell Spit Nature Reserve is included within our study area to capture the significant economic value of tourism activity associated with these terrestrial/coastal features, which are largely derived from their coastal location. To ensure that indirect TES values of this kind are captured, we have also created and used RESA of TES across the Nelson and Tasman regions combined.

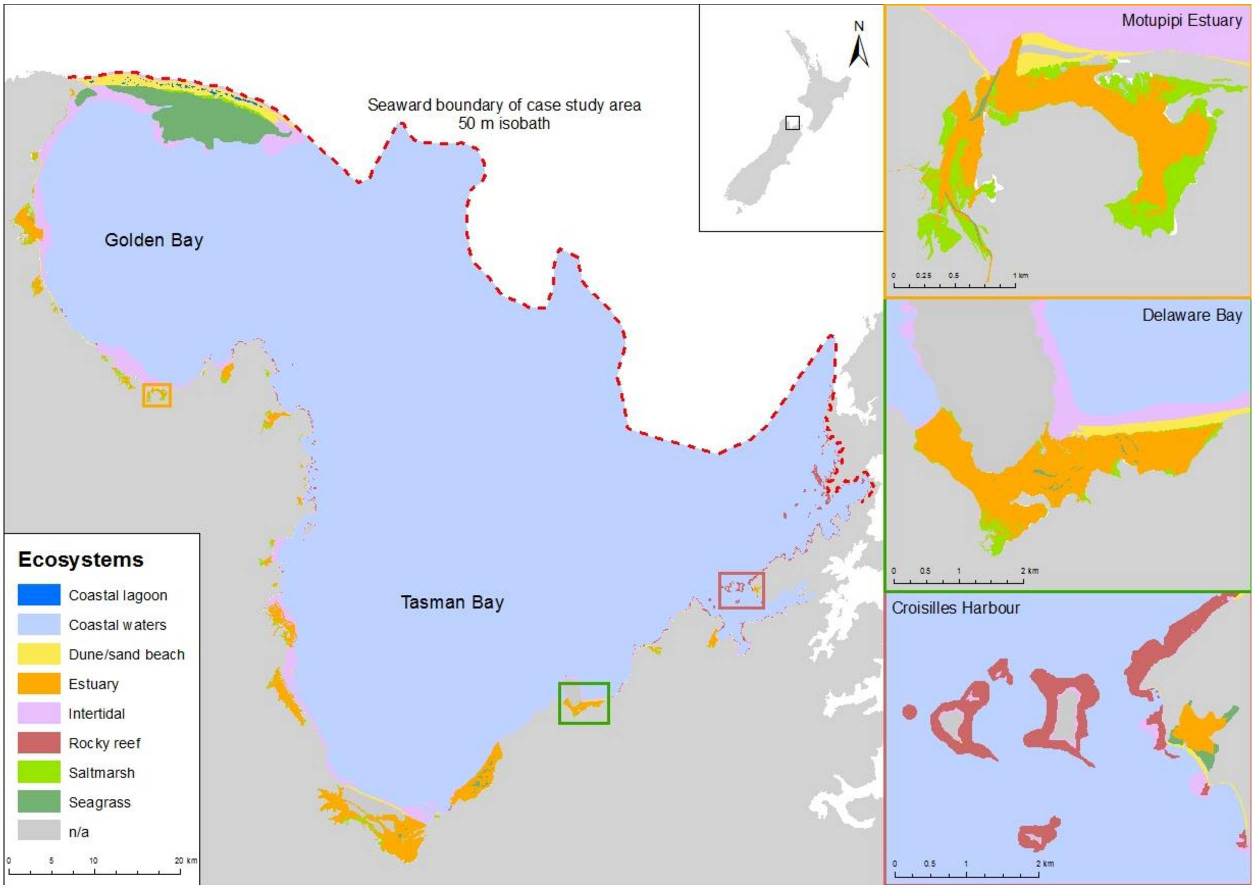

Figure A1 *The Nelson Bays study area depicting spatial extent of ecosystems. Insets show detail of three regions within the case study area*

Barbier (2012) suggests that inter-linkages between coastal marine and terrestrial ecosystem service flows (globally) can include terrestrial extent of up to 100km inland and seaward out as far as 50m depth. For this reason and because of New Zealand's environmental legislation (Government, 1991; Government, 2002a; Government, 2002b) it is difficult to fully isolate coastal marine ESV from its terrestrial ESV context. Key inter-linkages between terrestrial and CME include: *(i) the influence of landcover/use on water quality in aquatic ecosystems that flush directly to sea, (ii) the influence of point and non-point source pollution on aquatic ecosystem water quality, (iii) the almost total loss of coastal wetlands and semi-swamp forest*[23] *from coastal plains that previously provided terrestrial/marine buffering of water flows and effluent, (iv) ecosystem and food sources for marine birds, (v) air emissions linked with human induced global warming with consequent sea-level adjustment and (vi) the influences of terrestrial forest reserves on coastal marine recreational value.*

[23] This has occurred across New Zealand regions with an estimated national average of <10% of wetlands remaining.

In this study, the existence of the above inter-linkages makes it difficult to limit the use of ESV to a CME only. We have used the following strategy as an initial step towards addressing this problem.

First, in keeping with the international guidelines outlined by Barbier (2012), we include revised data from an earlier RESA of TES in the Nelson Tasman regions. These TESV estimates (Table 13 and 14) are: (i) a revision of previously published TESV estimates for the Nelson Tasman regions (Cole and Patterson, 2003) that are (ii) now based on a revised RESA method designed to correct double counting associated with the inclusion of supporting ES in earlier TEV calculations (Patterson and Cole, 1999a; Patterson and Cole, 1999c; McDonald and Patterson, 2003). This change in accounting method was made because it is now generally recognised that supporting services and some regulating services are inputs to provisioning and non-material services.

Inclusion of supporting services in TEV calculations creates a problem of double counting what are effectively single ecological processes composed of both supporting and provisioning parts (Boyd and Banzhaf, 2007b; Wallace, 2007; Balmford *et al.,* 2008; Fisher and Kerry Turner, 2008; de Groot *et al.,* 2010). We have also applied this new accounting adjustment to the marine RESA outlined in this report. The inclusion of TES value estimates means that it is possible to consider MESV in the broader ecological context of related TES. Beyond this more generalised analysis, more work is needed to isolate, measure and value specific marine-terrestrial inter-linkages of the kind listed above that are of central interest to planners and policy makers.

Second, consistent with international guidelines, our seaward boundary extends out to 50m water depth. Coastal marine inter-linkages within New Zealand's EEZ and beyond are also relevant to this study, but not considered in this report. A recent assessment of the annual monetary value of MES associated with Aotearoa/New Zealand's EEZ is currently in press (Van den Belt *et al.,* 2012).

As noted above, the explicit interlinking of TES and MES needs further work. This is especially necessary to ensure that the ESV models we create are aligned to planning, policy and business *legislative responsibilities*. Obviously, there is little point in creating ESV models to inform economic tradeoffs, if the ecosystems and ES being traded are not represented in the valuation classification. While attention to detail of this kind may well assist in making ESV more attractive to planners and policy makers, the preferred choice of ESV model variables is no simple matter. The development of a generally applicable and contextually relevant system of classification for ESV remains a topic of ongoing debate in the published literature (Boyd and Banzhaf, 2007a; Costanza, 2008; Wallace, 2008) as does the question of the role ESV should play in addressing the complex problem of global ecosystem decline (Norgaard, 2010).

A1.2 Map the coverage of ecosystems within the study area

Mapping the coverage of CME within the study area was accomplished with the aid of a spatial database that depicts coastal marine habitat types. A key assumption of our use of this spatial data is that 'habitat type' is broadly consistent with our use of the term 'ecosystem type'. This assumption is essential to most RESA studies because internationally the collection of spatial ecological data is made for biodiversity and conservation purposes and thus typically involves habitat, population and community systems of classification (Reyers *et al.,* 2010). A more serious limiting assumption associated with the use of spatial habitat data is that it depicts landcover (by habitat) rather than landuse. ESV focuses attention on the human appropriation of ecosystem goods and services. Landcover (by habitat) measures the upper ecological limit of what is available. By contrast, landuse measurements provide information on that portion of landcover that is appropriated by humans. This point draws attention to the fact that it is possible to estimate both supply and demand estimates of ESV. Internationally, RESA studies are typically based on supply-side (i.e. landcover) estimates of value.

The map shown in Figure A1 is based on data from a range of data sources (Grange *et al.,* 2003a; Robertson *et al.,* 2003b; Tuckey and Robertson, 2003a; Clark *et al.,* 2006b; Clark *et al.,* 2008a; Stevens and Robertson, 2008b; Gillespie *et al.,* 2011c; Gillespie *et al.,* 2011b; Robertson and Stevens, 2012b), compiled into a best estimate of the marine habitat types in Nelson Bays. In general, modifications to areas previously mapped by other researchers and/or research teams were avoided on the assumption that this data was fairly reliable. Where habitats from different sources overlapped, or for areas where no data was available, an educated guess was made to determine the most likely CME extent.

In some cases, previously mapped habitat obviously did not match recent aerial photos. To ensure consistency, aerial photos were obtained from the Nelson City Council using their GIS server. The Marlborough District Council supplied aerial photos for the coastal region from Cape Soucis to Greville Harbour on D'Urville Island. These photos are provided on the Nelson Bays Ecosystem Map CD along with a few extra aerial photo layers from around Nelson Haven and Delaware Inlet.

In addition to the spatial data sources listed in Appendix Table C1, sediment cores from a range of projects carried out by Cawthron, NIWA (Tuck *et al.,* 2012) and DOC (Davidson and Duffy, 1992) were used to provide information and thus make decisions on dominant sediment cover. For areas where there was no data, an educated guess was made as to the likely habitat/ecosystem type, based on geographic information system GIS data sources (Appendix Table C1) and sediment core information listed above. Every effort was made to achieve consistency with definitions used in earlier broad-scale surveys including Wriggle's mapping (Stevens and Robertson, 2008b; Robertson and Stevens, 2012b) and Rob Davidson's mapping of the Abel Tasman (Davidson 1992).

The CME definitions (Appendix Table C2) we have used in this study were classified according to a standard set of categories primarily based on the existing spatial classification system used by DOC and MFish (2011) for their broad-scale gaps analysis of coastal marine habitats and marine protected areas in the New Zealand territorial seas. We have not yet obtained exposure information for this data for Nelson Bays; therefore, distinctions based on exposure were not made in this classification. In addition to the categories used in DOC and MFish (2011), this classification system also included: (i) some terrestrial and artificial features (*e.g.* forest, pasture, wharves), (ii) the classification of saltmarsh to a much higher level and (ii) the addition of a few extra groups including 'unvegetated' (*e.g.* cobble/boulder/rock, mud/sand) and 'biogenic ecosystem' (*e.g.* shell bank, macro-algal bed) categories.

Different types of tests were applied to minimise errors in the spatial depiction of CME. First, a check was made for unmapped gaps by overlaying the ecosystem map onto a bright background. A random check was also made for sliver gaps (i.e. small gaps between adjacent polygons) along lines inside the merged study area polygon. This approach will usually assist in identification of gaps that are visually noticeable. Second, a check was made for duplicate polygons by checking for identical centroid coordinates. Third, check for overlaps was made using ET Geo Wizards Clean Polygon tool. Once 'slivers' (*i.e.* small areas of overlap between polygons) were identified, an area calculation was created using the ArcMap Calculate Geometry tool in the attribute table to find large accidental overlaps. Slivers and/or overlaps greater than 250 m^2 were removed. There are still a large number of small slivers present in the map (total ~23 ha.) and these can be removed automatically. However, the benefit of automatic elimination may be outweighed by the cost of accidently attributing slivers to the wrong ecosystem type or by deleting small polygons.

Table A1 *Summary of total areas (ha.) for different parts of the marine study area map*

Section of map	**Area (ha)**
Terrestrial section of study area (excluding Abel Tasman National Park)	6,531
Coastal section of study area[24]	400,122
Farewell Spit [25]	2,242
Abel Tasman National Park [5]	23,606
Total area mapped	432,501

Finally, an area check was made. Known total coastal study area was compared with the sum of areas for each individual ecosystem polygon. Total study area was determined by merging coastal polygons. Total CME area equals 400,122 ha. (excl. Abel Tasman National Park and Farewell Spit). The sum of all coastal polygons equals 402,398 ha. (Table 1), giving a difference of only 24 ha. Given that we could not detect any duplicate polygons or large overlaps, it can be assumed that this difference in area is attributable to a large number of very small overlaps. On checking total

[24] Excluding Farewell Spit and coastal sections of Abel Tasman National Park

[25] Based on Landcover Database version 3 estimates of landcover, therefore, primarily include terrestrial or terrestrial-type features. Coastal features are largely included in the coastal section of the study area.

overlap area, the sum of the sliver overlaps not removed (those < 250 m^2) was calculated to be 23 ha. As such, this extra area will be spread across all ecosystem types, not biased toward one, and so should not affect the valuation significantly. Total study area including Abel Tasman National Park and Farewell Spit is 425,970 ha and the total area mapped (coastal and terrestrial polygons) is 432,501 ha (Table 1).

A1.3 Cross match local marine habitat categories with CME categories

In this step, coastal marine habitat data (ha.) was sorted with the aid of a spreadsheet into CME categories. We prefer to use the coastal marine ecosystem (CME) in preference to ES biome, a term that has been widely adopted in the international ES literature. The term 'ES biome' has been adopted in published papers on ES (e.g. Costanza *et al.,* 1998; Boumans *et al.,* 2002; Konarska *et al.,* 2002; Viglizzo and Frank, 2006; Chisholm, 2010) to name what are in effect highly generalised ecosystem types. The term 'biome' is generally used to refer to areas of similar ecological character as determined by climate and geographical drivers, at landscape to sub-national scales. Our study concentrates on what could be described as one sub-national area (i.e. a CME associated with the Nelson Tasman regions). Strictly speaking the term 'biome' is not an appropriate ecological descriptor for this level of scale; even though the use of this term has been adopted internationally as part of an emerging ES technical vocabulary. Therefore, our study is based on the area measurement of what we think it is more appropriate to refer to as CME (listed in Table A2). CME used in this RESA are defined and illustrated using local photographs in Appendix Table C2. Additional information needed to appropriately interpret the CME categories listed in Appendix Table C2 is contained in Appendix Table C3. Appendix Table C3 defines and illustrates the GIS structural classes used to create CME for this study. Evaluation of these spatial categories reveals a number of important points.

First, as is evident from the information presented in Appendix Table C2, the ecosystem categories used in this study (Table A2) are based on highly aggregated coastal marine structural classes. Our GIS database of the study area contains a level of spatial resolution that is not able to be easily used in this study because we don't have access to a correspondingly high resolution set of national and/or international BT estimates.

Second, the main reason for this high degree of aggregation is because the (aggregated) CME categories shown in Table A2 are currently supported by an internationally available BT literature. We need to use this literature to provide value estimates for New Zealand. This BT method used for obtaining ESV data is needed in the almost total absence of a suitable terrestrial/marine ESV literature for New Zealand. Thus, the level of resolution used in our choice of CME categories is currently constrained by internationally available BT literature. It is unlikely that the status of New Zealand specific value literature will change in the short to medium term future. However, the international ESV literature is currently growing at a rapid rate and will likely provide greater scope for higher resolution valuation studies in the near future.

Table A2 *A list of CME along with associated area estimates (ha.) used in this study.*

CME	Area (ha.)	% Area
Open sea/ocean	368,705	92.1
Estuary	7,628	1.9
Lagoons	10,353	2.6
Rocky Intertidal	260	0.1
Salt marshes/ wetland	1,491	0.4
Seagrass/Algae beds	7,404	1.9
Rocky reefs	1,270	0.3
Sand beach and dunes	3,008	0.8
Total[26]	400,121	100.0

Third, in departing from other international studies we have disaggregated the estuary /lagoon/intertidal CME category (Column 1, rows 2–4, Table A2) into its three component parts and attempted to provide improved BT data by using published saltmarsh value estimates. Justification for this change is provided in the text of this report.

Finally, the aggregation process (i.e. from coastal marine habitat to CME) is not as straight forward as it might seem. There are still a number of grey areas related to the 'project appropriate' placement of coastal marine habitats into CME categories. There is further work that can be done in refining our current concordance. Some questions related to appropriate classification may never be fully resolved in which case sensitivity analysis is ideally needed to determine if marginal changes in classification cause critical changes in net valuation estimates. This type of analysis of data quality has not featured as a common place part of past ESV (published) studies. However, this type of verification may well be needed as we seek to move these valuation tools into an applied context where decision stakes are dependent on improved data quality (i.e. our use of ESV/BT method, computational accuracy, transparency of assumptions and knowledge of uncertainties).

[26] Terrestrial ecosystem entities associated with the 10m landward buffer zone around the outside of our study area map are not included in the area estimates we have used for the assessment of ES value.

A1.4 Locate market and non-market values suited to study area ES

This step involved the transfer of international ES benefits to a New Zealand case study context. Separate to this report we provide a critical review of literature on the development of BT method (Cole, 2014). In this sub-section we describe the sources of benefit data for this research and then explain how it was collected.

Some benefits for human welfare derived from PES can be measured by using market values that are recorded in SNAs. Commercial markets for example exist for food and forestry products. Where available, these market values were used in our analysis. Some PES and all of the 'supporting', 'regulating' and 'non-material' ES, have no market value. In these instances, non-market valuation techniques need to be used to impute a value of these ES. In this analysis, in the virtual absence of suitable New Zealand non-market studies, overseas studies were used to estimate non-market values. These overseas studies utilise the non-market valuation methods described in Table A3.

Some ES research teams use the Costanza et al. (1997) internationally averaged BT values as a source of data for their studies. While this approach has limitations (Bagstad, 2009), in the absence of more suitable BT data it may still be necessary. Ideally, a gross and/or net valuation estimate is based on socio-economic and site similar BT data from *primary research papers.* Also, it is important to note that the theoretical development and testing of BT method generally suggests that more reliable BT data will be obtained from the use of transfer functions and meta-analysis, instead of dependence on the use of point estimates (as used in this study). Unfortunately, the data requirements for using transfer functions and meta-analysis mean that while these options may be preferred as a means to higher data quality, they are definitely not a cost-effective method of sourcing data for a study of this scale.

This current research project exceeded its allocated research budget in searching for suitable international BT literature and while doing so still only: (i) managed to survey a small portion of the extensive international literature that now exists in this area and (ii) gathered a relatively small number of *suitable* benefits to transfer. Furthermore, the BT data collected has only been used to provide point estimates and would not be suitable for the construction of transfer functions or meta-analysis. Despite the significantly large literature that was surveyed, the final selection of suitable point estimate values used in this case study was barely enough. After various attempts at creating a rapid assessment by using BT data we had collected, we lacked suitable BT data for some of the CME defined in this study. Therefore, we had to resort to filling these gaps by using ESV estimates provided by Molner *et al.,* (2012) and Costanza *et al.,* (1997). This outcome does not reflect an international shortage of non-market valuation data for these CME. However, this situation does reflect the need for a substantial investment of time to source and assess primary published papers for suitable value estimates that meet the similarity and transfer criteria we were hoping to satisfy.

Table A3 *Valuation methods and related welfare indicators used to value ES in primary studies (Based on Molner et al., 2012)*

Valuation method	Description	Welfare indicator
Direct market valuation approaches		
Market prices	Assigns value equal to the total market revenue of goods/services.	Total revenue
Replacement cost	Services can be replaced with human-made systems; for example waste treatment provided by wetlands can be replaced with costly built treatment systems.	Value larger than the current cost of supply
Avoided cost	Services allow society to avoid costs that would have been incurred in the absence of those services; for example storm protection provided by barrier islands avoids property damages along the coast.	Value larger than the current cost of supply
Production approaches	Services provide for the enhancement of incomes; for example water quality improvements increase commercial fisheries catch and therefore fishing incomes.	Consumer surplus, producer surplus
Revealed preference approaches		
Opportunity cost	Value of the next best alternative use of resources; for example, travel time is an opportunity cost of travel because this time cannot be spent on other pursuits. The travel cost method is a well accepted application of the opportunity cost approach.	Consumer surplus, producer surplus, or total revenue for next best alternative
Travel cost	Service demand may require travel, which have costs that can reflect the implied value of the service; recreation areas can be valued at least by what visitors are willing to pay to travel to it, including the imputed value of their time.	Consumer surplus
Hedonic pricing	Service demand may be reflected in the prices people will pay for associated goods; for example housing prices along the coastline tend to exceed the prices of inland homes.	Consumer surplus
Stated preference approaches		
Contingent valuation	Service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; for instance, people generally state that they are willing to pay for increased preservation of beaches and shoreline.	Compensating or equivalent surplus

Table A4 *ES and related MEA categories used in this study*[27]

MEA	ES	Definition/function
Supporting	*Nutrient cycling*	The transfer of nutrients from one place to another and the transformation of critical nutrients from unusable to usable forms.
Supporting	*Gamete/seed dispersal*	Wind, water, insects and animals play a vital role in gamete and seed dispersal.
Supporting	*Refugia*	Ecosystems provide living spaces for plants and animals that allow for the development and maintenance of biological and genetic diversity.
Supporting	*Carbon sequestration*	Plants acquire, metabolise and store atmospheric CO_2 as plant tissue during photosynthesis.
Supporting	*Primary Production*	Ecosystems support the continued reproduction, nurturing and growth of goods such as timber etc. that are used as primary inputs in industrial manufacturing processes.[28]
Regulating	*Gas regulation*	Regulation of greenhouse gases, absorption of carbon and sulfur-dioxide and the creation of oxygen as a product of photosynthesis.
Regulating	*Climate regulation*	Evapotranspiration, cloud formation and rainfall provided by vegetation and oceanic areas.
Regulating	*Disturbance regulation*	Protection from storms and flooding, drought recovery and the role of compensatory mechanisms.
Regulating	*Biological regulation*	Ecologically mediated control of plant, animal and insect populations including pest species.
Regulating	*Water regulation*	Water absorption during rainfall and release in dry times. Temperature and flow regulation for plant and animal species.
Regulating	*Erosion control*	Erosion protection provided by plant roots and tree cover.
Regulating	*Sediment formation*	Formation of marine sediments through natural processes.
Regulating	*Waste regulation*	Absorption of organic waste, filtration of pollution. Ecosystems dilute, assimilate, and chemically recompose a limited amount of organic and inorganic human waste. Services include air filtration by forests and water purification by wetlands.
Provisioning	*Water supply*	The filtration and storage of water. Vegetation and soil filter pollutants from water, while the topography and underground structure of ecosystems determines the storage capacity of lakes, streams, and aquifers'. This provides water for human consumption.
Provisioning	*Food*	Plant, insect, fish and/or animal biomass for human consumption.
Provisioning	*Raw materials*	Biological materials used for fuel, art and building; geological materials used for construction or other purposes. This category includes biotic renewable resources, such as wood and fibers, biological chemicals and compounds (latex, gums, oils, waxes, dyes, etc.), industrial materials, energy sources (wood, organic matter), and animal feed.
Provisioning	*Genetic resources*	Maintenance of the gene pool that forms the genetic basis of all living things on Earth.
Non-material	*Recreation*	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities.
Non-material	*Research and education*	Ecosystems play an important role in the development of human knowledge and processes of learning.
Non-material	*Aesthetic/artistic*	The role ecosystems play in providing non-material pleasure, joy, satisfaction, peace along with artistic and/or religious inspiration.

[27] A synthesis of definitions provided by Costanza et al., (1997), Molner et al., (2012), MEA (2003, 2005)
[28] Minerals and fossil fuels are not thought of as a service because they are non-renewable, nor are wind and solar energy, because they cannot be attributed to a specific ecosystem.

Because of the time required to source suitable BT data, we were eventually forced to relaxed our site similarity criteria and did not place as great an emphasis on filtering primary papers for socio-economic-cultural similarity as is ideally needed. Also, the filtering process was undertaken by one team member, when in reality, the expert opinion needed to filter papers for socio-economic and marine ecological similarity criteria ideally needs a coordinated, cross-disciplinary, research team effort. While the data we have produced might be suitable for scoping purposes, a much greater investment of research funding will be needed to create BT data for New Zealand conditions that will meet the accuracy requirements necessary for application in a policy and/or planning context. Details of the non-market BT research process used in this study follow.

Table A5 *A list of databases containing non-market values*

Database name	URL	Reference
Centre for the blue economy	http://www.oceaneconomics.org/nonmarket/NMsearch2.asp	(Economy, 2012)
Conservation gateway	http://www.conservationgateway.org/Files/Pages/ecosystem-services-databa.aspx	(Gateway, 2013)
NZ non-market valuation database	http://www2.lincoln.ac.nz/nonmarketvaluation/	(Kerr, 2013)
GecoServ marine ES valuation database	http://www.gecoserv.org/	(Plantier-Santos *et al.*, 2012; Mexico, 2013)
NOAA coral reef conservation database	http://coralreef.noaa.gov/aboutcrcp/whoweare/	(NOAA, 2013)
Environmental change database for Sweden	www.beijer.kva.se/valuebase.htm	(Sundberg and Söderqvist, 2004)
TEEB database	www.fsd.nl	(Van der Ploeg and de Groot, 2010)
Gateway: the nature conservancy	http://www.conservationgateway.org/Files/Pages/ecosystem-services-databa.aspx	(Conservancy, 2012)
Earth Economics ecosystem valuation toolkit	http://www.esvaluation.org/register.php	(Economics, 2012)
Environmental valuation reference inventory	https://www.evri.ca/Global/Login.aspx	(EVRI, 2013)

Ideally, BT research starts by defining the policy site ES that are relevant to the goals of a research project - *a priori*. However, the ability to pre-state your ecosystem goods and services of choice is based on an assumption of ideal 'benefit' data availability. What we ended up doing was allowing: (i) our selection of 'ES categories' and (ii) interpretation of MEA groupings to fall out of the selection of available BT papers we were able to find. Our final system of classification is outlined in Table A4. This approach was also partly necessary because of the differing shades of meaning associated with different author's interpretation of individual CME and MES categories. Finally, we also applied what we felt were necessary adjustments. For example, in Table A4, the ES name of 'pollination' (used mainly in a terrestrial ES context) was changed to 'gamete/seed dispersal' (more relevant in a marine context). We also added the category called 'carbon sequestration' because of the growing importance of this ES in the global economy.

Our literature search for appropriate BT papers followed three different approaches. First, we surveyed the international literature using keyword searches on appropriate bibliographic search engines. Second, a website search made it possible for us to identify the existence of nine international ES databases that contained potentially usable MESV studies (Table A5). Finally, retrieval of BT references and papers associated with databases listed in Table A5 then provided reference lists that could be used to locate other primary papers.

While using the above search strategy and we were only able to systematically and comprehensively complete an assessment of the GeoServ marine ES valuation database (row 4, Table 4), one of the ten databases identified as potential sources of BT values for CME. The New Zealand non-market valuation database was also checked. An effort was made to retrieve references from all databases; however there was not time to process all available reference data. Overall, using the three search strategies outlined above while drawing on published material from one international database, a total of 21,251 references were collected and loaded into an Endnote database. The Earth Economics database (row 10, Table A5) was not operational at the time of our BT literature search. Since going online it now claims to have a non-market valuation database in excess of 44,000 published references. Overall, by trawling international databases and reference lists in individual papers and reports it might be possible to create an international non-market valuation database of somewhere between 50-70 thousand terrestrial and marine references. A database of this kind would provide a valuable tool for ESV research. However, a substantive investment of time will be required to source review, process and bring this information.

The 21,251 references collected to date for this research project were sorted and classified in Endnote. 17,861 of these references were located using secondary sources (reference lists) and yet need to be comprehensively sorted and categorised beyond simple 'keyword' searching. The remaining references were categorised based on the main goal of each published paper or report. The highlights of this classification process include:

(i) 300 references focusing on non-market values of CME,
(ii) 115 references focusing on non-market values of terrestrial ecosystems,
(iii) 277 references focusing on non-market values of specific marine ES,
(iv) 337 references focusing on non-use values for marine and/or terrestrial ES,
(v) 286 references focusing on emerging developments in non-market valuation method
(vi) 1443 references focusing on emerging theoretical/research developments in marine ecosystem value/benefits more generally.

From the above category items (i-iii), a total of 284 individual benefits were identified as being potential candidates for transfer to the CME valuation part of this study. Primary papers supporting these benefits were then used to 'filter' this potential collection of references to a smaller group of 176 benefits based on geographic and socio-economic similarity (Bagstad, 2009) with the policy site. An estimated half of these 176 benefits were drawn from primary published papers. The remainders were extracted from previous ESV studies.

Of the 176 benefits selected for use in this study, very few of these papers were used to provide point estimates. Collections of benefits for the same MES were grouped, outliers removed and mid-range or averaged estimates identified for use. Some papers and/or reports contained value estimates that had been discounted. Most were not. Consistent with recent published recommendations for the use of BT value estimates, all benefits were converted from their source currency to New Zealand currency using PPP indices provided by the OECD website[29] (Ready and Navrud, 2006; Czajkowski and Scasny, 2010; Kerr and Latham, 2011). They were then adjusted from their year of estimation to 2012 (Q4) using CPI adjustments based on CPI data provided by Statistics New Zealand and available via the Reserve Bank of New Zealand website[30].

It has so far not been possible to source local *market data* for provisioning and raw material services associated with estuary; lagoon; intertidal; saltmarsh, seagrass, rocky reef and sand, beach and dune CMEs. Open ocean market fish harvest values for our study area were provided by Ministry of Primary Industries. In the absence of local market data for provisioning services, where available we have used international averages. Finally, in breaking from ESV method used in previous studies (Patterson and Cole, 1999b; Patterson and Cole, 1999c; Cole and Patterson, 2003) we have not attempted to transfer passive (non-use) benefits to our study area. While this may be necessary in later stages of this research programme, at present we lack the necessary demographic and socio-economic information that is ideally needed to ensure that our use of non-use benefits is based on transfer functions that make it possible to adequately align policy and survey site socio-economic contexts.

The collection of suitable BT data for use in this project has proved to be very challenging. While working well beyond what was budgeted for in this research programme we feel that we have still only captured a minimal number of benefit estimates that are arguably of a 'lower medium' to 'upper medium' quality/suitability. We still have gaps in our data for some ES and too many BT estimates for others (i.e. duplicated effort). Probably less than half of our benefit estimates were sourced from primary papers for which it was possible to adequately assess similarity criteria. Based on this experience, mainstreaming ESV in New Zealand and in particular aligning it with planning, policy and business management contexts will not be possible without a substantive amount of future work in the area of building an New Zealand relevant BT database.

A1.5 Calculate net value estimates

In this sub-section we describe a number of changes that we have made to our earlier published methods to calculate TEV estimates. In particular, we introduce the ideal of 'NTEV' and seek to

[29] http://stats.oecd.org/Index.aspx?DataSetCode=PPPGDP
[30] www.rbnz.govt.nz/statistics/discontinued/ha3discontinued.xls

relate its calculation to the MEA system of ES classification we have used. To begin this discussion we first define the mathematical relation that forms the basis of ES 'use' value calculations in equation 1. As noted already, we have not included 'non-use' value estimates in this study. In the remainder of this paper, all monetary ESV estimates have been adjusted to $\$NZ_{2012}$.

ESV = CMEA x BT (1)

Where:

ESV	= *ecosystem service value* ($\$NZ_{2012}/yr.$)
CMEA	= *CME area (ha.)*
BT	= *ES benefits transferred to this study* ($\$NZ_{2012}/ha./year$)

For the rapid assessment of *ESV* we have used the MEA framework to classify ES into the following categories: provisioning, regulating, non-material and supporting ES (Table A4). This is a departure from earlier studies (Cole and Patterson, 1997; Patterson and Cole, 19912), where the term 'direct' was used to refer to both 'provisioning' and 'non-material' services, and the term 'indirect' was used to refer to both 'regulating' and 'supporting' services. The advantage of using the MEA framework, is that it separates 'supporting services' from other MEA services (particularly regulating), which means that double counting of 'supporting services' can be easily avoided in the aggregation of individual value estimates ($/yr.) of ES to form a TEV estimate.

In aggregating individual ESV estimates ($/yr.) for our study area as per equation 1, provisioning, regulating and non-material values ($) should be added together, but not the value ($/yr.) of 'supporting' services' as their value is already included in the values ($) of the other 3 MEA service categories. This double counting adjustment is now well established in the ESV literature (Boyd and Banzhaf, 2007b; Wallace, 2007; Balmford *et al.,* 2008; Fisher and Kerry Turner, 2008; de Groot *et al.,* 2010). Thus, as indicated by equation 1, our ESV calculation now differentiates between the estimation GTEV and NTEV as indicated by equations 2 and 3, which show the basic column format for all results Tables included in this report.

GTEV = [SESV + RESV + CESV + PESV] (2)

NTEV = [RESV + NESV + PESV] (3)

Where:

GTEV	= *gross total economic value*
NTEV	= *net total economic value*
SESV	= *supporting ESV*
RESV	= *regulating ESV*

NESV = *non-material ESV*
PESV = *provisioning ESV*

Although GTEV (equation 2) is frequently used in the literature to 'add up' individual ESV, it is arguably incorrect to use this as a measure of the total value of ES (Haines-Young and Potschin, 2009). This is because it involves 'double counting' of the SESV. In adding up individual ESV it is therefore recommended to use NTEV (equation 3). The results Tables presented in section 2 of this paper also separate out the *component of PESV measured by GDP* from PESV estimates. This is done for the sake of convenience only and effectively makes the presentation of results visible in terms of both market and non-market value ($) contributions.

Finally, in equations 2 and 3, 'gross' and 'net' value estimates of TEV are measured according to the TEV taxonomy (Eade and Moran, 1996; Tallis and Kareiva, 2005; Plottu and Plottu, 2007). By definition, TEV is the sum of use-value and passive value (equation 4).

$$TEV = UV + PV \tag{4}$$

Where:
UV = *use value*
PV = *non-use or passive value*

Use Value refers to the utilitarian value that can annually be derived from ecosystems and their services. UV can be decomposed into four component parts adopted by the MEA taxonomy:

(a) *Provisioning ESV* - refers to the direct provision of goods and services by an ecosystem. This includes services such as the provision of food, fibre, freshwater and genetic resources. Usually provisioning services are measured by the System of National Accounts (SNA) and therefore they are included in GDP calculations, as they are traded on commercial markets, when they are supplied. Frequently, however provisioning services values are not recorded in the SNAs, as their provision involves no commercial transaction – e.g. the use of firewood obtained free-of-charge from forests

(b) *Regulating ESV* - refers to the *regulation* of biophysical and ecological processes in the environment in order to provide life support and a suitable ecosystem for human existence. This includes services such as regulation of the climate, flood control, drought recovery, control of pest species and so forth.

(c) *Non-material ESV*. In the MEA framework, what we here refer to as 'non-material' is called 'cultural' services. We have avoided the use of the word 'cultural' for this MEA category because it is so difficult to define. Instead, we choose to acknowledge that this

MEA category provides for an incomplete collection of non-material values. These values variously refer to how the ecosystem contribute to the maintenance of human health and well-being by providing services such spiritual fulfilment, aesthetics, education, scientific knowledge as well as artistic and/or spiritual inspiration.

(d) *Supporting ESV* - refers to the ecological and biophysical processes that support the 'provisioning' and 'regulating' services of ecosystems. This includes services such as nutrient cycling, sediment formation and provision of ecosystem[31].

Passive Value refers to the value not related to the actual use of ecosystems. It is therefore sometimes termed non-use value. Passive value can be decomposed into three component parts:

(a) *Option Value.* This is the willingness to pay for the preservation of an ecosystem against some probability that an individual will make use of the ecosystem at a later date.

(b) *Existence Value.* This is how much an individual is willing to pay to preserve an ecosystem, even though that individual may never intend to use that ecosystem. For example, an individual may wish to preserve tuataras on an offshore island of New Zealand, but have no intention or inclination of ever visiting such an island because of its isolation.

(c) *Bequest Value.* This is the willingness to pay to preserve an ecosystem so that future generations can gain the benefit from that ecosystem.

[31] This framework of 'provisioning', 'regulating', 'cultural' and 'supporting' ES is drawn from the *Millennium Ecosystem Assessment* report (2005). Refer to Section 1.4 of this chapter for a further explanation of the *Millennium Ecosystem Assessment* framework.

Appendix B *List of RESA assumptions important to this study*

B1. Limiting assumptions used in this study

As noted in section 2 of this report, RESA involves the use of limiting assumptions that ultimately influence the size of ESV and/or TEV estimates. To assist in interpreting the RESA results outlined in this report, it is important to keep the following limiting assumptions in mind.

B1.1 Representation of all 23 ES

This RESA is based on the evaluation of coastal ecosystems using 23 different ES. As is evident from results Tables 1, and 3-8, not all 23 ES contribute value towards each of our 8 CME. The main reason for this situation is a lack of national and/or international, market and/or non-market values for these ES. This includes a lack of value for some important ecosystems like rocky reefs that are known to play a vital role in marine biodiversity and productivity. As future research provides a greater range of value estimates, the GTEV and NTEV estimate of MES within our study area will increase.

B1.2 Ecosystem system services value estimates

Because of the dependency of this study on international value estimates for ES, the ESV estimates used in this study reflect a survey site socio-economic-cultural context that has not been adjusted for in any way to a New Zealand socio-economic-cultural context beyond the use of PPP currency conversion adjustments. In particular, accounting adjustments for a by-cultural context in New Zealand would likely result in a net increase in TEV estimates.

B1.3 Limitations of current knowledge

It is expected that scientific discoveries about the value of CME to human wellbeing will continue. Each new discovery will increase the instrumental value of a given ecosystem service and may well uncover new ES that we are currently unaware of. Thus, this rapid assessment of CME value is limited and/or constrained by the current state of scientific knowledge. As knowledge increases, TEV estimates will also increase.

B1.4 The assessment of disservices

An implicit assumption of this study is that CME provide *services* that can be measured. No effort has been made to differentiate between services that increase TEV and disservices that would effectively lower TEV. For example, an invasive coastal marine red algal bloom like *Noctiluca scintellans* can dramatically increase marine ecosystem productivity (i.e. a benefit). However, this same species depletes oxygen in the water, thus harming other marine life. Some species of marine algae can also produce highly toxic compounds. Most coastal marine algae in New Zealand are naturally occurring. However, invasive algae can be locally introduced from ships ballast. Defining disservice or disutility can involve human perception of value as well as our understanding about marine ecology. For example, the movement of stingray and/or sharks in near shore waters, while an essential marine habitat function, might well be perceived as a nuisance for human recreational and/or research purposes. An absence of accounting adjustments for disservices in this rapid assessment will result in an overestimation of TEV.

B1.5 Limitations of monetary (cardinal) values

TEV in this study is estimated in monetary (cardinal[32]) values. However, this method of value measurement provides an incomplete picture of the full range of potential socio-cultural values that maybe more effectively measured using ordinal[33] values. The use of an ordinal valuation and accounting method would make it easier to capture social fairness, ecological sustainability and cultural values that cannot easily be measured using market and/or non-market monetary values. The additional use of ordinal value would increase our perception of total value, although not necessarily in monetary terms.

B1.6 A supply side estimate of value

This study is based on a theoretical maximum supply-side estimate of TEV. This is because our GIS data measures land/marine *cover* in ha. as a theoretical maximum estimate of ecosystem area and relevant ES *supply*. In practice, the use that humans make of CME and indeed terrestrial ecosystems would be better assessed using GIS depictions of ecosystems based on actual human land/marine use. However, spatial data of this kind is difficult to find. This means our estimates of ecosystem service 'cover' area will tend to over-estimate 'use' area and its implied total economic (i.e. monetary) value.

B1.7 Changes in scarcity

This study is based on an assumption that supply in the ES we are measuring is constant over the period of measurement (i.e. 1 year) and that the levels of scarcity between our study and policy sites remain the same. In market economic theory, value is determined partly by the perceived scarcity of a resource or service. For example, our estimates of the value of water supply assume a given level of water availability. If water becomes a locally scarce resource, then the value of this ecosystem good and the ES that produce it will increase. Another example is coastal erosion. Upward adjustment in global sea-level caused by a warming atmosphere will increase the monetary value of coastal defence systems and thus increase TEV estimates. The international ESV estimates we have used may not adequately reflect levels of ES scarcity in our study area. This is especially because we are transferring ESV estimates across space (i.e. between countries) and across time (i.e. value estimates created as far back at 1997). Changes in scarcity during our measurement period (i.e. 1 year), differences in scarcity between survey and policy site socio-economic contexts and differences in scarcity caused by moving value estimates across time will change TEV estimates based on the existence of net scarcity increases (i.e. higher TEV) or net scarcity decreases (i.e. lower TEV).

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[32] Natural numbers used to measure the size of sets

[33] A number whose value is determined by its position in an ordered sequence of numbers

B1.8 Limitations of point estimates of value

This study seeks to estimate TEV based on assumed ecosystem wellbeing related to a point estimate (i.e. a 1–year sample interval of time). We have no way of assessing if this assumption actually holds without a series of TEV estimate sample points over time. Additional sample points make it possible to assess how indicators of wellbeing (e.g. levels of biodiversity, structural integrity, absence of pollution etc) are changing in net terms over time. This is called valuation at the margin. A decline in wellbeing indicators over time would indicate ecosystem service scarcity and this would increase TEV estimates.

B1.9 Bundles of ES

This study treats ecosystems and the services they provide as discrete entities (i.e. unrelated and not interdependently connected to other ES). In reality, this simplification of reality is actually untenable. All ecosystem types and ES are interrelated together in quite complex ways and science does not yet adequately understand this level of complexity. Thus, changes in scarcity on an individual ecosystem service actually have system-wide consequences that are not well understood. It would require complex mathematical models to depict this complexity in a way that makes it possible for us to measure the system-wide consequences of individual ecosystem service scarcity (in TEV terms). It is also evident that ES have different functional roles in ecosystems. Some ES are *critically* important for all ES. Changes in the scarcity of these critical ES would tend to produce dramatic increases in TEV estimates. An example of a critical service in terrestrial ecosystems would be pollination. An increase in the scarcity of this service would influence all flowering plants and this would have a dramatic impact on human agro-ecosystems and resultant contributions to GDP from decline in food harvest.

B1.10 Selection of ES indicators

This study has attempted to apply BT to 23 ES that have been defined as important to this study. This selection of ES indicators is strongly influenced by availability of value estimates in the international published literature. This literature tends to focus on ES indicators that are assumed to be important to the basic survival needs of all humans. Therefore, this selection of ES (indicators) may not be 100% relevant to a New Zealand socio-economic-cultural context and will likely be misaligned and/or incomplete in terms of representing high priority policy concerns like for example, aquaculture. If asked, New Zealand communities, planners, scientists and policy makers may prefer to come up with their own conceptualisation of relevant ES indicators. Valuation of these locally chosen indicators may result in net increases or decreases in TEV estimates when compared against estimates of TEV based on international valuation data and systems of classification. This point is highly relevant given that Māori culture is based on clearly defined cultural values, none of which are currently represented in this study that is based solely on international, western scientific conceptions of instrumental value.

B1.11 Reconciling top-down and bottom-up estimates of TEV

This study is based on a top-down estimate of value. Research shows that bottom-up estimates of individual ES tend to increase estimates of TEV as a function of differences in measurement method.

B1.12 The validity of primary valuation studies

The transfer of ES benefits between countries and/or differing socio-economic contexts can involve the transfer of valuation measurement and/or computational errors associated with primary published data. It has not been possible to assess and verify the quality of *all* ES value estimates used in this study. This limitation may cause over or underestimation in TEV estimates. To remove this limiting assumption would require time, access to information and resources that are currently not available to this investigation.

B1.13 Integration of biodiversity indicators

This study is based on a rapid assessment of flows of ecological goods and services measured at the *ecosystem level* of ecological organisation. The ecosystem service indicators used in this study do not adequately represent the *community* and/or *population* levels of ecological organisation. Inclusion of these 'biodiversity' indicators would add substantial value and thus increase current TEV estimates.

B1.14 Full cost accounting

This study is not based on full-cost accounting methods and in many respects our choice of value measurement boundaries is quite arbitrary. For example, when applying direct value estimates for food production and other market-based estimates of ES we have not removed labour and capital depreciation from our estimates of direct value. Also, in some cases we have used replacement cost values but do not have access to the socio-economic data that would be needed to ensure that our case study demography would be actually willing to incur these replacement costs. The use of market values also assumes the 'perfect' functioning of local and/or national markets and in practice we know that markets experience distortions caused by supply irregularities (i.e. gluts in production), taxes and subsidies. Another important area of full cost accounting concerns assumptions we make about the homogeneity of public property rights. This study assumes that ES values can be applied to all ecosystem areas. However, some of these areas may involve private property rights for which the actual beneficiary population is very small. Our accounting boundaries have been set by assumptions we make about the benefit-costs associated with making detailed full cost accounting adjustments compared to the quality improvement these adjustments would have on TEV estimates. It is likely that the use of these assumptions has led to a slight over-estimation of TEV. Further funding would make it possible for us to lower this over-estimation by adoption of more extensive and detailed full cost accounting methods.

B1.15 Demographic homogeneity

This study involves the use of simplifying assumptions associated with demographic similarity in applying monetary values to ES across survey and policy sites. In reality, defining the spatial extent of a beneficiary population can be challenging while the use of averaged international values is really dependent upon similarity in income distributions, socio-economic and cultural status – none of which we have been able to consider in this rapid assessment study. It is difficult to assess in net terms just how adjustments of this kind would change our current estimate of TEV.

B1.16 Value elicited from individual preferences

This study is based on valuation data that has involved the elicitation of individual preferences. It is a well-known fact that individual preferences cannot be used in the assessment of fairness, ecological sustainability and/or cultural dimensions of value that are typically based on collective and contributory values. Inclusion of collective and/or contributory values will generally increase TEV estimates. In the case of social fairness values, collective elicitation of value may assign value across generations and thus lower estimates of TEV relevant to this current generation.

B1.7 Areas of uncertainty

This study is based on assumptions about supply, preference and technical certainty. In reality, not all of these assumptions will hold. *Supply uncertainty* is associated with the adequacy of market and ecosystem information (i.e. such as scarcity and risk) used as a basis for expressing willingness-to-pay estimates. Adequate information cannot always be assumed. *Preference uncertainty* is associated with the assumption that survey respondents actually have a preference to articulate. Survey method can influence the determination of value and in particular the use of deliberative method. Finally, *technical uncertainty* also exists and concerns the accuracy of valuation estimates and the problem of appropriate discounting. Some, but not all of the international value estimates used in this study have been discounted. Uncertainty assumptions may result in either under or over estimation of TEV.

Appendix C *Information relating to the spatial depiction of CME within our study area*

Table C1 *Sources of information for the Nelson Bays habitat map generated by Cawthron Institute (2014)*

Source	**Description**
AbelTas (1992)	Digitized map from Davidson's (1992) report on the intertidal and shallow sub-tidal ecology of Abel Tasman. Based on 1988 aerial photos and ground-truthing in 1990/91. Geo-referencing was coarse so some areas do not line up exactly with coastline. Some boundary lines were difficult to distinguish so may not be exact - especially Rf and S-Rf, Rock-B and rock. Variations in the order of some components were not distinguished *e.g.* Rock-B vs. B-Rock. Habitat classification was based on Davidson's report.
Asher *et al.* (2008)	Shapefiles delineating the sponge gardens areas described in Asher *et al.* (2008). Data provided by Cawthron. Asher *et al.* (2008) describes two regions containing biologically diverse sponge-associated communities in Waimea Inlet (sponge gardens). The Traverse sponge garden is ca. 1.2 ha and consists mainly of *Mycale (Carmia) tasmani* and associated biota on a cobble/shingle substrate. The Saxton Monaco channel is ca. 4.8 ha and also dominated by *Mycale (Carmia) tasmani*. See report for more details.
Battley *et al.* (2005)	Battley *et al.* (2005) surveyed grain-size, macro fauna and seagrass distribution at 192 sites on the intertidal flats at Farewell Spit in 2003. Along with aerial photos[1], the sites containing seagrass were used as a guide to map the distribution of seagrass along the intertidal flats of Farewell Spit.
Coastal Series Sediments (1987)	Sub-section of NIWA's Coastal Series Sediment Tasman 1987 map 1:200,000. This layer contains the digitized coastal sediments series features with DOM and subsidiary classes combined into one feature class (FC) layer. All sheets have been updated again into one feature class layer with features from the newer sheets replacing features from older versions. This version has been renamed (see alternative name for the source copy of this layer). However, this version is to have its attributes and feature geometries modified based on Scott Nodders QC/QC check.
Delaware (2009)	Based on aerial photos (Jan 2009) and ground truthing in 2010. Relevant report is Gillespie *et al.* (2011d). Upper boundary was set at mean high water spring (MHWS), however, in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal, in which case it was included. The lower boundary was set at mean low water spring (MLWS). A 10 m wide riparian strip was also assessed visually to indicate the type of habitat surrounding the edge of the estuary. Habitat classification was in accordance with the EMP[34]. Data provided by Cawthron.
DOC Reefs	Outline of reef based on DOC shapefile of reefs around New Zealand. Primarily used for deeper reefs that were not entirely visible in aerial photos. Comparisons with aerial photos were still made[35].
Grange *et al.* 2003	'Silt/bryozoan' areas at Separation Point were defined using data from Grange *et al*. (2003b) based on side-scan sonar and ground-truthing with ROV video footage taken at Separation Point in 2002.

[34] EMP is the Estuary Monitoring Protocol; a standardised methodology developed by Cawthron for assessing and monitoring the condition of New Zealand estuaries

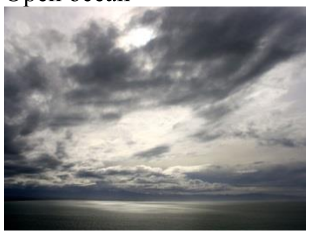
[35] Aerial photos were primarily obtained from the Nelson City council using their Top of the South Maps (www.topofthesouth.co.nz) GIS server.

Haven (2009)	Based on aerial photos (Jan 2009) and ground truthing in 2011. Relevant report is Gillespie *et al.* (2011a). Upper boundary was set at MHWS, however, in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal, in which case it was included. The lower boundary was set at MLWS. A 10 m wide riparian strip was also assessed visually to indicate the type of habitat surrounding the edge of the estuary. This estuary margin included the Boulder Bank habitats up to the highest elevation point on the estuary side only and all reclamation land bordering the mapped area. Habitat classification was in accordance with the EMP. Data provided by Cawthron.
LCDB3 (2008/09)	Landcare Research Landcover Database version 3, using landcover in summer 2008/2009. Primarily used to map the Abel Tasman national park and Farewell Spit.
Motueka (2001)	Based on aerial photos (Jun 2001) and ground truthing in 2002. Relevant report is Robertson *et al.* (2003a). Upper boundary was set at MHWS, however, in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal, in which case it was included. The lower boundary was set at MLWS. Habitat classification was in accordance with the EMP. Data provided by Cawthron.
Motupipi (2007)	Based on aerial photos (2004) and ground truthing in 2007. Relevant report is Stevens & Robertson (2008a). 200 m terrestrial margin included. Habitat classification was in accordance with the EMP. Data provided by Tasman District Council.
Moutere (2004)	Based on aerial photos (Jan 2004) and ground truthing. Relevant report is Clark *et al.* (2006a). Upper boundary was set at MHWS, however, in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal, in which case it was included. The lower boundary was set at MLWS. A 10 m wide riparian strip was also included to indicate the type of habitat surrounding the edge of the estuary. Habitat classification was in accordance with the EMP. Data provided by Cawthron.
No data	For areas where there was no data, an educated guess was made as to the likely habitat, based on the above sources and sediment core information. Every effort was made to achieve consistency with definitions used in Cawthron's broadscale surveys, Wriggle's mapping (Stevens and Robertson, 2008a; Robertson and Stevens, 2012a) and Davidson's mapping of the Abel Tasman (Davidson, 1992).
Rob Davidson (2011)	Rhodolith shapefile associated with the rhodolith beds described in Davidson *et al.* (2011) around D'Urville Island (Coppermine & Ponganui Bays). Davidson's estimate of the size of the bed was 22 ha, with rhodolith's found between 6 and 26 m depth, covering up to 100% of the silt and dead shells on the seafloor. Areas of rocky reef (according to the NelBaysHab_final.shp) were excluded from the original rhodolith shapefile, slightly reducing the area. Data provided by Rob Davidson, received 29/09/13.
Rob Davidson (2013)	Rhodolith shapefile associated with the rhodolith beds described in Davidson & Freeman (In prep) around Totaranui and Tonga Island. Areas of rocky reef (according to the NelBaysHab_final.shp) were excluded from the original rhodolith shapefile, slightly reducing the area. Data provided by Rob Davidson, received 29/09/13.
Ruataniwha (2000)	Based on aerial photos (Dec 2000) and ground truthing. Relevant report is Tuckey & Robertson (2003b). Upper boundary was set at MHWS, however, in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal. The lower boundary was set at MLWS. Habitat classification was in accordance with the EMP[36].
TDC (2012)	Coastal shapefiles mapped from Waimea Inlet to top of west coast of South Island. Relevant report is Robertson & Stevens (2012a), (Robertson & Stevens 2012). Major estuaries/beaches + 200 m coastal margin. Excludes Abel Tasman National Park and Farewell Spit. Based on

[36] Data provided by Cawthron Institute

	2008 aerial photos ground truthed in 2010/2011 and previous Cawthron/Wriggle broadscale mapping. Habitat classification follows EMP. Data provided to by TDC.
Waimea-D'Urville (2013)	Mapping was carried out by Dana Clark (Cawthron) based on aerial photos supplied by the Marlborough District Council from Cape Soucis-Greville Harbour. Every effort was made to achieve consistency with definitions used in Cawthron's broadscale surveys, Wriggle's mapping (Stevens and Robertson, 2008a; Robertson and Stevens, 2012a) and Davidson's mapping of the Abel Tasman (Davidson, 1992).
Waimea (2006)	Based on aerial photos (Nov 2006) and ground truthing. Relevant report is Clark *et al.* (2008b). Upper boundary was set at MHWS, however, in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal, in which case it was included. The lower boundary was set at MLWS. A 10 m wide riparian strip was assessed visually to indicate the type of habitat surrounding the edge of the estuary. Although cockles were detected in a number of habitats, it was not possible to provide useful estimates of the spatial extent of their occurrence because they live subsurface. Habitat classification was in accordance with the EMP. Data provided by Cawthron.
Whangamoa (2009)	Small section of northern arm of Whangamoa Estuary was mapped by Cawthron based on aerial photos (2009) and ground truthing. Upper boundary was set at MHWS, however, in some areas supra-littoral habitat was included where it was considered integral with the upper intertidal, in which case it was included. The lower boundary was set at MLWS. A 10 m wide riparian strip was assessed visually to indicate the type of habitat surrounding the edge of the estuary. Habitat classification was in accordance with the EMP. Data provided by Cawthron. Intention is to map the entire estuary in the near-future so habitat map could be updated at that time.

Table C2 *CME definitions*

Ecosystem types	Description	Structural classes/dominant cover
Open ocean  Location: Tasman Bay Photograph by Dana Clark	Area which is always covered by water (subtidal). Rocky reef, seagrass and macroalgae areas are not included in this CME. Benthic sediment type can range from mud to boulders. Includes areas with bryozoan mounds and rhodolith beds. Also includes 75% of the artificial structures in the case study area (excluding ramps & seawalls/rockwalls), with the other 25% assigned to the 'Rocky reef' CME.	Mud (excluding estuarine mud) Mud/sand (excluding estuarine mud/sand) Sand (excluding estuarine sand) Gravel (excluding estuarine gravel) Cobble/boulder/rock (excluding estuarine cobble, estuarine boulder, estuarine rock) 75% of artificial structure, excluding ramp & seawall/rockwall
Estuary  Location: Abel Tasman Photograph by Dana Clark	A partially enclosed coastal embayment where freshwater and seawater meet and mix. This CME does not include saltmarsh/wetland, seagrass or macroalgae, although these habitats may be present in some estuaries, because they have their own separate CMEs (below).	Estuarine mud Estuarine mud/sand Estuarine sand Estuarine gravel Estuarine cobble Estuarine boulder Estuarine rock Estuarine beach Estuarine rocky shore Shellfish bed Worm bed
Intertidal  Location: Ruby Bay Photograph by Dana Clark	Benthic area lying between the extremes of high and low tides. In this case, only rocky intertidal areas are included as sandy intertidal areas are captured in the 'Sand, beach and dunes' category (below). Does not include intertidal areas within estuaries. Boat ramps and seawalls/rockwall are also included in this CME.	Shoreline rocky sediment (excluding estuarine rocky shore) Ramp Seawall/rockwall

Lagoon  Location: Farewell Spit Photograph by John Wesley Barker	Shallow stretch of water separated from the ocean by coastal land. In the Nelson Bays case study area, lagoons are only found along Farewell Spit.	Water
Saltmarsh/wetland  Location: Riwaka Photograph by Ian Challenger	A saltmarsh is a community of halophytic (salt-tolerant), emergent vegetation rooted in soils alternately inundated and drained by tidal action. Wetlands are land areas that are saturated with water, either permanently or seasonally, with characteristic vegetation adapted to the unique soil conditions.	Estuarine shrubland Tussockland Grassland Sedgeland Rushland Reedland Herbfield
Sand beach  Location: Abel Tasman Photograph by Ben Knight	Sandy area lying between the extremes of high and low tides. Includes the boulder bank.	Shoreline soft sediment (excluding estuarine beach) Boulder bank

Dunes  Location: Tahunanui Beach Photograph by Dana Clark	Vegetated sand dunes in which the cover of vegetation in the canopy (commonly *Spinifex* spp., *Ammophila arenaria* or *Desmoschoenus spiralis*) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.	Duneland
Rocky reef  Location: unknown Source: Cawthron Institute	Subtidal rock larger than a boulder (> 200 mm diameter, often solid slab of rock). Biogenic reefs (*e.g.* those made of bryozoans or sabellid worms) are not included in this class. Also includes 25% of the total area of artificial structures (excluding ramps and rockwalls/seawalls) to account for the artificial reef function provided by these structures. Shown in the adjacent photograph is a rocky reef with sponge and ascidians.	Rocky reef 25% of artificial structure, excluding ramp & seawall/rockwall
Seagrass  Location: Nelson Haven Source: Cawthron Institute	Seagrasses (sometimes called eelgrass) are the sole marine representatives of the class Angiospermae. *Zostera muelleri* is the most common species of seagrass in New Zealand. It primarily grows in the intertidal zone with limited populations growing in sheltered subtidal areas with clear water.	Seagrass

Macroalgae  Location: Waimea Estuary Photograph by Allan Smith	Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain chlorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope. Shown in the adjacent photograph is sea lettuce (*Ulva* sp. and *Gracilaria sp.*).	Macroalgal bed

Note: no terrestrial structural classes were included in the ecosystem types for the RESA

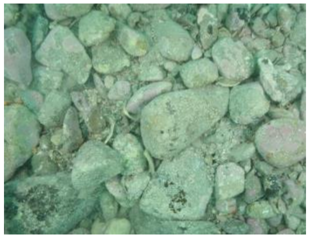
Table C3 *CME structural class definitions*

Structural class	Description	Source
Estuarine shrubland  Location: Waimea Estuary By: Allan Smith	Vegetation in which the cover of estuarine shrubs in the canopy is 20-100% and in which estuarine shrublandcover exceeds that of any other growth form or bare ground. Estuarine shrubland includes *Muehlenbeckia complexa* and *Plagianthus divaricatus*. Shown in the adjacent photograph is saltmarsh ribbonwood (*Plagianthus divaricatus*).	
Tussockland  Location: Waimea Estuary Photograph by Allan Smith	Vegetation in which the cover of tussocks in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussocks include all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and > 10 cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia*, and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla*, and *Celmisia*. Shown in the adjacent photograph is Needle sedge (*Stipa stipodes*).	(Robertson *et al.,* 2002)

Grassland  Location: unknown Photograph by Deric Charlton	Vegetation in which the cover of grass in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth-form. *Festuca* spp. is the only species present in the Nelson Bays case study area. Shown in the adjacent photograph is Tall fescue (*Festuca arundinacea*).	(Robertson *et al.,* 2002)
Sedgeland  Location: unknown Photograph by Jon Sullivan	Vegetation in which the cover of sedges in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it is probably a grass or a reed, if the stem is clearly triangular, it is a sedge. Included in the sedge growth form are many species of *Carex, Uncinia*, and *Scirpus*. Tussock-sedges and reed-forming sedges are excluded. Shown in the adjacent photograph is Slender clubrush (*Isolepis cernua*)	(Robertson *et al.,* 2002)
Rushland  Location: Waimea Estuary Photograph by Allan Smith	Vegetation in which the cover of rushes in the canopy is 20-100% and in which the rush cover exceeds that of any other growth form or bare ground. A tall grass-like, often hollow stemmed plant. Included in the rush growth form are some species of *Juncus* and all species of *Sporadanthus, Apodasimilis,* and *Empodisma*. Tussock-rushes are excluded. Shown in the adjacent photograph is sea rush (*Juncus kraussi*)	(Robertson *et al.,* 2002)

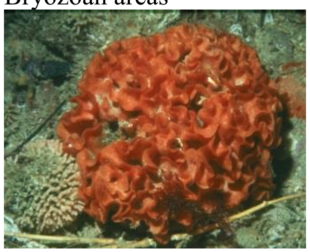
Reedland  Location: unknown Photograph by David Burgess	Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. If the reed is broken the stem is both round and hollow – somewhat like a soda straw. The flowers will each bear six tiny petal-like structures – neither grasses nor sedges will bear flowers, which look like that. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata,* and *Baumea articulata*. Some species, covered by Rushland or Sedgeland classes (above), are excluded. *Typha orientalis* is the only species present in the Nelson Bays case study area. Shown in the adjacent photograph is Raupo (*Typha orientalis*).	(Robertson *et al.,* 2002)
Herbfield  Location: Waimea Estuary Photograph by Allan Smith	Vegetation in which the cover of herbs in the canopy is 20-100% and in which the herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low growing semi-woody plants that are not identified as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens. Shown in the adjacent photograph is sea blite (*Suaeda novaezelandae*) on Glasswort (*Sarcocornia quinqueflora*) bed.	(Robertson *et al.,* 2002)
Saltmarsh  Location: Waimea Estuary Photograph by Allan Smith	A community of halophytic (salt-tolerant), emergent vegetation rooted in soils alternately inundated and drained by tidal action. Includes estuarine shrubland, tussockland, grassland, sedgeland, rushland, reedland and herbfield. This class was used when the saltmarsh species could not be identified down to a more specific structural class (*e.g.* when identifying it from aerial photos without ground truthing).	

Duneland  Location: Tahunanui Beach Photograph by Dana Clark	Vegetated sand dunes in which the cover of vegetation in the canopy (commonly *Spinifex* spp., *Ammophila arenaria* or *Desmoschoenus spiralis*) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.	(Robertson and Stevens, 2012a)
Mud  Location: Tasman Bay Source: Cawthron Institute	Combination of silts and clays with a grain-size < 63 µm. Usually appears brown on the surface with a shallow lack anaerobic layer. When rubbed between the fingers it appears soft and non-granular. May contain dead shell material at times.	Modified from Davidson (Davidson, 1992)
Mud/sand  Location: Nelson Haven Source: Cawthron Institute	A mixture of mud and sand, the surface appears brown, and may have a black anaerobic layer below. Used as a default class within the estuaries for areas where data on sediment type was unavailable.	Modified from Robertson *et al.* (2002)

Sand  Location: Tasman Bay Source: Cawthron Institute	Grain-size > 63 µm - 2 mm. May be mud-like in appearance but granular when rubbed between the fingers. May have a thin layer of silt on the surface making identification from a distance impossible. May contain dead shell material at times as well as occasional patches of cobbles, boulders or rocky reef.	Modified from Robertson *et al.* (2002)
Gravel  Location: unknown Source: Cawthron Institute	Dominant benthic cover is unconsolidated gravel (2-20 mm diameter) and exceeds the area covered by any one class of plant growth-form. Unless estuarine, this class is subtidal, and is often an extension of substrates located intertidally.	(Robertson *et al.,* 2002)
Cobble  Location: unknown Source: Cawthron Institute	Dominant benthic cover is unconsolidated cobble (20-200 mm diameter) and exceeds the area covered by any one class of plant growth-form. Unless estuarine, this class is subtidal, and is often an extension of substrates located intertidally.	(Robertson *et al.,* 2002)

Boulder  Location: Tasman Bay Source: Cawthron Institute	Dominant benthic cover is unconsolidated boulders (> 200 mm diameter) and exceeds the area covered by any one class of plant growth-form. Unless estuarine, this class is subtidal, and is often an extension of substrates located intertidally.	(Robertson *et al.,* 2002)
Rock  Location: Nelson Photograph by Dana Clark	Dominant benthic cover is larger than a boulder (often solid slab of rock) and generally partially exposed from the water. Includes limestone formations.	
Rocky reef  Location: unknown Source: Cawthron Institute	Subtidal rock larger than a boulder (often solid slab of rock). Biogenic reefs (*e.g.* those made of shellfish, bryozoans or sabellid worms) are not included in this class. Shown in the adjacent photograph is rocky reef with sponge and ascidians.	

Shoreline soft sediment  Location: Abel Tasman Photograph by Ben Knight	Sandy area lying between the extremes of high and low tides. Benthic cover can range from mud/sand to sand and may occasionally include cobbles, boulders or rock. Includes shorelines within estuaries.	
Shoreline rocky substrate  Location: Rabbit Island Photograph by Allan Smith	Rocky area lying between the extremes of high and low tides. Benthic cover can range from gravel to rock and may occasionally include patches of sand. Includes shorelines within estuaries and the boulder bank.	
Seagrass  Location: Nelson Haven Source: Cawthron	Seagrass (sometimes called eelgrass) are the sole marine representatives of the class Angiospermae. *Zostera muelleri* is the most common species of seagrass in New Zealand. It primarily grows in the intertidal zone with limited populations growing in sheltered subtidal areas with clear water.	

Macroalgae  Location: Waimea Inlet Photograph by Allan Smith	Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain chlorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope. While brown algae (*e.g. Ecklonia radiata*) are present in the Nelson Bays case study area, they are not well represented in habitat map due to a lack of data. Shown in the adjacent photograph is sea lettuce (*Ulva* sp.) and *Gracilaria* sp.	(Robertson *et al.,* 2002)
Bryozoan areas  Location: unknown Photograph by Ken Grange	Bryozoans are a phylum of marine invertebrates. In the Nelson Bays case study area only one area of bryozoans is identified, at Separation Point, however, others may exist. This area consists of bryozoan mounds interspersed with mud and silt. Bryozoan community is dominated by *Celleporaria agglutinans*, which form mounds up to 40 cm tall and 50 cm wide. The mounds are associated with many other bryozoan species as well as brachiopods, sponges, hydroids and horse mussels. Shown in the adjacent photograph is *Smittoidea* and *Cinctipora* spp.	(Grange *et al.,* 2003b)
Shellfish bed  Location: Waimea Inlet Photograph by Allan Smith	Area that is dominated by one or more species of shellfish. Includes oysters, mussels, cockles and mussels. Also include shellbanks, which are areas dominated by dead shells. May not be comprehensive across the study area. Shown in the adjacent photograph is Pacific oyster (*Crassotrea giganta*) bed	Modified from Robertson *et al.* (2002)

Sponge garden  Location: Waimea Estuary Source: Cawthron	Biologically diverse sponge-associated communities. In the Nelson Bays case study area both of the documented regions of sponge gardens are located within Waimea Inlet. The Traverse sponge garden is ~1.2 ha and consists mainly of *Mycale (Carmia) tasmani* and associated biota on a cobble/shingle substrate. The Saxton Monaco channel is ~4.8ha and also dominated by *Mycale (Carmia) tasmani*. Shown in the adjacent photograph is sponge garden.	(Asher *et al.,* 2008)
Worm bed  Location: unknown Photograph by Rob Davidson	Area that is dominated by raised beds of sabellid polychaete tubes. May not be comprehensive across the study area. Shown in the adjacent photograph is *Galeolaria hystrix*.	(Robertson and Stevens, 2012a)
Rhodolith bed  Location: Totaranui Photograph by Rob Davidson	Discrete assemblages of rhodolith algae. Rhodoliths are red algae that resemble coral. Shown in the adjacent photograph is Rhodolith bed.	

Water  Location: Lagoon, Farewell Spit Photograph by Helen Tribe	In the Nelson Bays case study region the only areas of water are the coastal lagoons on Farewell Spit. These are shallow stretches of water separated from the ocean by coastal land.	
Artificial structure  Location: Bridge, Rabbit Island Photograph by Dana Clark	Introduced natural or man-made materials that modify the environment. Includes bridges, man-miscellaneous made structures, boat ramps, seawalls/rockwalls and wharfs. Could potentially include 'natural' materials such as sand replenishment but not in this case study area.	(Robertson and Stevens, 2012a)
Terrestrial shrub/scrub/forest  Location: Nelson Photograph by Dana Clark	Includes terrestrial species of plants, which may be considered as shrub, scrub or forest and also lichen. Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm diameter at breast height (dbh). Commonly sub-grouped into native, exotic or mixed shrubland. Scrub: Cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants <10 cm dbh. Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm dbh. Tree ferns ≥cm dbh are treated as trees. Lichenfield: vegetation in which the cover of lichens is 20-100% and where lichen cover exceeds that of any other growth form or bare ground.	Robertson *et al.* (2002)

<table>
<tr><td>Terrestrial grassland

Location: Nelson
Photograph by Dana Clark</td><td>Land dominated by grass cover but not used for pasture and not obviously a maintained park/amenity area. Does not include the saltmarsh grassland vegetation Festuca spp.</td><td></td></tr>
<tr><td>Introduced weeds

Location: unknown
Source: Massey University</td><td>Vegetation in which the cover of introduced weeds in the canopy is 20-100% and in which the weed cover exceeds that of any other growth form or bare ground. Not comprehensive across the study area and occasionally some areas may have been classified as ‘Terrestrial shrub/scrub/forest’.</td><td></td></tr>
<tr><td>Industrial

Location: Waimea
Photograph by Dana Clark</td><td>Land dominated by industrial activities</td><td></td></tr>
</table>

Residential  Location: Nelson Photograph by Dana Clark	Land dominated by residential housing	
Pine debris  Location: Rabbit Island Photograph by Dana Clark	Debris originating from pine trees forestry areas.	
Road  Location: Rocks Road, Nelson Photograph by Dana Clark	Gravel or sealed roads. Not comprehensive – needs further updating if all roads are to be separated out.	

Maintained park/amenity area  Location: Tahunanui Photograph by Dana Clark	Area of terrestrial grassland maintained and used for recreation. Some areas that might fit into this class may have been categorised in the 'Terrestrial grassland' class.	
Horticulture  Location: Appleby Photograph by Dana Clark	Land dominated by horticulture activities	
Pasture  Location: Appleby Photograph by Dana Clark	Land dominated by pasture. When it was unclear if the land-use activity was pasture it was assigned to the 'Terrestrial grassland' category.	

Appendix D

Table D1 *Value estimate of ES derived from continental shelf CME (NZ_{2012}$M)*

Original assessment of ESV for the continental shelf CME							
Continental shelf CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling	1,354.22	-	-	-	-	1,354.22	-
Biological regulation	-	36.91	-	-	-	36.91	36.91
Food	-	-	1.45	-	1.45	1.45	1.45
Raw materials	-	-	1.89	-	-	1.89	1.89
Aesthetic	-	-	-	22.08	-	22.08	22.08
Research & education	-	-	-	2.21	-	2.21	2.21
Spiritual & historic	-	-	-	22.08	-	22.08	22.08
Unspecified (Nut. Cycl.)						-	-
Column totals	1,354.22	36.91	3.35	46.37	1.45	1,440.84	86.62

Table D1 *Continued … with accounting adjustment and final assessment of ESV*

Continued ...	**Accounting adjustment**				**Final assessment of ESV**						
Continental shelf CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling					1,354.22	-	-	-	-	1,354.22	-
Biological regulation					-	36.91	-	-	-	36.91	36.91
Food			22.71[1]		-	-	24.16	-	1.45	24.16	24.16
Raw materials			29.59[1]		-	-	31.48	-	-	31.48	31.48
Aesthetic					-	-	-	22.08	-	22.08	22.08
Research & education					-	-	-	2.21	-	2.21	2.21
Spiritual & historic					-	-	-	22.08	-	22.08	22.08
Unspecified (Nut. cycl.)[2]		1,354.22[2]			-	1,354.22	-	-		1,354.22	1,354.22
Column totals	-	1,354.22	52.30	-	1,354.22	1,391.13	55.65	46.37	1.45	2,847.36	1,493.14

Note: [1] Apportionment of nutrient cycling based on % contribution of ES to NTEV estimate in original TEV assessment
[2] 'Unspecified means' that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Table D2 *Value estimate of ES derived from estuarine CME ($$NZ_{2012}$M/yr.)*

Original assessment of ESV for the estuarine CME							
Estuarine CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling[1]	413.12	-	-	-	-	413.12	-
Habitat	2.56	-	-	-	-	2.56	-
Disturbance regulation	-	11.10	-	-	-	11.10	11.10
Biological regulation	-	1.53	-	-	-	1.53	1.53
Food	-	-	10.20	-	10.20	10.20	10.20
Raw materials	-	-	0.49	-	-	0.49	0.49
Recreation	-	-	-	1.61	-	1.61	1.61
Unspecified (Nut. Cycl.)						-	-
Column totals	415.68	12.63	10.69	1.61	10.20	440.61	24.92

Table D2 *Continued … with accounting adjustment and final assessment of ESV*

Continued ...	**Accounting adjustment**				**Final assessment of ESV**						
Estuarine CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling					413.12	-	-	-	-	413.12	-
Habitat					2.56	-	-	-	-	2.56	-
Disturbance regulation					-	11.10	-	-	-	11.10	11.10
Biological regulation					-	1.53	-	-	-	1.53	1.53
Food			169.08[1]		-	-	10.20	-	10.20	10.20	10.20
Raw materials			8.11[1]		-	-	0.49	-	-	0.49	0.49
Recreation					-	-	-	1.61	-	1.61	1.61
Unspecified (Nut. cycl.)[2]		235.93[2]			-	235.93		-	-	413.12	413.12
Column totals	-	235.93		-	415.68	248.56	187.88	1.61	10.20	853.72	438.04

Note: [1] Apportionment of nutrient cycling based on % contribution of ES to NTEV estimate in original TEV assessment
[2] 'Unspecified' means that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Table D3 *Value estimate of ES derived from lagoon CME ($\$NZ_{2012}M/yr.$)*

Original assessment of ESV for the lagoon CME							
Lagoon CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling	0.0031	-	-	-	-	0.0031	-
Net primary production	8.19	-	-	-	-	8.1930	-
Gamete/seed dispersal	0.0029	-	-	-	-	0.0029	-
Habitat	0.06	-	-	-	-	0.0641	-
Gas regulation	-	0.006	-	-	-	0.0057	0.01
Climate regulation	-	0.40	-	-	-	0.3952	0.40
Disturbance regulation	-	0.31	-	-	-	0.3066	0.31
Biological regulation	-	0.005	-	-	-	0.0052	0.01
Water regulation	-	4.18	-	-	-	4.1759	4.18
Erosion control	-	0.004	-	-	-	0.0044	0.00
Sediment formation	-	0.0008	-	-	-	0.0008	0.00
Waste regulation	-	1.35	-	-	-	1.3520	1.35
Water supply	-	-	0.04	-	-	0.0378	0.04
Genetic resources	-	-	4.71	-	-	4.7080	4.71
Recreation	-	-	-	0.07	-	0.0735	0.07
Research & education	-	-	-	0.00000021	-	0.0000	0.00
Spiritual & historic	-	-	-	0.0045	-	0.0045	0.00
Unspecified (NPP)						-	-
Column totals	8.26	6.25	4.75	0.08	-	19.33	11.07

Table D3 *Continued … with accounting adjustment and final assessment of ESV*

Continued …	Accounting adjustment				Final assessment of ESV						
Lagoon CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling					0.0031	-	-	-	-	0.0031	-
Net primary production					8.1930	-	-	-	-	8.1930	-
Gamete/seed dispersal					0.0029	-	-	-	-	0.0029	-
Habitat					0.0641	-	-	-	-	0.0641	-
Gas regulation					-	0.0057	-	-	-	0.0057	0.01
Climate regulation					-	0.3952	-	-	-	0.3952	0.40
Disturbance regulation					-	0.3066	-	-	-	0.3066	0.31
Biological regulation					-	0.0052	-	-	-	0.0052	0.01
Water regulation					-	4.1759	-	-	-	4.1759	4.18
Erosion control					-	0.0044	-	-	-	0.0044	0.00
Sediment formation					-	0.0008	-	-	-	0.0008	0.00
Waste regulation					-	1.3520	-	-	-	1.3520	1.35
Water supply					-	-	0.0378	-	-	0.0378	0.04
Genetic resources					-	-	4.7080	-	-	4.7080	4.71
Recreation					-	-	-	0.0735	-	0.0735	0.07
Research & education					-	-	-	0.00000021	-	0.00000021	0.00
Spiritual & historic					-	-	-	0.0045	-	0.0045	0.00
Unspecified (NPP)[1]		8.19[1]			-	8.19	-	-	-	8.1930	8.19
Column totals	-	8.19	-	-	8.26	14.44	4.75	0.08	-	27.53	19.26

Note: [1] 'Unspecified' means that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Table D4 *Value estimate of ES derived from intertidal CME ($\$NZ_{2012}M/yr.$)*

Original assessment of ESV for the intertidal CME							
Intertidal CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling	0.12	-	-	-	-	0.12	-
Net primary production	325.36	-	-	-	-	325.36	-
Gamete/seed dispersal	0.11	-	-	-	-	0.11	-
Habitat	2.55	-	-	-	-	2.55	-
Gas regulation	-	0.23	-	-	-	0.23	0.23
Climate regulation	-	15.70	-	-	-	15.70	15.70
Disturbance regulation	-	12.18	-	-	-	12.18	12.18
Biological regulation	-	0.21	-	-	-	0.21	0.21
Water regulation	-	165.83	-	-	-	165.83	165.83
Erosion control	-	0.18	-	-	-	0.18	0.18
Sediment formation	-	0.03	-	-	-	0.03	0.03
Waste regulation	-	53.69	-	-	-	53.69	53.69
Water supply	-	-	1.50	-	-	1.50	1.50
Food	-	-	29.09	-	29.09	29.09	29.09
Raw materials	-	-	1.79	-	-	1.79	1.79
Genetic resources	-	-	186.97	-	-	186.97	186.97
Recreation	-	-	-	2.92	-	2.92	2.92
Research & education	-	-	-	0.0000082	-	0.00	0.00
Spiritual & historic	-	-	-	0.18	-	0.18	0.18
Unspecified (NPP)						-	-
Unspecified (Water reg.)						-	-
Column totals	328.15	248.04	219.35	3.10	29.09	798.63	470.48

Table D4 *Continued … with accounting adjustment and final assessment of ESV*

Continued …	**Accounting adjustment**				**Final assessment of ESV**						
Intertidal CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling					0.12	-	-	-	-	0.12	-
Net primary production					325.36	-	-	-	-	325.36	-
Gamete/seed dispersal					0.11	-	-	-	-	0.11	-
Habitat					2.55	-	-	-	-	2.55	-
Gas regulation					-	0.23	-	-	-	0.23	0.23
Climate regulation					-	15.70	-	-	-	15.70	15.70
Disturbance regulation					-	12.18	-	-	-	12.18	12.18
Biological regulation					-	0.21	-	-	-	0.21	0.21
Water regulation					-	165.83	-	-	-	165.83	165.83
Erosion control					-	0.18	-	-	-	0.18	0.18
Sediment formation					-	0.03	-	-	-	0.03	0.03
Waste regulation					-	53.69	-	-	-	53.69	53.69
Water supply			0.53[1]		-	-	1.50	-	-	1.50	1.50
Food			20.12[2]		-	-	29.09	-	29.09	29.09	29.09
Raw materials			1.24[2]		-	-	1.79	-	-	1.79	1.79
Genetic resources					-	-	186.97	-	-	186.97	186.97
Recreation					-	-	-	2.92	-	2.92	2.92
Research & education					-	-	-	0.00	-	0.00	0.00
Spiritual & historic					-	-	-	0.18	-	0.18	0.18
Unspecified (NPP)[3]		325.36[3]			-	325.36	-	-	-	325.36	325.36
Unspecified (Water reg.)[3]		165.83[3]			-	165.83	-	-	-	165.83	165.83
Column totals	-	491.20	21.89	-	328.15	739.24	219.35	3.10	29.09	1,289.83	961.68

Note: [1] Apportionment of water regulation based on % contribution of ES to NTEV estimate in original TEV assessment
[2] Apportionment of net primary production based on % contribution of ES to NTEV estimate in original TEV assessment
[3] 'Unspecified' means that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Table D5 *Value estimate of ES derived from saltmarsh CME ($$NZ_{2012}$M)*

Original assessment of ESV for the saltmarsh CME							
Saltmarsh CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling	0.02	-	-	-	-	0.02	-
Net primary production	46.86	-	-	-	-	46.86	-
Gamete/seed dispersal	0.02	-	-	-	-	0.02	-
Habitat	0.37	-	-	-	-	0.37	-
Gas regulation	-	0.03	-	-	-	0.03	0.03
Climate regulation	-	2.26	-	-	-	2.26	2.26
Disturbance regulation	-	1.75	-	-	-	1.75	1.75
Biological regulation	-	0.03	-	-	-	0.03	0.03
Water regulation	-	23.89	-	-	-	23.89	23.89
Erosion control	-	0.03	-	-	-	0.03	0.03
Sediment formation	-	0.00	-	-	-	0.00	0.00
Waste regulation	-	7.73	-	-	-	7.73	7.73
Water supply	-	-	0.22	-	-	0.22	0.22
Food	-	-	4.19	-	4.19	4.19	4.19
Raw materials	-	-	0.26	-	-	0.26	0.26
Genetic resources	-	-	26.93	-	-	26.93	26.93
Recreation	-	-	-	0.42	-	0.42	0.42
Research & education	-	-	-	0.0000012	-	0.00	0.00
Spiritual & historic	-	-	-	0.03	-	0.03	0.03
Unspecified (NPP)						-	-
Unspecified (Water reg.)						-	-
Column totals	47.27	35.73	31.59	0.45	4.19	115.03	67.77

Table D5 *Continued … with accounting adjustment and final assessment of ESV*

Continued …	**Accounting adjustment**				**Final assessment of ESV**						
Saltmarsh CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling					0.02	-	-	-	-	0.02	-
Net primary production					46.86	-	-	-	-	46.86	-
Gamete/seed dispersal					0.02	-	-	-	-	0.02	-
Habitat					0.37	-	-	-	-	0.37	-
Gas regulation					-	0.03	-	-	-	0.03	-
Climate regulation					-	2.26	-	-	-	2.26	-
Disturbance regulation					-	1.75	-	-	-	1.75	-
Biological regulation					-	0.03	-	-	-	0.03	-
Water regulation					-	23.89	-	-	-	23.89	-
Erosion control					-	0.03	-	-	-	0.03	-
Sediment formation					-	0.00	-	-	-	0.00	-
Waste regulation					-	7.73	-	-	-	7.73	-
Water supply			0.08[1]		-	-	0.22	-	-	0.22	-
Food			2.90[2]		-	-	4.19	-	4.19	4.19	-
Raw materials			0.18[2]		-	-	0.26	-	-	0.26	-
Genetic resources			18.62[2]		-	-	26.93	-	-	26.93	-
Recreation					-	-	-	0.42	-	0.42	-
Research & education					-	-	-	0.00	-	0.00	-
Spiritual & historic					-	-	-	0.03	-	0.03	-
Unspecified (NPP)[3]		46.86[3]			-	46.86	-	-	-	46.86	46.86
Unspecified (Water reg.) [3]		23.89[3]			-	23.89	-	-	-	23.89	23.89
Column totals	-	70.75	21.78	-	47.27	106.48	31.59	0.45	4.19	185.78	70.75

Note: [1] Apportionment of water regulation based on % contribution of ES to NTEV estimate in original TEV assessment
[2] Apportionment of net primary production based on % contribution of ES to NTEV estimate in original TEV assessment
[3] 'Unspecified' means that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Table D6 *Value of ES derived from seagrass CME ($$NZ_{2012}$M)*

Original assessment of ESV for the seagrass CME							
Seagrass CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling	523.49	-	-	-	-	523.49	-
Habitat	360.82	-	-	-	-	360.82	-
Carbon seq/storage	6.22	-	-	-	-	6.22	-
Gas regulation	-	0.03	-	-	-	0.03	0.03
Climate regulation	-	0.19	-	-	-	0.19	0.19
Disturbance regulation	-	0.14	-	-	-	0.14	0.14
Biological regulation	-	0.03	-	-	-	0.03	0.03
Water regulation	-	0.62	-	-	-	0.62	0.62
Erosion control	-	0.02	-	-	-	0.02	0.02
Sediment formation	-	0.00	-	-	-	0.00	0.00
Waste regulation	-	3.55	-	-	-	3.55	3.55
Water supply	-	-	0.18	-	-	0.18	0.18
Food	-	-	3.57	-	-	3.57	3.57
Raw materials	-	-	0.22	-	-	0.22	0.22
Genetic resources	-	-	22.93	-	-	22.93	22.93
Recreation	-	-	-	0.36	-	0.36	0.36
Spiritual & historic	-	-	-	0.00	-	0.00	0.00
Unspecified (nut. Cycl.)						-	-
Unspecified (Habitat)						-	-
Unspecified (Carb. Seq.)						-	-
Column totals	890.53	4.57	26.91	0.36	-	922.37	31.84

Table D6 *Continued … with accounting adjustment and final assessment of ESV*

Continued …	**Accounting adjustment**				**Final assessment of ESV**						
Seagrass CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Nutrient cycling					523.49	-	-	-	-	523.49	-
Habitat					360.82	-	-	-	-	360.82	-
Carbon seq/storage					6.22	-	-	-	-	6.22	-
Gas regulation					-	0.03	-	-	-	0.03	0.03
Climate regulation					-	0.19	-	-	-	0.19	0.19
Disturbance regulation					-	0.14	-	-	-	0.14	0.14
Biological regulation					-	0.03	-	-	-	0.03	0.03
Water regulation					-	0.62	-	-	-	0.62	0.62
Erosion control					-	0.02	-	-	-	0.02	0.02
Sediment formation					-	0.00	-	-	-	0.00	0.00
Waste regulation					-	3.55	-	-	-	3.55	3.55
Water supply					-	-	0.18	-	-	0.18	0.18
Food			58.68[1]		-	-	62.25	-	-	62.25	62.25
Raw materials			3.61[1]		-	-	3.83	-	-	3.83	3.83
Genetic resources			259.93[2]		-	-	282.87	-	-	282.87	282.87
Recreation					-	-	-	0.36	-	0.36	0.36
Spiritual & historic					-	-	-	0.004	-	0.004	0.004
Unspecified (Nut. cycl.)[3]		461.20[3]			-	461.20		-	-	523.49	523.49
Unspecified (Habitat)[3]		100.89[3]			-	100.89		-	-	360.82	360.82
Unspecified (Carb. seq.)[3]		6.22[3]			-	6.22	-	-	-	6.22	6.22
Column totals	-	568.31	322.22	-	890.53	572.87	349.13	0.36	-	1,812.90	922.37

Note: [1] Apportionment of nutrient cycling based on % contribution of ES to NTEV estimate in original TEV assessment

[2] Apportionment of habitat based on % contribution of ES to NTEV estimate in original TEV assessment

[3] 'Unspecified' means that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Table D7 *Value of ES derived from rocky reef CME (NZ_{2012}$M)*

Original assessment of ESV for the rocky reef CME							
Rocky reef CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Net primary production	0.57	-	-	-	-	0.57	-
Habitat	0.02	-	-	-	-	0.02	-
Disturbance regulation	-	4.48	-	-	-	4.48	4.48
Biological regulation	-	0.01	-	-	-	0.01	0.01
Waste regulation	-	0.15	-	-	-	0.15	0.15
Raw materials	-	-	0.02	-	-	0.02	0.02
Recreation	-	-	-	0.75	-	0.75	0.75
Research & education	-	-	-	0.000001	-	0.000001	0.000001
Unspecified (Dist. Reg.)						-	-
Column totals	0.59	4.65	0.02	0.75	-	6.00	5.41

Table D7 *Continued … with accounting adjustment and final assessment of ESV*

Continued ...	**Accounting adjustment**				**Final assessment of ESV**						
Rocky reef CME	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Net primary production					0.57	-	-	-	-	0.57	-
Habitat					0.02	-	-	-	-	0.02	-
Disturbance regulation					-	4.48	-	-	-	4.48	4.48
Biological regulation					-	0.01	-	-	-	0.01	0.01
Waste regulation					-	0.15	-	-	-	0.15	0.15
Raw materials					-	-	0.02	-	-	0.02	0.02
Recreation					-	-	-	0.75	-	0.75	0.75
Research & education					-	-	-	0.000001	-	0.000001	0.000001
Unspecified (Dist. Reg.)[1]	4.48[1]				4.48	-	-	-	-	4.48	-
Column totals	4.48	-	-	-	5.07	4.65	0.02	0.75	-	10.49	5.41

Note: [1] 'Unspecified' means that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Table D8 *Value of ES derived from sand, beach & dune CME (NZ_{2012}$M)*

Original assessment of ESV for the sand, beach and dune CME							
Continental shelf	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Climate regulation	-	0.84	-	-	-	0.84	0.84
Disturbance regulation	-	197.12	-	-	-	197.12	197.12
Recreation	-	-	-	4.97	-	4.97	4.97
Research & education	-	-	-	0.00000240	-	0.00	0.00
Spiritual & historic	-	-	-	214.59	-	214.59	214.59
Unspecified (Dist. Reg.)						-	-
Column totals	-	197.96	-	219.56	-	417.52	417.52

Table D8 *Continued … with accounting adjustment and final assessment of ESV*

Continued ...	**Accounting adjustment**				**Final assessment of ESV**						
Continental shelf	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**Supp.**	**Reg.**	**Prov.**	**Non-mat.**	**GDP**	**Gross**	**Net**
Climate regulation					-	0.84	-	-	-	0.84	0.84
Disturbance regulation					-	197.12	-	-	-	197.12	197.12
Recreation					-	-	-	4.97	-	4.97	4.97
Research & education					-	-	-	0.00	-	0.00	0.00
Spiritual & historic					-	-	-	214.59	-	214.59	214.59
Unspecified (Dist. Reg.)[1]	197.12[1]				197.12	-	-	-	-	197.12	-
Column totals	197.12	-	-	-	197.12	197.96	-	219.56	-	614.64	417.52

Note: [1] 'Unspecified' means that the target ecosystem service needed for an accounting adjustment is either missing or unknown

Appendix E *Database of coastal marine ecosystem services non-market values*

E1. References classified by coastal marine ecosystem type

E1.1 Aquaculture

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