Environmental-economic values of marine and coastal natural assets, Cape York Peninsula NRM marine region, Great Barrier Reef

FINAL REPORT

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A report for the Cape York Peninsula NRM

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Context to the report
This report is one of several Supporting Studies for the development of the Cape York Peninsula NRM Water Quality Improvement Plan.

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EXECUTIVE SUMMARY

Ecological goods and services provide the conditions and processes for ecosystems to sustain human life and well-being, including the delivery, provision, production, protection and maintenance of these goods and services. The regulation of natural processes that ecological goods and services provide affects human welfare and production both directly and indirectly. The importance of the environment can be expressed in terms of its ecological, socio-cultural, and economic values. Economic use values refer to the benefits that humans realise when interacting with the environment in some way, and economic non-use values represent the value that an individual or community attaches to the environment in addition to or irrespective of their use values. The total of all ecological, socio-cultural and economic values of a resource or aspect of the environment is its total value. The total value of the Great Barrier Reef (GBR) could not be estimated here because many of these values have not been quantified (and may never be). This report summarises the most recent economic valuations that are available and can be consistently decomposed into regional scale estimates. The total values reported here at the GBR scale have therefore been generated purely to provide a consistent reference and context point against which regional estimates can be assessed and do not assume to provide a true estimate of total absolute value of the Great Barrier Reef.

Assigning monetary values to ecosystem goods and services can be a powerful way to ensure that ecosystem services are valued and represented in management and policy decision processes. This report collates existing information on monetary values of the GBR regions to support water quality improvement planning (WQIP) management prioritization tasks conducted using the Investment Framework for Environmental Resources (INFFER) process. Although estimates of the value of the whole GBR are useful for large-scale planning, they are a relatively blunt instrument for developing regional scale policy. To this end, regionally-specific estimates of the economic value of GBR ecosystems were derived to facilitate future analysis of the spatial distribution of social, economic and ecological costs and benefits of land management change to the Great Barrier Reef. Information on three main types of value of the GBR is readily accessible and suitable for application to the WQIP process;

1. the market (monetary) value of commercial activities dependent on GBR assets and resources,
2. non-market values measured as the amount (e.g. total area) of ecological asset present across regions of the GBR, and
3. monetisation of non-market values to obtain approximate total market estimates.

The Cape York Peninsula (CYP) Natural Resource Management (NRM) coastal and marine region comprises the largest asset area in the Great Barrier Reef. Reefs in the region comprise approximately 42 % (10,354 km^2) of total GBR reef area; seagrass accounts for approximately 30 % (11,378 km^2) of total GBR seagrass and wetlands account for 23 % (1,407 km^2) of total GBR coastal wetland areas. Within the Cape York region, asset area is dominated by seagrass (49 %) and reef (45 %) areas. Collectively, these assets represent approximately 34 % of the total area of the Great Barrier Reef. When monetized, the total value of these areas is estimated at A$77 m/yr.

Approximately 37 % (A$59 m/year) of the estimated total monetary value of the Cape York region is derived from commercial fishing; reef tourism contributes approximately 11 % (A$18 m/year), and recreation contributes 3% (A$5 m/yr) to total monetary value estimates. Monetised non-market values contribute approximately 48% (A$77 m/yr) to estimated monetary value of the Great Barrier Reef. For overall monetary value estimates, the Cape York Peninsula NRM marine region is the sixth highest of the six NRM regions.

There is substantial uncertainty associated with the habitat area estimates, particularly for seagrass, which changes dynamically and is monitored infrequently. Commercial value estimates also contain reasonable levels of uncertainty which arises from two primary sources; the scarcity of reliable non-market value estimates for the Great Barrier Reef and its regions, and a similar lack of information about environmental non-use values. To remedy this, the application of a systematic ecosystem services framework for the Great Barrier Reef is recommended to facilitate the development of a comprehensive assessment of ecological values for consideration in future prioritisation and policy decision tasks.

TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION

Ecological goods and services provide the conditions and processes for ecosystems to sustain human life and well-being, including the delivery, provision, production, protection and maintenance of these goods and services (Crabbé and Manno 2008). Their regulation of natural processes affects human welfare and production both directly and indirectly. Conventional agricultural practices, which rely heavily on non-renewable substitutes for natural processes, are the leading cause of habitat and biodiversity loss and degradation (Farley et al. 2011). Economic market mechanisms that favour immediate economic benefits over sustainable production are much of the cause. It is perhaps surprising that there are three reasons why adopting an economic perspective to environmental management issues can be useful for environmental protection (Farley 2010);

1. Environmental degradation is primarily of economic origin because all economic production relies on raw materials and energy
2. Economics provides a stopping rule, i.e., conversion of ecosystems to economic outputs should stop when costs of ecosystem services lost equal the benefits of economic services gained
3. Economics provides a framework to efficiently allocate resources towards scarce conservation resources across alternative desirable ends.

The three fundamentally desirable ends of economic activity are; sustainability (e.g. ecological resilience), justice (e.g. avoidance of inequalities) and efficiency (e.g. efficient use of resources); all of which are normative value judgments, and therefore socially determined (Farley 2012). This report collates information suitable to support the application of a cost-benefit valuation to aid prioritization during resource management decision processes, and considers what form may best support the strategic application of economic tools in future work.

1.1. Economic value of the environment

The importance of the environment can be expressed in terms of its ecological values e.g., its functional integrity or diversity; its socio-cultural values e.g., cultural identity and heritage (Chiesura and de Groot, 2003); and economic values (de Groot et al. 2010). There are two main types of economic values; use values and non-use values (Figure 1). Probably the most familiar types of values are 'use values', which typically refer to the benefits that humans receive and appreciate when interacting with the environment in some way (Barbier et al. 2011). Non-use values, on the other hand, represent the value that an individual or community attaches to the environment in addition to or irrespective of their use values, for example; its pure existence is valued (existence value), it is valued for its potential use by future generations (bequest value), or for its potential to be used in as yet unforeseen ways (option value) (Barbier et al. 2011).

The total of all use and non-use values, i.e., the total of all ecological, socio-cultural and economic values, of a resource or aspect of the environment is its "true" or total value (de Groot et al. 2010). Perhaps the simplest way to quantify environmental value is to use an existing measurement unit. Most commonly this is a monetary unit, such as Australian dollars (NRC 2005). Monetary values can provide intuitive metrics for goods and services that are traded in markets (i.e. bought and sold) because trading prices directly reflect consumer estimates of worth.

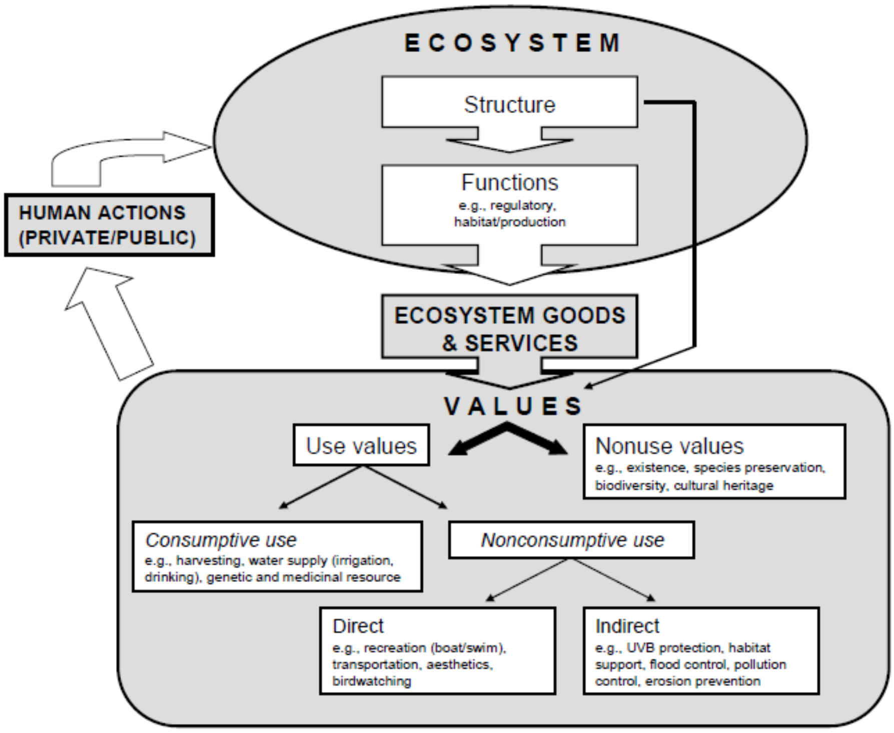


Figure 1. Classification of environmental values. Source: (Barbier et al, 2011; NRC 2005; Figure 7-1).

Assignation of monetary values (i.e. prices) to environmental goods and services that are not traded in markets (i.e. which have non-market value) allows the relative value of market and non-market services to be directly compared, and thus trade-offs can be explicitly assessed. Usually trade-offs across alternate economic ends are made using cost-benefit analysis (Baker and Ruting 2014). A number of techniques are available to elicit or translate economic and some socio-cultural values in monetary value terms, but these are not widely used in Australian environmental policy analysis (Baker and Ruting 2014). The most common types of non-market valuation are revealed preference and stated preference methods. Revealed preference methods are generally considered valid processes; however they cannot be used in all circumstances (Baker and Ruting 2014). Stated preference methods can estimate almost all types of environmental value but their application can be controversial (Baker and Ruting 2014).

The assignation of monetary values to ecosystem goods and services can be a powerful way to ensure that they are valued and represented in policy decisions. Valuation (i.e. the quantification of value attributes) of ecosystem goods and services is useful when (NRC 2005): informing policy trade-off decisions; providing compensation and liability estimate for damage assessment; and incorporating changes in natural assets into national accounts.

The first point is directly relevant to current WQIP processes, which require management decisions to be prioritized in terms of their implementation costs and likely consequences to the environment, the economy and society. In order to determine the relative values of goods and services, and how these values may change under alternative management decisions, the goods and services must be ranked, which requires that their values first be quantified (NRC 2005). In turn, the design of the valuation exercise must be dictated by the requirements of the decision context, which defines the purpose of valuation and how the valuation will be used in policy and management decision making (Boyd and Banzhaf 2007; Fisher et al. 2009; NRC 2005).

To be efficiently produced and distributed, market goods and services must be rivalrous and excludable (Daly and Farley 2010), as described in Table 1; where purely private goods are rival and excludable, and purely public goods are non-rival (generally free but costly or impossible to replace) and non-excludable (Brauman et al. 2014; Fisher et al. 2009). Table 1 shows a third characteristic, which applies to information. Information is neither rival nor excludable, but additive. Additive resources have the property of improving or becoming more valuable with increasing use.

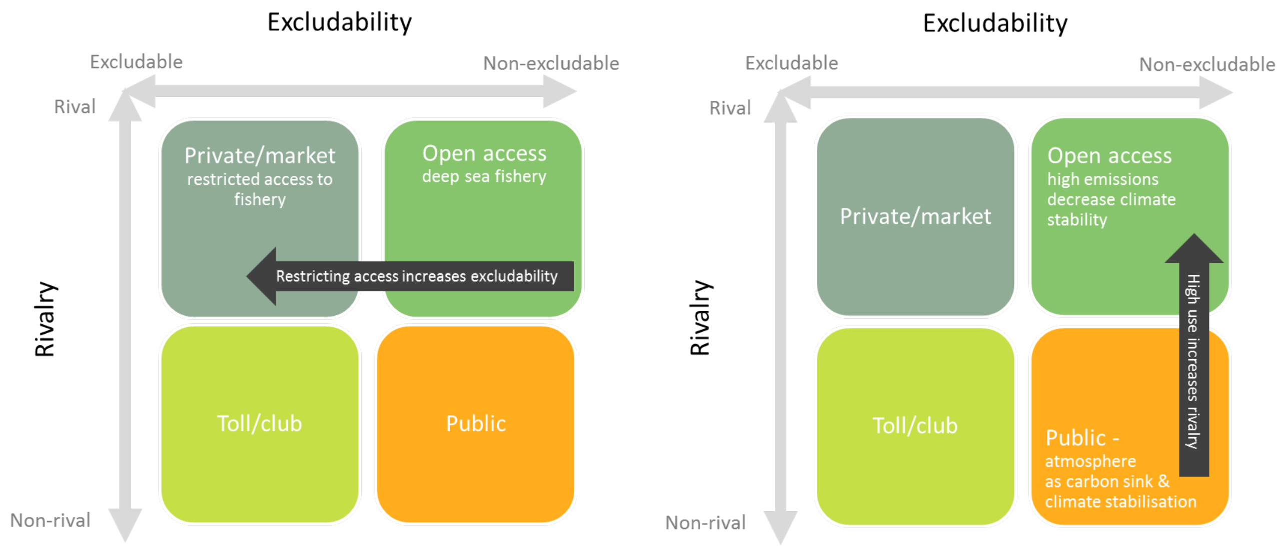
Table 1. The interaction between rivalry, excludability and congestibility. Adapted from: Daly and Farley (2010); Kubiszewski (2010); and Kubiszewski et al. (2010).

Characteristic	Easy to exclude	Almost impossible to exclude
Rival	**Market goods** Food, clothes, cars, houses, waste absorption capacity of regulated pollution	**Open access** Ocean fisheries, logging in unprotected forests, waste absorption capacity of unregulated pollution
Congestible *lightly used or abundant* *heavily used or scarce*	**Zero marginal value** Best efficiency if prices change with usage or clubs prevent resources becoming scarce **Operate as market goods**	**Open access** Efficient if excludable during periods of high use Example: non-toll roads, public beaches, national parks
Non-rival	**Potential market goods** Example: flood protection	**Pure public goods** Example: lighthouses, streetlights, national defense, most ecosystem services
Additive (non-rival)	Example: telephones	Example: internet

A rivalrous good or service is one for which use of a unit by one person prohibits use of the same unit at the same time by another, leaving less for others to use, for example, deep-sea fish (Daly and Farley 2010). A non-rival good or service is one for which use by one person has an insignificant impact on the quality or quantity available to another (Daly and Farley 2010). Rivalrous goods and services exist along a spectrum of exhaustibility; the more exhaustible (or congestible – a different type of exhaustion) they are, the more likely they are to operate rivalrously (Fisher et al. 2009). Excludable goods and services, on the other hand, exist along a spectrum of accessibility and exclusivity.

Completely excludable goods and services can be made unavailable to select users: that is, other users can be prevented from accessing them. Some goods and services are more easily made excludable than others. For example, in Figure 2a, a deep sea fishery can be considered rival because stocks are small and easily exhausted with modern fishing technology. It is also extremely difficult to prevent others from accessing those stocks. However if a new technology or environmental condition made it easy for a small number of people to restrict access, the fishery would move into the 'excludable' zone, and operate more like a private fishery. Most goods and services are quantitatively rivalrous, but some are more abundant than others, which affects their congestibility (Daly and Farley 2010).

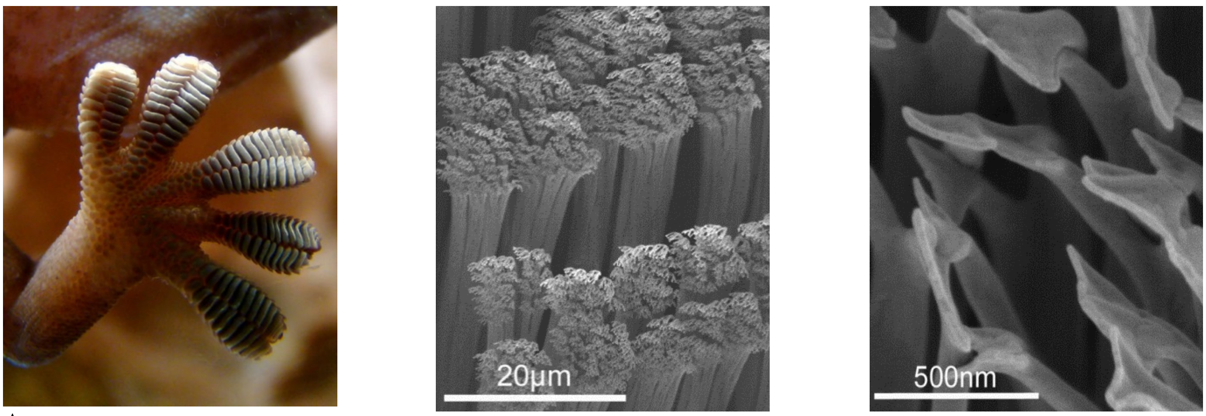
Goods and services that are congestible are subject to over-use or overcrowding. Figure 2b illustrates how a good or service's congestibility can affect the efficiency of social, economic or ecological costs and benefits. Carbon storage by the atmosphere provides an example. Before the industrial revolution, the capacity of the atmosphere to absorb carbon was large compared to the emissions being produced; it operated as a non-rival service (Fisher et al. 2009). As emissions grow the resource becomes congested; the opportunity for any one country to use it as a carbon sink is reduced and the atmosphere now operates akin to a rival service (Fisher et al. 2009). Another example of how congestion can increase rivalry might be if a small reef becomes crowded, decreasing the dive benefits (Szuster et al. 2011).



A B

Figure 2. a) Restricting access moves an environmental good or service towards a higher degree of excludability, making it more like a private good; b) Congestion and over-use can move a good or service towards a more rivalrous condition. Adapted from Fisher et al. (2009).

Exclusion can also occur with non-rival goods and services. Additive non-rival environmental goods and services include information about properties of the natural world. A famous example is the discovery that a multitude of specialized hairs on geckoes' toes allows them to bond with surfaces at a molecular level, enabling them to seemingly defy gravity (Rizzo et al. 2006; Figure 3). Information about how geckoes generate high adhesive strength is non-rival because it does not degrade with use, nor does your reading of it now leave less information for others. The information is also additive because increased use (more people accessing the information) can create increased value (the information is used to develop new and better ideas) (Kubiszewski et al. 2010). For example, scientific information on gecko morphology and function has been used to synthetically engineer commercial adhesives (e.g., NanoGrip http://www.nanogriptech.com; Geckskin https://geckskin.umass.edu).



A B(i) B(ii)

Figure 3. A. Close-up of the underside of a gecko's foot as it walks on a glass wall. Van der Waals forces, activated between finely divided hairs on the toes and the glass, provide the gecko with enormous adhesive strength. Photo: Tørrissen (2009); B. Scanning electron microscopy of; (i) setae attached to a section of toe pad, and (ii) an array of spatulae at the tip of a set. Source: Rizzo et al. (2006).

However as Figure 4 shows, non-rival goods can also transition between excludable and non-excludable states. Continuing the gecko example introduced above, if some person or institution were to patent their discovery of the adhesive properties of geckoes, access becomes restricted, and less public. It has been suggested that when basic research findings are patented and licensed exclusively to secure higher commercial profits, patent holders may also inhibit innovation and development that would have otherwise been available to some follow-on developers (Buchanan and Yoon 2000). Mirroring the problem of over-usage of publics goods terms the tragedy of the commons, such examples of under-usage of public goods (especially additive goods), have been termed the 'anti-commons' (Buchanan and Yoon 2000; Kubiszewski et al. 2010).

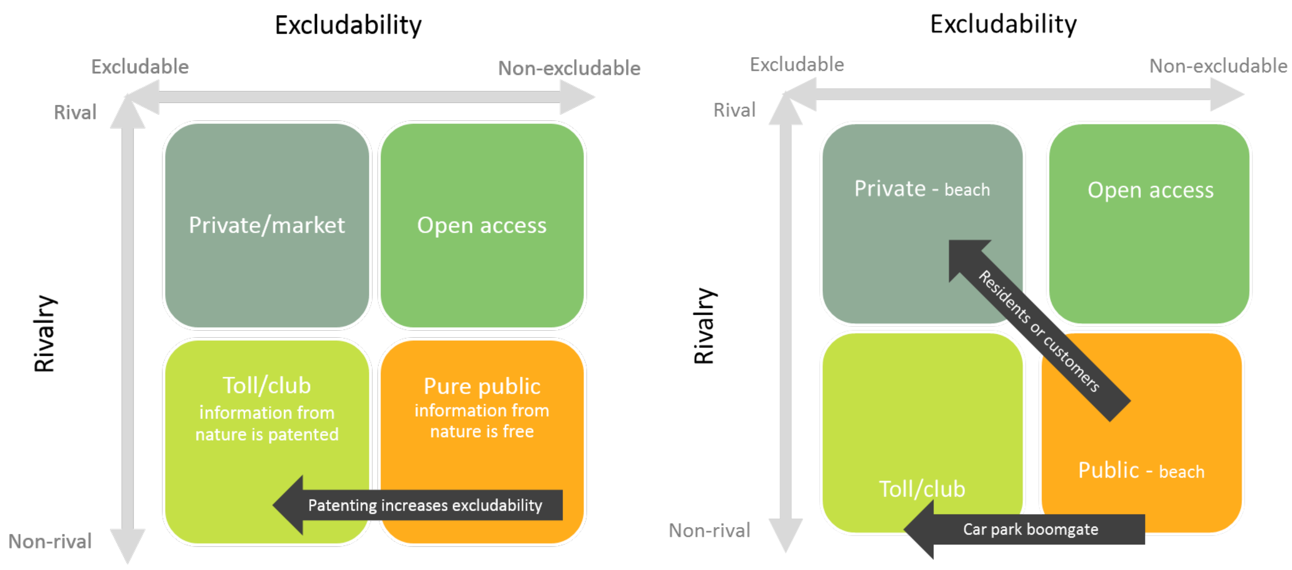


Figure 4. a) Patenting is one example of how an additive (non-rival) ecosystem service can be moved towards excludability; b) An ecosystem good or service can move towards both rivalry and excludability. Fencing off a beach may allow access to be controlled to different degrees. Adapted from Fisher et al. (2009).

Similarly, a non-rival public good or service, such as a beach can be made more excludable, as shown by the arrow moving to the left in Figure 4b. For example, beach access can be controlled non-selectively by installing a car park boom gate that opens when a toll is paid. Anyone can use the beach, as long as the toll is paid. Usually, goods and services that are mostly and difficult to manage exclusively sit closer to the non-excludable end of the spectrum, and goods that are cheap and easy for others to control are positioned more towards the excludable end of the spectrum.

It is conceivable that a public good or service can be made both more excludable and more rival, as shown by the arrow moving diagonally up and the left in Figure 4b. A long open beach adjoining some public lands may be too difficult and costly to fence and surveil, and not susceptible to congestion. Such a beach which is virtually non-excludable and non-rival, it is a public beach. Other beaches may be small, surrounded by private lands, or owned privately. If an exclusive group of people have this beach gated and fenced, access is no longer public. The beach functions with a higher level of excludability. The exclusive group decides who they grant access to, so it has become a private beach. However fencing the beach also leaves less beach space for everyone else to use (increasing congestion).

2. ECONOMIC VALUATION OF REGIONAL COASTAL AND MARINE ECOSYSTEMS

The regions of the Great Barrier Reef are socially, economically and ecologically diverse. These regions support different types and intensities of industrial development, including agriculture, fishing, tourism and mining, among others. Regional industries, and the communities that surround and support them, depend upon and value the Great Barrier Reef in different ways. Similarly, the coastal and marine ecosystems adjacent to each region are also diverse, supporting different amounts and types of seagrass, coral reef and wetland habitats. Consequently, the coastal and marine benefits that are provided to the each region vary, as are the management needs and priorities to maintain them.

The economic value of the Great Barrier Reef can be derived using different types of value estimates under varying levels of spatial and temporal resolution. Although monetary or other economic estimates of the value of the Great Barrier Reef are useful for large-scale planning, they are a reasonably blunt instrument for developing policy at the regional level. Regionally-specific estimates of the economic value of Great Barrier Reef ecosystems allow analysis of the spatial distribution of the relative social, economic and ecological costs and benefits of land management change (Thomas et al. 2012; van Grieken et al. 2013). Information on three main types of value of the GBR are readily accessible and suitable for application to the WQIP process;

1. the market (monetary) value of commercial activities dependent on Great Barrier Reef assets and resources,
2. non-market values measured as the amount (e.g. total area) of ecological asset present across regions of the GBR, and
3. monetisation of non-market values to obtain approximate total market estimates.

These values do not include the non-commercial values of indigenous coastal and marine resource use.

2.1. Market values

The monetary (market) value of ecosystem benefits provided by coral reefs and coastal systems globally has been estimated to be worth over 2 billion (international) dollars per hectare per year (de Groot et al. 2012). Estimates of economic value for the Great Barrier Reef reveal the significance of this asset at the national level. For example, an early study assessed the present value of the Great Barrier Reef at approximately 4.7% of Australia's annual (2007/08) gross domestic product (Oxford Economics 2009).

More recently, the direct economic contribution of the key reef-dependent industries was estimated at just over A$7 billion, of which tourism contributed approximately A$6.4b, recreation A$330m, and commercial fishing A$190m (DAE 2013). Tourism is a substantial industry in Great Barrier Reef regions. Snapshots of tourism economics studies reveal the breadth and diversity of the ecological structures and processes that support it. For example, Stoeckl et al. (2010) report that each year, live-aboard dive boats are directly responsible for generating at least A$16 million worth of income in the Cairns/Port Douglas region. Similarly, the annual value of tourism expenditure exclusively attributable to whale-watching in Hervey Bay is over A$7m per year, and over one season approximately A$30m is injected into the region each year, including indirect and employment values (Knowles & Campbell, 2011; Wilson & Tisdell, 2003).

The total recreational value of Australian coral reefs, including recreational fishing, is approximately US$120/visitor (Brander et al. 2007). The fishing component of recreational reef trips can be significant. For example, Prayaga et al. (2010) calculated the consumer surplus per trip on the Capricorn Coast at A$385.34 per (group) trip, or approximately A$5.53m for this region of the Great Barrier Reef alone. Similarly, earlier work by Fenton and Marshall (2001a) reveals the total annual gross value of production (GVP) for Great Barrier Reef charter fishing tourism businesses was approximately AU$23m. The same project showed that annual GVP for commercial fishing businesses at that time was tenfold more, at AU$224m (Fenton and Marshall 2001b).

Like tourism, commercial fishing in the Great Barrier Reef is diverse, and many species are dependent on seagrass meadows for substantial parts of their life cycle. Although few studies have examined the economic contribution of Great Barrier Reef seagrass meadows to fishery values, the loss in 1995/96 of 12,700 ha of seagrass meadows in Australia has been associated with losses to fishery production of approximately AU$235,000 (McArthur and Boland 2006). In contrast, international estimates have valued the provision of mangrove wood and fish nursery areas by mangroves and seagrass meadows at US$215,000 per hectare (Thorhaug 1990).

A purely financial-economic approach can be taken, whereby each region is allocated value reflecting the contribution that each makes to the total monetary value of the Great Barrier Reef (DAE 2013). Monetary values derived from commercial activity may be the simplest type of economic value both to directly quantify and also to apply in cost-benefit analyses for management prioritization planning.

2.1.1. Direct and indirect economic contributions

The tourist, commercial fishing and recreation sectors are the largest industry sectors undertaking commercial activities that are directly dependent upon the status and composition of the Great Barrier Reef. Reliable economic data are available for these sectors and these data have been summarized for the GBR on several previous occasions, the most recent update was produced by DAE in 2013. These values include direct expenditure as well as indirect monetary benefits that flow on to the rest of the economy via the multiplier effect. A brief explanation of the figures that were used from DAE (2013) follows, then the regional value breakdowns are presented.

Direct economic contributions occur when money is initially spent within a sector, e.g. for salaries, supplies, raw materials and operating expenses. This initial spending creates additional business-to-business supply-chain transactions; business that benefit from the initial spending will spend more on other businesses. These values are calculated using multipliers derived from national input-output tables, and this is the approach used in DAE (2013) to calculate the economic contribution of the GBR.

Induced economic contributions are a third type of impact, and can occur when businesses experiencing direct and indirect benefits increase payroll expenditures (e.g. by increased hiring, payroll hours, salaries etc.), increasing both personal income levels and household-to-business expenditure activity. Induced economic contributions are not considered in this report. The direct tourism demand is the price of the travelers meal the indirect tourism demand generated from the purchase of the meal is the value of intermediate inputs such as the electricity for cooking and the production of meat and vegetables (TRA 2013).

To avoid double-counting, direct value-added contributions are calculated as the value of direct outputs expenditures (meal prices) minus the value of inputs required to create them (the electricity and meal ingredients). That is, the direct contribution is the value added generated in the restaurant sector. This report uses the value-added and indirect estimates of economic contributions reported in DAE and updates them with regionally relevant information to increase their accuracy. In this report, regional breakdowns are presented for each of the industry sectors reported in DAE (2013), and updates and refinements to sectoral or regional estimates are described in corresponding ‘adjustment’ sections.

2.1.2. Issues with applying existing market valuations to WQIPs

The DAE (2013) report finds that the total value-added economic contribution (in 2012) by industries reliant on some aspect of the Great Barrier Reef to be A$5.7 billion, the Wet Tropics contributing roughly 40% of total GBR direct value-add contributions. Although economic contribution figures are provided at the industry level for each region elsewhere in that report, several issues prevent the DAE (2013) figures from being immediately and directly applied within current the WQIP process. These issues will be briefly introduced, and the means by which existing data can be used to develop and accommodate economic values assessments for purposes of WQIP prioritization planning will be described.

It is important to bear in mind that although dollar estimates of regional value across industries are useful for regional planning, inter-regional comparison of relative value are also important for GBR-wide planning. For these decisions to be made, a consistent estimate of total GBR value must be developed from which relative values can be calculated and consistently compared. This supporting study addresses a small number of shortcomings and misalignments between the DAE report and the WQIP requirements, to develop revised monetary value estimates for the GBR and its regions. These adjustments are as follows:

1. **Science and management.** The WQIPs do not consider that economic contributions from science and management are relevant to management planning prioritization decisions. For WQIP purposes these values are henceforth excluded from regional and total value estimates.
2. **Torres Strait.** The Torres Strait is not subsumed by the Great Barrier Reef Marine Park, and for WQIP purposes Torres Strait values are henceforth excluded from regional and total value estimates.
3. **Valuation of reef-based tourism.** Recent regional contribution estimates are available for commercial fishing and recreation sectors (DAE 2013), but similar breakdowns for reef-based tourism are not readily available. This is because the tourism values in the DAE (2013) report were collected from tourists who visited anywhere in the entire Great Barrier Reef catchment area, and were not restricted to reef-based tourism activity. Not everyone who visits the Great Barrier Reef catchment area visits the reef.
4. **Extension of the Burnett-Mary marine NRM region.** The Burnett-Mary coastal and marine NRM region encompasses the point at which the Great Barrier Reef ecosystem extends beyond the southern limit of the Great Barrier Reef Marine Park. For WQIP purposes, the assets both within the Great Barrier Reef Marine Park (GBRMP) boundary and those outside the boundary but within the Burnett-Mary NRM coastal and marine region are considered. Similarly, many GBRMP-based assessments, including DAE (2013), exclude the economic contribution derived from reef-based tourism, commercial fishing and recreational activities undertaken in the Great Barrier Reef adjacent to the Burnett-Mary region, but outside the Great Barrier Reef Marine Park (GBRMP) boundary, are excluded from the DAE (2013) estimates. The commercial economic values of these areas are relevant to WQIP processes and must be included in regional and total value estimates.
5. **Western Cape York.** The commercial economic values of activities undertaken in western Cape York Peninsula catchments and/or dependent on Gulf of Carpentaria coastal and marine ecosystems are not relevant to WQIP processes and must be excluded in regional and total value estimates.

Adjustments 1 and 2 are made implicitly by excluding these values from summary estimates reported here. The other three adjustments are described in detail below.

Valuation of Reef-Based Tourism

This report is concerned with the value of the Great Barrier Reef as an entity separate from adjacent or connected (e.g. catchment, Torres Strait) systems. For first-time visitors, rainforest destinations are almost as important as the reef (Prideaux 2013), and many visitors to the Great Barrier Reef regions generally undertake non-reef activities (Koo et al. 2010).

DAE (2013) does provide an estimate of the economic contribution that can be attributed purely to reef-related tourism; estimates used are based entirely on those reef tourism activities that are subject to the Environmental Management Charge. The report acknowledges some of the limitations of this approach, for example, it recommends further analysis to account for the additional 2.3 million passenger transfers to islands, for which sufficient expenditure data are not available (DAE 2013 p32). Although the full scope of recommendations for improving reef-related tourism estimates cannot be implemented in this supporting study (refer to DAE pp32-33 for detail), an interim improvement can be implemented. For example, 15.8% of the tourists who visit the Great Barrier Reef catchment also visit the Great Barrier Reef Marine Park (i.e., approximately 84% of tourists in the regions *don't* visit the reef; GBRMPA, 2009).

If a conservative assumption is made that 25% of the tourists who *do* visit the reef would have come to the region anyway, even in the absence of the reef (D. Pannell 2014 pers. comm.), reef-based tourism estimates can be conservatively updated as follows;

- Given that 15.8% of GBR tourists visit the reef, and
- 25% of those would have undertaken those activities even if the reef wasn't there, and
- If the total economic contribution of GBR catchment and reef tourism = x , and
- If it is assumed that on average, reef tourists spend the same amount in total as regional non-reef tourists.

The value of reef-dependent tourism (y) can then be calculated as per Equation 1:

Equation 1: $y = (x \times 0.158) \times 0.75$

These assumptions can be applied to the economic contribution of total tourism from DAE (2013) to estimate reef-tourism economic estimates.

Using the DAE (2013) total tourism value-added estimate for the GBRMP of A$5,175.4 m/yr, application of Equation 1 produces an estimated total (direct value-add and indirect) economic contribution of reef-dependent tourism to the entire Great Barrier Reef of approximately A$613 m/year. This comparable DAE (2013) estimate for reef-related tourism value-added contributions is A$389 m/yr for 2011-12.

The Great Barrier Reef Marine Park Authority's Environmental Management Charge data were used to disaggregate the whole-of-GBR value of A$613 m/yr to each region (Table 2 and Figure 5).

Table 2: The total number of visitor days per NRM region as measured by Environmental Management Charge data, 2011-12, and redistribution of estimated total economic contribution of reef-dependent tourism (A$613.2m) to align with the regional distribution of EMC expenditure data (see Table 2).

NRM Region	Visitor days ('000)	Regional visitation (%)	Value-added (A$m, 2011-12)
Cape York	159	6%	**34.4**
Wet Tropics	134	40%	**244.5**
Burdekin	1,271	5%	**29.1**
Mackay-Whitsunday	93	45%	**275.1**
Fitzroy	46	3%	**20.1**
Burnett-Mary	1,130	2%	**10.0**
Total	2,833	100	**613.2**

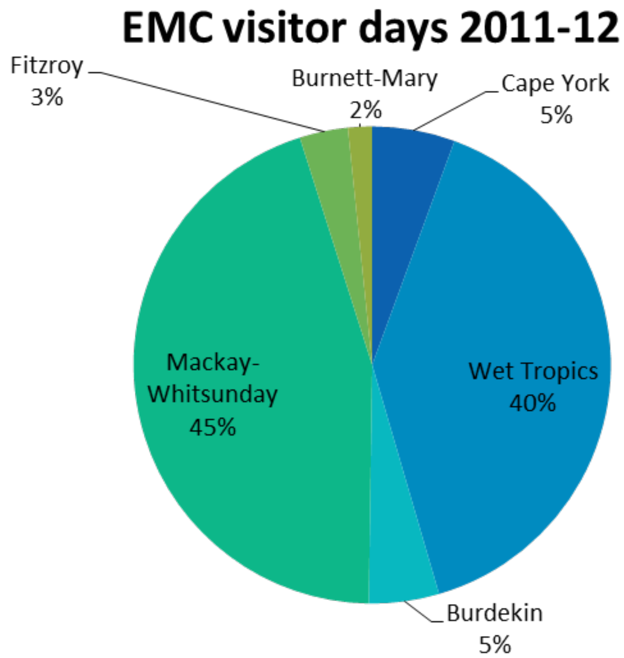


Figure 5: Distribution of visitor days for 2011-12 as measured by Environmental Management Charge data. Source: GBRMPA unpubl. 2015

Extension of Burnett-Mary region south of the GBRMP boundary

Reef-specific tourism, commercial fishing and recreational values arising from activities undertaken in coastal and marine waterways adjacent to the Burnett-Mary region that lie outside the Great Barrier Reef Marine Park (GBRMP) boundary are excluded from the DAE (2013) estimates. Regional comparisons that fail to account for the marine and coastal values of these waterways of the Burnett-Mary will be therefore invalid. To address this problem, additional commercial economic values of the Burnett-Mary, as published in the peer-reviewed literature, were used to adjust the values from the DAE (2013) report.

Reef-based tourism

Two data sets were identified for which relatively recent comparative direct expenditure (but not value-added) tourism data are available. The first comprises wildlife-based tourism at Hervey Bay and Mon Repos, to watch whales and nesting sea turtles, respectively, and the second refers to charter fishing activity.

Knowles and Campbell (2011) used data collected by Wilson and Tisdell (2003), O'Connor et al. (2009) and Stoeckl et al. (2005) to estimate the tourism value of whale-watching. They report the annual value of tourism expenditure that can be exclusively attributable to whale-watching in Hervey Bay to be at least A$7.2m per year (Knowles and Campbell 2011), which is equivalent to $7.69 m/yr in 2014 AUD currency value.

Similar analysis for the Mon Repos rookery indicates that the total expenditure that can be exclusively attributable to sea turtle viewing is approximately A$833,000 per season, and the total expenditure in the region during the season is approximately A$2.7m (Wilson and Tisdell 2003), which is equivalent to $4.2 m/yr in 2014 AUD currency value.

The charter fishing industry also contributes substantially to the tourism industry. Data collected by Fenton and Marshall (2001b) in 1999/2000 indicate that the annual total gross value of production for charter fishing tour operations in Hervey Bay was approximately A$1.9m (Fenton and Marshall 2001b).

These literature reports suggest that omitting the southern range of the Burnett-Mary NRM region under-estimates the economic contribution of reef-dependent tourism expenditures by at least A$11.8 m/year. Applying the expenditure to value add ratio of 0.45, as used in DAE (2013) to convert total tourism direct expenditure to value add, this converts to an additional A$5.3 m/year can be added to the total economic expenditure estimates for the Burnett-Mary region.

Reef-specific tourism values for the Burnett-Mary region were increased by A$5.3 m to a new value of A$235.6 m/yr. This estimate accounts for additional direct value from whale-watching in Hervey Bay (A$7.2 m), and Mon Repos turtle rookery visitation (A$2.7m) expenditures converted to value-added. These estimates are conservative, because indirect economic contributions have not been considered, and value estimates have not been adjusted for inflation. Value estimates will fluctuate with visitation levels over time.

<u>*Recreation*</u>

Deloitte Access Economics (2013) defines recreational contributions as expenditures generated by locals through the activities of fishing, boating, sailing and visiting an island. Locals were defined as (DAE 2013): "households within the Reef catchment, other than those in the following LGAs, which were deemed as far enough away from the Reef to be classified as tourists: Central highlands; Banana; North Burnett; Cherbourg; and South Burnett."

The DAE (2013) calculated recreational values based on trip-related households expenditure from Rolfe et al. (2011), which exclude recreation activities undertaken from catchment areas south of Bargara in the Burnett-Mary region that is, areas that lie south of the GBRMP boundary were excluded. The report also used estimates of expenditure on recreational equipment derived from the Australian Bureau of Statistics Household Expenditure Survey 2009-10 (ABS cat. no. 6530.0). The spatial scope of the ABS data used is not stated in that report.

Trip-related household estimates of recreational value for the Burnett-Mary region are likely to be significantly underestimated by the DAE (2013) report. The waterways of the Great Sandy Strait and Hervey Bay - adjacent to the Burnett-Mary region but outside the boundary of the GBRMP - are among the most intensively recreationally fished areas on the Queensland coast (FRDC 2013). For example Prayaga et al. (2010) report that recreational fishing trips contribute approximately A$5.5m/year to the Capricorn Coast.

Although Prayaga et al. (2010) report that recreational fishing trips contribute approximately AUD5.5 million per year to the Capricorn Coast, most of the data used in the study were collected from the Rosslyn Bay boat ramp, near Yeppoon. The boat ramp is located in an excised portion of the GBRMP, the waterway that this location provides access to is largely within the GBRMP boundary, and therefore may have been used in the recreational value estimates reported in DAE (2013). Monetary valuation studies of recreational activities directly and unambiguously attributable to the Great Sandy Strait and/or Hervey Bay waterways of the Burnett-Mary region could not be located.

Recreation values for the Burnett-Mary region were not adjusted and remain at A$60.3m per year.

<u>*Commercial fishing*</u>

Deloitte Access Economics (2013) estimates commercial fishing as the gross value product (2010-11) of line, pot, net and trawl fisheries, harvest, and aquaculture. The total annual gross value of production for commercial fishing businesses in 1999/2000 was A$19.9m (Fenton and Marshall 2001a). Converted to value-add using the multiplier reported in DAE (2013; 0.48), an additional A$9.6m in economic market value can be attributed to the Burnett-Mary region, and the Great Barrier Reef as a whole.

Commercial fishing values for the Burnett-Mary region were increased by A$9.6m to A$25.2m per year. This adjustment does not include indirect economic contributions, thus is considered a conservation estimate of the total economic contribution of reef-dependent commercial fishery activity in this region. Value estimates have not been adjusted for inflation and will fluctuate with catch effort and fishery health.

Exclusion of economic values within Western Cape York Peninsula and the Gulf of Carpentaria

Cape York Peninsula is the only region in the Great Barrier Reef Catchments that drains to a marine region other than the Great Barrier Reef (Figure 6). Data and statistics for environmental assets and economic values in the Cape York Peninsula NRM region are typically not reported separately for eastward- and westward-draining catchments. Neither DAE Report (2013) nor its predecessor (GBRMP 2009) disaggregate eastern Cape York Peninsula from western Cape York Peninsula economic values. It should be noted that very little economic data is available for the Cape York Peninsula region (EcoSustainAbility 2012).

Figure 6: Eastern Cape York Peninsula and Great Barrier Reef Marine Park (ReefPlan 2014).

Table 3: Visitation rates to eastern and western Cape York Peninsula (Source: Queensland Tourism, 2002)

Location*	Drainage	%	Nr visits
Mt Carbine	Western	5	1
Palmer River	Western	8	2
Lakeland	Eastern	34	44
Laura	Eastern	29	32
Hann River	Eastern	22	18
Musgrave Roadhouse	Western	54	110
Coen	Western	59	133
Archer River	Western	66	166
Weipa	Western	65	161
Moreton Telegraph Stn	Western	35	46
Heathlands	Western	12	6
Bamaga	Western	57	124
Injinoo	Western	4	1
Seisia	Western	64	156
Umagico	Western	4	1
Punsand Bayn	Western	43	70
Pajinka	Western	8	2
Cooktown	Eastern	63	151
Lockart River	Eastern	12	5
Aurukun	Western	1	0
Pormuraaw	Western	1	0

Reef-based tourism

The Cape York Peninsula Visitors Survey provides a breakdown of visitation rates reported as across the percentage of visitors responding to the survey at each important tourist location (Qld Tourism 2002). These data were disaggregated into eastern and western catchments (GBRMPA unpubl.), and the total number of visits was calculated (Table 3).

Based on these data, locations in eastern Cape York Peninsula receive 53% of the region's tourism. In the absence of data to the contrary it is reasonable to assume that the same east-west ratio applies for all types of tourism, including reef tourism. *Cape York Peninsula tourism data were adjusted by a factor of 0.53 to derive the adjusted market value A$6.8m/year of reef-dependent tourism activity to the Great Barrier Reef.*

Recreation

Recreational fishing is a substantial contributor to Cape York's economic value (Donald 2012), however no reports or data could be located that allow the relative contribution of GBR-based activities vs. those undertaken in the Gulf of Carpentaria. *No adjustment factors are currently available to disaggregate eastern from western Cape York Peninsula recreation value.*

Commercial fishing

Commercial fisheries that operate this region include the East Coast Trawl Fishery, the Northern Prawn Fishery, and set net fisheries for barramundi and threadfin salmon. Cape York Peninsula fish stocks are managed through the Queensland Fisheries Management Authority, advised by the Far North Queensland and the Gulf of Carpentaria Zonal Advisory Committee and similar committees (KBC 2007). Data on relative contribution of eastern and western fishery activities were not readily available at the time of writing however these management agencies should be approached in future value estimations to account for these discrepancies. *No adjustment factors are currently available to disaggregate eastern from western Cape York Peninsula commercial fishery value.*

2.1.3. Market values of reef-dependent industries in the Great Barrier Reef regions

Market value estimates of the economic contribution of three major reef-based industries were refined based on estimates provided in DAE (2013) report and the peer-reviewed literature. Five adjustments were made, with differing results to total market estimates. Each adjustment and its effect relative to those reported in DAE (2013) is summarised in Table 4 and Figure 7.

Table 4: Type and size of adjustment to economic estimates of the value of reef-dependent industries in the GBR (A$m 2011-12, as value-add) relative to estimates reported in DAE (2013).

Adjustment	Rationale	Change (A$m)
Science and management	Not relevant to WQIPs	-98.0
Torres Strait	Not part an NRM region	-1.2
Reef-based tourism	EMC data not disaggregated to NRM regions	+224.2
Burnett-Mary NRM extension		+14.9
Exclude west Cape York tourism	Western basins are not managed under GBR WQIPs	-16.2
	Net change from adjustments	*+123.7*

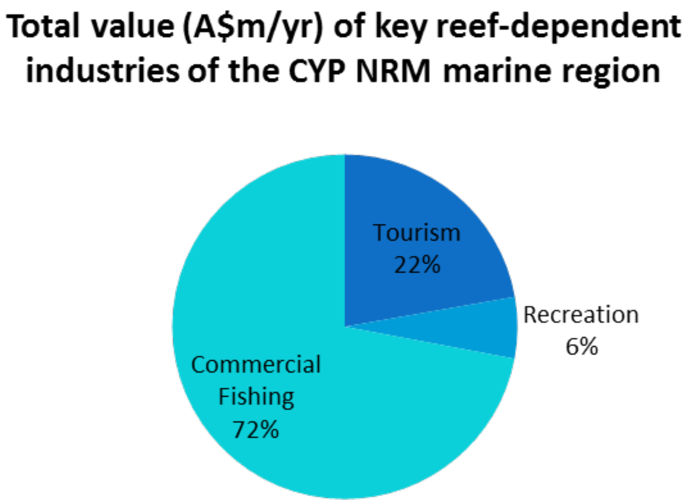


Figure 7: Total market value estimates (A$m; 2011-12) of economic contribution from the three main reef-dependent industries in the Cape York Peninsula NRM region to regional (via direct value-add) and Australian (via indirect value-add) economies.

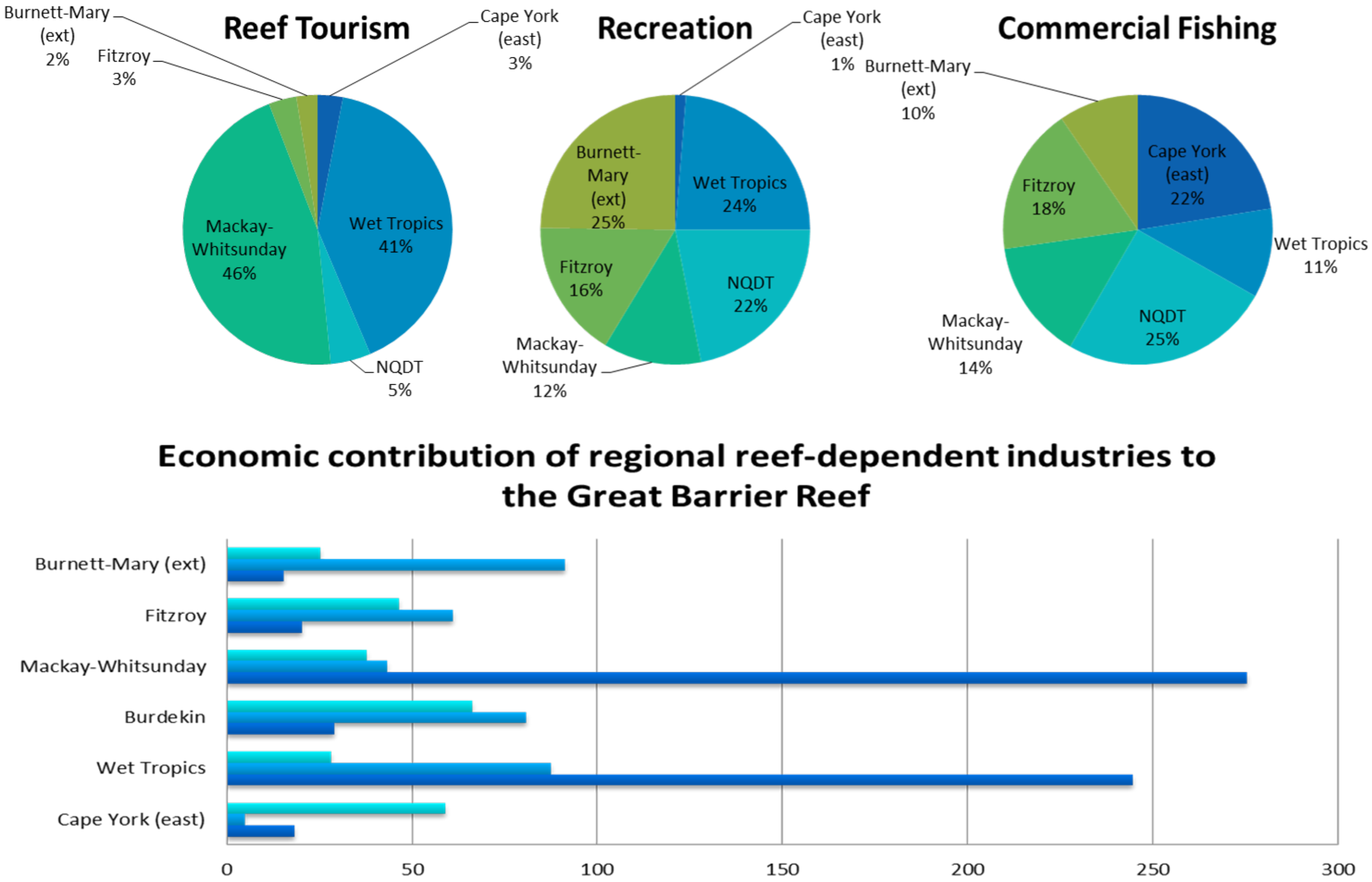
Relative to the rest of the GBR NRM regions (Figure 8), the Cape York east region represents the second largest regional contribution to the commercial fishing industry (22%, A$59m), an equal contribution to reef tourism as the Fitzroy region (3%, A$18m) and the smallest contribution to the recreation (1%, A$5m) and the same. If recreation estimates in DAE are based on place of purchase, then it is likely that recreation is underestimated for Cape York. Mackay-Whitsunday and Wet Tropics regions dominate the reef-tourism industry, collectively contributing 87% of total economic value.

2.2. Non-market value of the Great Barrier Reef and regions

The DAE (2013) report does not estimate non-market values associated with the Great Barrier Reef. It is not uncommon for non-market values to be considered more important than use or market values (Windle and Rolfe 2006; Marré 2014). As described in the introductory section, non-market values are often associated with market failures – situations where public goods or negative externalities are inadequately accounted for by the market. For example a factory might pollute a river because it is cost-free or cost—saving for them (a negative externality), the pollution may prevent people from swimming (a decrease in non-market value) and farmers from using the water for irrigation (a decrease in market value) (Baker and Ruting 2014).

Since the consideration of trade-offs between market and non-market outcomes are a common feature of public policy decisions, non-market values need to be included in WQIP cost-benefit assessment processes, however there are only two studies on the GBR's non-market values; Hundloe et al. (1988, cited in Stoeckl et al. 2011) estimate a non-use value of coral to 'vicarious users' of A$45m/yr, and Windle and Rolfe (2006) report marginal values (the value of a one unit change) for different regional NRM improvements to soil condition, waterways and vegetation of between $2.88 and $5.80 for each 1% improvement. The Hundloe et al. (1988) estimates cannot be applied here because they only refer to coral reefs. In contrast, Windle and Rolfe (2006) provide marginal estimates, which are useful for decision applications (Principe et al. 2012) but are unsuitable for the INFFER cost-benefit process being applied through most of the WQIPs.

Stoeckl et al. (2014) assess the total commercial (market) and wellbeing (quality of life) value of the entire GBR to be between A$15 billion and A$20 billion per annum. This is a much-needed addition to the environmental economic literature for the GBR however cannot be employed in the WQIP cost-benefit prioritization process for two reasons; 1) the value estimates are not readily disaggregated to regions and, 2) the relative contribution of industries and habitats to total value is not available.



	Cape York (east)	Wet Tropics	Burdekin	Mackay-Whitsunday	Fitzroy	Burnett-Mary (ext)
Commercial Fishing	59	28	66	38	46	25
Recreation	5	87	81	43	61	91
Tourism	18	245	29	275	20	15

Figure 8: Total market value estimates (A$m; 2011-12) of the economic contribution of the three main reef-dependent industries to the regional (via direct value-add) and Australian (via indirect value-add) economies.

These issues occur primarily because Stoeckl et al. (2014) seek to make progress towards developing an absolute value estimate of total economic value for the entire Great Barrier Reef. Estimates of total economic value (TEV) are largely used for awareness purposes, to characterize the contribution that ecosystem goods and services make to society's general well-being (Brouwer et al. 2013). The aggregated nature of TEV estimates make them less useful as decision instruments (Principe et al. 2012).

The focus of INFFER is not about developing one single absolute value, but rather to inform estimates of the degree to which projects and actions may contribute to maintaining or improving the condition of the GBR and its contribution to overall value. INFFER facilitates regional and sub-regional prioritisation decisions by identifying which management actions are most likely to have the greatest relative benefit to reef water quality improvement per investment dollar spent. The DAE (2013) report summaries the main use values of the GBR system relevant to WQIP prioritisation framework, however the method used to determine non-use values could under-estimate true values.

In order for the INFFER process to have maximum utility, the valuation and assessment process must be applied consistently across GBR regions. This requires value estimates of the GBR environment to be developed and applied within, and consistent across, three hierarchical spatial scales; the sub-regional, the regional and the whole-of-GBR scale.

To facilitate the development of sub-regional, regional and GBR-wide value estimates, an ecosystem-based perspective was used to tease out regional differences that may be important to management and policy prioritisation decisions. It could be assumed that if all environmental assets are of equivalent value, regional values are proportional to their contribution to the total area of environmental assets in the Great Barrier Reef. The area of the main ecosystem assets (seagrass, coral reefs and wetlands) were used as proxy estimates of habitat value, and monetised.

2.2.1. Indigenous cultural values

A focus on monetized, quantified and spatially explicit concepts of value can restrict the types of values and perceptions that are explicitly considered in evidence-based decision processes (Gould et al. 2015). Nonmaterial cultural, social and ethical values associated with ecosystems are often qualitative, difficult to articulate, and incommensurable, thus often neglected in most valuation studies (Gould et al. 2015). Under the Millennium Ecosystem Assessment framework, cultural values are described as recreational, spiritual and aesthetic benefits (MEA 2005: v). Cultural ecosystem services include: place value; heritage; identity; the nonphysical value of activities; spirituality; artistic inspiration; ceremony; education; bequest/intergenerational; social relationships; kinship; and perspective (Gould et al. 2015).

It is likely that members of indigenous cultures hold many more non-use and indirect-use values than nonindigenous people. In this context, sacred values are particularly important and particularly resistant to price-based trade-offs (Venn & Quiggan 2007). However there are many challenges with non-market valuation of Australian indigenous cultural heritage, as has been summarised by Venn and Quiggan (2007).

Much of the difficulty in quantifying Indigenous cultural values for natural resources assets arises from the disparate conceptualisation that Indigenous and western cultures have for natural systems. The *ngurra-kurlu* ("country within people") framework recognises that for Indigenous people nature and culture are not separate, as they are for the Australian general population, but one symbiotic unit, and cultural connections to land facilitate a stewardship ethic (Holmes & Jampijinpa 2013). During visits to country the ecological landscape is transformed into a social one, where systems of knowledge and behaviour that sustain country also sustain people's lives (Holmes & Jampijinpa 2013). Holmes & Jampijinpa (2013) quoting (Chapin 2009:56), state that; "Cultural connections to land, particularly those that inform group identity, "strongly influence peoples' sense of stewardship" and offer "excellent opportunity for natural resource managers to both learn from and contribute to stakeholder efforts to sustain livelihoods and environments".

Similarly, Low Choy et al. (2010) report that, within the context of regional planning, "indigenous landscape values are holistic and interconnected; physical and spiritual; non-living and living; past, present and future", and comprise four key elements; boundaries, pathways, biodiversity matters, and important sites/areas, can help clarify relationships between the regional landscape and specific sets of landscape values related to Indigenous communities' connection to/use of marine and coastal resources for values that are of high regional importance.

Cultural values have perhaps been examined most vigorously in northern Australia, where wild harvests contribute significantly to customary economies and account for up to 23 % of the value of food consumed in remote communities (Jackson et al. 2014). For example, Jackson et al. (2014) estimate the value of species important to subsistence resource users in customary economies by determining the cost of replacing these resources as the measure of value. These researchers find that ten species account for 95 % of the replacement value of subsistence harvests. In a choice modelling non-market valuation study, Rolfe & Windle (2003) show that within a water development context, the regional Indigenous population (Rockhampton) valued the protection of cultural heritage more than the general population, who preferred the protection of environmental values, even though most Indigenous residents of Rockhampton are spiritually connected to regions other than Rockhampton (Venn and& Quiggan 2007).

European uses of water resources and impacts of water resource development can degrade cultural values, for example, the unimpeded flow of a river is a valued cultural principle (Jackson et al. 2005). However environmental valuations are likely to differ between people depending on for example the cultural beliefs, practices, and values within their social context (Jackson et al. 2006). It has been suggested that for Aboriginal and Torres Strait Islanders, it is the relationship and cultural practices associated with the water resource rather than the objects (e.g. food) contained within the resource, which is highly valued (Jackson et al. 2006; Stoeckl et al. 2013).

Indigenous communities in northern Queensland may have a relatively small commercial presence in the supply of goods and services to natural resource markets, but social and cultural values of wild animal trade, cultural heritage tourism and nature-based activities are a source of income for many communities (Stoeckl et al. 2013).

The literature on Indigenous and non-Indigenous cultural values is small and under-developed. Monetisation of cultural values is a contentious issue and there are significant questions about whether these values are even susceptible to reliable quantification. This report is unable to account for the cultural value of coastal wetland, seagrass and coral reef habitats; however the current evidence suggests that these values are likely to be high in the Cape York Peninsula region.

The Indigenous makeup of this region is larger than that of the other NRM regions, and Indigenous values are very important. With a population in which 55% of residents identify as Indigenous people, the Cape York area comprises the most substantial Indigenous population of all the Indigenous Regions (IREGs) along the GBR coast (i.e. Cairns/Atherton IREG 11%, Townsville-Mackay IREG 6%, Rockhampton IREG 4%; ABS 2013).

Cultural, spiritual and subsistence values associated with the Great Barrier Reef are likely to be higher in the CYP region than elsewhere due to the large indigenous population and their strong cultural dependence upon and connection to these resources. It is important to recognize that, under regional planning processes which use price-based economic analyses of alternative resource management policies, indigenous cultural values will most likely be systematically underrepresented relative to non-indigenous values (Venn and Quiggan 2007).

2.2.2. Monetisation of non-market value estimates

The most recent available data for coral reef, seagrass and coastal wetland asset areas (DEHP 2014) were used to estimate the relative value in terms of asset area for each NRM region. These data are described in detail in the Marine Status Supporting Study. Briefly, wetland areas included in these estimates comprise all artificial and highly modified, estuarine, lacustrine, palustrine and riverine wetlands areas (Queensland Wetland*Info*[1]) within the coastal zone as defined by the Queensland Coastal Plan. Seagrass estimates are based on both the area of mapped subtidal and inter-tidal seagrass and the modelled area of suitable deep-water seagrass habitat.

Total area of the key coastal and marine assets of the Cape York Peninsula NRM coastal and marine region is presented in Table 5 and Figure 9. The most extensive ecological asset in the region is seagrass habitat, which represents 49 % of the total asset area for the region. Wetlands comprise 6% of the total measured Cape York asset area. Of the 67,980 km^2 of key habitat mapped in the Great Barrier Reef NRM regions 23,139 km^2 (34 %) is associated with the Cape York region (Table 5). The Cape York Peninsula NRM region has the largest total area of key assets mapped for this project, twice that of the next-largest region.

Table 5: Estimated non-monetary contribution (km^2) of key environmental assets to the total asset area Fitzroy NRM region of the Great Barrier Reef. Source: DEHP 2014

NRM Region	Reef	Seagrass	Wetland	Total	%
Cape York (east)	10,354	11,378	1,407	23,139	34%
Wet Tropics	2,427	4,868	749	8,043	12%
Burdekin	2,965	6,083	946	9,994	15%
Mackay-Whitsunday	3,212	430	613	4,255	6%
Fitzroy	4,855	5,775	1,848	12,478	18%
Burnett-Mary (inclusive)	323	9,209	539	10,071	15%
Total	24,135	37,743	6,102	67,980	100%

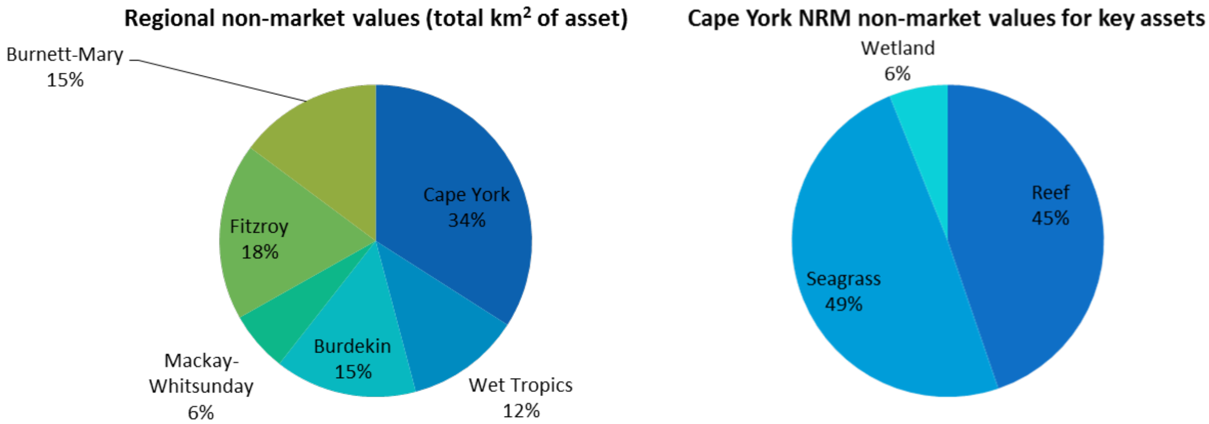


Figure 9 Estimated non-monetary contribution (km^2) of key environmental assets to the total asset area of the Cape York Peninsula NRM region. Source: DEHP 2014

2.2.3. Monetised non-market values

Using a study of the non-market values for environmental improvements in Queensland as an approximate guide, non-market values were subjectively estimated as $10 per person per year, equating to a present value of $193 over 50 years for every person in Australia (i.e., 22.7 million) to give a total non-market value of $227 million per year. Non-market value was distributed across the regions in proportion to each region's total asset area to derive a monetary non-market value per region. Since the monetised values are

[1] http://wetlandinfo.ehp.qld.gov.au/wetlands/facts-maps/ Accessed March 2015

distributed according to asset area, the relative value rankings remain the same as the non-monetised non-market value reported in Table 5 and Figure 9.

The approach used here essentially generates a blanket non-market value of A$3,154/year/km^2 of coral reef, seagrass or coastal wetland assets mapped in the Great Barrier Reef. It is unlikely that each habitat is valued equally by all those who experience it. Further research is required to refine these estimates and derive habitat-specific non-market values for the GBR.

2.3. Regionalised monetary value of the Great Barrier Reef

Market and monetised non-market value estimates derived from DAE (2013) and the peer-reviewed literature allow a monetary value estimate for the GBR and NRM regions to be derived, as presented in Table 6 and Figure 10. Based on these estimates, the monetary value of the Great Barrier Reef industries and assets reviewed here is A$1,460 m/yr.

The highest regional monetary contributions are from the Wet Tropics (27 %, A$387 m/yr) and Mackay-Whitsunday (25 %, A$370 m/yr). Both regions' reef-dependent economies are dominated by flows generated by reef-based the tourism industry. These two regions are 10-15 % higher than the remaining four regions, which each represent between 11-14% of the total GBR economic value estimate.

The Cape York Peninsula NRM region contribution to the economic value of the Great Barrier Reef, comprising 11 % of monetary value, is approximately A$160 m/yr.

Table 6: Market and non-market monetary value (A$m/yr) estimates for NRM regions of the Great Barrier Reef.

Region	Monetised Non-Market	Market	Non-Market + Market
Cape York (east)	77	82	159
Wet Tropics	27	360	387
Burdekin	33	176	209
Mackay-Whitsunday	14	356	370
Fitzroy	42	128	169
Burnett-Mary (inclusive)	34	132	165
Total	227	1,233	1,460

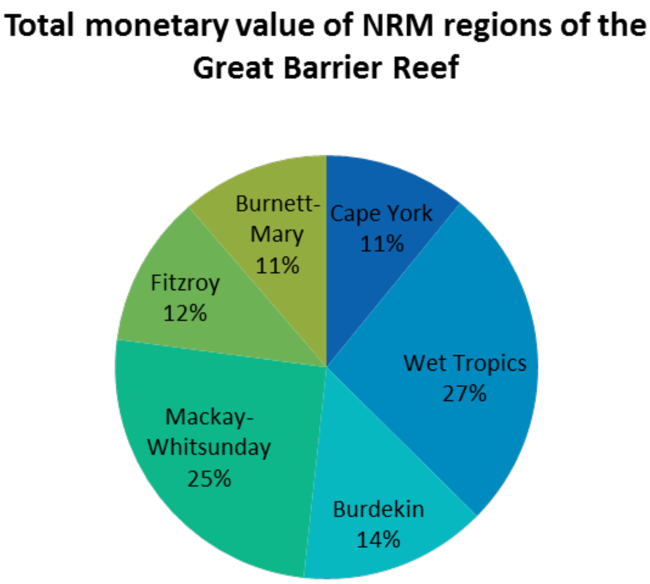


Figure 10: Estimated annual market contribution (A$m/yr) of NRM regions to the total market value of the Great Barrier Reef.

2.4. Conversion of environmental economic value to V scores

To compare the relative environmental-economic costs and benefits of a region's management options, all sub-regional environmental-economic value estimates are normalised to a whole-of-region unit-free score (called 'V scores') for use in INFFER (applied in WQIP regions other than CYP). Normalisation preserves the value of each environmental component relative to the total value of the region. The influence of each NRM investment dollar can then be understood in terms of the change in relative value (quality, number, diversity, functionality) of associated downstream environmental components

INFFER requires users to score the value of an asset in benchmark (or good) condition relative to a set of examples – a table of well-known environmental assets with suggested V scores. It defines asset value as being worth $20 million per point.

Combining both benefits (financial and non-market) gives a total benefit attributable to the GBR of $1,460 million per year. Taking a present value over 50 years using a real discount rate of 5% gives a total value of $28,100 million, or $28 billion. Converting this to a *V* score for use in INFFER gives *V* = 1,400.

The scoring system has been calibrated to give an asset of very high national significance a score of 100. The Great Barrier Reef, in its entirety, has been assigned a value of 1,400 in the INFFER scoring system. It is possible to use non-market valuation (i.e. dollar values) in place of the scoring system proposed below, where this information is available.

The benchmark condition can be thought of as a reference state, to which current projects are striving to reach. For the Great Barrier Reef the benchmark could be defined as its condition at a past date, say 1980. Regardless of whatever benchmark condition is assigned, it is this state that must be used as a consistent point of reference throughout the assessment, especially when thinking about goals and effectiveness of works.

Using the monetary value estimates summarised in Table 6, INFFER V scores can be calculated for non-market and market environmental-economic values at NRM region and whole-of-GBR scales (Table 7). These scores can then be used as inputs to the cost-benefit prioritisation processes, such as INFFER.

Table 7: Monetised non-market and market V scores for coastal and marine assets adjacent to NRM regions of the Great Barrier Reef

NRM Region	Monetised Non-Market	Market	NM+M	%
Cape York (east)	74	79	**153**	11%
Wet Tropics	26	345	**371**	26%
Burdekin	32	169	**201**	14%
Mackay-Whitsunday	14	341	**355**	25%
Fitzroy	40	122	**162**	12%
Burnett-Mary (inclusive)	32	126	**159**	11%
Great Barrier Reef	218	1,182	**1,400**	100%

3. LIMITATIONS OF THIS STUDY

3.1. Limitations of monetary valuation

Environmental benefits are the result of environmental processes and functions such as carbon cycling, nutrient trapping, and products such as plants and animals. A key assumption when using monetary values is that people are willing to trade goods and services with something that can be quantified in dollars i.e., market values (Fisher et al., 2009). This means that for environmental goods and services to be assigned monetary values they must be tradable (i.e. in markets), or else substitutable or replaceable by other goods and services that can be bought using money. Although environmental value is most commonly measured using market valuation processes which invoke this assumption, market valuation cannot quantify the value or importance of all the environmental benefits that humans recognise. By failing to fully account for non-market and/or non-use (e.g. existence or subsistence) values, monetary valuation processes can underestimate ecosystem worth.

Non-market benefits generated by Great Barrier Reef ecosystems can have substantial economic value, for example the provision coastal protection by the Great Barrier Reef is estimated to be worth AU$10 billion, and non-use value has been estimated in the order of $17 billion (Oxford Economics, 2009). Recent research suggests that up to 80% of ecosystem service values may not be captured in markets, and consequently these values are unavailable to conventional monetary (market-based) assessments (de Groot et al. 2010; Brander & van Beukering 2007). A local example is provided by Wilson & Tisdell (2003), who report that visitors to Hervey Bay are willing to pay AU$2-8m per year to protect safeguard the survival of sea turtles and whales. These and similar benefits are not routinely considered in environmental valuation processes.

Differences between pure-private and pure-public goods and services make traditional financial-economic approaches to ecosystem service valuation problematic. Brauman et al. (2014) summarise these issues as:

1. In markets, goods are valuable when supply is low and demand is high.
2. There are few direct market mechanisms to indicate value or signal scarcity or degradation
3. Well-functioning ecosystems produce more services than poorly-functioning ecosystems, increasing service supply and decreasing price. This creates little market incentive for environmental protection.
4. Prices are based on current conditions. Traditional economic measures (prices) won't anticipate reductions in supply even if future environmental degradation is anticipated.
5. Market prices are based on marginal utility, which is the value of gaining or losing a single service. This is problematic in ecological systems where aggregation of single services can change their value. For example, the value of a single tree may be higher when harvested than when left in the woods, but the value of the services provided by the woods may be higher than the total value of individual trees.

These issues are pertinent to WQIPs because the Great Barrier Reef ecosystems are largely open access, and many of the products and services they provide have public good characteristics. That is to say, the ecosystem services provided by the Great Barrier Reef are characterized by a high degree of non-rivalry and non-excludability, which have no direct market mechanism to indicate value or to signal scarcity or degradation. This mismatch between market approaches and public goods and services creates market failures. The most notable market failure within environmental economics is perhaps the tragedy of the commons, or free-rider problem, which states that little incentive exists for people to invest in protecting the environment if they believe that others will do it for them (Kotchen 2013).

One role of environmental policy is to provide instruments such as quantity, price, and technology regulations to correct market failures by requiring or encouraging more efficient allocation of public goods (Kotchen 2013). A market's maximum efficiency is when the marginal cost of producing a good equals its marginal benefit and price (Daly and Farley 2010). More efficient allocation of public goods will create more balanced cost-benefit outcomes. However, the non-excludability and non-rivalry of public goods and services depends upon the definition and allocation of property rights, or their perceived value and availability, which means the value of public goods is mostly institutionally-determined (Crabbé and Manno 2008). As a result, markets for coral reef and similar services are absent or under-developed, leading them to be undervalued in decisions relating to their use and conservation (Brander et al. 2007).

Given that many ecosystem services are public goods that provide services which are vital to human well-being, it is concerning that existing political and economic institutions are poorly equipped to manage public goods (Daly and Farley, 2010; p184). The tendency in Australia to equate ecosystem service with market-based approaches to natural resource management has inhibited discussion about the broader social implications of human dependence on ecosystems (Pittock et al. 2012). Valuation processes that account for many types of value provide a more complete representation of a system's environmental values are required which facilitate consideration of the relative importance of different types of benefits and values that humans associate with ecosystems (e.g. Lopes and Videira 2013; Farley 2012).

3.2. Reef-specific tourism as a proportion of total tourism

This report estimates that the daily spending patterns of reef-specific tourism are equal to those of rainforest and other tourism activities. The relative contribution of reef-specific tourism to total tourism in the Great Barrier Reef regions is not well studied, however there is likely to be some benefit to completing a literature review on the topic to assess the current status of knowledge and recommend the approach for accurately attributing expenditure data to each sector, and possibly also for proposing data collection techniques that will allow these data collected in more directly useful formats.

Additionally, it should be noted that EMC data were used to estimate tourism visitation, which could double-count trip-related recreation visits.

3.3. Clarification of non-market and non-use values

Application of monetary valuation process to develop market values for environmental benefits generated through commercial activities such as tourism and fishing are relatively straightforward. Like market values, non-market values can also be high, but they are more complicated to collect and compare between locations and through time.

Revealed preference methods "use observations of purchasing decisions and other behaviour to estimate non-market values" (Baker and Ruting 2014). For example, the travel-cost method uses information about expenditure and travel time to estimate the value people place on visiting a specific site, and the hedonic pricing method estimates the economic benefits or costs of non-market ecosystem services that directly affect market prices, such as air pollution or aesthetic views (Baker and Ruting 2014). Revealed preference methods are generally considered valid estimate of non-market value, however suitable data sets are usually unavailable. Additionally, their reliance on behavioural measures (purchasing behaviours), they cannot be applied to non-use values (Baker and Ruting 2014).

Stated preference methods, such as contingent valuation and choice modelling, are survey-based instruments which operate by asking respondents to make choices between policy options which are associated with differing levels of environmental impact and cost (Baker and Ruting 2014). Theoretically these tools are able to estimate all types of values; however they can be difficult to design well, and are generally not as widely accepted (Baker and Ruting 2014). These instruments can be used to assess non-use values, and in the marine planning have mostly been used for charismatic species, or coral reef ecosystems (Börger et al. 2013).

The benefit transfer approach transfers valuation estimates from one place and time to another, and should only be used if a high degree of similarity exists between the two sites, which is rarely the case (Baker and Ruting 2014).

Some suggest that economic valuation creates an anthropocentric commodification of nature that is unethical and should be avoided (Schröter et al. 2014). More moderate voices suggest that non-monetary valuation is preferable in some cases, particularly when the services in question are considered to be critical and/or scarce, and whether the service is trending towards greater or lesser levels of criticality or scarcity (Farley 2012).

Non-market values have been estimated in this report, however non-use values have not. Oxford Economics (2009) provides national and international monetary estimates of non-use values which may be appropriate for integration into the estimates presented here. Future work may benefit from considering the appropriateness of this option. Additionally, the non-market value that is reported here (i.e., approximately AU$3,100m per km^2) is much lower than estimates obtained for other locations. For example, the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) report non-market values ranging from US$14,000 to US$3.5 million per km^2 (UNEP-WCMC 2006; Table 8).

Table 8 Literature values of non-market ecosystem services (UNEP-WCMC, 2006)

Country	Asset type	Ecosystem service	Value (US$/$km^2$)	Year reported
global	coral reefs	not stated	100,000 - 600,000	1997
global	mangroves	not stated	900,000	1997
Indonesia	mangroves	erosion control	600/household/yr	1992
Indonesia	coral reefs	shore protection	829 – 1 million/km	1996
Sri Lanka	coral reefs	not stated	140,000 - 7.5 million	1998
Thailand	mangroves	not stated	2.7 - 3.5 million	2001
Sri Lanka	mangroves	storm protection	7,700/km	2003
Caribbean	coral reefs	shore protection	2,000 – 1 million/km	2004
American Samoa	mangroves	not stated	104,000	2005
American Samoa	coral reefs	not stated	14,300	2005

Given the large difference between the non-market estimates adopted in this report, and those reported in the wider literature, a comprehensive review of non-market values of ecosystem services in the Great Barrier Reef is warranted.

An important distinction must also be made between the value of environmental assets and the value of environmental services. For example, a wetland might provide a range of valued services such recreation opportunities, habitat, and regulation of water flows. The wetland is an asset with a value that depends on the future services it can provide (Baker and Ruting 2014). The non-use values applied here are derived purely from the size of the three assets, and not the services they might provide, so are likely to underestimate overall non-use value.

4. RECOMMENDATIONS

Strategic and integrated assessment of human impact on the marine environment is becoming increasingly important (Börger et al. 2013). The ecosystem-based approach, which takes account of environmental, social and economic factors, is a critical aspect of marine planning in the UK and USA (Börger et al. 2013). In the marine environment, the focus on the management of places is one of the key features of ecosystem-based frameworks, and represents “a marked departure from existing approaches that usually focus on a single species, sector, activity or concern” (Potschin and Haines-Young 2013).

Different ecosystems and their components exhibit interdependencies across scales, requiring decision makers to make trade-offs across ecosystem services, benefits and beneficiaries (Granek et al. 2010; Maguire et al. 2012; Pittock et al. 2012). By providing a common set of details and a common process for measurement, the ecosystem services concept can provide a common language for ecosystem-based management decision processes across diverse beneficiaries (Granek et al. 2010).

Estimating the provision of ecosystem services under alternative management scenarios offers a systematic way to incorporate biogeophysical and socioeconomic information and the views of individuals and groups in the policy and management process (Figure 11; Granek et al. 2010). Ecosystem service values could be used to provide objective and transparent data and a framework to help decision-makers track how management alternatives can and do affect marine ecosystems (and ultimately, people), and what changes are most important from economic, ecological and social perspectives (Börger et al. 2013). By assessing how current ecosystem service delivery could respond to alternative or status quo land use and management practice regimes, ecosystem services analysis can help avoid unintended social and ecological consequences (Brauman et al. 2014; Thomas et al. 2012).

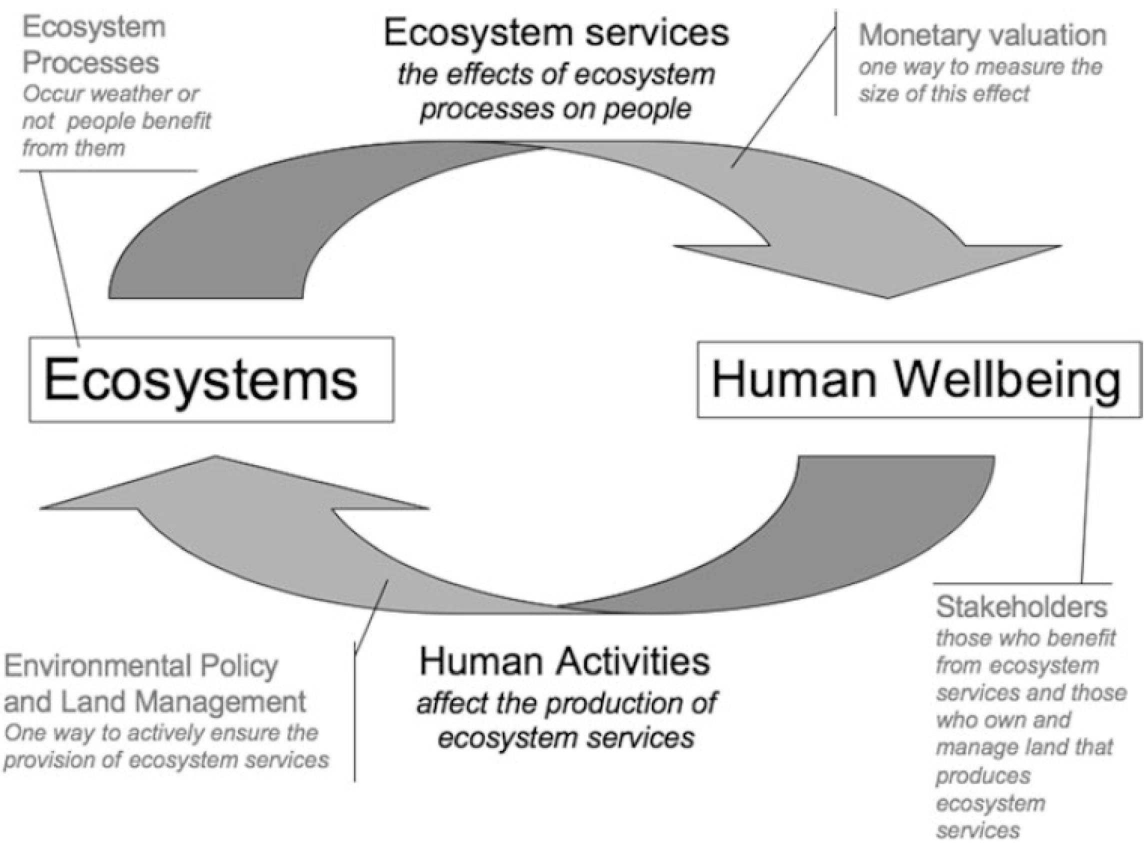


Figure 11. The ecosystem services concept provides an organizing framework for considering the relationships between ecosystems and their beneficiaries. Source: (Brauman et al. 2014).

4.1. Ecosystem services in global and local marine policy and planning

The current driving role of ecosystem service frameworks in US and EU agricultural policy suggests the concept will have increasing influence in shaping environmental policy internationally (Matzdorf and Meyer 2014). The strengths of the ecosystem services framework for policy makers are mainly conceptual, such as cross-sectoral cooperation, a landscape-scale focus, and explicit consideration of win-win and trade-off objectives (Matzdorf and Meyer, 2014). The main weaknesses of the framework are operational, particularly with respect to ecosystem service valuation processes (Matzdorf and Meyer 2014). Although restricted to an assessment of market-based policies, Matzdorf and Meyer (2014) provide guidance to defining an 'ideal' ecosystem services policy. They suggest four conditions must be met:

1. **Ecosystem capacity**: focus on the capacity of the ecosystem to maintain or enhance the supply of goods and services
2. **Socio-economic assessment**: goals will be determined by the economic and social benefits derived from natural processes and structures
3. **Environmental trade-offs and sectoral collaboration**: consider the interrelationships and trade-offs between environmental objectives, and foster the cross-sectoral collaborations required to make these trade-offs
4. **Financial incentive programs**: focus on beneficiary demand and implementation of financial incentives including, but independent from, monetary valuation

Application of the ecosystem service concept globally appears to be most highly developed in the arena of water policy, for example in the European Water Framework Directive (Matzdorf and Meyer 2014). In Australia the concepts, frameworks and language of the ecosystem services paradigm have been used extensively by governments and non-governments to describe the dependence of humans on ecosystems; however a lack of effective strategic frameworks, goals and leadership has hampered the realisation of expected achievements (Pittock et al. 2012).

Despite this, strategic application of the ecosystem services concept is credited as instrumental in shifting the focus of governance from individual reefs to regional seascapes in the Great Barrier Reef (Olsson et al., 2008), despite limited understanding of the processes supporting the social-ecological system (Bohensky et al. 2011; Stoeckl et al. 2011; Thomas et al. 2012). Generally, the approach by the Great Barrier Reef Marine Park Authority appears to somewhat satisfy conditions 1 and 3, and progress towards condition 2 is being addressed in efforts such as the Social and Economic Long Term Monitoring Programme for the Great Barrier Reef catchments (Marshall et al. 2015). On the whole, policies to support and maintain the development and implementation of a strategic ecosystem services framework for the GBRMP are likely to see continued future investment.

The mainstreaming of ecosystem services concepts into strategic policy and planning processes requires that a suitable framework be available (Potschin and Haines-Young 2013). Effective ecosystem service frameworks are essential to provide consistent, structured, multidisciplinary and collaborative processes for identifying and applying useful knowledge about the relationships between ecosystem processes, services and beneficiaries (Cowling et al. 2008).

Programs which attempt to manage multiple values across multiple jurisdictions will do well to consider the full range of ecosystem services, benefits and beneficiaries and the processes that support them, as a process for informing planning and, ensure that participants in the process have clear expectations of what can be achieved (Pittock et al. 2012). Nahlik et al. (2012) propose that, although ecosystem service frameworks will necessarily differ in the detail of how they meet specific objectives, successful frameworks will share the following attributes:

1. **A conceptual framework**: at minimum, a definition the ecosystem service concept being applied and a classification system for identifying and categorising services
2. **A trans-disciplinary approach**: the language, concepts and methods used within the framework should be accessible to all relevant disciplines and audiences
3. **Community engagement**: individuals, groups and firms with an interest in the ecosystem should be involved in service identification and/or valuation to facilitate legitimacy
4. **Flexibility**: the framework needs to have strategies that accommodate changing social attitudes, economies, environmental conditions and policy and management decisions
5. **Cohesion and coherence**: the framework needs to be conceptually sound, logically structured and feasible
6. **Policy relevance**: the framework should collect information that helps identify and inform potential ecological outcomes of policy and management decisions

The importance of these attributes is reiterated by Jax et al. (2013; Figure 12), who state;

> *"Although there are… problems associated with the conceptualisation and use of the ecosystem services concept, many of them can be dealt with when it is clearly defined and by making explicit the specific aim, value dimensions under consideration, and possible trade-offs involved in specific decision- or policy-contexts. This can be achieved by adopting integrative perspectives that involve and balance different scientific disciplines and divergent stakeholder groups and perspectives. Different contexts and purposes entail different needs for the definition of ecosystem services, and these in turn have different ethical implications accompanying its use and influencing its usefulness."*

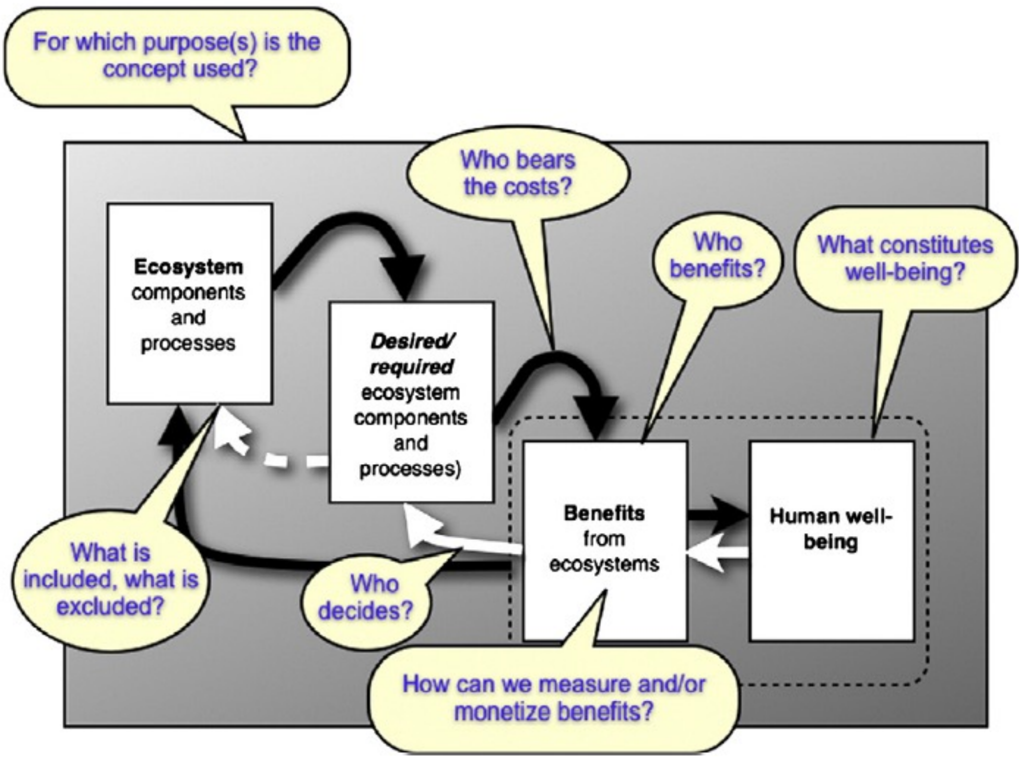


Figure 12 Considerations for applying the ecosystem service concept. Effects of ecosystem service provision to human well-being, and the effects of human use on ecosystems, are represented by black arrows. Societal choices about what counts as a service or benefit, and which ecosystem processes and components are desirable for promoting them, are represented by white arrows. The integration of societal preferences about values and choices with ecological

information is achieved by posing questions about the different components of the ecosystem services concept, and how it should be applied. Source: Jax et al. (2013).

Perhaps the best example of a policy-relevant, operational ecosystem service framework is the South East Queensland (SEQ) Ecosystem Services Framework (Maynard et al. 2010; Nahlik et al. 2012). This framework assesses 28 ecosystem services, and is established as the programme for regional planning policy including State of the Region and other regional and local natural resource management reporting tools (Maynard et al., 2010). The SEQ framework comprises four hierarchical components for assessment, shown in Figure 13, primarily derived from Millennium Ecosystem Assessment (MEA) reporting structures (MEA, 2005). Inter-relationships between adjacent components were captured in matrices with simple scores and supported by GIS mapping;

1. ecosystem reporting categories - adapted from MEA reporting categories,
2. ecosystem functions - adapted from MEA categories of regulating, provisioning, supporting and cultural ecosystem services,
3. ecosystem services – categorised as regulating, provisioning and cultural services and,
4. constituents of human well-being – developed from the MEA and categorised as; existence, health, security, good social relations, and freedom of choice and action.

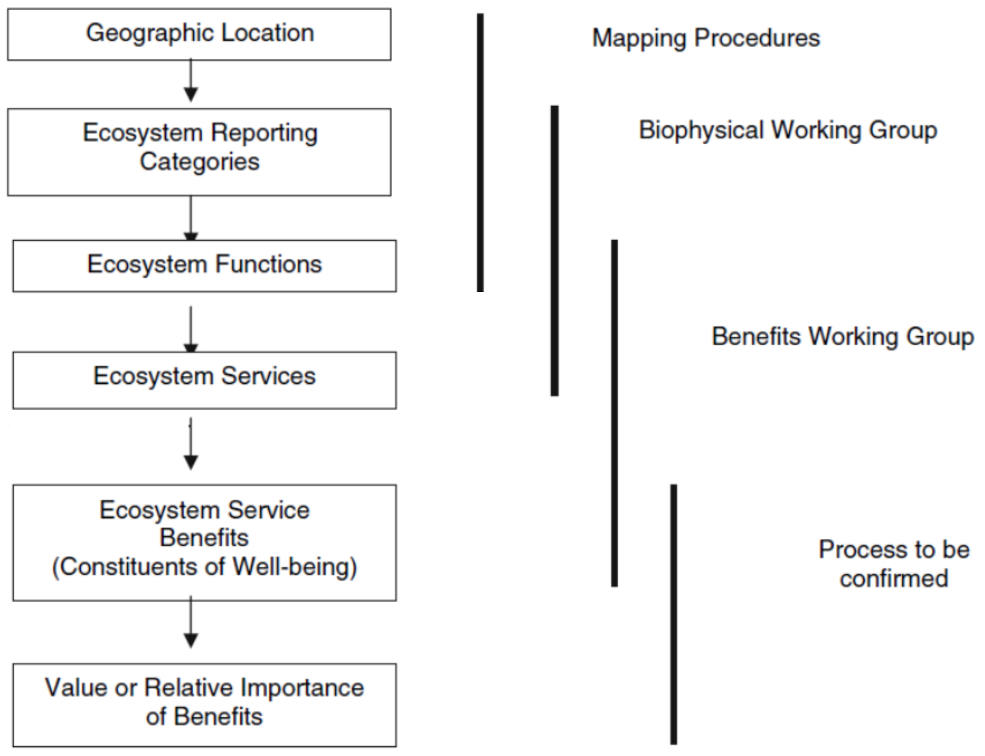


Figure 13 Processes and components of the SEQ Ecosystem Services Framework. Information about factors affecting service provision, such as socio-economic considerations, legislation and community values and preferences need to be added by users separately. Source: Maynard et al. (2010).

4.2. Ecosystem services for WQIPs: a preliminary analysis

> *"At its heart the decline in Australia's ecosystems can be attributed to a habit of seeing every ecological debate as a contest between biodiversity and socio-economic benefit, where the resulting compromise decisions diminish ecosystem health. The ecosystem services concept provides an increasingly rigorous framework to engage a broad range of stakeholders in considering these debates in a more sophisticated light. Using this framework to identify a greater diversity of ecosystem services and options for their management can help Australian institutions choose actions to provide a broader range of benefits for people."*
>
> - (Pittock et al., 2012)

Clear and precise definitions of ecosystem services are important for comparing or combining ecosystem research across teams, contexts and studies (Ringold et al., 2013). That said, ecosystem services must also be defined in way that is consistent with the decision- or policy-context (Boyd and Krupnick, 2013). For the purposes of the xxxx WQIP, ecosystems services need to be defined in a way that facilitates their application to management prioritization processes.

Consequently, for the purposes of this investigation, ecosystems services are defined as those aspects of an ecosystem (biophysical features, quantities, and qualities) which actively or passively contribute to human well-being (Boyd, 2007; Boyd and Banzhaf, 2007; Boyd and Krupnick, 2013; Fisher and Turner, 2008; Ringold et al., 2013). More specifically, we define ecosystem services as final services. Final services are the things humans experience as a result of accessing a component of nature; because ecosystem services are explicitly defined from a perspective of human values, they can be considered end-points of nature (Boyd and Banzhaf, 2007). Many researchers describe advantages of defining ecosystems services as final, rather than intermediate, services (for example; Boyd and Banzhaf, 2007; Boyd and Krupnick, 2013; Cosier and McDonald, 2010; Cosier and Sbrocchi, 2013; Ringold et al., 2013). Most notably, these advantages are:

- encapsulation of the most appropriate features to be communicating about with beneficiaries,
- application to social well-being analysis,
- avoidance of double-counting,
- application to environmental accounting applications,
- application to cost-benefit analysis, and,
- differentiation of service price from service quantity, allowing changes in each to be tracked.

In both common and scientific usage, concepts of ecosystem services and ecologically-derived economic benefit are often conflated (Principe et al., 2012). In contrast to services, benefits have a specific impact on human well-being, for example beautiful views, clean air, recreation, hazard avoidance and drinking water (Boyd, 2007; Fisher and Turner, 2008). Benefits often rely on and are created by the combination of final ecosystem services with additional inputs including time, human resources (skill), and capital (i.e. complementary) goods or services, as shown in Table 9 for recreational fishing and drinking water (Boyd, 2007; Boyd and Banzhaf, 2007; Fisher and Turner, 2008).

A downside of defining ecosystem services as final services is that information on quantity and price are often not wholly available, particularly for non-market services realized (benefits delivered) at the local scale. A second problem is that although double-counting is avoided, the intermediate services that support the realization of final services are not explicitly acknowledged, but are instead embedded within the estimate of final service value (Brouwer et al., 2013). This problem could easily be remedied by providing additional documentation or conceptual models describing key dependencies between and/or ecological processes supporting intermediate and final services.

Table 9. Identification of intermediate and final services is dependent on the benefit being valued. An individual final service may be instrumental for multiple benefits, and some benefits require complementary (non-ecosystem) goods and services to be available before they can be realised. Adapted from Boyd & Banzhaf (2007) and Fisher et al. (2009).

Intermediate services	Final services	Benefits	Complements
water quality safe for secondary contact	the water body		access points, equipment
water quality suitable for sustaining fish	fish population	recreational angling	
soil quality	riparian cover		
wetlands riparian cover	**water quality** safe for human consumption	drinking water	infrastructure
mangroves	storm protection	property protection	nil
coral reefs	storm protection	protection of livelihood assets	nil
upstream land cover	natural stream flow		access points, equipment
wetlands	**water quality** safe for secondary contact	kayaking	
upstream land cover	natural stream flow	irrigation	infrastructure
upstream land cover	natural stream flow	hydroelectric power	built capital

A beneficiary-based approach emphasizes identification of spatially explicit, concrete beneficiary groups for modeling and valuation (Boyd and Banzhaf, 2007; Fisher et al., 2008; Haines-Young and Potschin, 2010; Nahlik et al., 2012). This approach is consistent with recommendations to identify consistent sets of "final ecosystem goods and services" (Johnston and Russell, 2011; Nahlik et al., 2012). It also avoids the double-counting problem by considering ecosystem services to be only those processes that directly contribute to a benefit, and not those processes that indirectly support other benefits (Bagstad et al., 2013a).

4.2.1. Defining ecosystem services for application in WQIPs

Final ecosystem services can be explicitly identified for the WQIP in terms of the wants, needs and perceptions of human beneficiaries to create a range of potential benefits. Some basic types of benefits have been provided in Table 10.

Different beneficiaries may interact with different ecosystem components, and are thus accessing different ecosystem services, or different users may interact differently with the same ecosystem components, and are thus creating different service-benefit relationships (Ringold et al., 2013). Such benefit-dependency is a recognized characteristic of most of ecosystem service classification systems (Boyd and Banzhaf, 2007; Fisher et al., 2009). To systematically develop a comprehensive inventory of benefit-dependent ecosystem services, a comprehensive benefits inventory is required. Following Ringold et al. (2013) beneficiary categories spanning monetary (market and non-market) and non-monetary (non-use) values can also be developed to help clarify ecosystem service components and identify how benefits can be distributed within and across systems (Section A.2; Table 11).

Table 10. An example of how types of ecological benefits that can be realized from a local system might be defined to simplify the process of generating an inventory. Adapted from Boyd and Banzhaf (2007)

Benefit types	Description
Harvests	Managed commercial, subsistence, traditional hunting, pharmaceutical
Amenity and fulfilment	Aesthetic, bequest / spiritual / emotional, and existence benefits
Coastal protection	Protecting property e.g., shoreline erosion, storm surge, flooding
Waste assimilation	Avoided disposal cost, e.g. waste dumping, dredge spoil disposal, sewage discharge, bilge discharge, runoff
Recreation	Fishing, boating, swimming
Commercial tourism	Fishing, diving, snorkelling, island resorts

These techniques were applied in a trial application of an ecosystem services approach for commercial reef-based tourism in the Burdekin region. Section A.2, Table 12 provides a preliminary list of the likely coastal and marine ecosystem components that are providing ecosystem services in the region. This table was used to help generate the inventory of specific ecosystem services to commercial reef-based tourism that could be affected by a change in water quality and are important to track through time (Section A.2; Table 13). For example, water clarity (visibility), coral cover, coral diversity and coral reef structural complexity are all important determinants of tourist diver satisfaction and willingness to return. Trends in these characteristics could therefore be prognostic of future demand for tourism activity in affected regions.

In order to determine the relative values of goods and services, and how these values may change under alternative management decisions, the goods and services must be ranked, or quantified and aggregated (NRC, 2005). In turn, the design of the valuation exercise must be dictated by the requirements of the decision context, which defines the purpose of valuation and how the valuation will be used in policy and management decision making (Boyd and Banzhaf, 2007; Fisher et al., 2009; NRC, 2005). WQIP processes require management decisions to be prioritized in terms of their implementation costs and likely consequences to the environment, the economy and society.

A comparative analysis of the decision support tools available for ecosystem-based management and ecosystem services assessment and/or valuation suggests that environmental valuation studies have a history of being ad hoc and unsystematic (Bagstad et al., 2013b). Continuation along this path will not equip scientists and managers to address the basic challenges required to incorporate ecosystem services values in marine planning.

5. CONCLUSION AND RECOMMENDATIONS

Four approaches were trialled for estimation of regional contribution to the value of the Great Barrier Reef. This report finds that the most comprehensive approach that is both suitable for application to the INFFER process and which draws extensively upon and integrates the existing literature on the environmental values of the Great Barrier Reef is a convergence of recent monetary valuation data with non-market (monetary) valuation data that have been adjusted for asset area (approach number 4). On the basis of this approach, the CYP NRM coastal and marine environmental assets contribute an estimated AU$160 million per year (or 11 % of total monetary value) to the Great Barrier Reef, mainly through the commercial fishing industry and non-market coral reef and seagrass asset areas.

The approach used here has some limitations, which can be improved in future studies. Monetary valuations allow aggregation of ecosystem service values into total estimates that are easily comprehended by a wide range of stakeholders and which allow the like-for-like comparisons between multiple ecosystem services that are required in trade-off analysis. Monetary valuation is only one of several economic techniques for comparing ecosystem services. Processes that support trade-off analysis across monetary and non-monetary benefits can overcome the limitations of a single method of valuation (e.g. health or well-being indices) and the different economic perspectives of value that arise across stakeholders, contexts and scales of application. Some aspects of ecosystem function may be best assessed in terms of their proximity to tipping points and managed in terms of safe minimum standards. The issue is to systematically determine the most appropriate valuation process for the decision context at hand. It is currently unclear how comprehensively this process has been applied to the WQIP context.

There is substantial uncertainty associated with the habitat area estimates, particularly for seagrass, which changes dynamically and is monitored infrequently. Commercial value estimates also contain reasonable levels of uncertainty which primarily arise from two sources; the scarcity of reliable non-market value estimates for the Great Barrier Reef and regions, and a similar lack of information about environmental non-use values. The valuations in this study also do not include the cultural and spiritual values of the indigenous communities of Cape York Peninsula or the contributions of subsistence fishing, hunting and collecting to the economies of these communities. The effect of these uncertainties on estimates of the relative contribution of regions to the value of the Great Barrier Reef is unknown. It is recommended that uncertainty analysis be integrated into future iterations of this work.

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A APPENDICES

A.1 Estimating the value of the Great Barrier Reef

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10 June 2014

Deloittes Access Economics (2013) completed a study “Economic Contribution of the Great Barrier Reef”. In that study, financial benefits generated by the GBR region were estimated as $5.68 billion for Australia as a whole. Of this amount, 92% is attributable to tourism, and most of the rest to commercial fishing and recreation. These benefits include indirect benefits (multiplier effect) representing flow-on effects to the rest of the economy.

Unfortunately, these benefits include tourists who visit anywhere in the GBR catchment area, not necessarily the GBR Marine Park. To estimate the reef-specific value, the value was adjusted to account for the following factors:

- Only 15.8% of tourists who come to the region actually visit the reef (based on the equivalent Access Economics study for 2006-7).
- Of the tourists who visit the reef, it is assumed that 25% would come to the region anyway, even in the absence of the reef. It seems reasonable to assume that the percentage would be at least that high, given that 84% of tourists in the regions don’t visit the Reef.
- It is assumed that, on average, reef tourists spend the same amount in total as tourists to the region who don’t visit the reef.

Given these assumptions, the financial benefits from tourism attributable to the Reef are $613 million per year. These are combined with other benefits (calculated as value added) as follows.

Tourism	$613 million
Commercial fishing	$160 million
Recreation	$244 million
Science and management	$98 million
Total	$1,115 million

The Deloittes Access Economics study did not include non-market values associated with the Reef. We consider that these are important and need to be included. Using a study of the non-market values for environmental improvements in Queensland (Windle and Rolfe 2006) as an approximate guide, we subjectively estimated non-market values as $10 per person per year equating to a present value of $193 over 50 years for every person in Australia (all 22.7 million). This gives a total non-market value of $227 million per year.

Combining both benefits (financial and non-market) gives a total benefit attributable to the GBR of $1,342 million per year.

Taking a present value over 50 years using a real discount rate of 5% gives a total value of $25,800 million, or $26 billion. Converting this to a V score for use in INFFER gives V = 1,300.

A.1.1 References

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A.2 A preliminary ecosystem services framework: reef-specific tourism

Table 11. Categories of ecosystem benefits and example associated services. Adapted from Boyd and Banzhaf (2007)

Benefit type	Benefit sub-type	Example services
Harvests	Managed commercial[1,2]	sediment quality
		shade and shelter
		water availability
	Subsistence	target fish
		crop populations
	Unmanaged marine	target populations
	Pharmaceutical	biodiversity[3]
Amenities and fulfillment	Aesthetic	natural land cover in viewsheds[4]
	Bequest/spiritual/emotional	wilderness
		biodiversity
		varied natural cover
	Existence benefits	relevant species populations
Damage avoidance	Health	air quality
		drinking water
		land uses or predator populations hostile to disease transmission
	Property	wetlands
		forests (e.g. mangroves)
		natural cover
Waste assimilation	Avoided disposal cost	surface and ground water
		open land
Drinking water provision	Avoided treatment cost	aquifer
		surface water quality
	Avoided pumping and transport cost	aquifer availability
Recreation	Birding	relevant species population
	Hiking	natural land cover
		vistas
		surface water
	Angling	surface water
		target population
		natural land cover
	Swimming	surface water
		beaches

NOTES: 1) managed commercial crops include row crops, and marine and terrestrial species managed for food, fibre or energy; 2) commercial services may not be valued in environmental accounting frameworks; 3) biodiversity is thought by some to promote pest resistance; 4) the area from which a particular sight can be seen.

Table 12: Assets and environmental values likely to be present in an example NRM region.

Ecosystem Component		Environmental value					
		Harvests	Amenity & fulfilment	Coastal protection	Waste assimilation	Recreation	Commercial tourism
Coral reef	inshore	✓	✓	✓	x	✓	✓
	offshore	✓	✓	✓	x	✓	✓
Seagrass	inshore	✓	✓	✓	✓	✓	x
	offshore	✓	✓	✓	x	✓	x
Mangroves		✓	✓	✓	✓	✓	✓
Coastal wetlands		✓	✓	✓	✓	✓	x
Islands		x	✓	✓	x	✓	✓
Iconic spp.	cetaceans	x	✓	x	x	✓	✓
	seabirds	x	✓	x	x	✓	✓
	dugong	✓	✓	x	x	✓	✓
	turtle	✓	✓	x	x	✓	✓
	fish/sharks	✓	✓	x	x	✓	✓
	crustaceans	✓	✓	x	x	✓	x

NOTE: for details on categories of environmental values, see Table 10

Table 13: Example of a trend assessment of selected ecosystem services and benefits to commercial reef-based tourism beneficiaries as a result of water quality change in the Burnett-Mary region under the scenario that assumes a WQIP is not implemented by 2020

Environmental benefit	Final ecosystem service[1]	Trend	Score
Diving and snorkelling[2]	Water clarity (visibility)	Stable (offshore - good) Stable (inshore- moderate)	3
	Coral cover	Decline (inshore) Stable (offshore)	1
	Coral diversity	Decline (inshore) Stable (offshore)	1
	Coral reef structural complexity	Stable (offshore) Moderate decline (inshore-WQ)	2
Viewing fauna and wildlife[3]	Iconic species e.g., grouper, whales, sharks, turtles	Moderate decline	2
		Status score	**9**
		Overall status score	**2**

NOTES: 1. only natural features that are expected to be affected by water quality change are considered; 2. offshore reefs and seagrass in the north and inshore reef and seagrass in the south; 3. inshore to mid-shelf e.g. Mon Repos turtle rookery, Hervey Bay whale-watching.