

A state-wide economic assessment of coastal and marine ecosystem services to inform sustainable development policies in the Northern Territory, Australia

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ABSTRACT

This paper offers a state-wide assessment of coastal and marine ecosystems services (ES), including Indigenous perspectives, in the Northern Territory (NT) of Australia, to inform policy developments in the region. An economic impact of AUD 1.3 billion/yr and additional economic contribution to the NT economy of AUD 1.4 billion/yr was estimated for the selected key services, in addition to affording > 6,000 jobs. The selected ES include: provisioning—commercial fisheries, and pearl and crocodile cultivation; regulating and maintenance—blue carbon, storm protection and erosion control, and genepool protection; cultural—recreational fishing, tourism, amenity and other non-fishing recreational, and Indigenous cultural values, which were evaluated applying a mix of market and non-market valuation tools. A simple framework of measuring each ES both for its 'Economic Impact'—direct and indirect market value (i.e. reflection in GDP), and 'Economic Value'—market and non-market values for their contributions to the broader NT economy (i.e. human well-being), was applied. Due to methodological limitations, Indigenous cultural values were partially measured using a substitute value for 25% of government Indigenous expenditure on four welfare sectors that relate to benefits people obtain from their coastal and marine resources. It advocates for payments for ES (PES) mechanisms to support equitable enterprises involving Indigenous communities. Overall, this economic assessment of the NT coastal and marine resources presents integrated information to initiate a dialogue on alternative and sustainable development options in the region, and can help in addressing similar development issues occurring in many parts across the globe.

1. Introduction

Marine and coastal ecosystems provide myriad of services to humans—a rich variety of seafood, regulation of climate and water resources, and protection from storms and cyclones, etc.—worth about USD 24 trillion per year [1–3]. In Australia, marine ecosystem services (ES) contribute about AUD 69 billion each year to the economy but only AUD 44 billion of that value is formally recognised in economic accounts comprising marine-based industries such as commercial fishing and aquaculture, shipping and ports, offshore oil, gas and renewable energy, and marine and coastal tourism [4]. The marine environment provides numerous other goods and services including recreational fishing catches and fisher activities, climate and water regulation, breeding grounds for marine life, and pest and disease control, that are

not bought or sold in formal markets. But these non-market goods and services also have real economic value because they enhance people's well-being locally, regionally and globally [3,4]. Measuring total economic value of marketable and non-marketable ES (above and beyond the market) of marine and other environments is critical for appropriately informing policy decisions (Intergovernmental Platform on Biodiversity and Ecosystem Services [5–7]).

This paper assesses the total economic value (which includes but is not limited to the market values) of goods and services provided by the coastal and marine resources in the Northern Territory (NT)—a state-level jurisdiction in North Australia—occupying an area of 1.4 million km² with 11,000 km long coastline including its 398 islands [8] (Fig. 1). This assessment particularly addresses both Indigenous and non-Indigenous values of marine and coastal resources, which are of relevance

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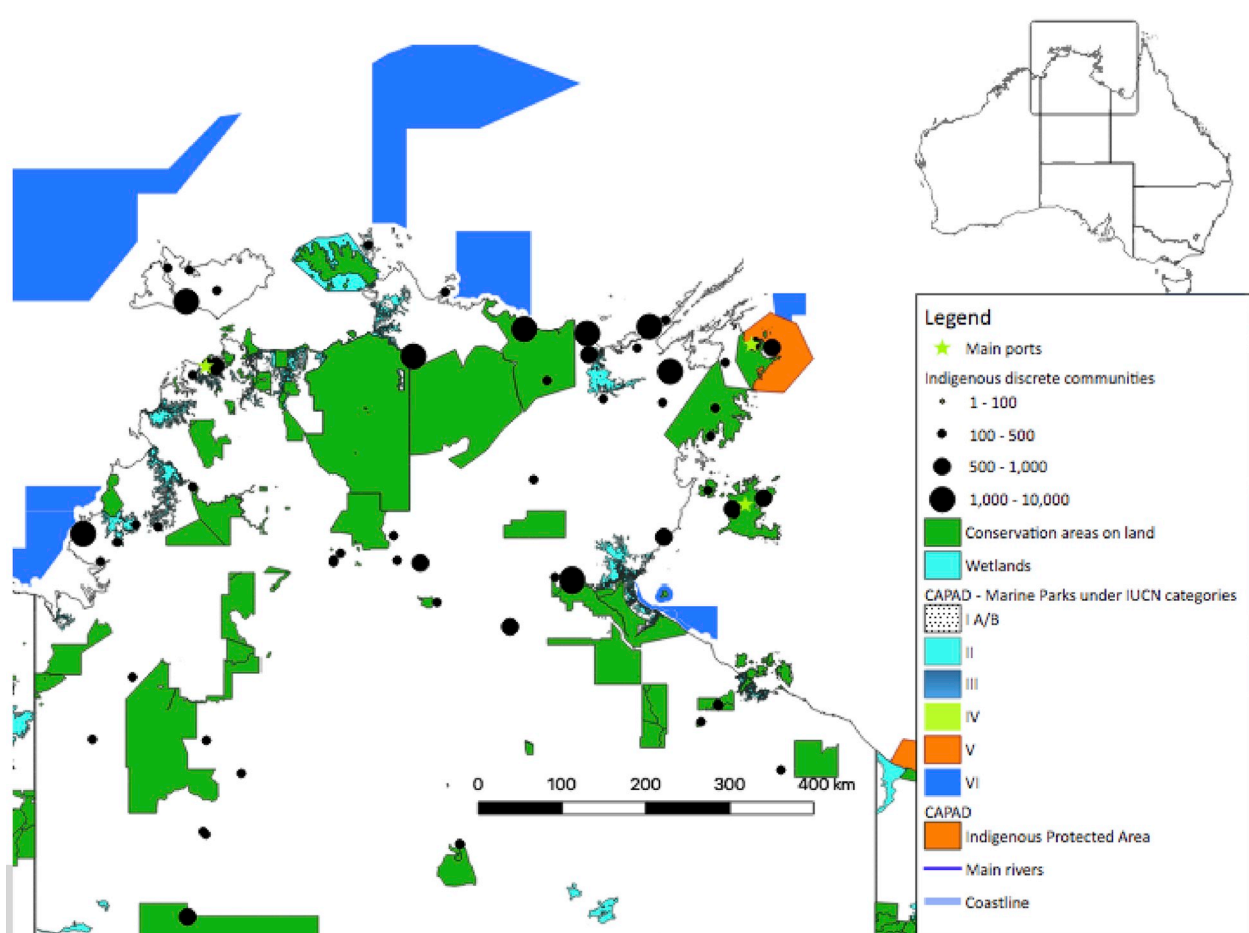


Fig. 1. The NT coast with terrestrial and marine protected areas, including inset map of Australia (Source: CAPAD 2016 database [97], Marine reserves in Commonwealth waters from the Australian Marine Parks (draft) 2017 database, and the ABS [9] census for Indigenous discrete communities).

for other communities across the globe.

The marine waters of the NT extend from the high water mark out to 3 nautical miles (approximately 5.5 km) and include the 88,400 ha Limmen Bight Marine Park and the 229,000 ha Garig Gunak Barlu (formerly Cobourge) Marine Park (Fig. 1). Several land-based parks and reserves, namely the Charles Darwin National Park, Berry Springs Nature Park, Casuarina Coastal Reserve, Shoal Bay Coastal Reserve, Tree Point Conservation Area, and Kakadu National Park include marine and coastal areas. The coastal area also includes Indigenous Protected Areas (IPA), particularly Dhimurru which covers both land and sea *country* (a term often used by the Indigenous people to describe their familial and customary relationship with land and sea), and others, i.e. Yanyuwa, Anindilyakwa, Laynhapuy, Djelk, south-east Arnhem Land, Marthakal and Marri-Jabin, which have coastal boundaries. For this study, we consider the full extent of mangroves, estuaries, and any other areas subject to storm surges along the NT coastline (Fig. 1).

The NT coastal and marine resources support six of the world's seven marine turtle species - the leatherback, loggerhead, green, hawksbill, flatback, and olive ridley [8]. Marine turtles are a global iconic species that are threatened and dependent on the coastal and marine habitats of the NT. They are ancient animals that have lived in the oceans for more than 100 million years. In addition, other unique species such as dugongs, snubfin dolphins, sawfish, and a high diversity of mangroves play an integral role in supporting various ecosystem functions and processes that collectively deliver myriad of ES for the local and regional populations.

About 35,000 Indigenous people living along the coast of the NT

hold unique cultural values that dates back thousands of years as acknowledged by James [10,11]; Barber et al. [12]; Butler et al. [13]; and others. Many of these values include continue longstanding traditions, customs and rituals, and customary lores related to the knowledge and management of these resources and contribute to peoples' well-being [11,13,14] yet fall outside the market mechanisms. This paper particularly highlights and evaluates some of these values for how they play a role towards peoples' well-being. Hence, this economic assessment of Indigenous values could prove useful for many policy decision makers to understand the dependence of local and Indigenous communities on coastal and marine resources so as to develop sustainable coastal and marine resource management strategies.

This state/territory scale assessment of NT marine and coastal waters integrates information from various sources to present the monetary values of ES to address: (i) their direct and indirect impacts on the local economy (the value reflected in Gross Domestic Product); (ii) their economic value (formally, the contribution of ES towards people's well-being); and suggests relevant ES valuation methods, with an aim to inform policy development at local and international scales. Currently, the Australian Government plans to develop the north under the 'Developing the North' policy agenda (2015) while overlooking natural resource-based economic opportunities as outlined by Russell-Smith et al. [15]; thus posing serious concerns for the future of the NT unique, unspoiled, pristine and culturally significant coastal and marine resources [8]. This study underlining the monetary values of ES of the NT marine and coastal resources is timely for informing local (Territory's Coastal and Marine Management strategy developed by the [16]) and other similar development policies elsewhere impacting local and

Indigenous communities across the globe to sustainably manage our precious coastal and marine resources and flow of their services in the future.

2. Ecosystem services valuation framework and methods

2.1. Framework

Derived from the original ES classification system by the MEA [17], the Common International Classification of Ecosystem services (CICES) framework is used (https://cices.eu/content/uploads/sites/8/2012/07/CICES-V43_Revised-Final_Report_29012013.pdf; [18]). Three categories of ES, in line with CICES framework and many other studies, were used for evaluating their vital role in local economy and people's well-being: provisioning—commercial fisheries, and pearl and crocodile cultivation; regulating and maintenance—blue carbon, storm protection and erosion control, and genepool protection; cultural—recreational fisheries, tourism, amenity and other non-fishing recreational, and Indigenous cultural values.

2.2. Valuation methods

We acknowledge that all ES contribute to human well-being [17] and thus have economic 'value' but only some are closely associated with market activities that make measurable contributions to employment and GDP, i.e. economic impact, while others are often ignored. Following the MEA [17]; human well-being is defined here as people living a healthy and satisfying life where ES play a critical role in provisioning basic materials for life, health, security, social relations, and offer freedom of choice and action for people to do what they like to do. Coulthard et al. [19] suggested that well-being prospects of ES can help advance sustainability agendas, however assessing them is still a challenge. TEEB [6] proposed a 'Total Economic Value' framework including measuring both use (direct, indirect and option) and non-use (existence and bequest) values of ES. Our approach integrates TEEB [6] and CICES frameworks (as the latter is more recent and widely accepted in ES area) to simplify and categorise services that have direct and indirect market and non-market values. Therefore, we assess the total monetary and non-monetary values for measuring the 'economic impact' of ES i.e. contribution to GDP (direct use), and their 'economic value' i.e. contribution to well-being (indirect and existence use) (following [20]).

Economic 'impact' and 'value' measure different uses/values – as

illustrated in Fig. 2. Simplistically, impact includes measures that use market prices, essentially focus only on the flow of revenues/incomes in an economy (left panel, Fig. 2) and fail to consider both the costs of production and 'value' beyond the market (see Ref. [8] for a more detailed explanation). Economic value includes measures of consumer/producer surplus and net economic 'value' allowing one to consider the net benefits i.e. total benefit minus total costs (right panels, Fig. 2).

Techniques for assessing the economic impact are generally straight-forward – e.g. assessing industry revenues/expenditures and if looking to assess both direct and indirect measures also using multipliers. The market price was used for both direct and indirect outputs where applicable or using a multiplier of direct market value following local/regional studies where indirect data was missing (details in Table 1). For example, direct economic impact of commercial fishing was estimated from gross output (e.g. annual production of fish) and indirect from industry-related expenditure (e.g. value of fishing vessels, repairs, etc.) to calculate the total impact.

To assess the 'economic value' of ES when price-tags are absent, non-market techniques are applied. It is more difficult to assess the contribution that non-marketable ES make to well-being. Nevertheless, a range of techniques were applied for assessing the economic value of selected ES as outlined in Table 1 (following [59–61]). These include, but are not limited to:

- Techniques using market prices: Direct market pricing, Expenditure, Replacement Cost, Avoided Cost
- Techniques using indirect (linked) markets to infer value: Hedonic Pricing, and Travel Costs

We have also used benefit transfer. We acknowledge that benefit transfer is, sometimes (arguably) erroneously referred to as a type of valuation method. Strictly speaking, it is not. Instead, benefit transfer describes the practice of transferring valuation estimates that have been generated in one context, to another context [62]. The reliability of estimates reported in a benefit transfer study depends, inter alia, on the reliability of the non-market valuation studies generating the initial valuation estimates. To minimise transfer errors, we compiled estimates from other studies that are biophysically and socio-economically similar to the NT. Details of assessing various ES are provided below:

2.3. Provisioning services

Provisioning ES are the material benefits such as food that people

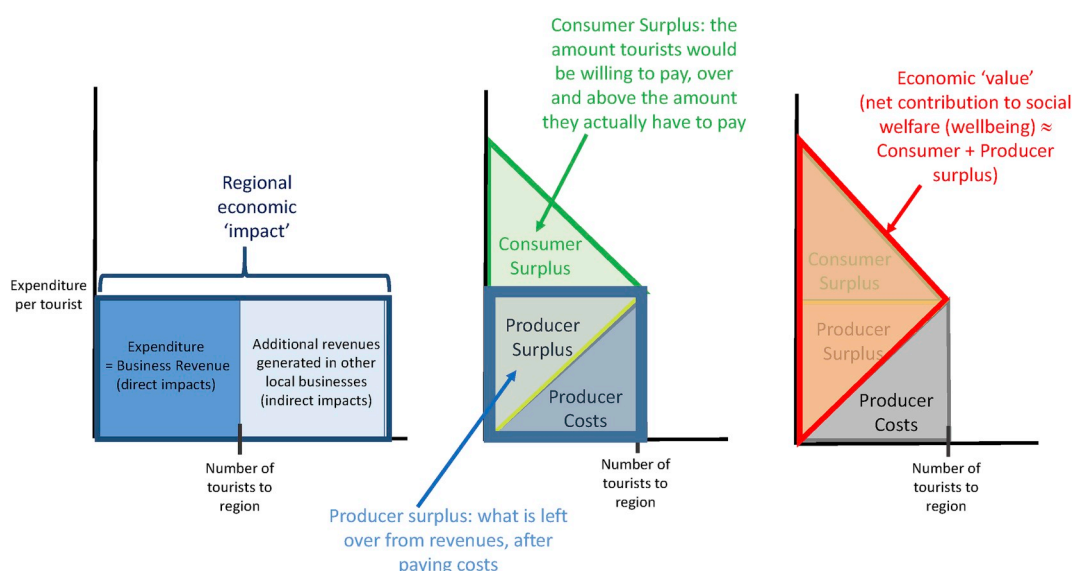


Fig. 2. The economic impact (left) and economic value (middle, right) estimations using an example of tourism [8].

Table 1
Main sources of information and valuation methods applied in this assessment (further details mentioned in the results section as footnotes).

ES	Type of ES	Methods used to estimate direct economic 'impact'	Methods used to estimate direct and indirect/total economic impact (or only total impact, in the absence of indirect impact data, using multiplier estimates)	Methods used to estimate economic 'value'	Sources
Provisioning	Commercial fishing & Aquaculture	Direct market price for the amount of annual catch/production (e.g. fin fish, NT crustaceans, aquaculture, Northern Prawn Fleet, molluscs and echinoderms, etc.), as reported.	Additional indirect expenditure including other market-related expenses linked to this industry e.g. value of fishing vessels, repairs, maintenance, etc. to the rest of the economy, as reported.	No available studies provide estimates of 'value' (i.e. producer and consumer surplus), so the direct market price (direct impact) was used as a proxy.	Department of Primary Industry and Resources [21]; Department of Primary Industry and Fisheries [22]; DPIF annual report [22] and outlook [23]; ABS [24]
	Pearl cultivation	Direct market price for the annual amount of pearl production (Gross Output).	A multiplier of 2.8 for the direct impact (following [25]) was used to measure the total impact.	As above.	Pearl Producers Association [26]
	Crocodile cultivation	Direct market price for the annual amount of crocodile production (Gross Output).	Additional indirect impact was estimated using market-related expenditure generated by this industry including supporting farm tourism, royalty payments for remote communities, etc., following Ernst and Young and Department of Trade, Business and Innovation [27]	As above.	Ernst and Young and Department of Trade Business Innovation [27]; Crocodile Farmers Association of the Northern Territory and the Northern Territory Government [28]
Regulating	Blue carbon stocks	Not bought/sold in the market, so no economic impact.	Not bought/sold in the market, so no economic impact.	Value was estimated from the extent of mangroves, seagrasses and tidal saltmarshes multiplied by their respective carbon sequestration rate for the area per year (t C/ha/yr), which was further multiplied with a conservative market carbon price of \$12.10/tCO _{2-e} (an average price from past three auctions held by Australia's Clean Energy Regulator). Range of values were calculated to address variations in the area and sequestration potential for each vegetation type.	Interagency Working Group on Social Cost of Greenhouse Gases [29]; Australian Government [30]; Roelofs et al. [31]
Cultural	Storm protection and erosion control	Not bought/sold in the market, so no economic impact	Not bought/sold in the market, so no economic impact	Values were estimated for the length of coastline of urban localities along the NT coast containing mangroves, using an average benefit transfer value derived from two referenced studies.	Das and Vincent [32]; Costanza et al. [33]
	Genepool protection	Not bought/sold in the market, so no economic impact	Not bought/sold in the market, so no economic impact	Applying benefit transfer value from TEEB database for the genepool/nursery of mangroves and seagrasses in the NT coastal and marine waters that maintains continuity.	Chang et al. [34]; Beaumont et al. [35]; McArthur and Boland [36]; Turpie et al. [37]; all from TEEB [7] database (developed by Ref. [38])
	Recreational fishing	Applying the amount of expenditure incurred on recreational fishing related goods and services including boats, maintenance and repairs, etc.	Using a multiplier of 3.2 for the NT retail and wholesale sector, following Jarvis et al. [25]	Median value of \$183/trip/angler (based on three regional studies) was used for the average annual number of trips per angler.	Expenditure data from Northern Territory Government [39,40]—the DPIF survey 2010 report; and Angler surplus from Farr and Stoeckl [41]; Rolfe et al. [96]; Prayaga et al. [42]
Tourism	Tourism	Using the number of tourists visiting the NT coastal and marine waters, longevity of their stay and the expenses they incurred to visit the area, particularly for tourists visiting the coastal region.	Using a multiplier of 2 for the tourism industry as suggested by the State Tourism Satellite Accounts (2015–16).	Using benefit transfer for the median estimates of the consumer surplus associated with marine tourism across northern Australia (\$522 per visitor based on several studies) for the total annual number of marine tourists (302,200) in the NT	Tourism NT [43]; State Tourism Satellite Accounts (2015–16); Deloitte Access Economics [44]; Stoeckl [45]; Tremblay [46]; Knapman and Stoeckl [47]
	Aesthetics, amenity and other (non-fishing) recreational values	Not bought/sold in the market, so no economic impact	Not bought/sold in the market, so no economic impact	Using the average amount of expenditure per head per visit for the tourists visiting the coastal areas such as Kakadu National Park and others in the region.	O'Mahoney et al. [48]; Kragt and Bennett [49]; Fleming and Cook [95]; Knapman and Stanley [50]; Carr and Mendelsohn [51]; Buckley [52]
	Indigenous cultural values	Not bought/sold in the market, so no economic impact	Not bought/sold in the market, so no economic impact	Using replacement cost for food (turtle and dugong hunting), and other well-being benefits that people derive from accessing the coastal and marine resources.	Delisle et al. [53]; Sangha and Russell-Smith [54]; Sangha et al. [55]; Social Ventures Australia [56]; Barber et al. [12]; Adams et al. [57]; Jackson et al. [58]

obtain from ecosystems. The NT coastal and marine waters supply a diverse range of these services including fish, oysters, shellfish, mud crabs, prawns, crocodiles, mangroves and other sources of food, leather, jewellery, etc. [8]. We selected three main sub-categories of provisioning services i.e. commercial fisheries including aquaculture, and pearl and crocodile cultivation. To evaluate these services, several publications (i.e. government and business reports) as outlined in Table 1 were reviewed and analysed for calculating their direct and indirect market value. Since provisioning services were marketed, so their values were obtained directly from the market (i.e. direct impact; e.g. market value of fish) and indirectly from the expenditure related to market values, e.g. value of fishing vessels to catch fish.

2.4. Regulating services

Only three regulating ES were evaluated, i.e. blue carbon stocks using the current market price for the amount of carbon sequestered in seagrasses and mangroves; storm protection and erosion control using the replacement cost for building a storm wall; and genepool protection using average benefit transfer values from four relevant studies listed in the TEEB (The Economics of Ecosystems and Biodiversity) database (Table 1). Value of the carbon stock was estimated using sequestration rates for the extent of mangroves, seagrasses and tidal saltmarshes, multiplying that by a carbon price of \$12.10/tCO₂e (an average price from past three auctions held by Australia's Clean Energy Regulator; <http://www.cleanenergyregulator.gov.au/>). Storm protection value was estimated from saving the urban localities coastline from storms and cyclones using a replacement cost for a storm wall following Das and Vincent [32] and Costanza et al. [33]. Likewise, genepool was estimated for the continuity of nursery of mangroves and seagrasses in the NT coastal and marine waters (following [6]; details in Table 1). Because these services have no direct or indirect impact in the market, so only their economic value was estimated.

2.5. Cultural services

Only some of the cultural services, recreational fishing and tourism, listed in Table 1 are directly linked to markets for expenditure associated with those activities, so we have some estimates of their contribution to GDP. For aesthetic, amenity and other non-fishing recreational values, we used the average amount of expenditure/head/visit for tourists visiting the coastal areas. There are many indirect links (e.g. property prices higher for houses with sea views) enabling us to infer economic values (transferring estimates, for example, from hedonic pricing for aesthetic values, and travel cost studies for recreational use values – from tourism and recreation, above and beyond monies spent in the market). Despite the fact that there is much qualitative evidence of cultural values associated with intellectual and representational interactions with nature, we were unable to find any studies that could be used to infer relevant values for the NT – mostly likely because our current tool-kit of non-market valuation studies does not yet include techniques that facilitate the valuation of goods and service that generate complex inter-related benefits for society as a whole [20]. There is much evidence of contribution that spiritual, symbolic and other interactions with the marine environment make to well-being, enabling us to transfer estimates from other (mostly contingent valuation and choice modelling) studies.

Cultural values of the NT marine and coastal waters are particularly important for Indigenous people, given the importance of Indigenous connections to country including both land and sea. We acknowledge that in many societies it is considered unethical to value some types of cultural services, particularly spiritual [63], but also note that to omit them altogether is to risk them being given an implicit value of zero. Indigenous cultural values were thus assessed in two ways: i. applying a substitute value for the well-being benefits that people obtain from their coastal/marine systems; ii. Supplementing information from a

replacement cost study of value for the amount of food obtained from accessing the coastal resources. For method (i), we only accounted for 25% of the total government welfare expenditure on healthy lives, early childhood learning and development, secure environment, and economic development that directly link to the services people accrue from the NT coastal and marine resources (details in Ref. [55]). For method (ii), replacement cost for turtle and dugong hunting was used from relevant local studies.

An overview of above-mentioned techniques and related sources is provided in Table 1, with a more detailed explanation of approaches provided below the relevant ES table in the results section. This integrated approach allows to quantify the contributions that different ES associated with the NT's marine environment make to (a) GDP; and (b) human well-being.

Where the ES values were presented in other currency than AUD, these were first changed to USD for the year of study, converted to AUD and then updated to 2017 using the official corresponding exchange rate from the World bank database (<https://data.worldbank.org/indicator/PA.NUS.FCRF?type=points&view=map&year>).

3. Results

The total economic impact of provisioning services, as reflected in the market, accounted for \$359 m/yr including 788 jobs, and the economic value, as contributions towards people's well-being, was worth \$218 m/yr (Table 2). The estimated conservative value of annual amount of carbon sequestered by mangroves, seagrasses and tidal marshes in the NT coastal waters accounted for \$39 m/yr (lower-bound; or \$468 m/yr as upper-bound value) (Table 3). Only 9,327ha of mangrove habitat within 1 km of urban areas along the coast of the NT was

Table 2

Value of provisioning services from the NT coastal and marine resources (in 2017 \$ values) as contributions directly to NT economy—Economic Impact, and to the well-being of people—Economic Value, including the number of jobs in each sector.

Provisioning services	Total economic impact (estimated as direct and indirect market value) \$m/yr	Economic value- contribution to NT Economy	
		\$m/yr	Jobs
Commercial fishing & Aquaculture	128.34 (Direct) + 51.26 (Indirect) = 179.6 ^a	128.34 ^a	424 ^b
Pearl cultivation	24.88*2.8 (Total) = 69.66 ^c	49.56	100 ^d
Crocodile cultivation	64.49 (Direct) + 45.37 (Indirect) = 109.86 ^c	64.49 ^f	264
Total value	359.12	217.71	788

^a DPIF [22] - \$124.3 m/yr worth direct economic output including aquaculture, and \$99.8 m/yr excluding aquaculture; and \$49.7 m/yr additional output for the rest of the economy (values were reported in 2015 which were updated to 2017 using RBA inflation calculator).

^b DPIF annual report [22] for year 2015–16 and outlook [23]; ABS [64] - Catalogue no. 5220.0 (cited in Ref. [22]); ABS [24]- year book; and ABS [94] census data suggesting 149 jobs in the relevant Agriculture, Fisheries and Forestry sectors (assuming 1/2 of those jobs exist in the fisheries).

^c Pearl Producers Association [26]; and ABS [24] suggesting direct market value of \$19 m/yr during 2009–2010 which was updated to 2017. Then a multiplier of 2.8 for aquaculture, forestry and fishing sector in the NT was used following Jarvis et al. [25] to estimate total impact in the absence of any indirect impact value.

^d Pearl Producers Association [26]. In total 600 jobs are created by the Paspaley Company with six distribution centres, we assumed 1/6th of those will be in the NT due to its base in the region.

^e Direct and indirect market value from CFANT and the NT Government (2015) Strategic plan 2015–2021; Ernst and Young (EY) and the Department of Trade, Business and Innovation (DTBI) [27].

^f Additional market value reported by EY and DTBI [27].

used to estimate their protection value for the coastal populations from storm surges, high speed winds and waves, floods and for preventing soil erosion; affording services worth at \$116 m/yr. To account for the diversity of genepool and its protection, the value was estimated for affording continuity of habitat services at \$67 m/yr using TEEB database [6] (Table 3). It is important to note that mangroves in the NT are highly diverse and endemic with more than 50 species representing 35% of total mangroves in Australia and 2.5% worldwide [71].

For cultural services, the total impact of recreational fisheries was estimated at \$251 m/yr, which constitutes a direct market value of \$78.5 m/yr from expenditure incurred by the anglers and other fishing-related expenses and its multiplier of 3.2 (in the absence of any indirect impact value) for measuring the total impact. Tourism is a major sector attracting international and national visitors to the region, offering an economic impact of \$691 m/yr and an economic value of \$156 m/yr including 5,530 jobs, based on the number and average expenses per tourist (using a multiplier of 2 following State Tourism Satellite Accounts 2015–16 by Tourism Research Australia [72]) for calculating the impact and an average median consumer surplus (\$522/visitor) for the total economic value. About 120,000 non-Indigenous and 35,000 Indigenous population live within 200 km of the coastline who enjoy their special cultural connections with the NT coastal and marine waters [9]. Aesthetic, amenity and non-fishing recreational values were only assessed for non-Indigenous users who visit the beach regularly at a cost of \$178/yr, delivering an economic value of well-being benefit worth \$21 m/yr in total.

Indigenous cultural values of the NT coastal and marine environments comprise a variety of links with people's well-being including food, art and craft, spiritual, language, customary, learning and others. But only the food value for the coastal Indigenous population, affording a lower estimate of \$52.5 m/yr, and the substitute value of government welfare benefits, an estimate of \$395 m/yr, were assessed (as shown in Table 4).

Overall, the economic impact of selected cultural services was estimated at \$942 m/yr. Depending on lower or upper bound, the economic value of cultural services varied between \$235–\$557/yr (Table 4).

4. Discussion and conclusion

This economic assessment of NT marine and coastal resources is the first of its kind at a state (territory) scale in Australia, suggesting the total economic impact of selected services at \$1.3b/yr (in 2017 values) and the economic value, estimated conservatively, at \$674m–\$1.4b/yr, in addition to creating > 6,000 jobs. This article is based on an earlier report by Crossman et al. [8]; commissioned by the Australian Marine Conservation Society (AMCS). Data from that report was further analysed and refined to offer reliable and robust economic assessment including details of methods for informing similar local/global development initiatives, particularly where Indigenous and local communities values are imperative yet are not reflected in the policy arena. Usually, the underlined economic value of ES largely remains hidden (Table 5) mainly because of the absence of appropriate measuring tools [74–76]. Ignorance of appropriate economic values in policy decision-making is a well-recognised topical issue across the globe at various local, national or regional scales [5,7,17]. By assessing the monetary values of the NT coastal and marine resources, this study addresses that critical gap to inform development policies in northern Australia and elsewhere.

Among the selected ES, the economic impact and value of cultural services including recreational fisheries, tourism, aesthetic and amenity values, and Indigenous values is particularly high. The jobs offered through cultural services-related sectors (e.g. tourism) are seven-fold than those in sectors related to provisioning services (i.e. commercial fishing, crocodile and pearl farming). Underlining the value of these services for Indigenous people (\$52–\$393 m/yr) offers a reliable estimate for decision-makers to understand the importance of NT coastal

and marine waters. Our assessment, applying a substitute value for government welfare expenditure and replacement cost for food, affords a conservative estimate as locals hold multiple values [11]. Challenges to evaluate monetary value of cultural services are well discussed by Milcu et al. [77] who reviewed 107 articles, out of which 12 estimated monetary values that were only related to recreational and tourism and other values were more descriptive or narrative. Typically, for ES assessments the monetary value of Indigenous cultural services is missing due to associated complexity. There are several alternative methods such as deliberative decision making, relational value, narrative, scenario planning or subjective values that are useful to inform decision making [99,55,78,79].

We used economic valuation tool to inform the NT Coastal and Marine strategy which was released in March 2018 [16] as the uptake of economic assessments has been strong in Australia particularly among the commercial fisheries and recreational sectors but limited globally [80]. In addition, it informs national 'Developing the North' agenda proposed by the Australia Government [81]. The foundation report by Crossman et al. [8] was well publicized by the media and AMCS with its launch at the NT Parliament House.

Although estimated economic value of NT marine and coastal ecosystems at \$1.4b/yr represents only ~5–6% of the NT Gross Domestic Product (GDP) in 2016–17 (\$25.4b), these resources support several sustainable and unique nature-based enterprises and afford local employment. Most importantly, exceptional natural wealth in the NT such as vast and pristine savannas, Indigenous cultural and heritage sites of international significance – Kakadu National Park, wild rivers and unspoiled coastal and marine resources, offers distinctive opportunities to realise sustainable development in the north as advocated by Russell-Smith et al. [15]. However, this view of sustainable development is challenging for the current government vision described in 'Developing the North' policy agenda [81]. Our ES assessment thus offers a critical and valuable perspective for highlighting the importance of nature-based economies not just for the NT but for the whole northern region.

To develop northern Australia, existing nature-based opportunities in the NT such as recreational fishing, commercial fisheries or aquaculture, can be expanded and developed by applying equitable benefit-sharing principles and appropriate governance mechanisms [82]. Currently, Indigenous people have rights to > 80% of the NT coastline, but they only own a very few businesses, namely crocodile farming or art and craft in few locations. Most of the Indigenous businesses are social entity. In comparison, a few private business owners such as Safari hunting in the Garig Gunak Barlu NP or King Ash Bay Fishing club in the Carpentaria Gulf operate very successfully, without delivering or sharing any benefits with the local communities who contribute substantially towards the provision of resources to afford those eco-businesses. Using common assets for supporting private business interests is a typical situation at many places across the globe which is largely attributed to market failures [76,83,84]. Further, it results in compromising the interests of many local and Indigenous communities under the label of 'development' [84,98]. The ES-economic assessments offer a reliable tool to analyse the landscape-scale opportunities and distribution of benefits to support equitable and sustainable use of resources. Such assessments could be used to develop Payments for ES (PES) mechanisms to ensure equitable benefit delivery to the local communities [6,85,86]. Moreover, implementation of PES can help advance five Sustainable Development Goals (SDGs), i.e. poverty, health and well-being, decent work and economic growth, reduced inequalities, and sustainable cities and communities, proposed by the United Nations [87] for advancing well-being and development of local and Indigenous communities.

Following PES, currently the savanna landscape offers substantial carbon abatement and sequestration opportunities with existing abatement methodology operating above 600 mm rainfall isohyet across northern Australia delivering ~\$40 m/yr to the locals [88]. If carbon abatement and sequestration methodologies apply to the coastal

Table 3
Total economic value of regulating services from the NT coastal and marine resources.

Vegetation type	Extent (000 ha)	Carbon stock (t C/ha)	Annual sequestration rate (t C/ha/yr)	Total economic value ^a (\$m/yr)
i. Blue carbon				
Mangroves	334 ^b –380 ^c	1,500 ^g –2,139 ^h	1.74 ^b –3.5 ^k	39–468
Seagrasses	70 ^d –90.6 ^e	50.8 ⁱ –610 ^g	0.54 ^h	26–292
Tidal saltmarshes	500.5 ^f	69.77 ^j	0.55 ⁱ –1.5 ^h	2–11
ii. Storm protection and erosion prevention from mangroves	9,327 ⁱ	Protection service \$12,444/ha/yr ^m		11–165
				\$116
iii. Conserving and valuing biodiversity for its gene pool and continuity of habitat services	334,000 ha area of mangroves; 70,000 ha of seagrasses; and 500,000 ha of tidal saltmarshes ⁿ			67.3
Total value				222–651

^a Total area was multiplied with the annual sequestration rate and those C estimates were converted to CO₂-e by multiplying with a factor of 3.664 and then the price of C. Price of \$AU 12.10 per tCO₂-e average carbon price from the past three auctions held by Australia's Clean Energy Regulator [65]. Price of US\$ 42 is a central estimate of social cost of carbon for 2020, at 3% discount rate (in 2007 USD; equals to USD 48 or AUD 60 in 2017), derived from Ref. [29].

^b Australian Government [30].

^c Northern Territory Government factsheet https://nt.gov.au/_data/assets/pdf_file/0007/204694/mangrove-education-pack.pdf.

^d Roelofs et al. [31].

^e Estimate of seagrass habitat along 671 km coastline of Gulf of Carpentaria, all in the Northern Territory, from Kirkman [66].

^f Bucher and Saenger [67].

^g Howard et al. [93]. Existing C stock is not evaluated in here.

^h Estimates from a global database in Alongi [68].

ⁱ Estimates for tropical Australia from Lavery et al. [69].

^j Estimates for soil only from Macreadie et al. [65]. Soil OC comprises about 95% of total carbon in tidal salt marshes.

^k Lovelock and Ellison [70].

^l Area of all mangroves mapped in the Geoscience Australia Coastal Waterways Habitat Mapping within 1 km of Urban Localities, as mapped by the ABS [9].

^m Using average benefit transfer value from Costanza et al. [33] and Das and Vincent [32]; i.e. USD 8,470/ha (USD 9,357 in 2015) which equals to AUD 12,444 (in 2017) at an exchange rate of 1 USD = 1.33 AUD.

ⁿ Using TEEB database ES value for gene pool and nursery for mangrove and sea grasses. These values were first adjusted to USD for the year of study, converted to AUD and then updated to year 2017 using Official Exchange Rates from the World bank database (<https://data.worldbank.org/indicator/PA.NUS.FCRF?type=points&view=map&year>). An average value of \$99.76/ha/yr was used for mangroves and seagrasses and \$49/ha/yr was used for tidal saltmarshes.

Table 4

Total economic value of cultural services from the NT coastal and marine resources.

Cultural services	Coastal region 'marine' visitors ^a -no. and expenditure/person	Total economic impact \$m/yr	Economic value- contribution to NT Economy	
			\$m/yr	Jobs
Recreational fisheries (NT residents)	NA	78.47 (Direct)*3.2 = 251 ^a	5.58 ^b	
Domestic & International tourists ^c	302,200	345.6 (Direct)*2 = 691 ^d	156 ^e	5,530 ^f
	\$1,144			
Aesthetics, amenity and scenic, and non-fishing recreational values (for residents only)	120,000		21.4 ^g	
	\$178/person/yr			
Indigenous cultural values (food and overall well-being benefits)	Residents only	No suitable studies for benefit transfer found; but very few links to market, so the 'impact' is expected to be small.	52.5 ^h and 395 ⁱ	Difficult to measure
Total value		942	235–557	5,530 +

^a For direct impact, total estimate of expenditure on goods and services i.e. \$1500/angler*93% of that expenditure on recreational fisheries*no. of visitors 30,358 = \$43 m/yr (\$ value in 2015) ([92] (2009–10 survey)) was used. Since 80% of the fishing activities occurs in the marine waters so we discounted that value to 80%, i.e. \$34 m/yr in 2010 or \$38.1 m/yr in year 2015 which was multiplied by 2 (following State Tourism Satellite Accounts 2015–16) for additional indirect impacts of fishing; and the values were updated to 2017 values (hence \$78.47 m/yr). For indirect impacts, a multiplier of 3.2 was used following Jarvis et al. [25].

^b A median value of consumer surplus, \$183/angler/trip (based on regional studies by Refs. [41,42]) was applied to 30,500 tourists who visit the NT coast each year.

^c Marine-focused tourists (e.g. those going on diving trips, or fishing charters) may spend more than terrestrial tourists (likely, at least partially because of the cost of boat trips). If the total number of visitors to the NT remain unchanged, an increase in the proportion of those engaged with marine activities could generate an increase in the economic benefit of tourism.

^d Direct impact was estimated using the expenditure incurred per tourist (\$1,144) for total number of tourists (302,200) visiting the coastal region. For total impact, a multiplier of X2 (State Tourism Satellite Accounts 2015–16, Tourism Research Australia, Canberra) was used. We acknowledge that the distribution of jobs and income between Indigenous and non-Indigenous people is likely to be unequal (with a disproportionate share going to non-Indigenous people) unless tourism enterprises are specifically Indigenous and/or other measures are taken to redress structural problems that tend to skew the distribution of benefits (incomes and jobs) in favour of non-Indigenous people [91] (Stoeckl et al., 2014).

^e Using benefit transfer - multiplying median estimates of the consumer surplus (\$522 per visitor) associated marine tourism for the total number of tourists, based on several regional case studies as listed in Table 1.

^f Estimated employment (FTE) associated with marine tourism as 1 job per \$125,000 [43].

^g Estimated using average non-fishing recreational value of \$178/person/yr for 120,000 residents per year.

^h Estimated based on value of food (Turtle and dugong) hunting (@\$1500) by the coastal Indigenous population [53].

ⁱ Estimated as substitute value for 25% of the money spent by the Australian government on four sectors of Indigenous welfare (i.e. healthy lives, early childhood learning and development, secure environment and economic development that directly link to the services people derive from their natural systems; a total of \$45,201/person/yr [55,73]).

Table 5

Summary of ES valuations of the NT marine and coastal resources.

Ecosystem services	Economic impact \$m/yr	Economic value- contribution to the economy	
		\$m/yr	Jobs
Provisioning	359	217	788
Regulating	NA	222–651	
Cultural	942	235–557 (latter incl. well-being benefits)	5,530
Total value	1,301	675–1,425	6,318

areas, especially mangrove vegetation, then the associated economic opportunities are enormous. Likewise, several coastal and marine areas, such as King Ash Bay in the Carpentaria Gulf, can also afford considerable eco-tourism and fisheries opportunities in addition to offering local employment, saving the costs for welfare, domestic violence, and health, for remote Indigenous communities where currently employment opportunities are negligible [12,55]. Moreover, six marine reserves, two marine parks, and several IPAs support pristine environments of high conservation significance (Fig. 1). Nonetheless, unspoiled coastal and marine environments of the NT offer considerable and unique eco-tourism and other enterprise potential (e.g. art and craft, Indigenous cultural camps), but it firstly requires genuine consultations with the local communities to develop good management and governance strategies.

We acknowledge that the estimates presented in this paper are conservative for several reasons including: 1. Selecting a short rather than an extensive list of provisioning, regulating and cultural services

which could include variety of food - fish, mud crabs, prawns; mitigation of excess nutrients, purification and regulation of water flows; use of sea shells as ornaments, organisms or other features as totems; or the spiritual experience; 2. Missing the value of significant recreational events such as local and regional fishing competitions and festivals that happen over 6–7 months (from April to October) every year; 3. Lacking full assessment of millennia old, Indigenous cultural values e.g. songlines, customary practices and rituals, language, etc. which are difficult to evaluate. Moreover, there are no studies on ES of marine areas in the NT, and those from a neighboring state, Queensland, represent much greater values. For example, Prayaga et al. [42] suggested the recreational fishing values along the Capricorn coast of Queensland as consumer surplus per fishing trip worth \$2,360 per angler per annum in contrast to \$1500/angler/yr used in this study.

With greater recognition of marine and coastal resources towards economy, the international Organisation for Economic Cooperation and Development (OECD) has defined 'Ocean Economy' as the sum of the economic activities of ocean-based industries, and the assets, goods and services of marine ecosystems [89], whereas, others such as WWF prefer to use 'Blue Economy' for its focus on sustainable economic development including peoples' livelihoods and well-being. This assessment presenting figures for both economic impact and value clearly demonstrates the value of economic activities—Ocean, and goods and services for peoples' well-being, following the Blue Economies concept, supports sustainable development in the region.

Our current estimate of 5–6% contribution of marine and coastal ES to the NT economy is in line with a recent study of blue economy of marine resources in Australia suggesting a total direct contribution of \$74.2 b/yr i.e. 4.8% of the national Gross Domestic Product (GDP),

with > 400,000 full-time equivalent jobs [90]. However, with increasing pressure on coastal and marine resources and competing interests, maintaining sustainable, equitable and efficient use of resources is a challenge [89,90]. For that, local scale value assessments, like this one, can help inform policy decision-making for considering the value of not just marketable but many non-marketable services that are vital to support and enhance Indigenous and local communities' livelihoods and well-being across the globe.

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Appendix A. Supplementary data

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