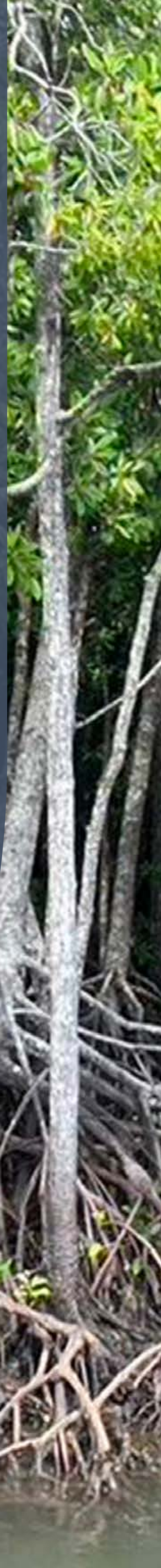
Australian Government
Department of Climate Change, Energy, the Environment and Water

Accounting for the benefits from coastal restoration:

A case study from East Trinity Inlet



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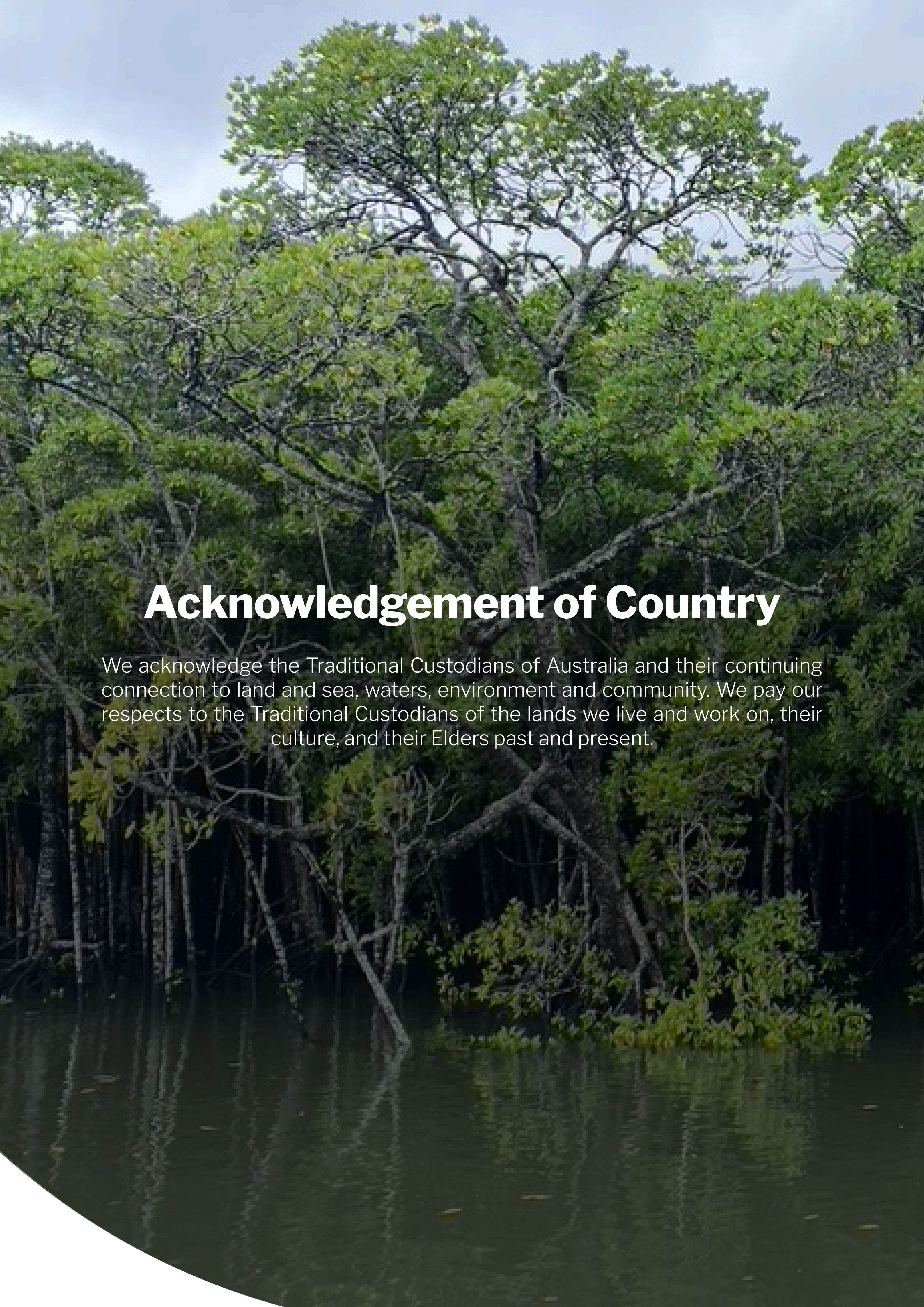

Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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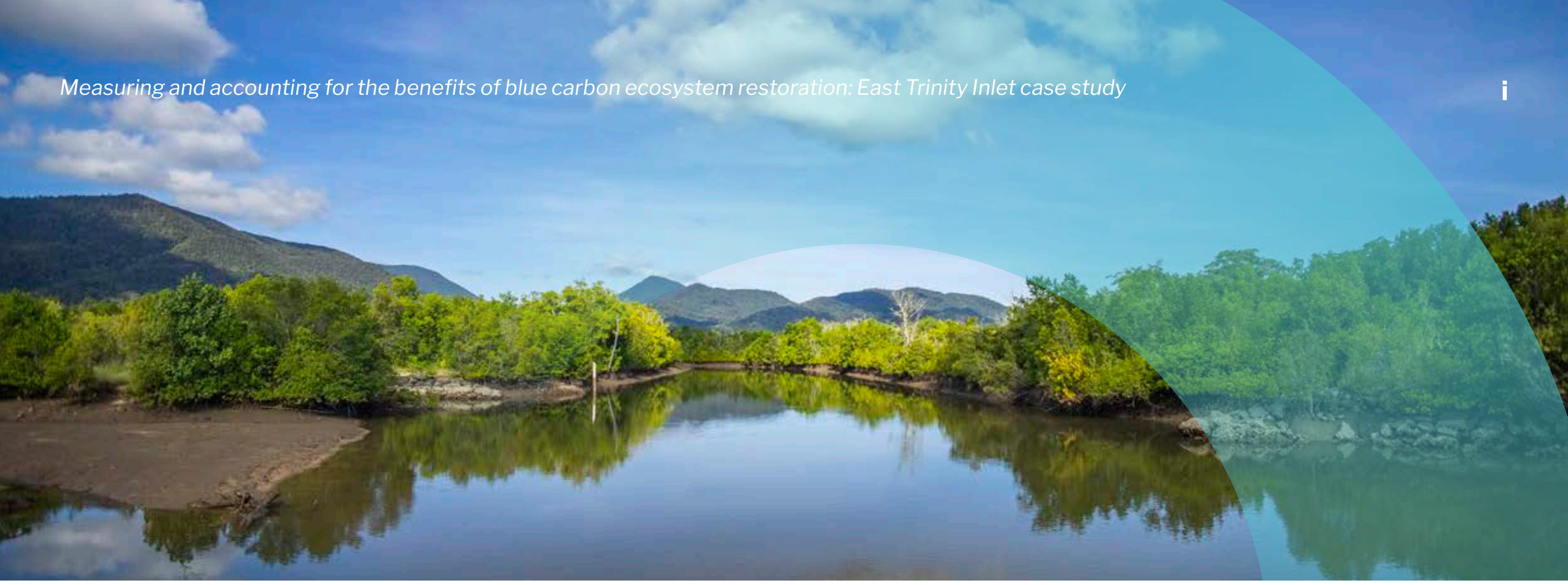

Executive Summary

This report was prepared for the Commonwealth Department of Climate Change, Energy the Environment and Water (DCCEEW) by a consortium led by Deakin University as part of a project to develop a Guide to Measuring and Accounting for the Benefits of Restoring Coastal Blue Carbon Ecosystems - Version 1 (hereafter the Guide).

This case study demonstrates how restoration of blue carbon ecosystems can benefit society by implementing the Guide, testing the proposed processes and methods in a real-world example of a blue carbon ecosystem restoration project. It provides a practical case study for potential users of the Guide. Since this case study was developed using existing data, rather than planned using the methods outlined in the Guide, in some instances the approaches detailed in the Guide had to be adapted to take this into account. This case study also includes a General discussion and lessons learned section and information on the author's Reflections relative to the Guide. These sections represent the authors' experience in developing and applying the Guide and case studies.

This case study implements the Guide and includes a cultural account, which was co-developed with the Mandingalbay Yidinji people, on whose country the site is located. This case study assesses the benefits of the restoration of a site in East Trinity, a region containing a mixture of wetland habitats (which include mangroves and salt marshes), adjacent to the east of Cairns. This site has been impacted over the years by works that resulted in extensive acid sulphate soil formation and in 2001, the Queensland Parks and Wildlife Service began remediation of the site. The restoration resulted in ecological improvements and effective remediation of acid sulphate soils across most of the site, including reduction of acid run off.

The process used to document the impacts of the restoration at East Trinity was designed around the System of Environmental Economic Accounting Ecosystems Accounting (SEEA-EA) method, which employs a rigorous approach to building accounts that can be used to inform decision making. Various methods were used to measure and estimate changes to the ecosystem services provided by the site following restoration.

This report presents the results of the application of these methods to assess changes produced by the restoration activities in relation to:

- ecosystem extent and condition, particularly in relation to salt marsh, mangroves and forests.
- ecosystem services including carbon sequestration and emissions; water purification; coastal protection; fish nursery and biomass provisioning; and Indigenous cultural values and services as well as recreational services such as fishing, tourism and birdwatching.

The results are used to facilitate the development of a set of output SEEA tables, which are included in this document.

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Results

Some key biophysical results of the restoration project are presented in **Table ES1**. Analysis of ecosystem extent found a net increase in blue carbon ecosystem extent of 110 hectares. Increase in saltmarsh extent was largely offset by decrease in mangrove extent. Other land covers decreased significantly while waterbodies increased.

In relation to condition, an increase in the connectivity of coastal ecosystems excluding mangroves was identified. A decrease in connectivity of other land covers was associated with the increase in saltmarsh, supratidal forest and waterbody ecosystem connectivity. An increase in above-ground biomass was detected for supratidal forest and other land covers. Increased vegetation cover and greenness for mangrove and other land covers was also detected, indicating increases in plant health. Landscape wetness of all vegetated ecosystem types decreased post-restoration.

Analysis of First Nations cultural values, a range of ecosystem service values and other impacts are summarised in **Table ES2**. East Trinity provides a range of cultural services to the Traditional Owners. First Nations cultural services relate to harvesting, ceremony, knowledge generation, transmission and governance. The site is important to Traditional Owners for identity, recreation, wellbeing, family and community. The analysis of cultural services demonstrates the circular nature of ecosystem services, as it includes both services derived from the ecosystem, but also other services, such as Caring for Country, which offer benefits to the ecosystem. Ecosystem service values included increases in recreational fishing and bird watching activities, significant water quality improvements, and carbon abatement changes.

Table ES.1: Key estimated ecosystem extent and condition impacts of the East Trinity Restoration Project

	Aspect measured	Change attributable to the project
Ecosystem extent	Area of blue carbon ecosystem	+110 ha
	Supratidal forest	+109 ha
	Saltmarsh	+9.9 ha
	Mangrove	-9.1 ha
	Waterbodies/mudflats	+46.7 ha
	Other land covers (Cultivated areas, bare areas and artificial surface land cover)	-157 ha
Ecosystem condition	Mangrove - Vegetation cover	Increasing: 160 ha; Decreasing: 198 ha; Net: -38 ha
	Mangrove - Above-ground biomass	Not provided
	Mangrove - Vegetation greenness	Increasing: 290 ha; Decreasing: 69 ha; Net: 221 ha
	Mangrove - Landscape wetness	Increasing: 176 ha; Decreasing: 182 ha; Net: -6 ha
	Mangrove - Connectivity	No change
	Saltmarsh - Vegetation cover	Increasing: 2 ha; Decreasing: 3 ha; Net: -1 ha
	Saltmarsh - Above-ground biomass	Increasing: 4 ha; Decreasing: 1 ha; Net: +3 ha
	Saltmarsh - Vegetation greenness	Increasing: 1 ha; Decreasing: 4 ha; Net: -3 ha
	Saltmarsh – Landscape wetness	Increasing: 2 ha; Decreasing: 3 ha; Net -1 ha
	Saltmarsh - Connectivity	Marginal increase (0.03 index points)
	STF – Vegetation cover	Increasing: 104 ha; Decreasing: 131 ha; Net: -27 ha
	STF – Above-ground biomass	Increasing: 158 ha; Decreasing: 77 ha; Net: +81 ha
	STF – Vegetation greenness	Increasing: 109 ha; Decreasing: 127 ha; Net: -18 ha
	STF – Landscape wetness	Increasing: 116 ha; Decreasing: 120 ha; Net -4 ha
	STF - Connectivity	Marginal increase (0.05 index points)

Table ES.2: Key estimated ecosystem service impacts (and selected other impacts) of the East Trinity Restoration Project.

Component	Aspect measured	Change attributable to the project (2022 data unless otherwise stated)	$AUD ($2022 unless otherwise stated)
Cultural services – First Nations	The aim of this project was to identify First Nations values and cultural services	East Trinity provides a range of cultural services to the traditional owners. These include services from harvesting, ceremony, knowledge generation, transmission and governance. Emphasis is on the importance of the site for identity, recreation, wellbeing, family and community. Account also demonstrates the circular nature of ecosystem provision, as it includes both services derived from the ecosystem, but also other services, such as caring for Country, which offer benefit to the ecosystem. Economic values were not estimated for First Nations values.	
Cultural services – recreation	Recreational fishing	9,125 fishing trips per year	$187,063 per year ($474,500 welfare value)
	Recreational bird watching	180 birdwatching trips per year	$17,712 per year ($31,446 welfare value)
Water quality	Removal from water of Nitrogen, Total Suspended Solids, Total Phosphorus	7 tons of N, 1,220 tons of TSS, and 1.1 ton of TP per year	$119,646 per year
Carbon abatement	Emissions avoided	2,307 t CO2e – 37,419 t CO2e over analysis period*	$62,645 - $5,612,921 over analysis period
	Carbon sequestered in vegetation and soil	79,578 t CO2e – 104,268 t CO2e over analysis period*	$2,447,023 - $15,640,268 over analysis period
	Net abatement amount [avoided emissions + carbon sequestration]	81,615 t CO2e – 141,688 t CO2e over analysis period*	$2,509,667- $21,253,189 over analysis period
Existence value	Community existence value for restoration	Value of community preferences for wetland restoration	$22,932 per year (welfare value)
Restoration costs	Total cost of restoration over project period	Tidal gate modification and removal, 1.2 km of additional levee, maintenance and monitoring, pest management	$9,822,961 in combined expenditure since 2001

**Calculations from using the nationally consistent approach or detailed approach, the detailed approach provided higher apparent benefits than the national approach.*

Reflections

The results from the East Trinity case study highlight that overall, the restoration of coastal wetlands at the site provided diverse ecological (extent, condition, and water quality), socio-economic (First Nation, recreational and existence), and climate benefits (carbon sequestration and emissions).

The application of the SEEA-EA framework as articulated by the Guide demonstrated the utility of the Guide but also revealed some challenges. One of these was the difficulty of aligning First Nation accounting with the SEEA-EA framework. Another challenge was the lack of data across some aspects (notably condition and extent accounts), which made collection of information and then analysis of associated ecosystem benefits more difficult. Variability between the resolution, detail, and spatial nature of data sets also posed challenges. A clear and defensible set of condition indicators will be needed by project proponents at the start of a project to ensure the integrity of restoration actions over time. While many aspects of condition can be estimated, it is challenging to define and then measure a limited set of indicators that appropriately encompass the relevant changes that a restoration project produces, particularly as some changes will inevitably be unpredictable. These hurdles are discussed in greater detail in the relevant sections.

This case study demonstrates the value of restoration of blue carbon ecosystems and demonstrates the application of methodologies that can be used in other areas.

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1. Introduction

1.1 Introduction to this report

The ability to measure the impacts of restoration projects in blue carbon ecosystems is critical for demonstrating the diverse benefits that restoration projects produce. The report, ‘A Guide to Measuring and Accounting for the Benefits of Restoring Coastal Blue Carbon Ecosystems’ was developed to describe a process and methodologies to measure the services these ecosystems can provide, including value provided to Traditional Owners, commercial fisheries, recreational activities, carbon sequestration, and coastal protection.

The Guide outlines recommended methods that should be used to establish a baseline, monitor, and report on the benefits of restoration projects in blue carbon ecosystems. To test this guidance and demonstrate how it can be used in practice, the process and methodologies outlined in the Guide were applied to two case study areas, and any deviations from the Guide are explained where they have occurred. This report outlines its application to a restoration project in the East Trinity Inlet blue carbon ecosystems in Queensland, Australia.

1.2 East Trinity, Cairns

The East Trinity restoration site is part of Queensland’s Wet Tropics World Heritage Area. Adjoining areas include Grey Peaks National Park, Trinity Forest Reserve, Malbon Thompson Forest Reserve, Great Barrier Reef Coastal Marine Park and Trinity Inlet Fish Habitat Area. The site contains a mixture of wetland habitats including mangroves and saltmarshes and is located directly to the east of Cairns. The restoration area itself is surrounded by mangrove and saltmarsh ecosystems that have not been impacted by land reclamation works (**Figure 1.1**).

In 2000, the Queensland Government bought 940 ha of land in East Trinity to protect the Cairns scenic rim from development. This included an area of 774 ha of abandoned sugar plantation with acid sulphate soils (ASS). Restoration by Queensland Parks & Wildlife Service began in 2001. Since then, Queensland Parks & Wildlife Service has conducted ongoing acid sulphate soil remediation as well as feral pest and weed control. Previous surveys have indicated ecological improvements, with regrowth of supratidal forest, mangroves, and the return of wetland plant and animal species (e.g. the spectacled flying fox and southern cassowary). Soil remediation has been effective across much of the site and has reduced acid run-off into Trinity Inlet.

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1.3 Cultural significance of East Trinity wetlands

The restoration area is on the traditional lands of the Mandingalbay Yidinji people, who still live and work in and around the site. The site and surrounding parks and reserves (Grey Peaks NP, Trinity Forest Reserve) host many historically significant sites like middens and meeting places. The Traditional Owners hold knowledge of these sites. In 2006, the Australian Government recognized Native Title pertaining to the site and some surrounding areas, based on evidence of long term (pre-European) residence and culture.

Stories of Mandingalbay Yidinji Country inform tradition, social order and norms, as well as guidance for what - in western tradition is now understood - as 'ecologically sustainable management practices'. The restoration site therefore relates to the wider land, sea, flora, and fauna in both meaning and practice, and is a part of Country integral to the identity and values of the Mandingalbay Yidinji people.

Taking account of traditional values is essential for generating authentic and transparent environmental accounting, and for nature repair. This case study aims to build a framework that is co-created with the Traditional Owners, as best practice, to rightly acknowledge traditional economies and management of Country over millennia. Elder Vincent Mundraby, a leader in the Native Title claim, encapsulated this perspective;

'The richness and diversity of resources on our land and sea Country and our sustainable use and management of those resources, gave us a strong traditional economy for thousands of years. We established semipermanent camping areas always within easy reach of year-round food supplies.' - p.7 (Tabled Paper 3.1 Public Hearing 18/10/2012)

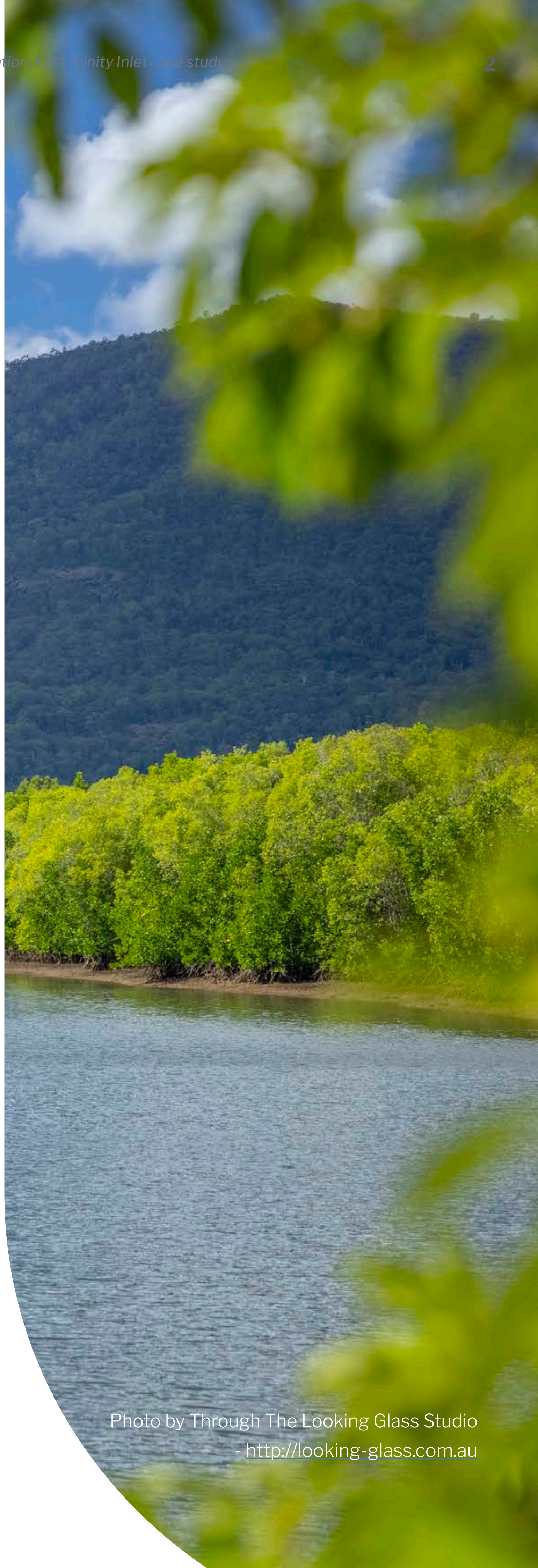

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Figure 1.1: Aerial imagery of the East Trinity Inlet restoration project, with downtown Cairns to the West. Image from Nearmap.

1.4 Recent history prior to restoration

Prior to restoration, this site had been heavily degraded starting in the 1970s because of clearing and drainage of wetlands for agriculture. A 7 km-long bund wall was erected to prevent any tidal effects within the wetland area, effectively disconnecting the habitat from the ocean nearby. In addition, the pyrite-rich sediments within the wetland were now exposed to the air since tidal flows had stopped, causing the soils to begin releasing very large quantities of acid sulphates. This in turn made the waters within the wetland highly acidic, leading to fish kills within and outside the wetland whenever large downpours occurred[1]. An estimated 3,000 tonnes of sulphuric acid was released annually[2]. As a by-product of the change in tidal regimes, nearly all mangrove and saltmarsh habitats were lost and replaced with various species of paperbark (Melaleuca spp.). The highly acidic waters (pH < 1) relative to natural wetlands (pH > 6) also meant that only three aquatic species of fish and crustaceans were able to survive within the site.

1.5 Restoration project description

The 740 ha wetland site was purchased by the Queensland State Government in 2000 with the aim of restoring the site and stopping acid sulphate runoff. A collaboration between Department of Science, Information, Technology and Innovation (QLD Govt.), CSIRO, the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment, and Southern Cross University assessed the site using detailed surveys and hydrological models to determine the optimal path forward. While numerous methods were considered, the only financially viable option was to reintroduce tidal exchange in a controlled fashion, and supplement this with lime to neutralise additional acid flows.

Tidal flows were reintroduced by modifying existing flow gates, so inundation levels were 0.5 m above sea level. Tidal height would then be progressively increased once enough acid sulphates had been neutralised. The initial height of inundation was chosen based on a modelling forecast, which showed that most soils in the area would be kept wet more frequently, preventing the production of acids. Even in these conditions, some acid flows that could impact the nearby waterways would still be produced, so an automated lime dispenser was used to treat waters that were below pH 6. By 2016, after a slow increase to the maximum height of tidal exchange, there was little evidence of acid being released into the system, and lime release was discontinued.

Aside from the reduction in acidic waters, the tidal reintroduction resulted in visible changes to the wetland. These included diebacks of Melaleuca woodlands and increases in the area covered by mangroves and mangrove fern (*Acrostichum aureum*). Pastures were replaced by low woodlands and native grasses (*Phragmites karka*). Species richness and abundance of fishes and crustaceans increased, including the mud crab (*Scylla serrata*) of commercial, recreational, and traditional importance. Fishes and crustaceans are now predominantly euryhaline species capable of living in brackish water[3]. Given the response times for animals is typically longer than for flora, it is expected that the abundance and diversity of animals within the restoration site will increase for many more years. Crucially, the abundance and diversity of species within the site is now not significantly different to a natural, undisturbed wetland nearby[4].

As the site remediation project was considered successful, the site was returned to Indigenous ownership and management.

[1] Hanabeth, L., Martens, M. A., Moon, E. M., Smith, D., Ward, N. J. & Bush, R. T. (2017). Ecological restoration of a severely degraded coastal acid sulfate soil: A case study of the East Trinity wetland, Queensland. Ecological Management & Restoration, 18(2), 103-114.

[2] Hicks, W. S., Bowman, G. M. & Fitzpatrick, R. W. (1999). East Trinity acid sulfate soils Part 1: Environmental hazards. Technical Report, CSIRO Land and Water.

[3] Sheaves, M. & Abrantes, K. (2016) Fish and crustacean communities of East Trinity 15 years after remediation of acid sulphate soils. Report to Queensland Department of Science, Information Technology and Innovation, Brisbane.

[4] Russell, D. J., Preston, K. M. & Mayer, R. J. (2011). Recovery of fish and crustacean communities during remediation of tidal wetlands affected by leachate from acid sulfate soils in north-eastern Australia. Wetlands Ecology and Management 19(1), 89-108.

1.6 Methods used to measure and value the restoration project

The approach used in this study to report on the value of blue carbon ecosystems is based on that of the System of Environmental Economic Accounting Ecosystem Accounting (SEEA–EA) method developed by the United Nations Statistical Commission . While there are other approaches that can be used for ecosystem accounting, the SEEA approach has been adopted to inform policy in more than 92 nations and therefore has global recognition. It employs a rigorous approach to building accounts that can be used to inform decision-making by allowing cost-benefit analyses or increasing broader awareness of the value of ecosystems. This approach was the basis of the methodology developed specifically for measuring the benefits of blue carbon ecosystem restoration in the Guide.

Various methods were used to measure and estimate the changes to ecosystem extent and condition as well as changes to the ecosystem services produced on the site following restoration. These are described in detail in subsequent sections.

1.7 Aims of case study

The aims of this case study are:

- To test the process and methods recommended in the Guide, which was in draft form when the case study was implemented. The experience of applying the Guide to a site allows for a greater understanding of the appropriateness of the guidance in the Guide, and feedback to improve this guidance.
- To facilitate the development of a set of output SEEA tables from a restoration site, which are included in this document.

One important contextual difference between this application of the Guide and future uses of the Guide is that we expect future users to apply the Guide to projects that are being planned or are newly commenced. These projects would apply the relevant monitoring approaches from the Guide to collect baseline data prior to restoration in order to capture the changes produced from restoration over time (planned).

However, to demonstrate the before/aftereffects of restoration when the Guide was applied, this case study relied on existing historical data from commencement of the restoration project until today. As a result, monitoring requirements at the case study site were not set with the goals of the Guide in mind. Thus, when the Guide was applied to these case studies, methods sometimes deviated from those recommended in the Guide because of constraints associated with the availability of existing historical data. The affected sections outline why and the rationale behind the adapted methodology.

[5] United Nations et al. (2021). System of Environmental-Economic Accounting— Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available at: https://seea.un.org/ecosystem-accounting.

2. Analysis and design

The initial steps of the Guide provide the framework for implementing an assessment of a restoration project; elements that define the scale and scope of the project, which are then used in subsequent measurement of project impacts. The steps of this process are presented in **Figure 2.1**. In this section, we discuss the project team's experience in defining these aspects and define the outputs for the East Trinity Inlet assessment.

2.1 Step 1: Project scoping & framing

As per the Guide, the first step in implementing an assessment of a blue carbon restoration project is to define the project scope and frame, including the following components:

Spatial coverage

A spatial coverage must be defined that captures the extent of impact of the restoration project. As the initial objective of the restoration project was to eliminate outflows of acid sulphate soils from the wetland into Trinity Inlet, the spatial coverage of this case study was extended to the vegetated areas surrounding the downstream portions of the restoration site (**Figure 1.1**). Since all the causes for acid sulphate flows into Trinity Inlet occur within the restoration site, we expected all major changes to occur within the restoration area. However, since the main objective of the restoration project was to reduce flow-on impacts on the adjoining river system, we included the adjacent vegetated area most likely to be affected by changes in acid sulphate flows. For the same reason, we considered including the mudflats directly to the north of the restoration site as well as the surrounding water system itself. However, we excluded these areas due to a lack of primary data and time allocated for this case study.

Temporal coverage

The prescribed temporal coverage of these case studies defined in the project Terms of Reference was to have two snapshots; one representing the site before intervention, and one after. Projects using the Guide may wish to have additional timepoints where accounts are assessed so that trajectory of change may be measured, especially for systems that are subject to inter-annual variation. In this case study, however, only t¬¬he 'sum' effects of the rehabilitation were measured, and thus only two timepoints were assessed.

Restoration commenced on the project site in 2001, and data are in many cases available up to 2022. Consequently, these two years were chosen as start and end points for this case study. For data points that were not available for 2022, team members projected data forward to 2022. As stated previously, this is due to the retrospective nature of this case study. As outlined in the Guide, we recommend collecting data from the project site within the same accounting period where possible.

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1. Project scoping and framing

2. Account design

3. Identify and collect data

4. Account compilation

5. Repeat data collection and account compilation

6. Report results

Define:

1. Spatial coverage
2. Temporal coverage
3. Ecosystem assets
4. Metrics to be used for measuring condition
5. Ecosystem services of interest
6. Benefits and beneficiaries

Data collection methods for each component:

5. Ecosystem extent
Using pre-existing products or one of many Earth observation data options available, map the extent change of ecosystems in the project area using the Global Ecosystem Typology.

6. Ecosystem condition
Using a conceptual understanding of the ecosystems in question, develop a list of variables that can be measured against a baseline to inform ecosystem condition.

Ecosystem services - physical ( ) & monetary ( )

7. Global climate regulation - Carbon stocks, sequestration and emissions
Carbon sequestration and stocks can be estimated using BlueCAM, but some situations may require on-ground measures. They are typically reported as tonnes Carbon per ha, and can then be upscaled across the site using ecosystem extent. CO_2e (physical) converted to $ (monetary) using ACCU carbon price.

8. Water purification services
Using equations provided and information on inflow nutrient concentrations, inundation frequency, and extent, soil carbon and vegetation cover, the total N and P removed can be estimated and valued using an appropriate price on N and P.

9. Coastal protection: erosion, storm mitigation, and flood control services
Decide which of the three potential components of coastal protection (if any) is applicable to your site, then use a mixture of measurement and modelling to estimate. Value using Annual Average Damages or Replacement Cost.

10. Nursery population and habitat maintenance service
This represents the contribution to populations of fish and invertebrates, prior to them contributing to other services (e.g. commercial fisheries or tourism). Measured using field surveys or monitoring.

11. Fisheries biomass provisioning service
Measured using fisheries catch data, data on diet compostion (from stable isotopes), and extent of ecosystems. Valued using Gross Value of Product and total economic output.

12. Cultural services: recreation and non-use values
Measured using site-specific data collection or benefit transfer based on the most important values of the site. Currently, the SEEA framework only includes exchange values in te monetary account, such as values from direct visitation.

13: Cultural services: First Nations values
Indigenous worldviews are holistic, with individual services difficult to quantify on their own. However, Indigenous values are many and varied, and thus values to be measured need to be developed and co-designed with the relevant Indigenous groups/representatives and a 7-step process of data collection.

Environmental protection accounts

14 Restoration activities
Measured based on the physical actions at the site, but also project management and engagement as necessary for the specific project.

15 Restoration activities
The exchange values of the physical activities in 14.

Figure 2.1: Steps in compiling site-level environmental economic accounts of blue carbon ecosystems, integrating the steps from the SEEA-EA framework with the detailed methods considered here. Accounts where physical services are quantified is denoted by the tree icon and accounts where monetary services are quantified denoted by the money icon.

Ecological extent and condition

While we expect future users of the Guide to be planning or commencing new restoration projects, this case study was restricted to using existing historical data, and focused on a project that commenced many years ago. As such, historical data available from the inception of the restoration project was imperative for identifying how the project has led to changes in ecological extent and condition. Ecological extent of habitats was in this case measured exclusively from satellite imagery.

Ecological condition is a complex component of environmental economic accounting (EEA) that needs to be defined at the commencement of a restoration project to identify success targets (see **Section 3.2** for more discussion). In some instances, when assessments are being made post-hoc, condition will be assessed in the context of anticipated outcomes of restoration. We advocate users undertake scoping prior to selecting condition metrics and commencing condition assessments. The purpose of restoration should be characterised, and the selection of indicators undertaken only after the anticipated outcome of restoration is defined. Specific indicators of condition can then be selected that align with the purpose and proposed outcome. As per best practice, selection of condition metrics should follow the SMART principles of monitoring and evaluation, which specifies that indicators should be specific, measurable, achievable, relevant, and time-bound (SMART). Following these principles when selecting condition metrics will ensure that indicators are well-defined; relate to the purpose and proposition; and can be effectively applied to measure progress towards the proposed outcome of restoration.

Ecosystem service scoping

While users of the Guide will scope out the intended impacts of the restoration activities and the ecosystem services that they expect to enhance through restoration, for this case study the restoration activities took place over 20 years and the ecosystem services to be considered were defined in the project Terms of Reference, including:

- Traditional Owner values
- Recreational activities
- Carbon sequestration and emissions
- Water quality enhancement

Effects of intervention

Knowing the method of restoration intervention can help to identify the effects of restoration on extent and condition of ecosystem stocks and services. The effects that drive the changes in ecosystem function should be identified as the most important to measure. Since this project is reliant on existing historical data, it was simple to identify the effects of intervention. However, for those using the Guide when planning, expert advice can identify the likely effects of intervention, either from expertise alone or using modelling approaches such as hydrological modelling.

In this system, the progressive increase in inundation through controlled floodgate opening was the main intervention, with the added use of lime to control any acidic outflows. Over time, this increased salinity and changed the water level, driving changes in condition, extent and ecosystem services provided by the restoration site.

Stakeholder mapping

Identifying stakeholders to consult is critical to best understand the effects of a restoration project, collect relevant data, and provide a social license for restoration approaches (**Table 2.1**). A social license would provide broad support from the community to conduct the restoration project.

Table 2.1: Key stakeholders engaged

Stakeholder	Role
Mandingalbay Yidinji Aboriginal Corporation	Traditional Owners & co-managers, admin of Djunbunji Land & Sea Rangers
Mandingalbay Yidinji Aboriginal Corporation	Provision of anecdotal evidence on recreational fishing and birdwatching inside the restoration site
Department of Environment and Sciences	Provision on data on water quality and contribution of their knowledge on the restoration of Trinity Inlet Provision of vegetation mapping reports and datasets
Department of Environment and Sciences	Provision of anecdotal evidence of recreational fishing in the restoration site. Provision of data on restoration costs
Queensland Parks & Wildlife Service	Natural resources, compliance & remediation co-management
Great Barrier Reef Marine Park Authority	Policy on compliance & management of conservation & fisheries
Wet Tropics Management Authority	Policy on conservation & restoration management
Cairns Regional Council	Policy on development for infrastructure & business at the site, also public compliance & access
Yarrabah Aboriginal Shire Council	Documents on history of region, & local residents utilise & work at site
Ports North	Documentation on Trinity Inlet, environmental impact assessment re site
Tour operators (Fish Tales Charters)	Provision of anecdotal evidence about the contribution of East Trinity for recreational fishing activities outside the restoration site
Blue Carbon Lab (Deakin University)	Provision of unpublished carbon and nitrogen accumulation rate datasets

2.2 Step 2: Account design

Outputs from project scoping were used to inform the account design, particularly the temporal and spatial coverage. As noted, the scope of ecosystem assets and services to include were defined in the project Terms of Reference (see **Glossary**).

- Final temporal and spatial scope were as defined in the scoping stage (2001/2022; project boundaries)
- Account structures: the project team drew upon three main types of physical ecosystem accounts including ecosystem extent, ecosystem condition, and ecosystem supply and use tables. Tables were drawn from the Guide to be tested in this analysis. Final tables can be found in **Section 8**.
- Each project sub-team used this information and table structures as a starting point for their analysis, producing the analysis and results found in subsequent report sections.

2.3 Step 3: Identify and collect data

Evaluation of the restoration project impacts requires a broad range of datasets across the ecosystem service areas mentioned in **Section 2.1** above, underpinned by relevant indicators of ecosystem extent and condition.

While some data were available, the project needed to collect data to build Traditional Owner accounts as well as accounts for recreational fishing activities. Given the short time period available to complete this case study, primary data collection was possible but limited the scope of the accounts that could be built.


Photo by Through The Looking Glass Studio - http://looking-glass.com.au

3. Ecosystem extent and condition

This section provides detailed information on the methodologies used to assess the biophysical and economic impacts of the restoration project, as well as detailed results and discussion related to each major section of analysis. This corresponds to Steps 4 and 5 of the Guide: account compilation as well as repeat data collection and account compilation (noting again that this case study is reliant on existing historical data, so the project team is assembling 'before' and 'after' restoration accounts).

The section starts with extent and condition accounts, which are then used to produce ecosystem services accounts.

3.1 Extent account

Intent of work

A key measure of the success of restoration activities in blue carbon ecosystems is the change in areal extent. Ecosystem extent is defined as the size of an ecosystem asset, with the assets in this case being ecosystems within the project area. Ecosystem conversion or the conversion of 'other' ecosystems to coastal ecosystems (and vice-versa) can be determined by assessing coastal ecosystem extent before and after a restoration activity.

Measuring changes in coastal ecosystem extent for environmental economic accounts can be done using remote sensing to produce maps of vegetation community distributions and extents. Remote sensing approaches are cost effective, reproducible, standardised, and are effective for measuring coastal ecosystem extent and changes in extent over time. For project level environmental economic accounts, extent calculations are influenced by the resolution of Earth observation data, mapping approaches and accuracy of vegetation community boundaries. However, production of accurate maps should be balanced against the costs and expertise required to produce them. In addition to potential data limitations, capacity to separate blue carbon ecosystems that are present at each site must also be identified before starting data collation and analysis.

For the Trinity Inlet restoration activities, we focused on change in ecosystem extents of mangrove, saltmarsh, supratidal forests, intertidal seagrass, intertidal mudflats, and conversion of 'other' ecosystems.

Header photo by Through The Looking Glass Studio - http://looking-glass.com.au

Approach taken

Trinity Inlet provides an excellent example for the application of project-level environmental economic accounts to calculate extent from nationally consistent datasets. Several publicly available datasets were used as well as some currently in development that will be publicly released. These are produced using Landsat satellite imagery with a 30 m resolution. Pre- and post-restoration years were identified to calculate extent of ecosystems, 2000 and 2022 respectively. All analysis was done using DEA sandbox, where all necessary data were freely available, however it could also be undertaken in a desktop GIS platform with data downloaded. When all pre- and post-restoration datasets for coastal and 'other' ecosystem types were generated as raster layers, pixel counts for each ecosystem type were summed to provide areal extent in hectares. Post-restoration was subtracted from pre-restoration to provide net change in ecosystem extent.

Results

The restoration activities resulted in a net increase in blue carbon ecosystem extent of 110 hectares. This was primarily due to an increase in supratidal forest ecosystem extent (109 ha). An increase in saltmarsh extent (9.9 ha) was largely offset by decrease in mangrove extent (9.1 ha), however these were not necessarily similar areas within the site. Other land covers decreased significantly (157 ha) while waterbodies increased (46.7 ha). Intertidal seagrass and intertidal mudflats were not detected within the restoration site boundary.

Reflection relative to the Guide

Here, we used two approaches to quantify extent: national and detailed approaches. There were differences in extent between these approaches, which was anticipated given differences in spatial resolution. Moreover, the ability to detect ecosystems and the precision in doing so was anticipated to be greater in the detailed approach, and we would expect higher confidence in this approach. However, in many locations, the detailed approach was not viable due to a lack of data. It is in these situations that the national approach should be undertaken. We would recommend using the detailed approach wherever possible. If data collection occurs prior to the restoration activity (i.e. opening date), we advocate using aerial photography from Nearmaps, or collecting imagery using a remotely piloted aircraft.

In this instance, the assessment of pre-restoration extent occurred after the restoration activity (i.e. 20 years later). This posed a few problems. Data availability for the detailed assessment approaches was different between these periods. In addition, assessing the accuracy of extent maps was difficult since they could not be validated. This was particularly evident when comparing the national and detailed approaches at the pre-restoration date. For instance, unclassified areas needed to be considered 'other habitats' and may lead to undervaluing or even overvaluing the restoration outcomes.

Careful consideration of site boundaries for this location was required as the intended target for the restoration was to address acid sulphate soil impacts. As the impact of acid sulphate soils occur beyond the boundaries of the restoration, the boundaries for defining extent required some adjustment to be able to quantify changing effects in all impact areas outside of the restoration area.

3.1.1 Extent account supplementary material

Trinity Inlet provides an excellent example of a project-level EEA to calculate extent from nationally consistent datasets. Several publicly available datasets were used as well as some currently in development that will be publicly released soon. Here we provide more information detailing the approach undertaken. Data was not available to apply a detailed approach with sufficient rigour as in the Hunter case study[6].

National approach

Data availabilty

Several publicly available datasets were used as well as some currently in development that will be publicly released soon. These are produced using Landsat with a cell size of 30 m. Pre- and post-restoration years were identified to calculate extent of ecosystems, 2005 and 2021 respectively. All analysis was undertaken in the DEA sandbox (https://docs.dea.ga.gov.au/setup/Sandbox/sandbox.html), where all necessary data is freely available, however could also be undertaken in a desktop GIS platform with data downloaded.

- Mangroves: DEA Mangroves (https://cmi.ga.gov.au/data-products/dea/634/dea-mangrove-canopy-cover-landsat)
- Saltmarsh: Australian Saltmarsh Map (https://www.saltmarshes.org/home). This product will be publicly available in 2023.
- Supratidal Forests: An Australia-wide product is currently in development by the authors. Test outputs have been generated for the Trinity Inlet restoration boundary. This product will be publicly available in 2024.
- Intertidal seagrass: IMAS Seamap (https://seamapaustralia.org/map/)
- Waterbodies/mudflats: DEA Land Cover (https://www.dea.ga.gov.au/products/dea-land-cover)
- Mudflats: Global Intertidal change (https://www.intertidal.app/)
- 'Other' ecosystems: DEA Land Cover (https://www.dea.ga.gov.au/products/dea-land-cover)

Methods

Many of the nationally consistent datasets are produced annually, or with the prospect of being annual in the near future. First, the before and after restoration years were identified, 2000 and 2021 respectively. Where annual data was not available for these years, datasets either side of these years was considered fit for purpose (i.e. 2022 dataset). Second, the project site boundary was defined, where restoration activities were undertaken. All analysis was undertaken in the DEA sandbox (https://docs.dea.ga.gov.au/setup/Sandbox/sandbox.html), where all necessary data is freely available, however could also be undertaken in a desktop GIS platform with data downloaded as per links above. Details of analysis steps for each layer are described below.

Mangroves:

- Site boundary used to extract are of interest of DEA Mangrove Canopy Cover annual dataset for 2005 and 2021.

Saltmarsh:

- Site boundary used to extract area of interest from the Australian saltmarsh map (2022 snapshot, used as post restoration dataset).
- Pre-restoration dataset generated by hindcasting the Australian saltmarsh map modulated with the annual Woody Vegetation Cover Fraction (WCF - http://wenfo.org/tree/) for 2005. To obtain likely non-woody vegetation within the Australian saltmarsh map, thresholds were set on the WCF layer, whereby saltmarsh was considered present if WCF > 0.05 and WCF < 0.4.

[6] Glamore, W., et al. (2023). Accounting for benefits from coastal restoration: a case study from the Hunter River. Report to DCCEEW.

Supratidal forests

- Calculated by combining DEA Mangroves, Woody Vegetation Cover Fraction (WCF), Shuttle Radar Topography Mission (SRTM), and Intertidal Extent Model (ITEM) using a rule-based approach. WCF threshold was set to > 0.5 based capturing vegetation that were likely to be woody (i.e. shrubs/trees). SRTM elevation data was used to limit extent of supratidal forests to an expected common range based on existing literature and field surveys (1 m – 10 m AHD). DEA Mangroves and ITEM was used to mask out areas considered mangrove ecosystems or intertidal areas.
- Pre- and post-restoration datasets were generated using annual available datasets (e.g. DEA Mangroves, WCF) for 2005 and 2021.

Intertidal seagrass

- Site boundary used to extract area of interest from the Australian intertidal seagrass dataset (2019-2020 snapshot, used as post restoration dataset).
- No pre-restoration nationally consistent dataset was available.

Waterbodies/Mudflats

- Site boundary used to extract are of interest of DEA Land Cover annual dataset for 2005 and 2020.
- Waterbodies/mudflats land cover class extracted out for both datasets.

Intertidal mudflats

- Site boundary used to extract area of interest from the Global intertidal change dataset for pre- and post-restoration (2005 and 2014 available).

Other land covers

- Site boundary used to extract are of interest of DEA Land Cover annual dataset for 2005 and 2020.
- Cultivated areas, bare areas and artificial surface land cover classes extracted out for both datasets.

When all pre- and post-restoration datasets for coastal and 'other' ecosystem types were generated as raster layers, these were combined to produce a pre- and post-restoration map. As several datasets were used to generate extents for each ecosystem type, conflicting attributions were identified (e.g. where a pixel was classified as both mangrove and saltmarsh). To ensure each pixel within the study boundary was only attributed to one ecosystem type, required for SEEA-EA, a layer priority was formulated whereby if a pixel was identified as more than one ecosystem type, the highest priority layer was given preference and the pixel labelled accordingly. This order of layer priority was based on confidence in accuracy of a dataset according to whether the dataset was well-established, publicly available, peer-reviewed, and operationalised at national scale. For the Trinity Inlet restoration site, order of layer priority was mangrove, followed by Waterbodies/mudflats, other land covers, mudflats, intertidal seagrass, saltmarsh, and supratidal forests. In addition, where pixels within the Trinity Inlet restoration boundary were not identified as an ecosystem type (i.e. unclassified), these were considered as 'other' land covers.

Pixel counts for each ecosystem type were summed to provide areal extent in hectares for input into the SEEA-EA table (**Table 3.1**) where post restoration was subtracted from pre restoration to provide net change in ecosystem extent.

Results

Restoration activities demonstrated a net increase in blue carbon ecosystem extent of 110 hectares (**Figures 3.2** and **3.3**). This was primarily due to an increase in supratidal forest ecosystem extent (109 ha). An increase in saltmarsh extent (9.9 ha) was largely offset by decrease in mangrove extent (9.1 ha), however these were not necessarily similar areas within the site. A substantial decrease in other land covers was detected (157 ha) as well as an increase in the areal extent of Waterbodies/mudflats present (46.7 ha). Intertidal seagrass and intertidal mudflats were not detected within the restoration site boundary.

Table 3.1: Change in extent (ha) of different ecosystem types before (2000) and after (2021) restoration actions had taken place for Trinity Inlet[7].

	Selected ecosystem types (based on Level 3 -EFG of the IUCN Global Ecosystem Typology)						Total blue carbon ecosystems	Total ecosystem extent
Realm	Marine-Freshwater-Terrestrial			Marine	Marine-Terrestrial	Terrestrial		
Biome	MFT1 Brackish tidal			M1 Marine shelf	MT1 Shorelines biome	T7 Intensive land use		
Selected Ecosystem Functional Group (EFG)	Mangroves MFT1.2*	Saltmarsh MFT1.3	Supratidal forests MFT1.2*	Intertidal seagrass M1.1	Muddy shorelines** MT1.2	Other land covers T7.1		
Opening extent (pre-restoration)	368.82	4.95	281.52	-	18.09	441.72	655.29	1115.10
Additions to extent	0.00	9.90	109.17	-	46.71	0.00	119.07	166
Reduction to extent	9.09	0.00	0.00	-	0.00	156.93	9.09	166
Net change in extent	-9.09	9.90	109.17	-	46.71	-156.93	109.98	0
Closing extent	359.73	14.85	390.69	-	64.80	285.03	765.27	1115.10

[7] *Supratidal forests technically are classified within the same category as mangroves (Intertidal forests and shrublands MFT1.2), but have been split here.

Intertidal seagrass and mudflats were not detected within restoration activity boundary.

**Muddy shorelines=waterbodies.

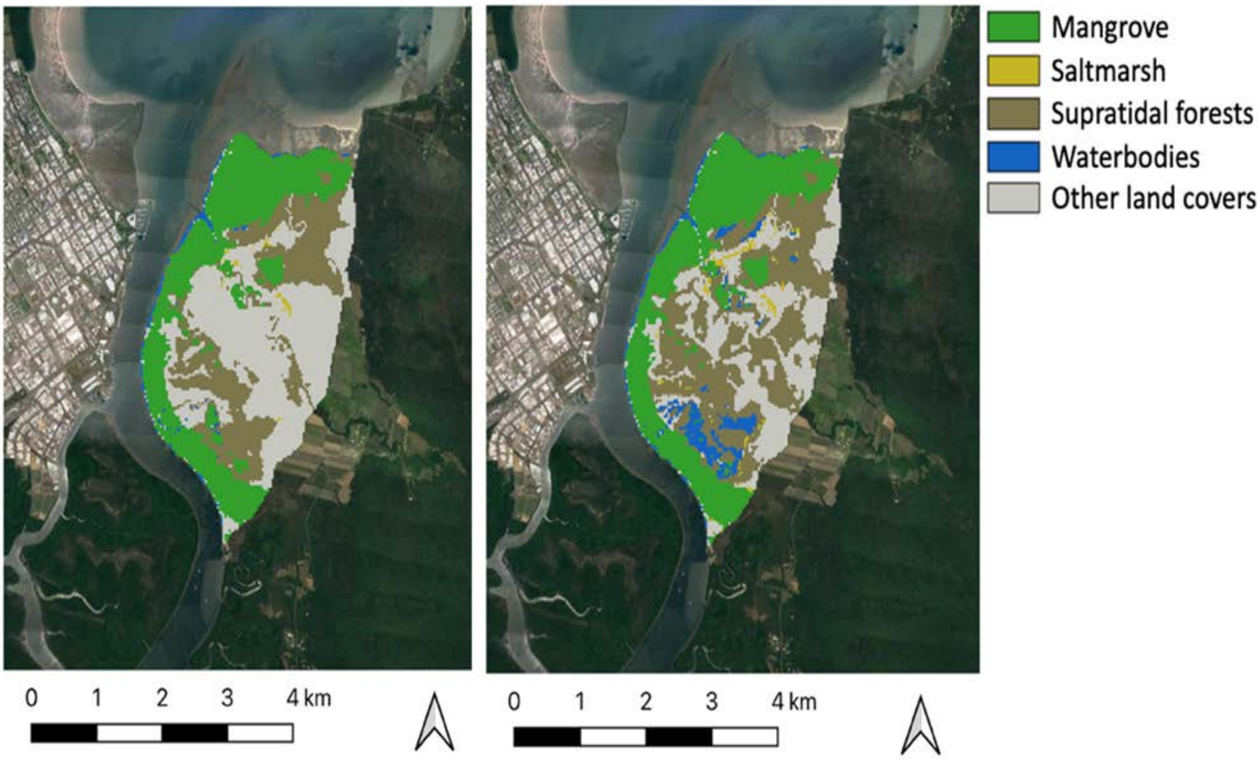

Figure 3.1: Trinity Inlet ecosystem extent before (~2000) and after (~2021) restoration activities. Waterbodies=mudflats.

Interpretation and discussion

While the standard SEEA-EA table format provides a gross indication of the change in extent, it does not provide sufficient spatial information to ascertain whether the changes in extent occurred in anticipated locations, or were contrary to the restoration target. Therefore, in addition to the standard SEEA-EA extent table, we recommend projects complete an ecosystem type change matrix (Table 4.2 in the SEEA-EA guidelines), which can also be displayed via maps.

There were also issues with accounting for the influence of climatic variability on some land cover classes. In particularly, the extent of standing water changed remarkably over the study period, with high standing water during La Niña periods, and low standing water during El Niño periods. The outcome of this variation is that the opening or closing dates may align with one of these extremes, and the reported extent may not sufficiently represent the trajectory of change over the study period. This variation should be quantified in some manner, or at least acknowledged as a footnote in the tables.

When using multiple datasets to quantify extent, as was undertaken at the national scale, it is important to be aware of the accuracy and precision in the datasets. In some cases, the accuracy may be low, and when there are multiple datasets with moderate to low accuracy being used, the errors may be substantial. This is difficult to overcome at this national scale, but should be sufficiently acknowledged. To assess the overall influence of accuracy and precision errors, the extents could be compared against the global wetland change product to provide a first order validation.

A number of assumptions were necessary, such as the layer prioritisation that was undertaken. This was an essential step that was undertaken at our discretion, but informed by knowledge of the changes that were targeted to occur during the restoration activity. Consideration should be given to layer prioritisation.

3.2 Condition account

Intent of work

Ecosystem condition is key to restoration planning, implementation, and monitoring and evaluation of restoration success. Ecosystem condition is defined in the SEEA-EA as 'the quality of the ecosystem measured in terms of its abiotic, biotic and landscape/seascape characteristics.' Measures of condition are ecosystem-specific, and should have a conceptually similar reference baseline as the basis for developing indicators of condition. The reference state should be 'natural'. In an Australian context, this is typically an estimate of pre-European colonisation state, often based on example sites representing 'best of what's left'. Identifying the change in condition of vegetation-based communities requires additional information about the state of the ecosystem not described by measurements of ecosystem extent.

Condition accounts are made up of ecosystem-specific condition variables that cover many ecosystem attributes (composition, structure and function, as well as landscape context and connectivity across biotic and abiotic components of the ecosystem). Measurements of variables are often converted into indicators by normalising variables so that values occur on a scale of 0-1. The reference state is an exemplar of high condition (e.g. a value of 1) and a transformed or degraded state is low condition (e.g. a value of 0). Ecosystem condition variables can be collated from diverse data sources including field-based data, remotely-sensed data, expert judgement and modelling. For this case study, remote sensing is key to informing pre- and post-restoration condition due to limited pre-restoration field-based data collection on ecosystem condition. For project level environmental economic accounts, ecosystem condition variables calculated from remote sensing data are influenced by the resolution of Earth observation data, mapping approaches and overall accuracy of vegetation community boundaries. However, production of accurate maps should be balanced against the costs and expertise of production. In addition to potential data limitations, ability to capture meaningful condition variables of blue carbon ecosystems that are present at each site must also be outlined before starting data collation and analysis.

For the Trinity Inlet restoration activities, our focus was on change in ecosystem condition of mangrove, saltmarsh, supratidal forests and conversion of 'other' ecosystems. Intertidal seagrass and intertidal mudflats were not detected in the extent calculations and therefore were not considered for ecosystem condition calculations.

Approach taken

Trinity Inlet provides an excellent example of project-level environmental economic accounting to calculate condition from nationally consistent datasets. Several publicly available datasets were used as well as some currently in development that will be publicly released soon. These are produced using Landsat satellite imagery with a 30 m resolution. Pre- and post-restoration extents for each ecosystem were combined to identify the the same areas (i.e. pixels that were the same ecosystem type for both before and after restoration activities). This was necessary for some condition indicators to ensure before and after restoration activities measurements were meaningful. Condition metrics were then derived for each ecosystem type including age since restoration activities, vegetation cover, above-ground biomass, vegetation greenness, landscape wetness, and connectivity of ecosystem. All analysis was undertaken in the DEA sandbox, where all necessary data was freely available, however could also be undertaken in a desktop GIS platform with data downloaded.

Condition variables were then transformed to a 0-1 scale where appropriate and assessed for each variable for each ecosystem type (process and rationale outlined in the Guide). All transformed pre- and post-restoration condition datasets for coastal and 'other' ecosystem types were generated as raster layers. Two approaches were then taken to report change in condition indicators. First, pixel counts for each ecosystem type were summed up and averaged over the extent area. Second, the direction of change of a pixel's value (i.e. positive = increase in condition, negative = decrease in condition) was identified and summed to provide a total change in area of the condition indicator. Negative change in condition indicator area was subtracted from positive change in condition indicator area to provide the net change area of positive or negative condition change.

Results

The restoration activities demonstrated an increase in connectivity of coastal ecosystems, except for mangroves, which remained similar. A decrease in connectivity of other land covers was associated with the increase in saltmarsh, supratidal forests, and waterbody/mudflat ecosystem connectivity. An increase in supratidal forest and other land cover above-ground biomass was detected, though other ecosystems remained constant. Supratidal forest cover and greenness both decreased post-restoration. However, increases in vegetation cover and greenness for mangrove and other land covers were detected. Landscape wetness of all vegetated ecosystem types decreased post-restoration compared to an increase in extent of waterbodies/mudflats. Many indicators demonstrated spatial variability for coastal wetland ecosystems before and after restoration activities, where trends are hard to generalise.

Reflection relative to the Guide

Multiple issues emerged while undertaking condition assessments. Initially we had ambitious goals, but there were considerable data availability and data quality limitations that prevented this. Of note was limited access to LiDAR data, and the unavailability of LiDAR data that describes vegetation height changes over time. Ideally, we would recommend the collection of detailed datasets prior to undertaking restoration activities. These datasets would serve as a benchmark for monitoring changes through the reporting period.

It was also critical to ensure that condition indicators were meaningful in relation to the restoration activities being undertaken. This required some understanding of the restoration targets prior to selecting indicators.

There was some variability in condition indicators. However, it was difficult to ascertain whether this variability arose because of errors in the dataset, the sensitivity of the indicator to detect changes, natural variability arising from climate change, or the restoration activity itself. Wherever possible, consideration should be given to all of these factors when reporting changes, and if the reported changes are arising from factor other than restoration success, these should be noted.

As per analyses of extent, the reflection of the authors of this section is that the standard SEEA-EA tables alone do not provide sufficient capacity to report on the spatial changes in condition. In this case study we found the overall outcome of this is that the reporting can be too reductive, and minor successes at a large scale can be masked by declines in condition occurring elsewhere. Therefore, we recommend projects follow similar approaches to those demonstrated here to map the changing condition at project sites in addition to the standard SEEA-EA tables.

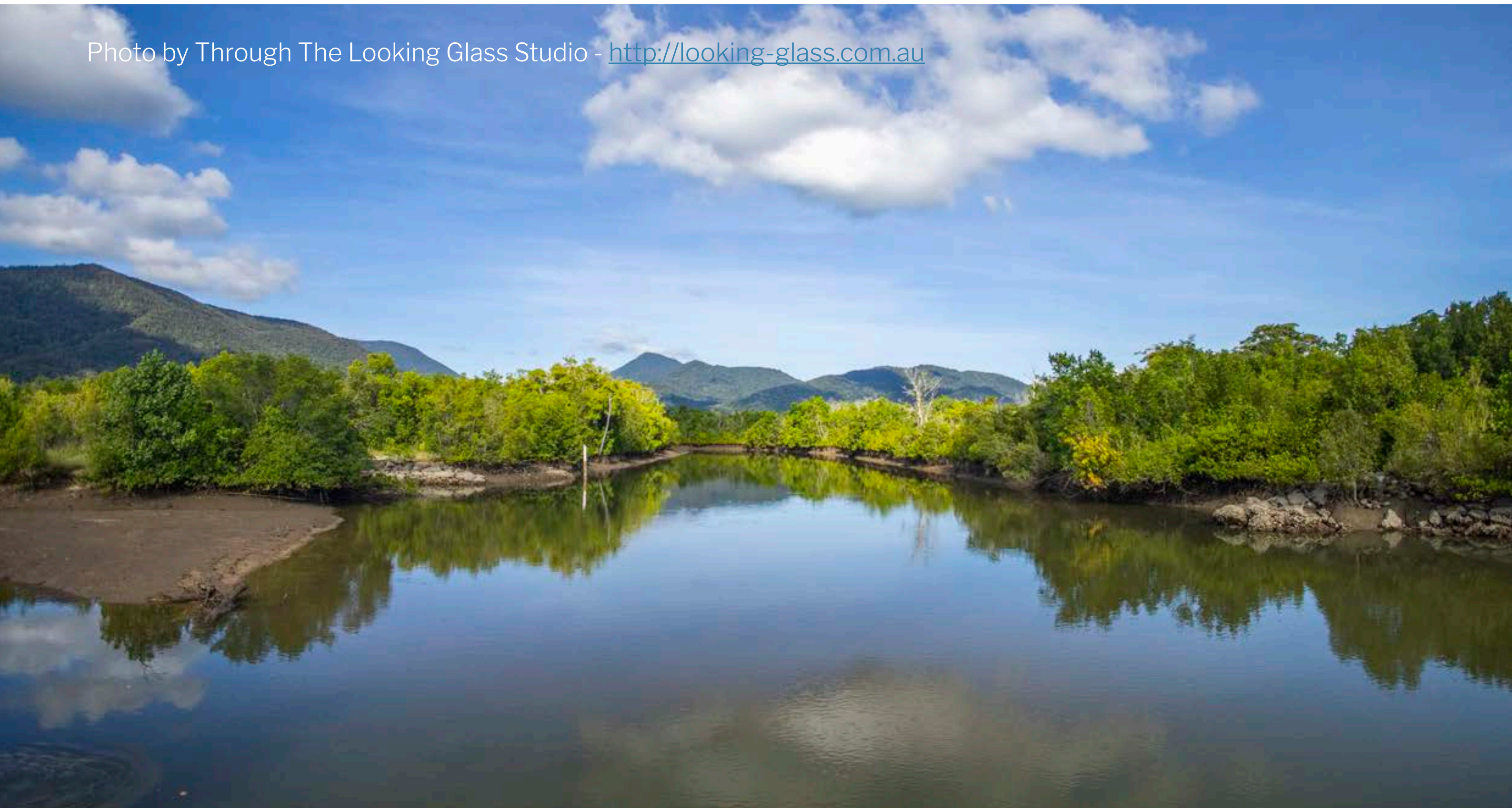

Photo by Through The Looking Glass Studio - http://looking-glass.com.au

3.2.2 Condition account supplementary material

Condition assessments have been undertaken at Trinity Inlet using nationally consistent datasets. Several publicly available datasets were used as well as some currently in development that will be publicly released soon. Here we provide more information detailing the approach undertaken for condition assessment.

National approach

Data availabilty

Pre- and post-restoration extents for each ecosystem were combined to identify the the same areas (i.e. pixels that were the same ecosystem type for both before and after restoration activities). This was necessary for some condition indicators to ensure before and after restoration activities measurements were meaningful. Condition indicators were then derived for each ecosystem type including age since restoration activities, vegetation cover, above-ground biomass, vegetation greenness, landscape wetness, and connectivity of ecosystem. All analysis was undertaken in the DEA sandbox (https://docs.dea.ga.gov.au/setup/Sandbox/sandbox.html), where all necessary data is freely available, however could also be undertaken in a desktop GIS platform with data downloaded. To derive condition indicators, additional datasets were used than those used for extent:

- Age since restoration activities: Same as datasets used to detect ecosystem extents.
- Vegetation cover: Woody Vegetation Cover Fraction (http://wenfo.org/tree/).
- Above-ground biomass: ESA CCI Biomass (https://climate.esa.int/en/projects/biomass/).
- Vegetation greenness: Annual Landsat Geomedians (https://cmi.ga.gov.au/data-products/dea/645/dea-geometric-median-and-median-absolute-deviation-landsat).
- Landscape wetness: Annual Landsat Geomedians (https://cmi.ga.gov.au/data-products/dea/645/dea-geometric-median-and-median-absolute-deviation-landsat).
- Connectivity of ecosystem: Ecosystem extent outputs for before and after restoration.

Methods

Many of the nationally consistent datasets are produced annually, or with the prospect of being annual in the near future. Firstly, the nationally consistent approach to generating ecosystem extent datasets was used to define ecosystem type boundaries for pre and post restoration activities. Pre- and post-restoration extents for each ecosystem were combined to identify the same areas (i.e. pixels that were the same ecosystem type for both before and after restoration activities). This was necessary for some condition indicators to ensure before and after restoration activities measurements were meaningful. Condition indicators were then derived for each ecosystem type including age since restoration activities, vegetation cover, above-ground biomass, vegetation greenness, landscape wetness, and connectivity of ecosystem. All analysis was undertaken in the DEA sandbox (https://docs.dea.ga.gov.au/setup/Sandbox/sandbox.html), where all necessary data is freely available, however could also be undertaken in a desktop GIS platform with data downloaded as per links above. Details of analysis steps for each condition indicator are described below.

Age since restoration activities

- Methods used to generate ecosystem extents was also done for each year between pre- and post-restoration extents.
- Post-restoration extent area was used to extract each annual extent of mangrove, saltmarsh, supratidal forests, Waterbodies/mudflats, and other land covers.
- For each pixel, a cumulative sum over the presence of the ecosystem was generated, whereby if the ecosystem was not present for a particular year, the cumulative sum was reset.

- A relative age of each pixel for the post-restoration dataset for generated for each ecosystem type.
- Age reported in years since restoration, with no capacity to calculate pre-restoration age.

Vegetation cover

- Woody Vegetation Cover Fraction (WCF) was extracted for pre- and post-restoration years using site boundary.
- The pre- and post-restoration overlapping areas were used to extract WCF for mangrove, saltmarsh, supratidal forests, and other land covers.
- An increase in WCF for mangrove, supratidal forests, and other land covers was considering an increase in vegetation cover, however a decrease in WCF was considered an increase in vegetation cover for saltmarsh (due to dominant species composition).
- Vegetation cover reported as a scaled condition indicator between 0 (poor) and 1 (good).

Above-ground biomass

- Above-ground biomass data was available for 2010 and 2018 and these were used as pre- and post-restoration years respectively.
- The pre- and post-restoration overlapping areas was used to extract above-ground biomass for mangrove, saltmarsh, supratidal forests, and other land covers.
- Above-ground biomass reported in Mg ha^{-1}, where an increase in above-ground biomass was considered an increase in ecosystem condition.

Vegetation greenness

- Landsat Annual Geomedians were extracted for pre- and post-restoration years using site boundary.
- Geomedians were used to calculate the Normalised Difference Vegetation Index (NDVI) using the red and near-infrared spectral bands of the Geomedians.
- The pre- and post-restoration overlapping areas was used to extract NDVI for mangrove, saltmarsh, supratidal forests, and other land covers.
- Vegetation greenness reported as a scaled condition indicator between 0 (poor) and 1 (good) by shifting NDVI values (-1 to +1) in a linear fashion.

Landscape wetness

- Landsat Annual Geomedians were extracted for pre- and post-restoration years using site boundary.
- Geomedians were used to calculate the Modified Normalised Difference Wetness Index (MNDWI) using the green and short wave infrared spectral bands of the Geomedians.
- The pre- and post-restoration overlapping areas was used to extract MNDWI for mangrove, saltmarsh, supratidal forests, Waterbodies/mudflats, and other land covers.
- Landscape wetness reported as a scaled condition indicator between 0 (poor) and 1 (good) by shifting MNDWI values (-1 to +1) in a linear fashion.

Connectivity of ecosystem

- Pre- and post-restoration extents for each ecosystem type were used to generate an indicator for connectivity of each ecosystem type.
- For each pixel of the ecosystem type, the surrounding pixels were used to provide a ratio of connectedness of the pixel (e.g. connectivity score of 0.125 (1/8) where pixel was only connected to 1 other pixel of same ecosystem type).
- Connectivity of an ecosystem was reported as scale condition indicator between 0 (poor) and 1 (good) based on ratio of connectivity for each pixel.

Two approaches were taken to report change in condition indicators. First, pixel counts for each ecosystem type were summed up and averaged over the extent area. The mean value was input into the SEEA-EA tables (**Table 3.2**) where post-restoration was subtracted from pre-restoration to provide change in ecosystem condition for each indicator. Second, the direction of change of a pixels value (i.e. positive = increase in condition, negative = decrease in condition) was identified and summed up to provide a total change in area of the condition indicator, reported in hectares. Negative change in condition indicator area was subtracted from positive change in condition indicator area to provide net change area of positive or negative condition change and reported in SEEA-EA tables (**Table 3.3**)

Results

The restoration activities demonstrated an increase in connectivity of coastal ecosystems, with the exception of mangrove that remained similar. A decrease in connectivity of other land covers was associated with the increase in saltmarsh, supratidal forests and Waterbodies/mudflats ecosystem connectivity. An increase in supratidal forest and other land cover above-ground biomass was detected, though other ecosystems remained constant. Supratidal forests cover and greenness both decreased at post-restoration, however increase in vegetation cover and greenness for mangrove and other land covers were detected. Landscape wetness of all vegetated ecosystem types decreased in post-restoration compared to an increase in extent of Waterbodies/mudflats. Many indicators demonstrated substantial spatial variability for coastal wetland ecosystems before and after restoration activities, where trends are challenging to generalise.

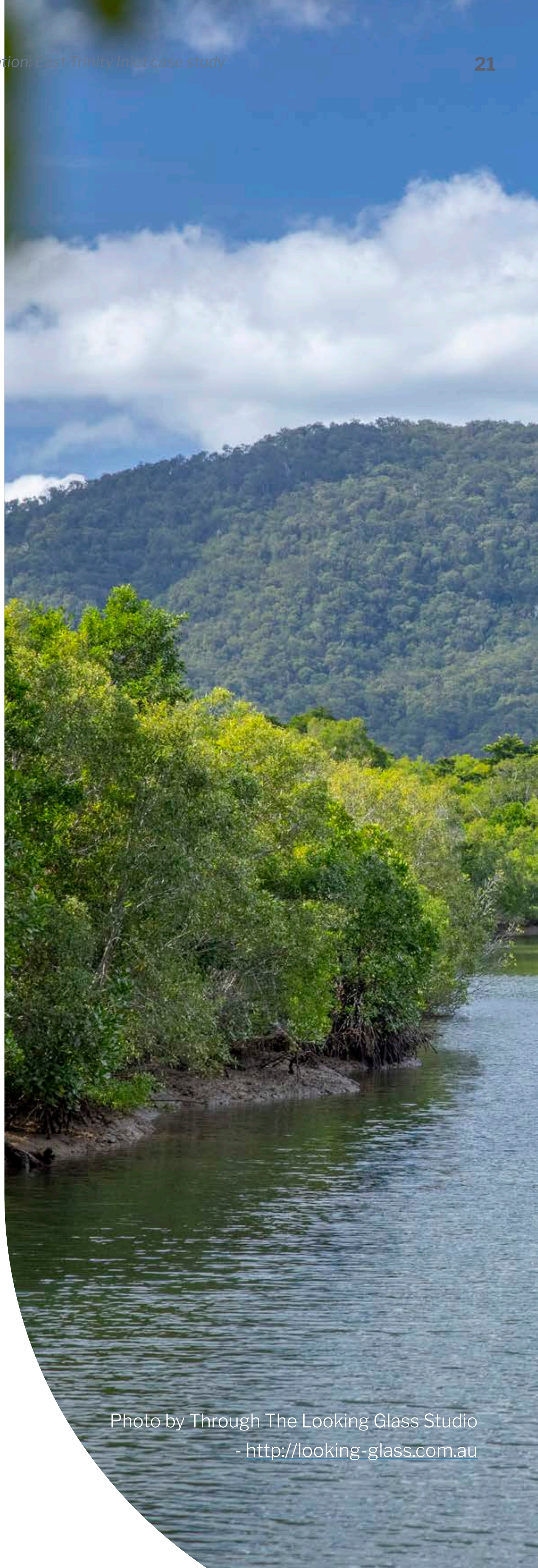

Photo by Through The Looking Glass Studio
- http://looking-glass.com.au

Table 3.2: **Ecosystem indicator account for restoration project at Trinity Inlet**[8]. *Continued over page.*

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	Measurement unit	Opening value	Closing value	Change in indicator
Mangrove	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	0.4 (0.05)	0.04 (0.06)	0
	Biotic	Structural state	Age since restoration activities	Years	-	21.84 (0)	-
			Vegetation cover	% cover, rescaled (0-1)	0.81 (0.1)	0.79 (0.1)	-0.02
			Above-ground biomass	Mg ha^{-1}	*	*	-
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	0.88 (0.04)	0.9 (0.05)	0.02
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.75 (0.31)	0.75 (0.32)	0
Saltmarsh	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	0.27 (0.02)	0.27 (0.03)	0
	Biotic	Structural state	Age since restoration activities	Years	-	12.16 (7.94)	-
			Vegetation cover	% cover, rescaled (0-1)	0.78 (0.08)	0.68 (0.15)	-0.1
			Above-ground biomass	Mg ha^{-1}	43.84 (82.65)	24.27 (33.04)	-19.57
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	0.83 (0.05)	0.79 (0.03)	-0.04
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.23 (0.15)	0.23 (0.15)	0
Supratidal forests	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	0.3 (0.03)	0.32 (0.07)	0.02
	Biotic	Structural state	Age since restoration activities	Years	-	14.06 (6.47)	-
			Vegetation cover	% cover, rescaled (0-1)	0.78 (0.14)	0.75 (0.15)	-0.03
			Above-ground biomass	Mg ha^{-1}	61.08 (74.8)	61.92 (67.71)	0.84
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	0.88 (0.03)	0.87 (0.03)	-0.01
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.62 (0.33)	0.62 (0.32)	0

[8] Opening account year = 2000, closing account year = 2021. Values are mean of all pixels in restoration activity boundary, values brackets indicate standard deviation. Comparison area for opening and closing mean values is the same areas of the ecosystem type (i.e. where mangrove was present in both pre- and post-restoration activities). *unreliable estimates from datasets and not included.

Table 3.2: Cont.

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	Measurement unit	Opening value	Closing value	Change in indicator
Waterbodies/ muddflats	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	-	-	-
	Biotic	Structural state	Age since restoration activities	Years	-	15.06 (5.22)	-
			Vegetation cover	% cover, rescaled (0-1)	-	-	-
			Above-ground biomass	Mg ha^{-1}	-	-	-
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	-	-	-
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.23 (0.13)	0.36 (0.25)	0.13
Other land covers	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	0.28 (0.04)	0.28 (0.05)	0
	Biotic	Structural state	Age since restoration activities	Years	-	20.52 (2.95)	-
			Vegetation cover	% cover, rescaled (0-1)	0.31 (0.29)	0.46 (0.25)	0.15
			Above-ground biomass	Mg ha^{-1}	33.44 (68.86)	58.1 (66.8)	24.66
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	0.84 (0.04)	0.86 (0.04)	0.02
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.71 (0.33)	0.55 (0.32)	-0.16

Table 3.3: **Ecosystem indicator account for restoration project at Trinity Inlet[9].** *Continued over page.*

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	Measurement unit	Increase in indicator value/ opening value	Decrease in indicator value/ closing value	Change in indicator
Mangrove	Abiotic		Landscape wetness	Hectares	176	182	-6
	Biotic	Structural state	Age since restoration activities	Years	-	16.93	0
			Vegetation cover	Hectares	160	198	-38
			Above-ground biomass	Hectares	*	*	*
		Functional state	Vegetation greenness	Hectares	290	69	221
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.23 (0.11)	0.23 (0.11)	0
Saltmarsh	Abiotic		Landscape wetness	Hectares	2	3	-1
	Biotic	Structural state	Age since restoration activities	Years	-	10.21 (3.96)	-
			Vegetation cover	Hectares	2	3	-1
			Above-ground biomass	Hectares	4	1	3
		Functional state	Vegetation greenness	Hectares	1	4	-3
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.51 (0.31)	0.54 (0.3)	0.03
Supratidal forests	Abiotic		Landscape wetness	Hectares	116	120	-4
	Biotic	Structural state	Age since restoration activities	Years	-	9.88 (5.12)	-
			Vegetation cover	Hectares	104	131	-27
			Above-ground biomass	Hectares	158	77	81
		Functional state	Vegetation greenness	Hectares	109	127	-18
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.47 (0.29)	0.52 (0.32)	0.05

[9] Opening account year = 2000, closing account year = 2021. Indicating the change in extent (ha) that has improved or declined in condition. Values for connectivity of ecosystem are mean of all pixels in restoration activity boundary, values brackets indicate standard deviation. Comparison area for opening and closing mean values is the same areas of the ecosystem type (i.e. where mangrove was present in both pre and post restoration activities. Note that for vegetation cover, biomass, greenness, and wetness this is reported as change in hectare area for descriptor (i.e. opening value = area gained or maintained in value of descriptor, closing value = area loss in value of descriptor, change in indicator = net change in area for condition indicator). *unreliable estimates from datasets and not included.

Table 3.3: Cont.

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	Measurement unit	Increase in indicator value/ opening value	Decrease in indicator value/ closing value	Change in indicator
Waterbodies/ muddflats	Abiotic		Landscape wetness	Hectares	-	-	-
	Biotic	Structural state	Age since restoration activities	Years	-	6.82 (2)	-
			Vegetation cover	Hectares	-	-	-
			Above-ground biomass	Hectares	-	-	-
		Functional state	Vegetation greenness	Hectares	-	-	-
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0	0.5 (0.31)	0.5
Other land covers	Abiotic		Landscape wetness	Hectares	95	180	-85
	Biotic	Structural state	Age since restoration activities	Years	-	15.73 (1.24)	-
			Vegetation cover	Hectares	220	55	165
			Above-ground biomass	Hectares	242	33	209
		Functional state	Vegetation greenness	Hectares	212	63	149
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.59 (0.31)	0.41 (0.26)	-0.18

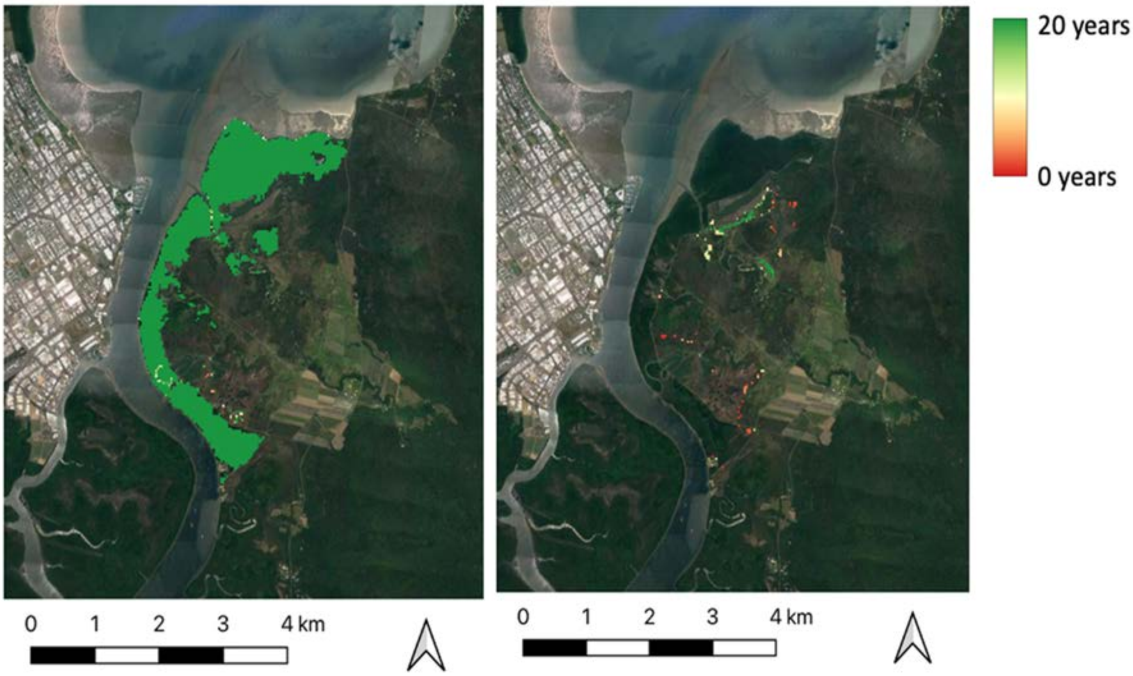

Figure 3.2: Mangrove (left) and saltmarsh (right) age since restoration activities at Trinity Inlet.

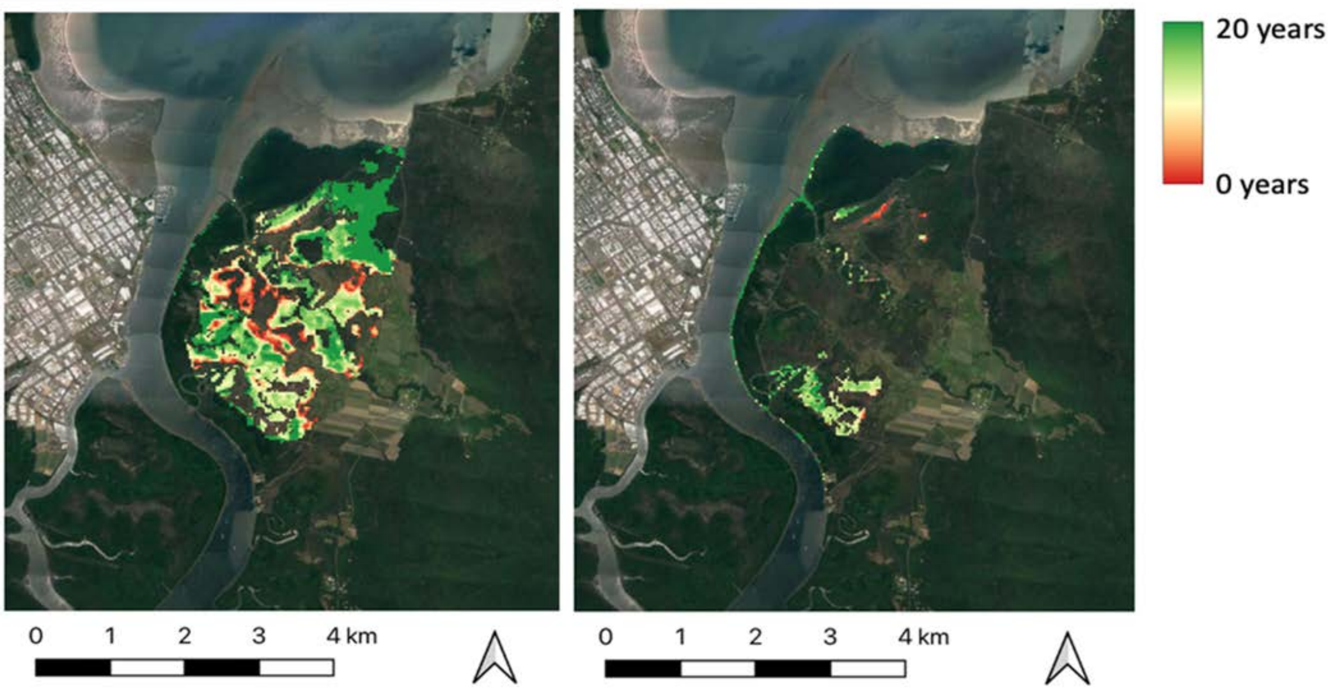

Figure 3.3: Supratidal forest (left) and Waterbodies/mudflats (right) age since restoration activities at Trinity Inlet

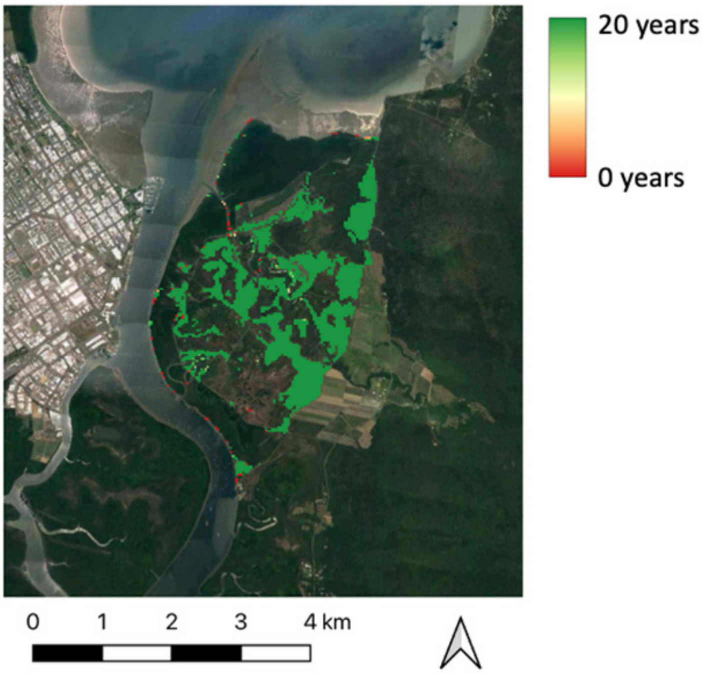

Figure 3.4: Other land covers age since restoration activities at Trinity Inlet.

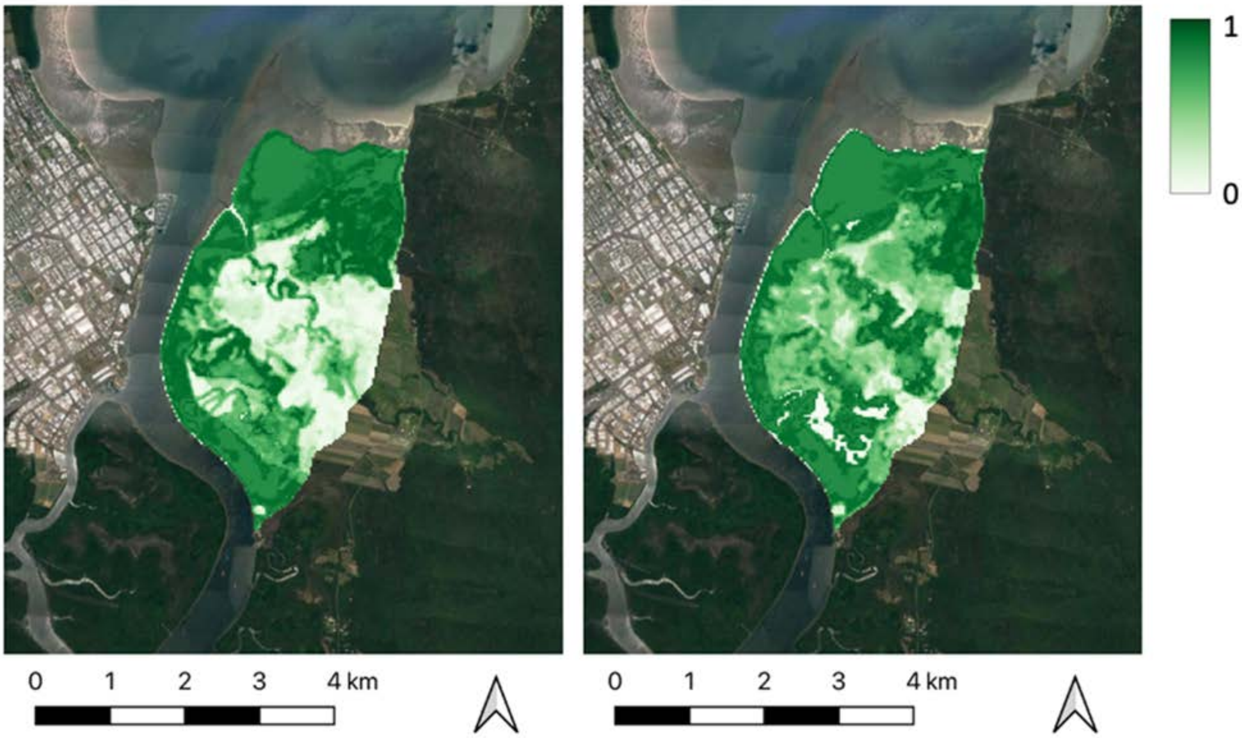

Figure 3.5: Vegetation cover before (~2000) and after (~2021) restoration activities at Trinity Inlet.

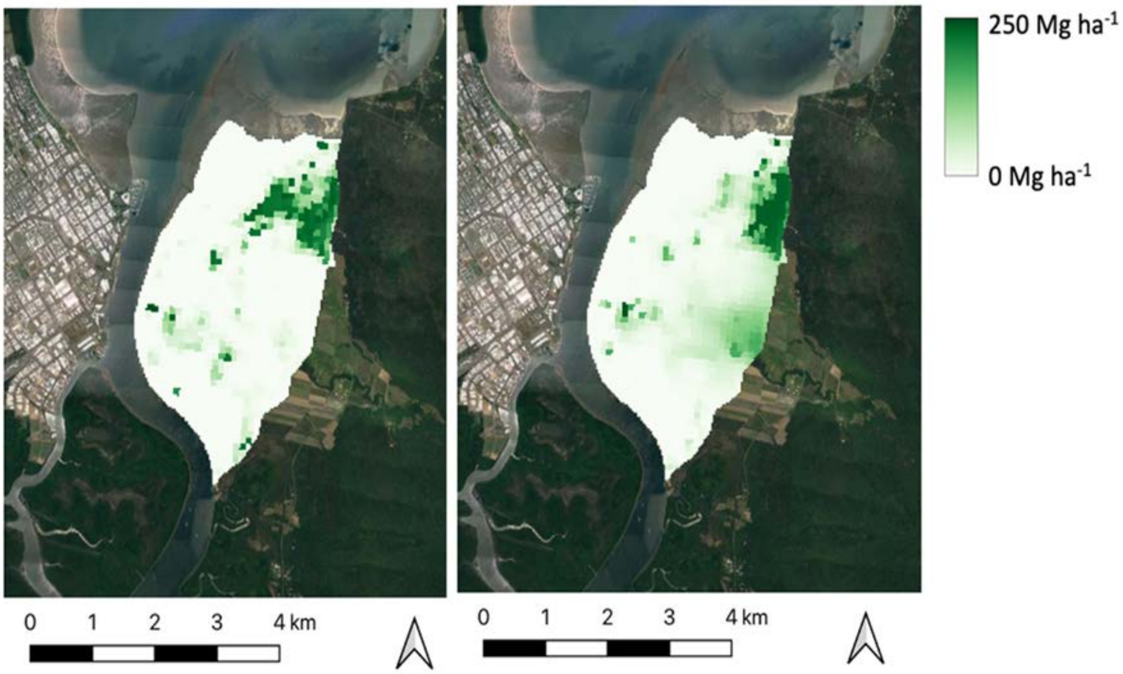

Figure 3.6: Above-ground biomass before (~2010) and after (~2018) restoration activities at Trinity Inlet.

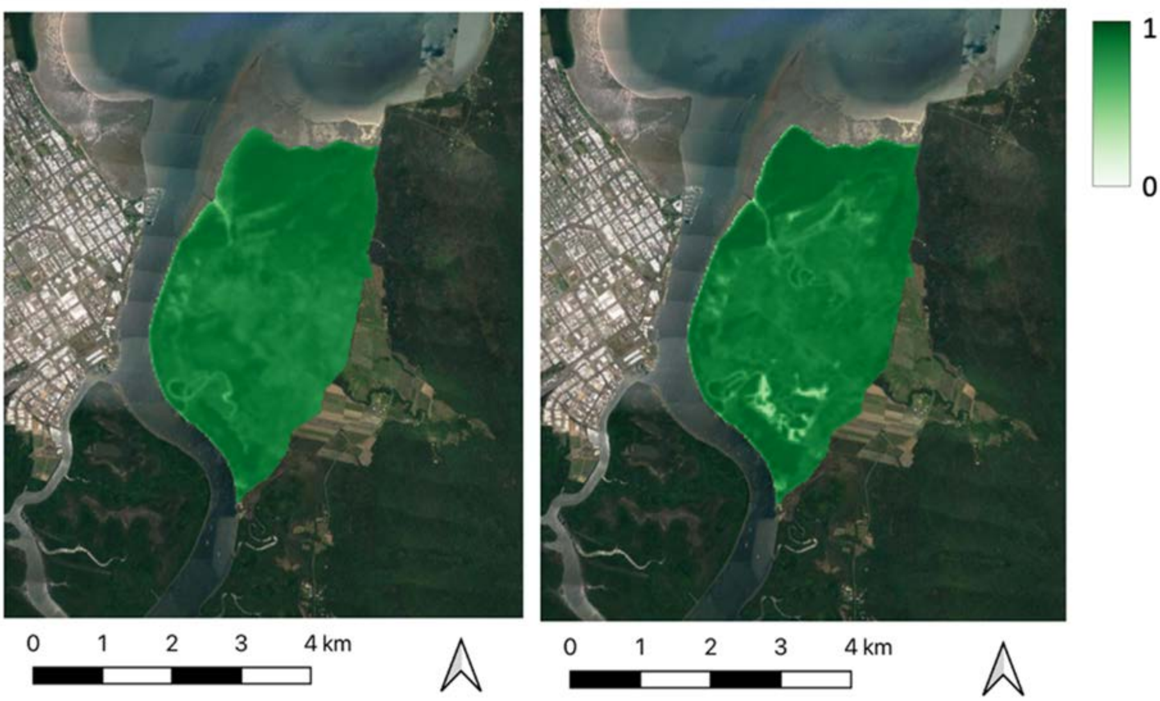

Figure 3.7: Vegetation greenness before (~2000) and after (~2021) restoration activities at Trinity Inlet.

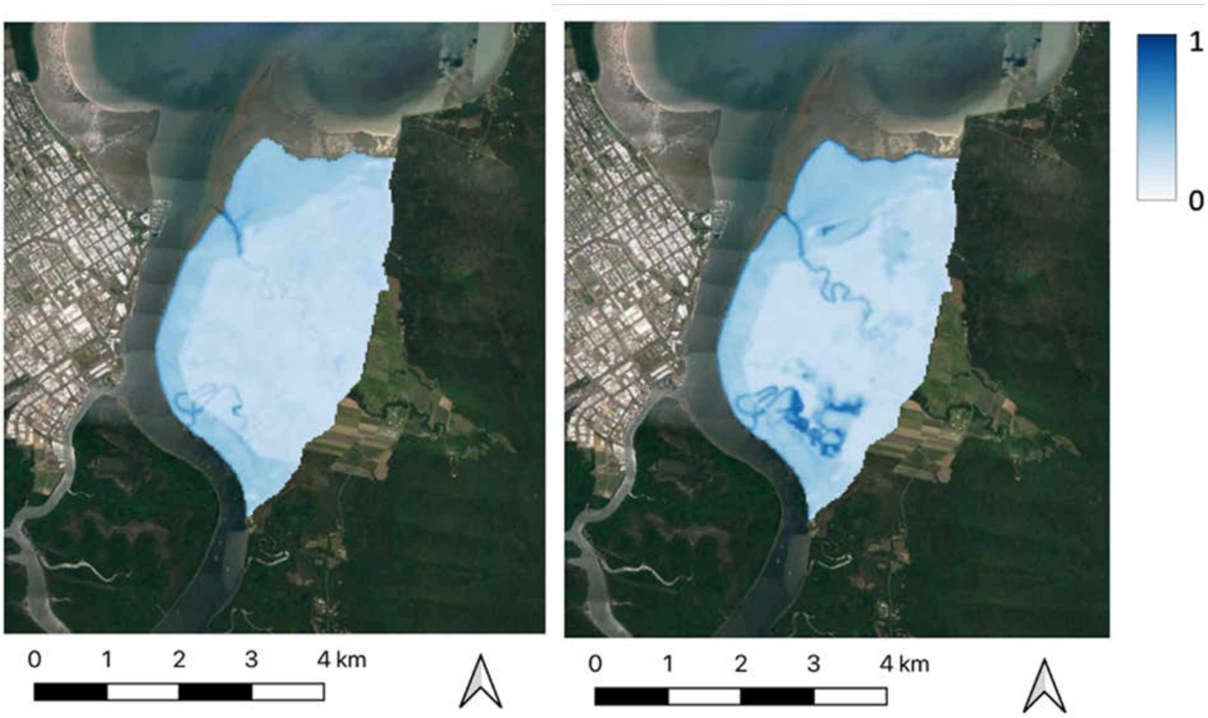

Figure 3.8: Landscape wetness before (~2000) and after (~2021) restoration activities at Trinity Inlet.

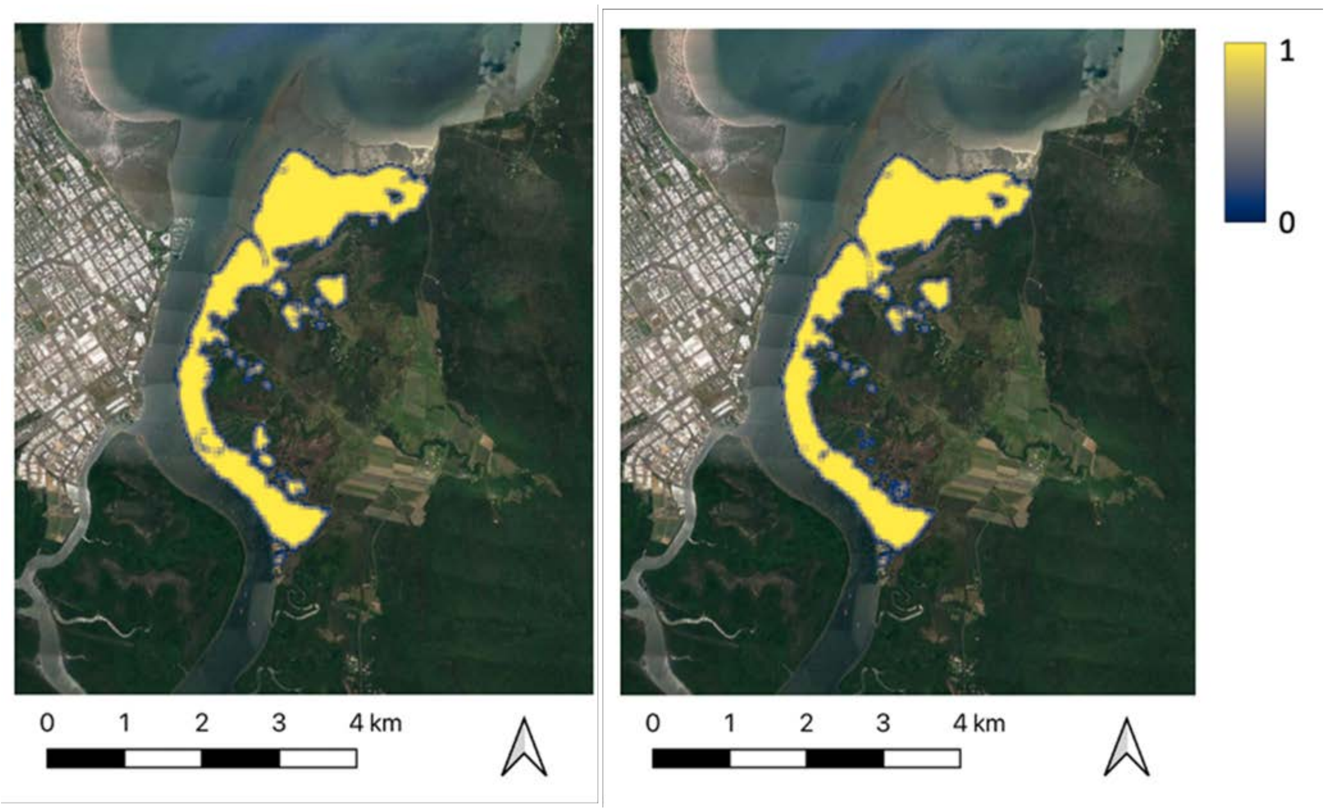

Figure 3.9: Mangrove ecosystem connectivity before (~2000) and after (~2021) restoration activities at Trinity Inlet.

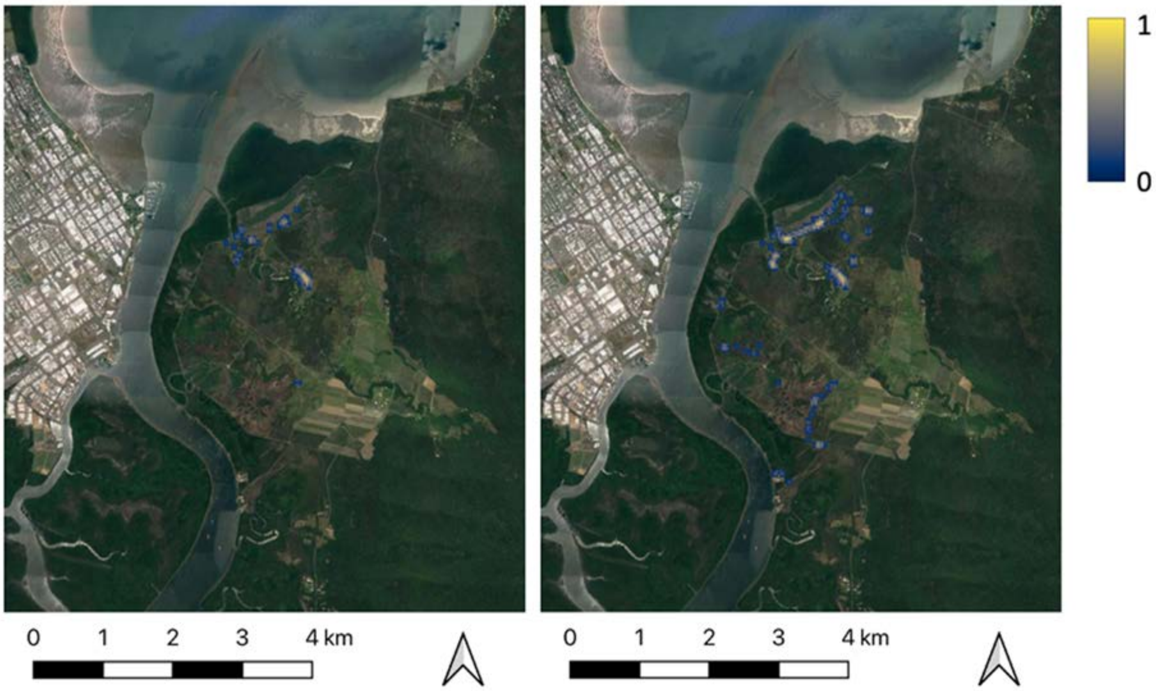

Figure 3.10: Saltmarsh ecosystem connectivity before (~2000) and after (~2021) restoration activities at Trinity Inlet.

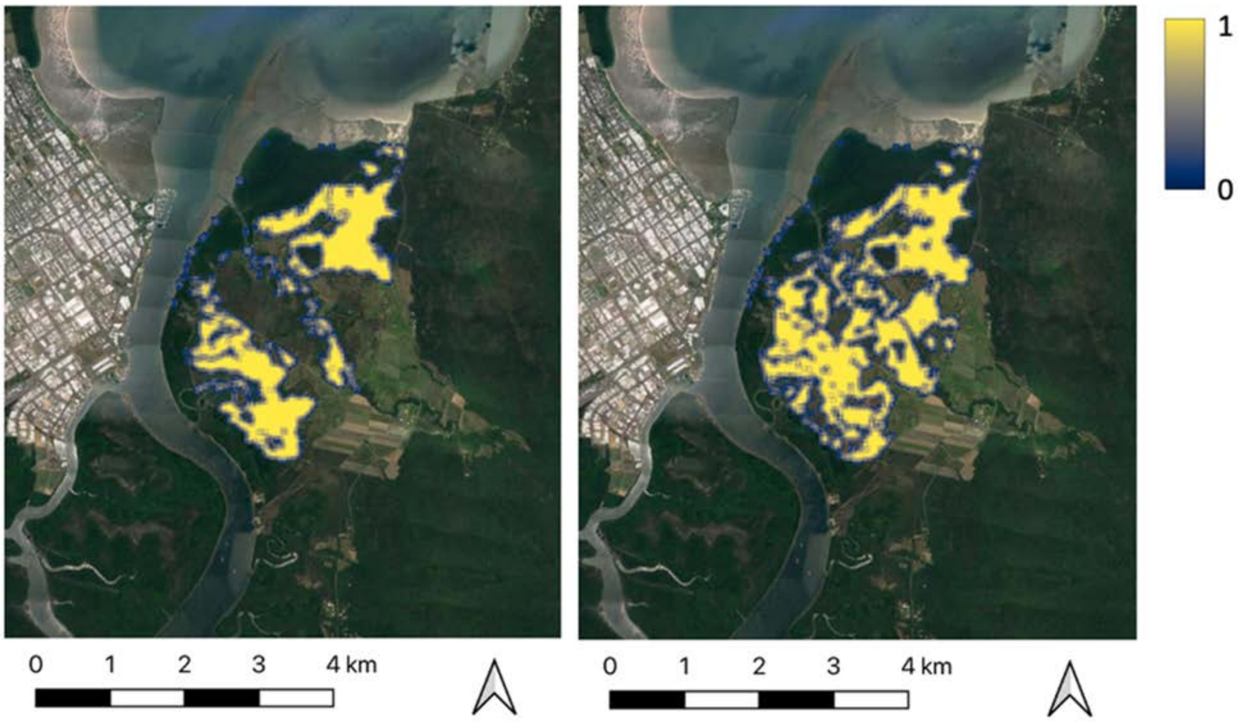

Figure 3.11: Supratidal forest ecosystem connectivity before (~2000) and after (~2021) restoration activities at Trinity Inlet.

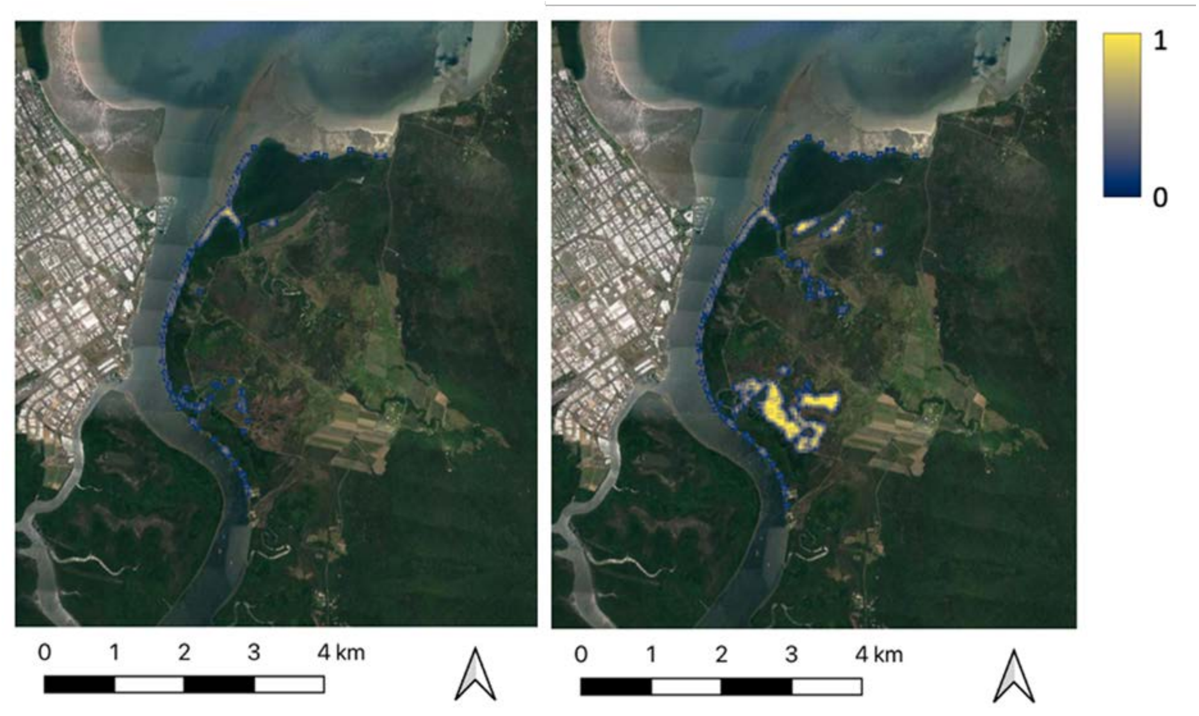

Figure 3.12: Waterbodies/mudflats connectivity before (~2000) and after (~2021) restoration activities at Trinity Inlet.

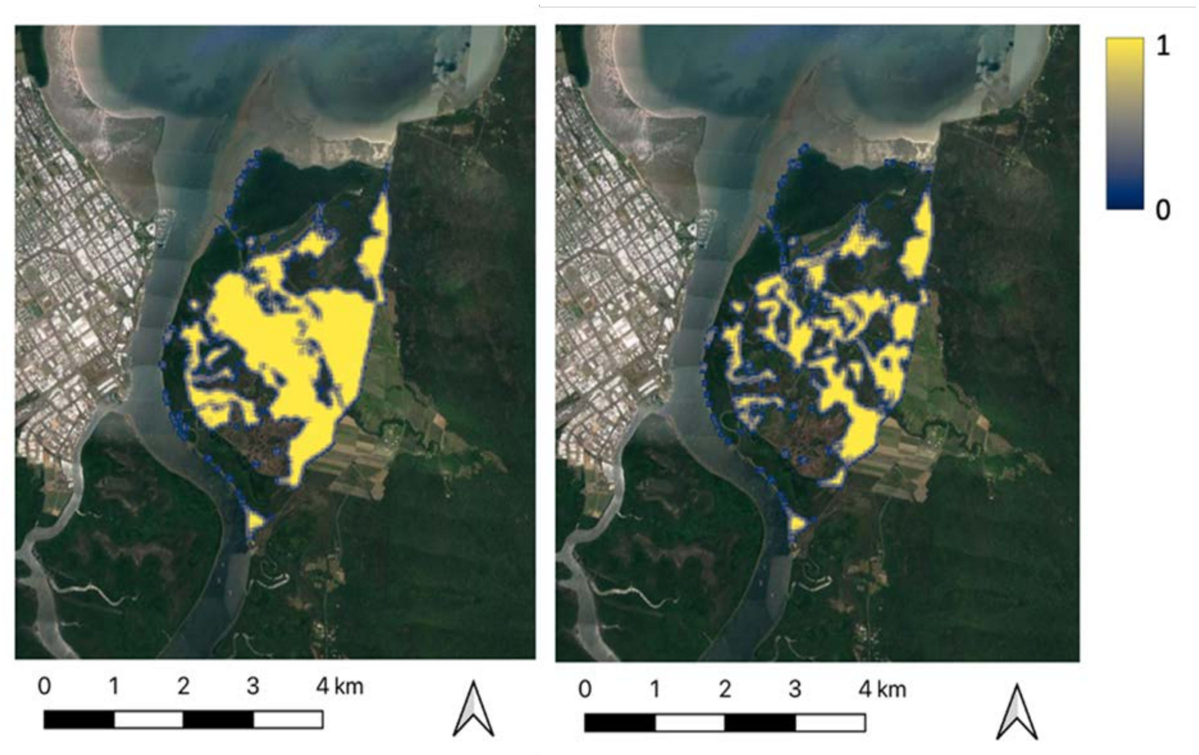

Figure 3.13: Other land covers connectivity before (~2000) and after (~2021) restoration activities at Trinity Inlet.

Interpretation and discussion

The overall capacity to assess condition at the national scale was dependent upon access to the best data available and consistent methodology for assessment of condition. There are, however, a range of other indicators that could be used to assess the structure, function and composition of an ecosystem, provided sufficient data were available.

It was critical that the condition of saltmarsh over time was based on assessing saltmarsh in areas that were always saltmarsh, not areas that were not saltmarsh prior to the restoration activity. This meant that condition was assessed in the same areas at the opening and closing data as a priority, and these condition changes were used to ascertain whether the areas that had changed extent had also improved in condition.

To overcome some of these issues with ensuring comparisons were made between same areas, we developed an approach that allowed us to report on the extent of area that either improved or declined in condition. We advocate this as the best approach for reporting changes in condition, rather than reductive approaches that rely on changes in mean values of indicators over time. It is also worthwhile emphasising that a condition indicator can be used to establish differences in condition between ecosystems, or over time. However, a step change in condition between indicators is not an appropriate comparison and should not be undertaken. For example, NDVI changes can be compared between ecosystems or over time but should not be compared to indicators of landscape greenness.

As with other assessments, access to data was limited, and this meant that Above Ground Biomass (AGB) could only be determined in 2010 and 2018, and the reporting values did not align perfectly with the opening and closing periods for the SEEA-EA tables. This approach is only utilised here due to relying on existing datasets, and measurements within the reporting period are the preferred method as outlined in the Guide.

Reflection relative to the Guide

The overall capacity to assess condition at the national scale and detailed level was dependent upon access to the best data available and that condition could be assessed using consistent methods. There are a range of other indicators that could be used to assess the structure, function and composition of an ecosystem, providing sufficient data was available. Unfortunately, there was not sufficient data to undertake condition assessment at the detailed level at Trinity Inlet. This could be resolved in future assessments when data availability improves, particularly when collection of pre-restoration data, specifically targeted for assessing condition relative to the restoration activity is prioritised prior to commencement of restoration.

It is also worthwhile emphasising that a condition indicator can be used to establish differences in condition between ecosystems, or over time, however a step change in condition between indicators is not an appropriate comparison, and should not be undertaken. For example, NDVI changes can be compared between ecosystems, or over time, but should not be compared to indicators of landscape greenness. To overcome this, condition was assessed within the same areas. For example, the condition of pre-restoration saltmarsh was compared to the condition of post-restoration saltmarsh, and these condition metrics were then used to assess the condition of areas that had changed from another ecosystem type to saltmarsh. This meant that condition was assessed in the same areas at the opening and closing data as a priority, and these condition changes were used to ascertain whether the areas that had changed extent had also improved in condition. The secondary approach that quantified the extent that either declined or improved condition provided the best means of comparing condition within the same areas, and it is strongly advocated that this approach be undertaken in future assessments.

4. Measuring and accounting for ecosystem services

4.1 Physical ecosystem services and monetary accounts

This section provides the detailed analysis of the change in physical ecosystem services and monetary valuation estimates associated with the restoration project.

For an explanation of terms used throughout compared to SEEA please refer to Glossary of relevant Ecosystem Services from SEEA (see Section 7).

4.2 Cultural services

4.2.1 Cultural services – First Nations values

Intent of work

Establishing a way to account for Indigenous cultural values and uses within an environmental economic accounting (EEA) process brings unique challenges and opportunities[10]. One challenge is that Indigenous worldviews are holistic, thus their relationships with the environment are not reducible to a use or service per se and their values are based on these relationships[11]. EEA processes rely on technocratic approaches to socio-ecological systems that presume all components are identifiable, discrete, material and hence measurable[12]. It is therefore problematic and possibly culturally unacceptable to separate and quantitatively measure values from or traded off from each other. In Indigenous terms, these relationships and values are unmeasurable[13].

Assessments need also to recognize cultural losses that may have occurred in the area due to colonisation[14]. Best practice cultural accounting in Australia should assess values not just on Indigenous owned lands, but Indigenous Country. Indigenous Country usually covers a much larger area, one that is now developed and used by multiple

[10] Manero, A., Taylor, K., Kikolakis, W., Adamowicz, W., Marshall, V., Spencer-Cotton, A., Nguyen, M. & Grafton, R. Q. (2022). A systematic literature review of non-market valuation of Indigenous peoples' values: Current knowledge, best-practice and framing questions for future research. Ecosystem Services, 54, 101417.

[11] Sangha, K. K., Russell-Smith, J. R., Morrison, S. C. & Costanza, R. (2017). Challenges for valuing ecosystem services from an Indigenous estate in northern Australia. Ecosystem Services, 25, 167-78.

[12] Reid, J. & Rout, M. (2018). Can sustainability auditing be indigenized? Agriculture and Human Values, 35(2), 283-94.

[13] Bell, S. & Morse, S. (2012). Sustainability indicators: measuring the immeasurable? Routledge, Sterling, VA, USA. Venn, T. J. & Quiggin, J. (2007). Accommodating indigenous cultural heritage values in resource assessment: Cape York Peninsula and the Murray–Darling Basin, Australia. Ecological Economics, 61(2), 334-44.

[14] Duffield, J. W., Neher, C. J. & Patterson, D. A. (2019). Natural resource valuation with a tribal perspective: a case study of the Penobscot Nation. Applied Economics, 51(22), 2377-89.

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other stakeholders. In the context of these issues, we worked in collaboration with the Mandingalbay Yidinji Aboriginal Corporation (MYAC) to develop a cultural account to offer a valuation of the cultural services of the ecosystem while acknowledging they are also cultural domains[15].

Approach taken

Engagement

Engaging the MYAC as co-researchers and leaders of the cultural account was an important first step. This included establishment of agreed principles of engagement as well as development of an action plan for establishing the account. A memorandum of understanding (MoU) and a co-developed ethics application ensured that we could start the accounting process. The MoU outlined agreements and understandings about the following: (i) who we needed to engage with; (ii) the purpose of the environmental economic accounting and questions to be asked; (iii) how to obtain cultural input; (iv) the benefits of the process;, (vi) intellectual property frameworks;, (vii) identification of which and whose values were to be considered; (viii) agreements on sources of information and how/when data will be collected and by whom, (ix) how information will be disseminated/published; and (x) process transparency and documentation of key limitations. Data availability depended on ethics approvals and ATSIS research protocols, which mean that data cannot be released in the public domain without express cultural permission.

Data collection

Data were collected through: (i) historical documentary analysis, (ii) semi structured interviews, (iii) a cultural workshop, (iv) site visits and (v) cultural site mapping using a 3D model of the site. Data were scrutinised to understand: (i) the cultural values pertaining to the site, (ii) the cultural benefits accrued from the ecosystems within the site, (iii) the benefits that the Traditional Owners gave to the ecosystems within the site; and (iv) the ways in which the restoration program had affected all of the above, pre- and post-implementation.

Cultural values and services are defined here as the importance people or groups assign to ecosystems and services in a place/Indigenous Country. This includes the idea of shared values and affiliation to Country, and whether people live within it. This definition enables a broader narrative about site value that goes beyond the aggregated utilities of individuals. Here cultural ecosystem services are the interactions between environmental spaces (i.e. physical settings such as coasts, woodlands, allotments) and the cultural or recreational practices (e.g. fishing, walking, gardening) that take place within them.

Analysis

Variations of thematic and narrative analysis were undertaken to identify key cultural values and services, including how they have changed pre and post reported key findings as a narrative. These were then developed into cultural account tables, which represented these findings. Definitions of cultural services within the SEEA-EA were applied as the springboard to develop tables. One table lists cultural services on the left, with columns describing attributes and indicators on the right. Drawing from qualitative data, many indicators were identified for each service, and placed in a second table enabling comparison of qualitative and quantitative data. This approach enables allocating numerical values to each different ecosystem type. The account table represents the services (rows), and each ecosystem unit (derived from the extent report), in columns. In conjunction with the socio-economic team, a separate table was developed that reflected the economic benefit the Traditional Owners derived from the site.

Cultural review

Throughout the project, MYAC assisted in facilitating cultural review from inception to final reporting. MYAC assisted with mapping and refining of the cultural account table. The inclusion of MYAC in all stages of the project was key to its success.

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[15] Scholte, S. S. K., van Teeffelen, A. J. A. & Verburg, P. A. (2015). Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecological Economics, 114, 67-78.

Results

Trinity inlet provides many cultural services to Traditional Owners. These include services from harvesting, using the site for cultural ceremony, for knowledge generation, transmission, and maintenance. The account emphasises the importance of the site for identity, recreation, wellbeing, family, and community. The account also demonstrates the circular nature of cultural services and highlights that while the ecosystems benefit the people, via their millennia old caring for Country practices, the people also benefit the ecosystem. These values are represented under 'other cultural services' and provide a new model for how to capture such services within the SEEA-EA framework. The findings also underscore the importance and perception of restoration sites as Country, a united whole, not divided regions. The region is interconnected with wider Country as well as to the people who claim it.

Reflection relevant to the Guide

The resulting cultural account provides information and a model with a more nuanced understanding of the cultural services provided by restoration sites. This approach is a new model for developing cultural accounts and processes for incorporating additional information not yet captured by SEEA-EA, while aligning with its essential definition of cultural services. This case study was able to document existing cultural services and provide an assessment of value for services that are often intangible. Results suggest that an addition to the guide could be the description of the benefits received by the ecosystem due to Caring for Country. In sum, the inclusion of a cultural account is an important part of the SEEA-EA process, but could be improved by fully representing the holistic nature of Indigenous ways of seeing and doing.

4.2.2 Introduction to cultural services valuation

This chapter presents the results of the development of a cultural account for the Trinity Inlet Restoration study. The chapter is divided into many sections, starting with context setting, an introduction to the Mandingalbay Yidinji people, and a description of the methods. A summary of results follows and will be presented in two parts including: (i) document analysis and (ii) results from fieldwork. The chapter then presents the cultural account table and ends with the discussion of the ways in which cultural values can be accounted for in environmental restoration projects, and their implications for blue carbon ecosystem accounting overall.

Establishing a way to account for Indigenous cultural values and uses within an environmental economic accounting process brings unique challenges and opportunities[16]. One challenge is that Indigenous worldviews are holistic and thus their relationships with the environment are not reducible to a use or service and their values are relative. Yet the value of building multi-faceted biocultural approaches is important not just in restoring ecosystems but in embedding and accounting for equitable societal outcomes[17]. Indigenous knowledge systems provide opportunities to build ecosystem services and management[18]. Analysis of cultural ecosystem services can also help document links to landscape, heritage and identity[19].

EEA processes rely on technocratic approaches to socio-ecological systems that presume all components are identifiable, discrete, material and hence measurable[20,21]. Further, current models for SEEA–EA do not explicitly recognize Indigenous

[16] Manero, A., Taylor, K., Kikolakis, W., Adamowicz, W., Marshall, V., Spencer-Cotton, A., Nguyen, M. & Grafton, R. Q. (2022). A systematic literature review of non-market valuation of Indigenous peoples' values: Current knowledge, best-practice and framing questions for future research. Ecosystem Services, 54, 101417.

[17] Morishige, K., Andrade, P., Pascua, P., Steward, K., Cadiz, E., Kapono, L. & Chong, U. (2018). Nā Kilo ʻĀina: Visions of biocultural restoration through indigenous relationships between people and place. Sustainability 10(10), 3368.

[18] Pyke, M., Toussaint, S., Close, P., Dobbs, R., Davey, I., George, K., Oades, D., Sibosado, D., McCarthy, P., Tigan, C., Angus Jnr, B., Riley, E., Cox, D., Cox, Z., Smith, B., Cox, P., Wiggan, A. & Clifton, J. (2018). Wetlands need people: A framework for understanding and promoting Australian indigenous wetland management. Ecology and Society, 23, 43.

[19] Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K. & Wetterberg, O. (2012). Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity. Ecosystem Services, 2, 14-26.

[20] Reid, J. & Rout, M. (2018). Can sustainability auditing be indigenized? Agriculture and Human Values, 35(2), 283-94.

[21] Bostedt, G. & Lundgren, T. (2010) Accounting for cultural heritage — A theoretical and empirical exploration with focus on Swedish reindeer husbandry. Ecological Economics, 69(3), 651-57.

benefits and services[22]. It is therefore problematic and possibly culturally unacceptable to separate and quantitatively measure these values. It is not possible to measure what is considered unmeasurable in Indigenous terms. There is also no substitute for sacred goods and services. Indigenous knowledge is specific and culturally held by certain people, so how it gets treated within an EEA process needs care.

Assessments need also to respect and reflect recognition of various cultural losses that may have occurred in the area due to colonization[23]. The inherent variability in Country-based value systems means a common EEA assessment process may not be appropriate[24], and different communities may hold different preferences/values around/ for the benefits of the system. For example, Indigenous peoples that still live on Country may have different views to those that live outside it. The heterogeneities amongst Indigenous groups may pose challenges in aggregating responses and the communal property rights amongst some Indigenous groups preclude individual utility structures.

Best practice cultural accounting in Australia should also assesses values not just on Indigenous owned lands but Indigenous Country. Thus, in attempting to separate services within a bounded site, which is included within but not all of Indigenous Country, it is harder to gauge the extent and value of those services.

However, identifying Indigenous values in EEA process can have benefits; it can assist in caring for Country for the relevant Indigenous group but also identify the impact /value of Indigenous cultural resource management (ICNRM) on / for the system[25,26,27,28]. Further, current EEA processes focus on the flow of benefits from nature to people but does not recognize the reciprocal responsibilities of people to care for the environment, enacted by Australian Indigenous peoples via the process of caring for Country. Cultural accounts can also help to document biocultural values in formats relevant to management (ibid).

The inclusion of sociocultural valuation techniques such as those suggested here, combined with knowledge gained via other EEA processes, can enable the development of policies and programs that can build/protect blue carbon in ecosystems while acknowledging they are also cultural domains[29]. The approach taken for this case study was informed by the 7 key questions Manero et al. (2022)[30] suggest for non-market valuation of Indigenous people's values, which were amended to align with a cultural accounting approach. These questions include understanding what the purpose of the account is, how Indigenous knowledge can inform the account, questions about who benefits and what ethical frameworks apply, whose values to consider, examination of the expected change and consideration of how to handle the limitations of cultural accounting within the SEEA-EA process.

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[22] Normyle, A., Vardon, M. & Doran, B. (2022). Ecosystem accounting and the need to recognise Indigenous perspectives. Humanities and Social Sciences Communications, 9(1), 133.

[23] Duffield, J. W., Neher, C. J. & Patterson, D. A. (2019). Natural resource valuation with a tribal perspective: a case study of the Penobscot Nation. Applied Economics, 51(22), 2377-89.

[24] Sangha, K. K., Russell-Smith, J. R., Morrison, S. C. & Costanza, R. (2017). Challenges for valuing ecosystem services from an Indigenous estate in northern Australia. Ecosystem Services, 25, 167-78.

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[27] Normyle, A., Vardon, M. & Doran, B. (2023). Aligning Indigenous values and cultural ecosystem services for ecosystem accounting: A review. Ecosystem Services, 59, 101502.

[28] Stoeckl, N., Jarvis, D., Larson, S., Larson, A., Grainger. D. & Ewamian Aboriginal Corporation. (2021). Australian Indigenous insights into ecosystem services: Beyond services towards connectedness – People, place and time. Ecosystem Services, 50, 101341.

[29] Scholte, S. S. K., van Teeffelen, A. J. A. & Verburg, P. A. (2015). Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecological Economics, 114, 67-78.

[30] Manero, A., Taylor, K., Kikolakis, W., Adamowicz, W., Marshall, V., Spencer-Cotton, A., Nguyen, M. & Grafton, R. Q. (2022). A systematic literature review of non-market valuation of Indigenous peoples' values: Current knowledge, best-practice and framing questions for future research. Ecosystem Services, 54, 101417.

The cultural accounting process was also built on via specific recognition of issues raised by Larsen et al. (2023)[31] and Stoeckl et al (2021)[32], who in work with Indigenous peoples in Australia, forecast areas that could be developed in cultural accounts. For example, the interconnectedness of Indigenous connection to and Caring for Country suggests a need to develop circular rather than linear modes of gathering information and developing a cultural account. Aligned with this approach, the approach incorporated the complementary concept of people's contribution to nature as being as important to a cultural account as what nature/ ecosystems can offer to people[33]. The relationship between nature's contributions to people and people's contribution to nature is thus recognized explicitly and emphasises the circular and holistic nature of interconnection, which contrasts with the linear and atomistic character of most accounting models.

Obtaining reliable research outputs on the cultural values and services of the restoration site requires an acknowledgement of different worldviews. External researchers work from the worldview implicit in the environmental economic accounting approach, which holds the site as a distinct or bounded part of the landscape, to which service provisions can be attributed. This contrasts with the Indigenous worldview, which does not delineate between the site and wider landscape, particularly when it comes to the value and meaning of that landscape. As one community leader put it;

"So with the site itself, in the first instance, it's part of Country. It's a make-up of Country. So we have approached from day one, our Country has been tenure blind and we've told everyone on our journey that that's how we view Country... we made it very clear from the beginning that we see Country as tenure blind and that it's been - it's been a process of putting Country back together. So East Trinity site itself in terms of a cultural landscape forms part of the larger cultural landscape of our people..." - p.2

This holistic worldview of the Traditional Owners has been acknowledged and maintained as a point of practice throughout all analyses and reporting. Notwithstanding this context, in this case study, the restoration site remains the focal point. To that end, team members created a delineation of any benefits, values or services that can be attributed specifically to the restoration of the site over the last 20 years.

The site

The site is part of the traditional Country of the Mandingalbay Yidinji people and incorporates sections of Native Title and Indigenous Protected Areas.

East Trinity Reserve is directly adjacent to the Grey Peaks National Park, a place of global ecological significance and part of the Wet Tropics of Queensland World Heritage Area. This region is important for migratory birds from Japan, China, and Korea, and regarded as essential habitat for the endangered southern cassowary. There are nineteen regional ecosystems represented in this relatively small area, some of which are endangered. The region is also part of the National recovery plan for the endangered spectacled flying fox.

Methods

This project used qualitative techniques based on a co-design approach with the Traditional Owners. This began with the development of agreements between the project lead and the Mandingalbay Yidinji Aboriginal Corporation (MYAC) which were encapsulated in a written and co-signed agreement which detailed protocols and actions around consultation, engagement, dissemination resourcing, cultural review, expectations and publishing. The ethics application listed the MY representatives as co-researchers.

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[31] Larson, S., Jarvis, D., Stoeckl, N., Barrowei, R., Coleman, B., Groves, D., Hunter, J., Lee, M., Markham, M., Larson, A., Finau, G. & Douglas, M. (2023). Piecemeal stewardship activities miss numerous social and environmental benefits associated with culturally appropriate ways of caring for country. Journal of Environmental Management, 326, 116750.

[32] Stoeckl, N., Jarvis, D., Larson, S., Larson, A., Grainger. D. & Ewamian Aboriginal Corporation. (2021). Australian Indigenous insights into ecosystem services: Beyond services towards connectedness – People, place and time. Ecosystem Services, 50, 101341.

[33] Matuk, F. A., Turnhout, E., Fleskens, L., Ferreira do Amaral, E., Haverroth, M. & Hendrik Behagel, J. (2020). Allying knowledge integration and co-production for knowledge legitimacy and usability: The Amazonian SISA policy and the Kaxinawá Indigenous people case. Environmental Science & Policy, 112, 1-9.

Once these initial but crucial steps of establishing the engagement and who to work with had occurred, it was then possible to develop the approach that would be used to develop the cultural account. Co-design of the First Nations account began with defining values and services for the site with Indigenous partners. While resulting value accounts may be translated to academic or industry report formats, outputs should faithfully reflect the views of the community, and cultural review is essential, to check if researchers' interpretation of data is faithful to the intended meanings. Cultural value accounts are only reliable and ethical to the extent that they are true to the meanings held by custodians of the culture being represented. The value framework (**Table 4.1**) was thus co-created with community leaders. Throughout all stages of the project, MYAC assisted in facilitating cultural review of all stages – from inception to final reporting. They also worked with us to map and refine the cultural account table. This process was an integral part of the project.

Further information on methodology and extended examples of qualitative data samples is provided in **Appendix A3**.

Findings presented in tables

Basic definitions of cultural services within the SEEA-EA served as springboard for development of the tables. One table lists cultural services on the left, with columns describing attributes and indicators on the right. From the qualitative data, the number of distinct kinds of indicators for each service were collated into a second table to translate qualitative data to a quantitative estimate. The conversion of indicators of services to a quantitative form, enabled the allocation of numerical values to each different ecosystem type, according to the ecosystem types relevant for each indicator. The account table represents the services (rows), and each ecosystem unit (derived from the extent report), in columns. In conjunction with the socio-economic team, a separate table was developed that reflected the economic benefit the Traditional Owners derived from the site.

Co-creation of value representations is paramount. Economic value that translates to wellbeing, security and self-determination of the Traditional Owners is important, but not the only layer of value in this case study. The value of Country - and the many dimensions of its meaning - must be acknowledged and described, using qualitative methods that account for significant non-monetary value.

How best to render an authentic account of the interlinked values that are afforded by the restoration, is a question to be answered in a co-creative process with the people themselves. Value representation encompassing and going beyond the monetary, is not just necessary for reliable research outputs, but central to them.


Photo by Through The Looking Glass Studio - http://looking-glass.com.au

Table 4.1: First iteration of value framework, developed for the East Trinity Reserve restoration case study (QLD, Australia), by Professor Melissa Nursey-Bray with Mandingalbay Yidinji elders Dale Mundraby and Dewayne Mundraby 2023.

Values/Services Grouping	Examples of values/services dimensions
Physical sites supporting cultural activity	Dreaming sites, food sites
Natural resources supporting cultural activity	Medicine science, water, air, soil, plants, animals
Accessibility to the system	Level of disruption; level of revitalisation; extent, scope of access to Country
Knowledge about the system	Language, stories, TEK (traditional environmental knowledge), lore, calendar
Wellbeing indicators	Employment on Country, housing and Country, social/ family relations, education, health indicators, security/ work
Uses of the system	Hunting, harvesting, medicine, recreation, art and craft
Connective benefits of the system	Spiritual, economic, environmental

Table 4.2: Document Analysis: The document analysis was based on thematic analysis of a range of data sources.

Source	Type	Number
Traditional Owner accounts/ historic information	■ Newsletters e.g. Djunbunji Land & Sea Program ■ Letters e.g. submissions to parliament ■ Arts e.g. Web-based exhibitions and creative or journalistic writing	33
Other sources	■ Academic articles, consultant or non-indigenous media reports ■ Industry reports e.g. Ports North EIS Government e.g. Queensland Parks & Wildlife Service & Cairns Regional Council	15

Document Analysis

Iterative thematic analysis was applied with four main stages. First, a scan for relevant content in each document was conducted across all documents. Documents were grouped into those containing direct quotes from or authored by traditional owners (as direct, cultural knowledge sources) and those produced by non-indigenous authors (as indirect cultural knowledge sources). Direct cultural knowledge sources were treated as the primary data source for this document analysis, while non-indigenous sources were treated as contextual information (**Table 4.2**).

In the second stage, 'coding' was based on the value dimension listed in the schema (**Table 4.1**). Relevant text sections in each document were identified and notes made as to which value dimension/s (codes) were represented, along with general descriptions in the researchers' words. Notes also recorded context and any overlap or intersection with other codes. The location of each relevant passage of text was recorded to assist iterative review of themes and later extraction of textual excerpts. Rather than exporting passages of text to a separate analysis software, text was reviewed in the original document, so that iterative distillation of themes did not result in text meaning being distorted beyond the original source.

The third stage was a deeper review of shared or diverging meanings (theme development from codes). Through this iterative process it became evident that all references to cultural value fell into one or more of the three '**connective benefits of the system**' depicted in the schema (**Table 4.1**). This pattern highlighted that connectedness is central to cultural value representation in this case study. From this point, the main themes were derived from 'connective benefits of the system' and adapted to reflect the particular emphases found in documents. Therefore, the value dimensions 'spiritual, economic and environment' are reflected in the theme groups of **Country**, **socio-economic capacity** and **stewardship** and described in more detail in the next section.

A fourth and final stage involved gathering example textual excerpts to illustrate the expressed value dimensions within each of three main themes. Textual excerpts were only taken from direct cultural knowledge sources, for the most direct cultural representation.

Empirical data collection - site visits

While many interviews and meetings were conducted by phone and zoom, a number of site visits were made. During data collection for the case study, we visited the East Trinity Reserve restoration site three times. The first occasion was to gain first-hand experience of the cultural tour hosted by the Mandingalbay Yidinji Traditional Owners. Notes and photographs were used to record details to contextualise qualitative accounts of cultural value. An additional purpose of this initial visit was to introduce the community members to researchers who were on their first visit to the site and had only spoken to the Traditional Owners via internet prior to that. This tour included the boat trip from Cairns that is normally used for tourist trips to the site. We were in company with representative from all research disciplines involved in the case study, a total of 12 researchers. During this first visit, we were also given a bus tour of the main features of the restored landscape, including monitoring stations. During these tours, we took notes about the restoration process, and the cultural meanings and actives that were described by our hosts. Our research group met the following day in Cairns, to report on the progress of their respective sections of the case study. Elder Dewayne Mundraby attended this meeting, providing guidance and feedback with regard to cultural matters.

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Cultural workshop

The purpose of the second visit was to gather more detailed qualitative data. This was a smaller group, with three researchers focused on the cultural account. On Monday 21 March 2023, researchers met with elder Dale Mundraby to discuss plans for gathering the data. On Tuesday 22 March 2023, researchers conducted a workshop at the ranger station adjacent the restoration site. Seven participants (aside from Dale) attended the workshop. Participants were all working within the Djunbunji Land & Sea ranger program, and some had also assisted with tours. They varied in experience and age from 22 and volunteering for a few months, to middle age and having worked at the site for more than 16 years. The purpose of the workshop was to give participants an opportunity to discuss ideas and elicit aspects of value and use of ecosystem and cultural services.

Elder Dale Mundraby introduced the research team, before Professor Melissa Nursey-Bray gave an overview of the case study and its purpose for workshop participants. Then participants were invited to think about change at the site over the last two decades, and what the site and any changes meant to them. The participants had a 'brainstorming session' using note paper, and sticky notes that could be attached to areas on either a printed map, or the '3D' map of the site, on display at the ranger base. We had open and friendly discussion with the rangers and elders that attended, and shared lunch with them. Sufficient detail was gathered during this workshop, to compile a table of values and challenges related to the East Trinity restoration. However, it was apparent that attendees found it easier to talk one-to-one, than in a group. As a result, the workshop was concluded, and three interviews were conducted in the office of the ranger base. A summary of workshop outputs is provided (**Table 4.3**).

The day after the workshop, researchers were given a third tour of the restoration area as a small group of three researchers. During this tour, there were more in-depth discussion about the landscape features and events, led by elder Dale Mundraby. Notes and photographs were also taken on this tour (**Figure 4.1**) to add further depth to our study.

Interviews

Several interviews were conducted on site and over the phone. Interviews sought to gather information about the site, the cultural and ecosystem services attributed to the site and information about pre and post restoration services. Questions were focused on the following areas:

- **i.** Position and years of working experience at the site
- **ii.** Values and services accrued from the site
- **iii.** Any visits to and recollections of the site earlier in life
- **iv.** Any changes observed over that time
- **v.** Reflections on what the changes mean for them
- **vi.** Any benefits they can see directly from the remediation
- **vii.** Any other comments about the cultural and other services and values of and about the site

Recruitment of participants for workshops and interviews was mediated by Mandingalbay Yidinji elders who also drafted the Memorandum of Understanding in collaboration with the project lead. Participants were directly invited by these elders and where they agreed to provide contact details, a researcher contacted them by phone. Some participants were met in person at the workshop. About half of the interviews took place over the internet prior to the workshop and the other half at the conclusion of the workshop.

Figure 4.1: Mudflat/pond (left) and saltmarsh (right) connectivity post-restoration (~2021) using the detailed approach.

All participants were working either paid or voluntary, for the Djunbunji Land and Sea Program and most had also had some experience with aspects of the ecotourism business. Prior to interviews, participant information sheets were provided, along with consent forms as per the requirements of the Human Ethics Research Committee of the University of Adelaide.

Semi-structured interviews were recorded on a mobile electronic device, with permission of the participants. These were done during March 2023. During the first two interviews a list of questions was refined to assist the interview to flow in a more natural, conversational style. All questions and responses were transcribed, except greeting and parting conversation.

Thematic analysis

Thematic analysis was also applied to interview transcripts. The procedure applied the stages of iterative thematic analysis described by others [34,35,36] and included: 1) getting familiar with the texts, 2) generating initial codes, 3) refining codes by reflecting across the data, 4) forming themes by identifying shared meanings, 5) clarifying core ideas of a theme; (6) mapping links to other themes; and (7) reporting on themes with examples. Initial codes were in the form of single words, for example 'belonging' or 'fauna'. Codes that represented closely related concepts were grouped together, with consideration of shared meaning in the phrases that these codes represented. Groups of codes with shared meaning were considered together and in the context of each interview. Resulting notes on shared meaning were distilled into themes. This approach of deriving themes from codes was detailed by Braun & Clarke (2019), who clarified the meaning of a theme as a group of codes with 'shared meaning underpinned or united by a core concept' - p.589.

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[34] Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101.

[35] Braun, V. & Clarke, V. (2019). Reflecting on reflexive thematic analysis. Qualitative Research in Sport, Exercise and Health, 11(4), 589-97.

[36] Riger, S. & Sigurvinsdottir, R. (2016) Handbook of Methdological Approaches to Community-Based Research: Qualitative, Quantitative, and Mixed Methods. Glenwick, Oxford University Press, London.

Value domains expressed during interviews are shown in **Figure 4.2**. The interconnectedness between these values was continually evident. **Figure 4.2** illustrates that all values sit within a wholistic conception of Country. Connections between different layers of meaning are illustrated with examples in **Table 4.4**. The following paragraphs detail each main domain of value, providing example quotes.

Socio-economic analysis of tourism operation

Rather than attempt to disentangle recreational services from cultural services in relation to tourism at the Trinity Inlet restoration site, in this case study the Mandingalbay Authentic Indigenous Tours operation is nested within the cultural account. Mandingalbay Authentic Indigenous Tours is a First Nations owned and operated business, with the intention of educating and growing awareness of culture and environment in and around the Trinity Inlet site. Information for this section of the report was collected from an interview with the marketing manager of Mandingalbay Authentic Indigenous Tours. Additionally, budget documents, financial forecasting outputs and progress reports of the enterprise were shared. It is important to note that not all EEA accounts may be suited to placing the tourism operation under the umbrella of the cultural account in the same way as this case study. It will vary depending on the functioning, services, and operational details of the tourism enterprise.

Results

Through initial desktop analysis three key thematic clusters of cultural values were identified as enhanced by the restoration of the East Trinity site. These themes were corroborated by and consistent with more in-depth first-person accounts from the workshops and interviews, and confirmed the presence of three dominant clusters of values. These are *1. Country* (dimensions: story, identity, meaning, wellbeing, interconnectedness, maintaining cultural knowledge), *2. Socio-economic capacity* (dimensions: income, capital, independence, security, health, resilience, opportunity), *3. Stewardship* (dimensions: environmental leadership in conservation e.g. land management practices, ranger patrols, knowledge sharing e.g. tourists, wider community). See **Figure 4.2** for a visual overview of these thematic groups.

Each of these dimensions of cultural value represent 'connective benefits of the system'. They are not experienced in isolation, so accurate representation of each will include references to the others. Examples of data informing these themes are presented below, with more in-depth examples from interviews provided in **Appendix A3**.

1. ***Country*** (story, identity, meaning, wellbeing, interconnectedness, maintaining cultural knowledge)

The concept of *Country* related directly to functioning and health of the culture. Country is a foundation of culture, and knowledge about it is shared in stories (whether they are told through speech, dance or artworks). The overarching concept of Country explains identity, sustenance and life purpose, all of which are interwoven with the landscape, wildlife, and all natural phenomena; as explained by Elder Vincent Mundraby[37];

'Our cultural tradition tells us that the mountains, streams, estuaries, beaches, and reefs are part of a cultural landscape created during the travels of our ancestral Spirit Beings (Dreamings). Events that happened on these creation journeys are remembered today as many sacred places located throughout our land and sea Country.' p.7

Documents indicated that ecosystem health and the wellbeing of the Mandingalbay Yidinji people are not two separate things, but different vantage points from which to view the same thing. The restoration of East Trinity Reserve, as one part of a larger whole, is therefore literally a partial restoration of culture. This restoration manifests as increased links between different aspects of culture, like being 'on Country' as a spiritual home and managing natural resources. The overarching value of these links is the improved wellbeing of both people and Country together, as described in this excerpt from a conference article[38];

[37] Mandingalbay Yidinji Aboriginal Corporation (2009). Strategic Plan for Mandingalbay Yidinji Country.

'As Mandingalbay Yidinji people, we are inseparable from the land and see, we are part of Country and Country is part of us. Our traditional Country holds our creation stories, our knowledge and keeps us connected to our ancestors. Being on our Country and looking after Country helps keep our culture and our people strong.'

At the core of the positive effects of the restoration is the worldview that Country and identity are not separate, but instead are layers of one reality. This connectedness translates directly to wellbeing as expressed in the term 'healthy Country, healthy people' offered by one elder expressed in his initial explanation of what the restoration of the site meant for the Traditional Owners;

[88] "So healthy, healthy Country, healthy people. So if Country thrives, we thrive. We have a symbiotic relationship with Country as a people." p.5 ... "So when we talk about Country, we're talking about ourselves as well in terms of our identity." p10

In this Mandingalbay Yidinji worldview, the people see themselves as physically and spiritually part of Country and that it is part of them. They hold that what happens to Country is also happening to them. The landscape being made healthier by remediation means that the people's health is improved too, both spiritually and physically. The people's understanding of their own identity, as individuals, family groups and a community, stems from a foundation in the living systems of the land and sea. Other species that call this landscape home, are also part of this foundation.

Flora, fauna and identity

Country as a cultural concept encompasses all species that visit or live in landscapes and seascapes. Various species that are returning to or increasing at the site due to the restoration are culturally important for more than their resource value; they are seen as spiritual kin. One elder described it in this way;

[88] "Well, you live it and it translates into an intergenerational framework that is consistent with transfer of knowledge, culture, story and dance, song lines and the make- up that supports the make up or the landscape surrounding the site itself aligns with, you know, with the crocodile story, the stingray." p.5

Within the worldview that Country is part of the people and vice versa, other species are also part of Country and hence entwined with the identity of the people. Animal species are part of the people's identity, and when other species benefit from the restoration, the people see their identity as being restored. The link between the people and other species feeds directly into stories and other cultural activities, both traditional and new. An example of a new expression of this identity is in the eco-tourism business logo. The Mandingalbay Yidinji people have used turtles and scorpions in their organisational logos because these animals represent entities that play important roles in the functioning of Country.

"We've infused bush tucker into the menu, working with the head chef from Ochre. There's also traditional storytelling, dancing and an international harpist as part of the entertainment."

2. ***Socio-economic capacity*** (income, capital, independence, security, health, resilience, opportunity)

Restoration of the site has resulted in some restoration of natural resources and improved First Nation capacity to link these resources with the wider economy. For example, traditional foods sourced from the site (or adjoining areas affected by the site) supplement the foods acquired by local people, which has two-fold multiple benefits including saving the people money and keeping their traditional economy active. The Strategic Plan for Mandingalbay Yidinji Country[39] describes;

'The richness and diversity of resources on our land and sea Country and our sustainable use and management of those resources, gave us a strong traditional economy for thousands of years. We established semipermanent camping areas always within easy reach of year-round food supplies.' p.7

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[38] Mandingalbay Yidinji Traditional Owners. (2014). Participatory 3 Dimensional Modelling. Sydney.

[39] Mandingalbay Yidinji Aboriginal Corporation. (2009) Strategic Plan for Mandingalybay Yidinji Country

Another example of linkages between the Indigenous economy and wider economy is the direct incomes derived from work such as ranger or tour guide duties. The Mandingalbay Eco Cultural Tourism Infrastructure Project offers nature-based tourism and environmental education, with hosting facilities at the site (since 2018). By improving the setting for this business, the restoration contributes to the quality of the experience and therefore its value[40]. The value of the business translates to investment potential and employment. For example, an editorial article[41] in the Djunbunji Land & Sea Program newsletter (December 2020), refers to the economic benefits of the ecotourism venture for the local community;

"That foundation will translate into jobs and infrastructure, and create economic independence and prosperity for our people and the wider community of Yarrabah." p.5 - Dewayne Mundraby

Employment and skills training are offered through an expanding range of activities, from ranger duties and trades needed to construct and maintain facilities, to catering, teaching and entertainment including storytelling and dance. These skills and opportunities are the means by which socio-economic capacity and cultural thriving transfer benefit both ways, strengthening culture at the same time as strengthening the socio-economic circumstances of community members. This has been an aspiration for many years during the restoration process as expressed in the 2013 development proposal for the Mandingalbay Tourism Park at East Trinity;

'The Mandingalbay Yidinji Aboriginal Corporation has strong aspirations to develop employment for its people and those of the Yarrabah community in general with the intent of creating an economic hub of opportunities and intergenerational planning.' p.9

The opportunities for developing a variety of trade skills, not only supports current employment, but represents skills that can be transferred to positions in other locations. This training and work experience enhances the longer-term employment prospects of individuals, improving their financial autonomy. For example, one ranger described putting his construction skill to work at the site and why he valued that opportunity, having moved on to a supervisory role;

[29] "So like the infrastructure down in the East Trinity Reserve? Yeah. I actually helped build that." p.3

"…recently I've been put up to the supervisor role for the working for the dole, working for the dole crew. That's going to be helping working on the Pine Creek track… But before that, I was just a ranger." p.6

The diverse kinds of work that have been done and continue onsite not only offer work experience but develop social capital via increased opportunities to collaborate and develop networks across sectors. Whether it be in surveys and monitoring of remediation outcomes, maintenance and construction or tour guiding, expanded social networks are a highly valued by this community. In addition to enhancing capacity for ongoing development of the site, this social capital is important to facilitate the role of environmental stewards, which was another key dimension of the cultural value of the site.

2. ***Stewardship*** (environmental leadership in conservation e.g. land management practices, ranger patrols)

Given the global significance of the area, monitoring, protecting and educating about biodiversity in the restoration site and contiguous areas, adds to the Traditional Owners active role and voice in global conservation. For example, the main website for the ranger program djunbunji.com.au highlights 'caring for sea turtles'. Djunbunji rangers collaborate with the Wildlife Crime Taskforce to protect Turtles and Dugongs as well as conducting rescues and working with other agencies to clear marine debris, reducing risks for these species. The water draining from the restoration site into Trinity Inlet is a major factor in the health of this estuarine system. Therefore, active involvement in maintenance and monitoring of the restored site represents increased capacity of Mandingalbay Yidinji people to protect the

[40] More details as to how and what extent the restoration contributes to the tourism enterprise will be explored during interviews.

[41] Dnbunji Land and Sea Program. (2023). Latest News, http://www.djunbunji.com.au/news/

marine life. This stewardship role extends to how the ecotourism business is managed on a day-to-day basis at East Trinity. For example, in a Djubunji Land & Sea Program newsletter (December 2017) 'everything from worm farms and composting, to air and noise management' (p.3) is considered in the operation of the enterprise.

Texts commonly describe the role of biodiversity in and around the site, which increases the richness and strength of Country, generating more living connections between flora, fauna, abiotic elements (e.g. stone and water), people and Country. The return of species and increases in biodiversity resulting from restoration increases the capacity for Mandingalby Yidinji people to educate others and act as leaders in global conservation. The focal point of this role is the Djunbunji Land & Sea Program and Rangers, run by the Mandingalbay Yidinji Aboriginal Corporation. As the restoration has involved multiple stakeholders, it has created opportunities for Traditional Owners to collaborate, build their profiles and gain valuable experience in working with multi-stakeholder projects. Manager Dale Mundraby is quoted in the Djunbunji Land & Sea Program newsletter December 2020;

"Our rangers are managers of ecological and cultural knowledge and responsible for weed and pest management activities. Our rangers are people connectors and have positive partnerships with other agencies including the Commonwealth Government, Queensland Government, Indigenous Land and Sea Corporation, Wet Tropics Management Authority, universities, Cairns regional Council, Yarrabah Aboriginal Shire Council, local schools and other indigenous communities." p.2

The following excerpt from a development proposal to the Cairns Regional Council, encapsulates the value of the site to empower the Mandingalbay Yidinji people to act as stewards of the environment. It is a description of the purpose for the nature-based tourism venture at the East Trinity site[42];

'The use of land or premises for a tourism activity, including tourist and visitor short-term accommodation, that is intended for the conservation, interpretation and appreciation of areas of environmental, cultural or heritage value, local ecosystem and attributes of the natural environment. Nature based tourism activities typically:

- *maintain a nature-based focus or product;*
- *promote environmental awareness, education and conservation;*
- *carry out sustainable practices' p.184*

In this setting, the Mandingalbay Yidinji people are in a position of conservation leadership, and they value passing on their passion, knowledge and experience to others. The rangers and tour operators have multiple opportunities to teach local school children as well as university students and scientists from further afield. The context of the lessons learned can be varied according to who the students are. For example, one ranger spoke of teaching the local school children from Yarrabah about keeping their Country tidy and cared for;

[93] "So we'll go and get the kids... we'll do a marine debris exercise and showcasing the importance of our community, keeping it clean and what it means to keep it clean," p.4

This ranger, who has been working around the site for some 16 years, has also had the opportunity of sharing his knowledge with university students and described a section of the site deliberately left as it was before remediation, so that a comparison can be seen and learned from. They as rangers valued the opportunity to share this management knowledge with students at university level;

[93] "this is an area where we actually have left it for, um like for university students to come and do their research… there are still Melaleuca. We saved the last bit of Melaleuca to actually use it for yeah for showcasing to university students in terms of, "This is what it used to be and this is how it is now and that's the remaining of it there'." p.9

Key findings illustrate that past and present involvement at the site was important for

[42] East Trinity Reserve restoration area, identified as 'Lot 158 on NR5877 in this document: 'Agenda - Ordinary Meeting', Proposed change of use proposal (nature-based tourism attraction). (10 October 2018). Cairns Regional Council.

enhancing the identity, wellbeing and ongoing socio-economic capacity of individuals and the wider Indigenous community. In reality there is no sharp delineation between the benefits these people derive from the restored site, and benefits they share with visitors, whether students or tourists. To some degree the benefits derived by visitors is accounted for in the 'recreation and existence' values section.

However, the sense of connection between Traditional Owners and visitors is of value in itself. Indeed, connectedness between all of the value dimensions described above, is a part of the site's value, because remediation has increased the instances or quality of many of these connections. The schematic in **Figure 4.2** sets out the most notable distinct types of value, while also showing that connectedness between them must be recognised for a faithful representation of cultural value as it is experienced.

Other factors affecting values. Benefits and uses

As described, there were three dimensions that describe the values, uses and benefits of the site to the First Nations peoples. However, an additional factor emerged as a driver to how benefits and values were accounted for, and this was the external factors that affect the site, although do not occur directly within it. These factors were identified to both enhance and detract from the cultural services derived by the restoration area. In this case study, other human and environmental factors played a role in how cultural value was ascribed during the same time period as the restoration. One of these factors was the nature and history of land tenure and accessibility: the administrative status of the site and adjacent land influences the cultural value that is experienced from the restoration. This is mainly because it affects access to the site and determines how the site must be managed. The World Heritage status of nearby regions influences the priorities at the site, while Native Title adjoins the site assists the Traditional Owners with access to it. The status of the site itself as an Indigenous Protected Area (IPA) enhances the autonomy and agency of the Mandingalbay Yidinji people. The value of the site restoration is therefore enhanced by access and empowerment afforded by this legislation, as one elder explains;

[88] "what we do with, you know, hunting crabs or fishing and those cultural activities but knowing back in the day before they, when, you know, prior to 1992 when the Native Title Act came into play, a lot of these areas were not accessible because of the fact that we're pretty much locked out." p.2

"...Even though we don't have native title over East Trinity but we have surrounding East Trinity exclusive and non-exclusive native title and that's why we put the IPA at the top of it for its cultural and natural values." p.4

The cultural services experienced because of the remediation therefore would not be as great were it not for the access afforded by these administrative tools. But access would not result in the same benefits, were it not for the restoration. Other external factors include environmental change at the site, cyclones to incursion of feral animals. So, when considering change over time, and how change translates to value in remediation, it must be acknowledged that not all change is due to the remediation. For example, one ranger attributed some change in structure of mangroves at the site to a cyclone;

[64] "...but with the cyclones and stuff over time, you know, those trees would have fell down with the cyclone break off and died. And now the different mangroves that come through, in their place." p.3

This finding suggests that these external factors, can add to or detract from the values derived by a restoration and need to be considered/accounted for in some way in the accounting process.

The consistency between themes amongst all the data collected across multiple sources, highlights not only the benefits that First Nations receive from the restoration but also that they deliver benefits that enhance the restoration via Caring for Country informed by a holistic perspective on management. The key themes and values are represented in the following **Tables 4.3** and **Figure 4.4**.

Table 4.3: Workshop output summary- cultural value experiences & observations by participants. Black text = cultural values enhanced by the Trinity Inlet Restoration site. Red text = challenges arising from environmental changes at the site over the remediation period (or increased public profile).

Domains of values	Changes linked to site remediation			Workshop content	
Knowledge	Physical sites	Natural resources	Accessibility	Wellbeing	Uses
Traditional value of area	Wildlife & native flora returning / regrowing	Water pH returning to 'decent level'	Increased human traffic	Ancestors fought for us	Food / hunt & gather
Next generation	Mangroves coming back	Cleaner water	Camping	Future generations	Meat across seasons
Ancestors	Weeds and pests	Weeds		Coming together	Tools
East Trinity means a lot. Cultural values are now, not just in the past.	Sea level rising. Sea grass meadow returned & seed dispersed to surrounding areas	Fish more abundant	More illegal hunting (incl. firearms) undersized fish catches, taking native plants	Social & emotional wellbeing of 'the mob'	Deadly dinner' events. 'The mob returned & utilised the area again'
Stories shared, whether camping, meeting & hunting / gathering	Returning: Migratory bird species, crocodile / ferns, turtles, dugongs		More intruders / public access	Training for rangers & volunteers	Shell foods eg Wirral.
The name, the art, the design of an artefact.	Melaleuca areas returned to natural mangroves			Spiritual & physical connection	Rangers go hunting, camping & story telling
All of the significance is giving us a connection to the Country, the animals & everything that is there				Physically enriched in us - ceremony, places, song & dance.	
The name is family name - self-determined brand					
Wattle flowers mean fish ready to catch					

Table 4.4: Interview outputs: selected examples of connected values[43].

Examples of connected cultural values	Example quote
(activities) + (employment)	*[88] "but the dances, the dances, song traditionally that we deliver, whether it be in a social context or business context. You know talks about that site and Country, as it were, before it was impacted." p.4*
(generations, knowledge) (respect) + (training)	*[93] "So we'll go and get the kids [from Yarrabah school] we'll do a marine debris exercise and showcasing the importance of our community, keeping it clean and what it means to keep it clean," p.4*
(ecosystem health) + (employment)	*[88] "no-one wants to pay money to come along and have a look at, you know, destructive environment. ... They haven't – but it joins hands with the environmental value as well as the cultural value. So they're interlinked." p.3*
(activities, generations) + (uses) community	*'we practice a lot of our hunting methods and you know stuff within the area itself. Our old people occupied it for years and years and years before you know. And there's no there's no document to state that you know how long they were occupying the area but you can see before the sixties and that yeah, our people were - the area was thriving. The only thing was when CSR came in and wanted to cultivate cane after they put these drainages in, that's when the bacteria started oxidisation of the soil. p.13*
(agency, respect, wellbeing) + 3 (independence, employment)	*[93] 'Like what we're trying to do is become self-sufficient and we can get... grant money, and then we can create employment because it's going to push out 460 positions. Um, in Yarrabah itself, you have an unemployment rate of about 87%. So we want to try and re-stimulate that growth but in the positions that we're going to be pushing it from here.' p.6*
(employment, training) + (wellbeing, respect)	*[93]... 'we have shy young people who came through the doors and like when they first came here they were shy to speak. Now they're pretty... motivational speaker... Yeah, big, big change, you know? So yeah, like not only that, their well-being changed as well. They become more and more involved...' p.14*
(accessibility) + (belonging, activities) + (uses, resources)	*[75] 'I think that's one of the beauties of being a ranger is being able to access that area, whereas generally it's not open to the public... I've never known it to be open to the Mandingalbay people. So with the Ranger program, we're able to, you know, have people come back on Country... and be able to practice their, you know, hunting, collecting oysters, shell foods and fishing in that area.' p.1*

[43] Numbers correspond to the domains set out in the above figure. Words in parenthesis are specific layers of meaning in each value domain. The '+' sign denotes connection between the values. Illustrative example quotes are shown in the right hand column. Some quotes hold more than one layer of meaning in a value domain – shown as more than one word in parenthesis.

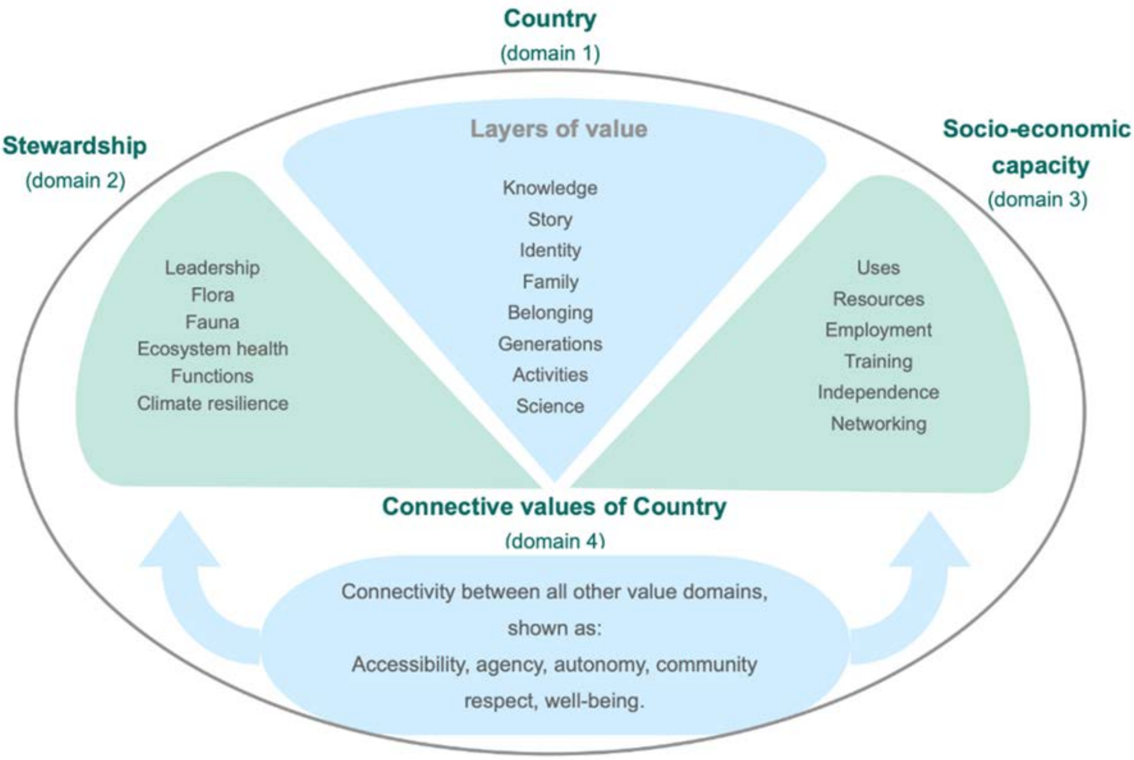

Figure 4.2: Interview output summary[44]

Results summary: Cultural Account

In summary, for these traditional owners, the site restoration represented healing. The restoration is seen as healing Country in a broader environmental sense, but also healing of their own sense of self and well-being. The external physical restoration of the site aligns with an internal restoration, which is felt through increased connection to ancestors and younger generations. Through ongoing monitoring, use and development of the restored site, the people are enacting the vision of their forbears. They also have new ways of connecting with their children through sharing cultural activities at the site.

The identity of the Mandingalbay Yidinji people is further enhanced by interacting with other stakeholders in relation to activities at the site. Interacting with tourists and various agencies, they demonstrate a pro-active, environmentally responsible and well organised presence at the site. They value this role as a way to counter negative stereotypes and to educate the broader community about their culture. The opportunity to watch over and care for the recovering and evolving ecosystem is valued, not only as meaningful work, but as enjoyable and satisfying daily life. The wildlife and plants at the site inspire a sense of discovery, and ongoing connection with cultural stories and meaning.

The main township of Yarrabah where the majority of participants live or grew up, is hampered by significant socio-economic disadvantage. The ranger program and ecotourism projects being hosted at the site are highly valued as a way to improve the socio-economic standing of the people, through provision of jobs, training, self-esteem and networking. These participants valued the hope and vision they shared,as a result of the viability of current and future plans for use of the site. This viability was made possible by the remediation.

[44] Conceptual diagram showing domains of cultural value: In each domain, specific layers of meaning are listed, based on data from interviews and site visits. This schematic is the basis for examples of connection between values. This figure acts as a conceptual tool to illustrate how values co-exist in a wholistic experience and perception of culture (also termed 'Country').

Economic Account for First Nation business: The eco-tourism venture

Mandingalbay Authentic Indigenous Tours

This section presents the results of the account undertaken for the value of the Mandingalbay Authentic Indigenous tours. This section is presented separately from the account described above, because it is a specific economic account, and could be included in the socio-economic section. This information provides an account of the value of the tourism operation, Mandingalbay Authentic Indigenous Tours, that operates within the Trinity Inlet restoration site. The tourist operation is operated by Mandingalbay Yidinji Aboriginal Corporation (MYAC), and currently provides, and will continue to provide many services and values to the local First Nation groups, as well as to the tourists who visit the site. Due to the complexities in disentangling recreational services from cultural services in relation to tourism at the Trinity Inlet restoration site, in this case study we have chosen to report on the Mandingalbay Authentic Indigenous Tours operation in the cultural account. It is important to note that not all EEA accounts may be suited to treating tourism operations in the same way, and this may vary depending on the functioning, services, and operational details of the tourism enterprise. Information here within includes the services and values that the tourism operation provides to both the Mandingalbay Yidinji Peoples and the Indigenous or non-Indigenous tourists which visit the site through the Mandingalbay Authentic Indigenous Tours.

Background on Mandingalbay Authentic Indigenous Tours[45]

Mandingalbay Authentic Indigenous Tours has two main business purposes:

- To enhance and grow a community-based visitor economy, whilst showcasing and protecting cultural and environmental values; and
- Use tourism as a vehicle for promoting the Mandingalbay Indigenous Protected Area's successful conservation model with clearly demonstrated outcomes for the renewal and protection of natural environment through a decade of Ecosystem Restoration.

The tourism operation operates solely out of the Trinity Inlet restoration site and is a relatively new business (founded December 2021). There are four different tour experiences and event products available onsite including hands-on Country eco tours, camping experiences, and three course evening meals(**Table 4.5**). Currently, Mandingalbay Authentic Indigenous Tours run three tourist events weekly, with this number predicted to build to five per week during the peak season. The event that is forecast to be the most popular in the current financial year is the Hands-on Country Eco Tours, with over 1700 tickets predicted to be sold (**Table 4.5**).

Economic values of Mandingalbay Eco Cultural Tours

Mandingalbay Eco Cultural Tours is a relatively new business enterprise and may take some time to see economic benefits and value. Economic evaluation of the business currently indicates that the profit business is currently operating at a loss (**Table 4.6**). This is driven by the high cost of bus hire ($114,400 annually), which uses almost all of the annual business revenue ($118,790). It should be noted that fianncial estimates were calculated from the 2021/2022 financial year, when the tourism hardships from the Covid-19 pandemic were still prevalent. The difficulties of Covid-19 to tourism are well documented, with International visitation to Cairns is still only at 20% of pre-pandemic levels, although these numbers are predicted to increase rapidly.

The financial goal of Mandingalbay Eco Cultural Tours is to break even by bringing in sufficient revenue to pay off operating costs for the 2023-2024 financial year. This will would be possible if an increased number of tourists visited the site, which could be achieved by increasing marketing efforts and attracting international tourists. Ticket prices would also need to increase by 7 %.

[45] Mandingalbay Authentic Indigenous Tours. (2023). Bang Media. https://mandingalbay.com.au

Table 4.5: Summary of the event products, costs and number of tickets sold in 2022-2023 financial year revenue forecast of Mandingalbay Authentic Indigenous Tours[46,47].

Event product	Description	Cost (2022 - 2023 for fully paying adult)	Number of tickets forecast to be sold July 2022 - June 2023
Hands on Country Eco Tour	A three-hour tour, including a boat ride to the Trinity Inlet site, a traditional smoking ceremony, and sharing of authentic knowledge and insights	$149 AUD	1710
Two Day Camping Experience	An overnight stay in the Trinity Inlet site, including a boat ride, all camping equipment, and the sharing of authentic knowledge and insights	$250 AUD	220
Deadly Dinner	An evening dinner event held within the Trinity Inlet site. Includes a boat ride to the site, a three-course dinner, ceremonial dancing by Mandingalbay Yidinji People and sharing of authentic knowledge and insights	$288 AUD	500
Small Group Private Charters	This tour option is for the corporate and conference market, and can include tours specific to the needs of the client	Variable	

Table 4.6: Estimates of economic activity for Mandingalbay Authentic Indigenous Tours, based on 2021/2022 revenue.

		AUD ($)
Revenue		118,790
Operating costs	Food	3,660
	Labour*	16,368
	Bus	114,440
Operating profit		-15,638
Fixed costs per year	Boat maintenance	15,000
	Marketing	25,000
Capital costs**		99,112

*Estimate of 176 hours, assuming 6 staff, half day per tour: 528 days of employment per year (excludes admin staff)

**Annualised value of boat and infrastructure costs, at 7% over 20 years

[46] Mandingalbay Authentic Indigenous Tours (2023). Bang Media. https://mandingalbay.com.au

[47] Brady, M. (2022). Mandingalbay Ancient Indigenous Tours 2022 Progress Report. Mandingalbay Yidinji Aboriginal Corporation.

Services and values provided by Mandingalbay Eco Cultural Tours

For the Mandingalbay Yidinji People the tourism operation provides employment opportunities, with six staff required to perform each Hands-on Country Eco Tour, occurring three to five times a week. This includes roles as skippers, tour guides, coach drivers, and supporting team members (e.g. food preparation and serving, infrastructure preparation etc). The training and education required to perform these roles, and the broad level employment skills needed (e.g. first aid training) are further benefits and values showcased by the employment opportunities.

Regarding economic value, the infrastructure (e.g. boat, facilities at pontoon, boardwalk, etc.) provides a long-lasting, invested economic value. This is predicted to increase in the coming years as the Infrastructure Tourism Project expands (for more information see future directions section below). Despite the current predicted profit loss of the business, it is expected that in the coming years the business will become profitable. This potential profit can eventually be fed back into Mandingalbay Yidinji Authentic Corporation and invested in the Indigenous People of the area, providing broad level economic benefit.

Summary of results and Future directions of Mandingalbay Eco Cultural Tourism

At the time of writing this case study, the tourism operation alongside Mandingalbay Yidinji Aboriginal Corporation has plans to expand its operation through an Eco Cultural Infrastructure Tourism Project. This project is costed at $46.8 million AUD and aims to showcase local Indigenous history, as well as the cultural and natural environment. The project plans to provide significant value to the Mandingalbay Yidinji people and the community of Yarrabahthrough both cultural and economic services and opportunities. These services and values will expand beyond the local Indigenous community and into the broader tropical North Queensland region.

The project is set to be completed in three stages, with the first stage already delivered and in operation. This involved the delivery of a 14 metre (42 passenger) river cruise vessel, a pontoon jetty with a 25 metres boardwalk to an arrival shelter and an amenity block (**Figure 4.3**). The next phases will include three main towers connected by a prominent boardwalk. The towers will include a variety of spaces where the Mandingalbay Yidinji culture, traditions, environment and beliefs can be shared and experienced by tourists such as meeting, learning and exhibition spaces. There are also proposals to include recreational activities such as ziplining, abseiling, bushwalking and seg-way tours. Extension of camping/overnight stays such as 'glamping' and other accommodation options are also being considered.

Figure 4.3: Photograph of the arrival shelter for Mandingalbay Authentic Indigenous Tours in the Trinity Inlet restoration site build as part of the Infrastructure Tourism Project.

The account for cultural services

Development of accounts for ecosystem cultural services is difficult because the SEEA-EA provides limited guidance on cultural ecosystem services. Further, ecosystem services in SEEA-EA are defined as what ecosystems provide to people and not what humans offer nature[48]. The protection and management of environment by people is covered in the SEEA-EA Central Framework[49] under 'Production of environmental protection specific services' (pp. 103 to 105, Section 45) which offers the basis of a potential accounting solution. As it stands in the SEEA-EA, the services refer only to such services as "produced by economic units for sale or own use" pp.103. This reference does not include non-monetary values, like identity or spiritual practices.

The circularity that is inherent in Indigenous perspectives' (**Figure 4.4**) and which was identified in the results of this cultural account is not apparent in ecosystem accounting. The following ecosystem services account seeks to reconcile the two elements and drawing on the key results, represent them, via a suite of cultural indicators that are mapped against the ecosystem services the site provides. In essence, the account seeks to represent what is a two-way relationship. As such, three tables and one account are presented: (i) **Table 4.7** provides the definitions of cultural ecosystem services as per the SEEA-EA augmented by additional services identified in this study; (ii) **Table 4.8** defines the attributes and indicators of each attribute that contribute to cultural ecosystems services. For the following additional tables see **Appendix A3** (iii) **Table 4.9** shows the interrelationships of cultural attributes and cultural services and the relative importance of each attribute to each service, and; (iv) **Table 4.10** and **Table 4.11** present a cultural ecosystem services account with some example recordings.

[48] Normyle, A., Doran, B., Vardon, M., Mathews, D., Melbourne, J. & Althor, G. (2022). An Indigenous Perspective on Ecosystem Accounting: Challenges and Opportunities Revealed by an Australian Case Study. Ambio, 51(11), 2227-39.

[49] United Nations et al. (2021). System of Environmental-Economic Accounting— Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available at: https://seea.un.org/ecosystem-accounting

Figure 4.4: Services are circular as they are either provided for nature to benefit society or by people to benefit nature.

Context

To develop the cultural account, a range of sources were used to determine what was meant by cultural services and the definition provided by the UNESCO Framework for Cultural Statistics (2009)[50] was applied, which defines cultural services as those that satisfy cultural interests or need and they do not represent cultural material goods in themselves but facilitate their production and distribution. Other definitions are also[51,52]. The SEAA-EA definition of cultural services which is services "which are generated from the physical settings, locations or situations that give rise to intellectual and symbolic benefits experienced by people from ecosystems through recreation, knowledge development, relaxation and spiritual reflection" also provides guidance for how to understand cultural services.

All definitions share a concern with how to articulate non-material benefits from ecosystems and the fact that they serve a [articular purpose that may be hard to tangibly measure. The Cultural Account tables have been prepared in alignment with these definitions. We suggest that the tables per se can be used not just for blue systems (as in this case study) but also for terrestrial systems. We acknowledge that the tables implicit reflect cultural services for Indigenous country, and as such, inevitably also reflect the interconnection between land and sea[53,54].

[50] UNESCO. (2009). The 2009 UNESCO framework for cultural statistics (FCS). Montreal, Canada: United Nations Educational, Scientific, Cultural Organization.

[51] Dickinson, D. C. & Hobbs, R. J. (2017). Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research." Ecosystem Services, 25, 179-94

[52] Hernández-Morcillo, M., Plieninger, T. & Bieling, C. (2013). An empirical review of cultural ecosystem service indicators." Ecological Indicators, 29, 434-44

[53] Normyle, A., Vardon, M. & Doran, B. (2022). Ecosystem accounting and the need to recognise Indigenous perspectives. Humanities and Social Sciences Communications, 9(1), 133.

[54] Vaz, A. S. & Santos, H. (2018). "Transplanetary" perspective of cultural ecosystem services – Extending Dickinson and Hobbs (2017)'s definitions, characteristics and challenges of cultural services' research." Ecosystem Services 29, 168-69.

Table 4.7: List of definitions of cultural ecosystem services, from Table 5.3 in SEEA guidelines , plus additional definitions of identified services (non-shaded).

Cultural services	Definitions
Recreation-related services	Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. This includes services to both locals and non-locals (i.e. visitors, including tourists). Recreation-related services may also be supplied to those undertaking recreational fishing and hunting. This is a final ecosystem service.
Visual amenity services	Visual amenity services are the ecosystem contributions to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual. This service combines with other ecosystem services, including recreation related services and noise attenuation services to underpin amenity values. This is a final ecosystem service.
Educational, scientific and research services	Education, scientific and research services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use the environment through intellectual interactions with the environment. This is a final ecosystem service.
Spiritual, artistic and symbolic services	Spiritual artistic and symbolic services are the ecosystem contributions, including physical sites and biophysical characteristics and qualities of ecosystems - recognized by people for their cultural, historical, sacred of religious significance, These services may underpin people's cultural identity and may inspire people to express themselves through various artistic media. This is a final ecosystem service.
Other cultural services	
Wellbeing Services	Wellbeing services are the ecosystem contributions to the specific enhanced wellbeing of local people. This includes improved wellbeing due to employment, housing, education and social benefits provided by the ecosystem. This is a final ecosystem service.
Stewardship services	Stewardship services are the set of practices that involve sustainably managing the natural resources and harvests of lands, territories, waters, and coastal seas. Stewardship services relate specifically to upholding these caring responsibilities for future generations. This is a final ecosystem service.
Provisioning Service – Wild animals, plants and other biomass provisioning services	Wild animals, plants and other biomass provisioning services are the ecosystem contributions to the growth of wild animals, plants and other biomass that are captured and harvested in uncultivated production contexts by economic units for various uses. The scope includes non-wood forest products (NWFP) and services related to hunting, trapping and bio-prospecting activities; but excludes wild fish and other natural aquatic biomass (included in previous class). This is a final ecosystem service

Table 4.8: List of attributes contributing to ecosystem services. Green text represents services provided to people to benefit nature, while blue text represents services provided by nature to benefit society. *Continued over page*.

Attribute	Definition	Indicator	Metrics/units of measurement
Knowledge	Traditional knowledge or 'lore', as handed on from preceding generations & from current – to new generations. Knowledge encompasses social rules, spiritual practices & identity, song-lines, social structure & connections (kinship). Includes knowledge of environmental cues & 'caring for Country' (see below). Knowledge also refers to any other knowledge types that TO's may use: e.g: **science** and '**western**' and '**eastern**' **philosophy**. **Knowledge** (all types) includes storage & preservation for long term maintenance of knowledge (e.g. library, museum).	**Number of TYPES of knowledge transmission, dissemination & maintenance facilitated or enhanced by the ecosystem. Measure amounts within each type where possible.** Example types: Stories, either verbal or written, regardless of medium. Songs, dances & artworks that contain knowledge about any elements as per definition. Refers to both 'in-person' and indirect transmission (e.g. online). Research outputs e.g. biological surveys, social sciences inquiry, neuroscience outputs, philosophical writings – determined by what TO's engage with / use.	Counts of distinct thematic meanings identified in qualitative data;
Recreation	Traditional Owners' use of the site for enjoyment / leisure / sport / entertainment activities. Activities may vary greatly according to landscape type.	**Number of TYPES of recreation activities at the site, or increased by the ecosystem. Measure amounts within each type where possible.** Example types: Family gatherings, camping, recreational fishing, handcrafts.	Counts of distinct thematic meanings identified in qualitative data;
Harvesting	Gathering and / or making use of any organisms or abiotic resources, for food, medicinal or other cultural practices, including ceremony. **Types of organisms should be reviewed by Traditional Owners**, who may recognise (hence value) categories of organisms differently from scientific 'species'.	**Number of TYPES of organism & resources used at, or increased by the ecosystem. Measure amounts within each type where possible.** Example types: Clay for body-paint, reeds for weaving, bark for shelter, herbs for medicine, meat, vegetables.	Counts of distinct thematic meanings identified in qualitative data;

Table 4.8: Cont.

Attribute	Definition	Indicator	Metrics/units of measurement
Identity	Ways of determining 'self' at all scales, Individual & group scales. Identity includes past, present & future; includes ways of understanding past identity, understanding & reviewing current identity & developing forward-looking identity. This attribute has deep overlap with knowledge. In accounting, determine whether data focusses on a) knowledge or b) participant expression of identity.	**Number of WAYS identity** (individual & group) **is facilitated or increased by the ecosystem. Not quantifiable beyond 'ways'.** Example types: (receiving) Self: **I am** recognised by Country Group: '**we are** children of ancestral spirits' (giving) Self: **I'm a** ranger, teacher, guide. Group: '**we are** protectors, healers, stewards…'	Counts of distinct thematic meanings identified in qualitative data;
Access	Capacity of Traditional Owners to be on Country & access parts of Country & move around freely. Critical context: extent of historic disruption from colonisation & external factors that affect current access e.g. tenure, Native Title.	**Number of WAYS access is facilitated or enhanced by the site ecosystem. Measure amounts within each 'way' where possible.** Example ways: Increase in visits (across all purposes). Increase in land area that can be accessed. Increase in times of day / year that Country can be accessed.	Counts of distinct thematic meanings identified in qualitative data;
Social capital	Non-market value of education, skills training, networking, self-respect, confidence, experience, reputation & increased public profile i.e. social capital. This attribute is distinct from dollar-values like 'income' or 'market value' – instead represents social aspects of capacity development.	**Number of WAYS socio-economic capacity is facilitated or enhanced by the ecosystem. Not quantifiable beyond 'ways'.** Example ways: Gaining broader work experience, engagements with external entities, building network & profile, i.e. reputation & social capital	Counts of distinct thematic meanings identified in qualitative data;
Community cohesion	Factors that strengthen solidarity, cohesion & contentment shared among members of the local community. This category accommodates any influences on collective wellbeing, not already represented in others.	**Number of WAYS community cohesion is facilitated or enhanced by the ecosystem. Not quantifiable beyond 'ways'.** Example ways: Conflicts / rifts that have been remedied. Effect of events & meanings that create sense of sharing & bonding. Negative influences that have been counter-acted. Events / initiatives that improve community cohesion.	Counts of distinct thematic meanings identified in qualitative data;

Table 4.8: Cont.

Attribute	Definition	Indicator	Metrics/units of measurement
Caring for Country	Country is a living entity, of which the people are part. 'Caring for Country' includes any actions to maintain the health and wellness of Country, whether those actions relate to physical features or spiritual features of Country. (Knowledge of such is accounted for under 'knowledge' attribute)	Number of ACTIONS considered 'caring for Country' by TOs - facilitated or increased by the site. Not quantifiable beyond 'actions'. For example: Spiritual: the right people visiting the right places at the right times. Appropriate communications with ancestors or totemic species. Physical: protecting Country from inappropriate harvesting & vandalism. Risk management via controlled burns & control of invasive species.	Counts of distinct thematic meanings identified in qualitative data;

Table 4.9: Matrix table showing interconnection of services where one attribute is relevant across a number of services. Different aspects of each attribute are represented within the service it is aligned with. Matrix table: n/a = either no thematic presence in data, or already counted elsewhere on matrix. 1 = low thematic prevalence, 2 = moderate, 3 = high thematic prevalence.

	Knowledge	Recreation	Harvesting	Identity	Access	Social capital	Community cohesion	Caring for Country
SEEA Cultural Service 1: Recreation-related services	3	n/a	3	2	3	1	3	1
SEEA Cultural Service 2: Visual amenity services	n/a	3	1	1	3	2	1	n/a
SEEA Cultural Service 3: Educational, scientific and research services	3	n/a	3	3	3	3	3	3
SEEA Cultural Service 4: Spiritual, artistic and symbolic services	3	n/a	3	3	3	3	2	3
SEEA Cultural Service 5: Other cultural	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3
Wellbeing Services	3	3	2	3	3	2	3	3
Stewardships services	3	1	2	3	3	3	2	3
SEEA Provisioning Service: wild animals, plants and other biomass provisioning services	3	n/a	3	3	3	1	2	3

Table 4.10: SEEA Cultural services account (supply). Totals in the far-right column reflect that area with greater diversity of ecosystem types, afford a richer overall collection of cultural service. Numbers represent distinct types of events or benefits described by participants in relation to a given cultural service (left columns) and within each ecosystem type.

	Available units of measure	Selected ecosystem type					
		Mangrove	Saltmarsh	Supratidal forest	Waterbodies	Other landcovers	Total
SEEA Cultural Service 1 Recreation-related services	*Counts of distinct thematic types, ways or actions (e.g. fishing, camping, family gatherings)*	4	4	4	4	n/a	16
SEEA Cultural Service 2 Visual amenity services	*Counts of distinct thematic types, ways or actions (e.g. growth, recovery of habitat)*	2	2	3	3	1	11
SEEA Cultural Service 3 Educational, scientific and research services	*Counts of distinct thematic types, ways or actions (e.g. scientists collecting data, biological surveys, school visits)*	6	6	4	3	n/a	19
SEEA Cultural Service 4 Spiritual, artistic and symbolic services	*Counts of distinct thematic types, ways or actions (e.g. sites, dances, artworks)*	4	4	4	4	1	17
SEEA Cultural Service 5 Other cultural	*Counts of distinct thematic types, ways or actions*	2	1	1	1	n/a	5
Wellbeing Services	*Counts of distinct thematic types, ways or actions (e.g. employment)*	3	3	3	3	n/a	12
Stewardships services	*Counts of distinct thematic types, ways or actions (e.g. knowledge passed on)*	2	2	2	2	2	10
SEEA Provisioning Service – Wild animals, plants and other biomass provisioning services	*Counts of distinct thematic types, ways or actions (e.g. hunting, medicine)*	6	3	16	n/a	3	28
SEEA Provisioning Service – Wild fish and other natural aquatic biomass provisioning services	*Counts of distinct thematic types, ways or actions (e.g. fishing, crabbing)*	n/a	n/a	n/a	4	n/a	4

Table 4.11: SEEA-EA Cultural services account (Use). Numbers in the right columns record distinct event or description of a value or benefit that is represented in either documents, interviews or workshops or field / site visit observations. The numbers are NOT metrics of value, but instances of experiencing a kind of value that are represented in the data.

	Available units of measure	Economic units	
		Households	Total
SEEA Cultural Service 1 Recreation-related services	*Counts of distinct thematic types, ways or actions (e.g. fishing, camping, family gatherings)*	16	16
SEEA Cultural Service 2 Visual amenity services	*Counts of distinct thematic types, ways or actions (e.g. growth, recovery of habitat)*	11	11
SEEA Cultural Service 3 Educational, scientific and research services	*Counts of distinct thematic types, ways or actions (e.g. scientists collecting data, biological surveys, school visits)*	19	19
SEEA Cultural Service 4 Spiritual, artistic and symbolic services	*Counts of distinct thematic types, ways or actions (e.g. sites, dances, artworks)*	17	17
SEEA Cultural Service 5 Other cultural	*Counts of distinct thematic types, ways or actions*	5	5
Wellbeing Services	*Counts of distinct thematic types, ways or actions (e.g. employment)*	12	12
Stewardships services	*Counts of distinct thematic types, ways or actions (e.g. knowledge passed on)*	10	10
SEEA Provisioning Service – Wild animals, plants and other biomass provisioning services	*Counts of distinct thematic types, ways or actions (e.g. hunting, medicine)*	28	28
SEEA Provisioning Service – Wild fish and other natural aquatic biomass provisioning services	*Counts of distinct thematic types, ways or actions (e.g. fishing, crabbing)*	4	4

Discussion

The process of implementing and documenting a cultural account for this site overall revealed some key priorities for the Indigenous peoples and some important lessons for those seeking to undertake cultural accounting in other projects.

The actual process of engagement, which is the first step in any cultural account, needs to be undertaken with care and respect. Paying attention to who are the appropriate contacts, who can speak for Country and how the engagement/accounting will occur is the most important part of the process. A few factors will help facilitate this engagement. Offering genuine co-design and partnership opportunities will ensure the process and account is driven and underpinned by Indigenous cultural perspectives. Selecting consultants or researchers who either have experience working with and/or have long standing relationships with the relevant Indigenous groups will help facilitate timely but also open and transparent recording. Selection of ta person with pre-existing rapport or reputation working with Indigenous groups will also mean that there is a higher likelihood of obtaining deeper knowledge and detail.

Developing a cultural account takes time and may require multiple site visits. Time pressures in this case study were intense and were only surmounted because of the willingness of all parties to work together to meet milestones. However, more time would have helped build detail for this case study. As one of the priorities for this project was trailing the methodology, the time constraints were not so pressing, but we would recommend that future accounts make appropriate provision for the time taken to do this kind of work. Second, this project factored in a financial allocation to the Traditional Owners right from the beginning. It is recommended this be adopted as a practice in similar accounting: cultural partnerships such as this cannot just rely on cultural good will, volunteer time and love of Country as the drivers for First Nation involvement in the project. Methods for this case study were selected from a wide suite of approaches that are available in collaboration with Traditional Owners. Others may use different methods that work better with their respective projects. Ensuring all the ethical obligations and requirements are fulfilled and cooperation is achieved with Indigenous groups provides an opportunity to openly discuss each other's expectations.

Commitment to cultural review was important, ongoing and part of the co-design process, including on the results, our findings, and write ups. Reports were then amended to include additional Indigenous insights and to correct any errors in interpretation. It is recommended that cultural review processes are included in the development of a cultural account.

The diversity and potential plurality of world views must be acknowledged. In this case, there was a clearly identified cultural group. However, there will be many cases where a relevant site will include many groups. Thus, the first principle of engagement is to acknowledge and find ways to embrace the cultural diversity and groups that may need to be involved and who will either deliver or benefit from cultural and ecosystem services.

For cultural accounts of Indigenous Australians, the difference between Indigenous Country and the site that is the focus of the account must be acknowledged. In this project, while the traditional owners understood the project concerned a bounded site – it was one that was within part of but not all of their Country, but their views, perspectives and experience of cultural and ecosystem services were all still couched within the idea of Country. Future accounts could develop ways of acknowledging this, especially as some of the observed changes did not just accrue from the restoration itself, but external factors that affected the site. The physical bounding of a site in this way can restrict the gathering of what would be useful information.

Following on from this, the ways that values and services were articulated within a paradigm of connection were unsurprising. The atomistic separation of services did not align with cultural understanding of how ecosystem services work, and hence, the account tries to reflect this circularity as it reflects the fundamental whole that is embedded in the idea of Country, connection to Country and caring for Country. This account provides one way of building the scope within the SEEA-EA accounting tables to incorporate the levels of connection and it is suggested that they offer an important contribution to enhance accounting practice, given that nature is itself so inter-connected.

One of the key issues for the Traditional Owners developing the account with was ensuring that they knew who was doing it, who was the appropriate person/people to talk to, who would benefit from it and how it would be done[55]. Hence, cultural negotiation over ethics and protocols and doing thing the 'right way' were paramount to establishing a successful partnership. It is important to define and commit to an open discussion about and clarity on the benefits that will accrue from Indigenous involvement in the project.

The development of this account has demonstrated the value of recognising the different ways of representing 'value' across different cultures. The findings also highlight a need of a cultural accounting framework with a holistic and circular foundation compared to the atomistic and linear models underpinned by SEAA-EA. It is recommended that future models adopt hybridised approaches to accounting that combine general and context-specific perspectives. This account within the Trinity Inlet case study provides a practical example of how to incorporate different world views and build more appropriate accounting models, which can be used to enhance decision making.

Reflection on First Nations accounts within a SEEA framework.

The resulting cultural account provides information and a model within the SEEA-EA framework that provides a more nuanced understanding of the cultural services provided by restoration sites than the standard tables outlined in the SEEA-EA guidelines. Our approach contributes a new and specific model for how to develop cultural accounts and processes for incorporating additional information into the SEEA framework. However, it should be noted, that to First Nations peoples, dividing up Country into atomised parts and attempting to place monetary value on what are often intangible benefits, still does not fully represent and cannot account for the holistic nature of Indigenous ways of seeing and doing.

We suggest therefore that cultural accounts need to be undertaken, as this one was, in collaboration with Traditional Owners, and in ways that give voice and recognition to Indigenous perspectives. The process may otherwise be seen as a colonial mode of making decisions about Country via its reductionist insistence to integrate and therefore to subsume cultural benefits from ecosystem services within Western scientific paradigms. Nonetheless, the incorporation of Indigenous values into such accounting can allow incorporation of millennia old and sophisticated knowledge systems, which can not only help identify the services and benefits the ecosystem brings to people but identify the benefits that Indigenous resource management practices also bring to the system today.

[55] Larson, J.D. et al. (2023). Piecemeal stewardship activities miss numerous social and environmental benefits associated with culturally appropriate ways of caring for country. Journal of Environmental Management, 326, 116750–. https://doi.org/10.1016/j.jenvman.2022.116750

4.2.2 Cultural services: recreation and existence values

Intent of work

This section reports the physical and monetary accounts associated with the recreational services provided by the East Trinity Inlet wetland restoration site, as well as other measures of values associated with the primary cultural services it provides. According to SEEA-EA, recreation-related services are defined as "the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in situ, physical and experiential interactions with the environment. This includes services to both locals and non-locals (i.e. visitors, including tourists). Recreation-related services may also be supplied to those undertaking recreational fishing and hunting. This is a final ecosystem service" . The focus of this study is restricted to two recreational services i.e. recreational fishing and bird watching. In addition, we considered the values associated with the 'existence' of the restored habitat that may be held by those who do not visit it.

Recreational and existence services included recreational fishing and bird watching, as well as values associated with the 'existence' of the restored habitat that may be held by those who do not visit it. Accounts for SEEA-EA are focused on services where an exchange has taken place; that is, either direct or indirect use of the restoration site or its exported services. For recreational fishing and bird watching, this is possible. For these services, 'exchange values' can be estimated to reflect the prices paid for exchanges associated with the service.

However, depending on decision-making objectives, other value measures may be relevant to report. These may include 'welfare values', which are also measured in monetary terms, but measure the total economic benefit that a service provides, rather than the price of exchanged items only. Welfare values provide an alternative measure of value for services considered by environmental economic accounting and provide values for services that are not otherwise considered.

Estimating welfare values can be particularly important for cultural ecosystem services, which include existence values and other forms of value that do not depend on use and exchanges occurring. These are referred to commonly as 'non-use' values in economic valuation. Accordingly, welfare value associated with recreational fishing, bird watching, are reported, along with broader non-market values associated with the restored habitat at East Trinity.

Approach taken

The physical recreational service accounts require data on: (i) the visitation rate by recreational users of the site; and (ii) the proportion of visits that can be attributed to the services provided by the restored habitat relative to the number of visits that would occur had it not been restored. Following the recommendations in the Guide, exchange values were calculated using trip expenditure data where the price of associated trip expenses (e.g. fuel costs for vehicles) was applied per visit to the site.

There were no primary data available that recorded recreational activity at the site. Instead, anecdotal evidence was provided from key informants to estimate the annual visitation rates for recreational fishing and bird watching activities at the site and inform the physical accounts. Monetary values for benefit transfer were identified through a literature review.

To estimate the contribution to welfare values from East Trinity's restored habitats, recreational services and existence values were considered. There were no primary studies available that estimate this value for the site, so a benefit transfer approach was used to estimate values.

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[56] United Nations. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. https://seea.un.org/ecosystem-accounting. p133.

Results

The opening account assumes there was no supply of recreational services from the East Trinity site given that pre-restoration, the site was disconnected from the estuary and consisted of poor-quality habitat that had been degraded by conversion for agriculture and subsequent declines in water and soil quality.

Results should be interpreted as indicative-only, noting that estimates are based on anecdotal visitation rates and not site surveys. Recreational fishing services from the restoration activities are estimated to have contributed 9,125 fishing trips per annum, $187,063 AUD annually in exchange value, and $474,500 AUD annually in welfare value. Recreational birdwatching services from the restoration activities are estimated to have contributed 180 bird watching trips per annum, $17,712 AUD annually in exchange value, and $31,446 AUD annually in welfare value.

Additionally, other non-market values associated with existence of the restored habitats are estimated to have contributed $22, 932 AUD annually in welfare value.

Reflection relative to the Guide

Implementing advice provided in the Guide has been challenging in this case study application primarily due to scarcity of relevant data. Visitation data was based on anecdotal evidence from managers and other key informants in the field, which does not allow for a precise understanding of visitation including seasonal variations. Without site-specific visitation data, there is also an absence of data about the socio-demographics of visitors, which prevents adjustment of secondary data used in benefit transfer, further reducing accuracy.

The guide provides explicit recognition that the quality of outcomes is determined by the level of investment available to generate primary data. Where that is not possible, the use of benefit transfer to provide estimates of the monetary values is the only path possible. The quality of benefit transfer is determined by the availability of existing studies and the degree to which the context and metric of valuation in those studies aligns with a restoration site. Recreational fishing is extensively studied, although the majority of studies are related to boat-based fishing, where expenditure and values may differ to land-based fishing experience relevant here. Birdwatching is less extensively studied in Australia and no existing studies estimated associated non-use values of local coastal wetlands. The lack of context-specific data means that a good quality benefit transfer could not be conducted and therefore the values estimated are not precise. Also note that the difference in magnitude of exchange and welfare values reported for recreational services identifies the importance of considering what the objectives are for estimating and using monetary estimates of ecosystem services to ensure the correct type of value is used. While the values estimated are not precise, the magnitude is sufficiently different for recreational fishing exchange and welfare estimates, for example, to highlight that a true difference is likely to exist between the value measures. The Guide provides advice on what values and economic tools are relevant for different types of common decisions.

Note that accounts for the SEEA-EA are focused on services where an exchange has taken place; that is, either direct or indirect use of the restoration site or its exported services. For recreational fishing and bird watching this is possible. For these services, we are able to estimate ‘exchange values’ which reflect the prices paid for exchanges associated with the service.

Welfare values, which are also quantified in monetary terms, measure the total economic benefit that a service provides, rather than the price of exchanged items only. It is important to note that welfare values provide an additional measure of value to the exchange values that are focused on in the SEEA-EA, and can be reported alongside exchange values focused on in the standard SEEA-EA account tables.

Estimation of welfare values can be particularly important for cultural ecosystem services, which include existence values and other forms of value that do not depend on use and exchanges occurring – these are referred to commonly as 'non-use' values in economic valuation. Accordingly, we also report on the welfare value associated with recreational fishing, bird watching, and the broader non-market values associated with the restored habitat at East Trinity.

Recreation and Existence Values Supplementary Information

Methods

The physical recreational service accounts require data on: (i) the visitation rate by recreational users of the site; and (ii) the proportion of visits that can be attributed to the services provided by the restored habitat, relative to the number of visits that would occur had it not been restored. Following the recommendations in the Guide[57] exchange values are then calculated using trip expenditure data, where the price of associated trip expenses (e.g. fuel costs for vehicles) is applied per visit to the site.

There was no primary data available that recorded recreational activity at the site. Instead, anecdotal evidence was provided from key informants to estimate the annual visitation rates for recreational fishing and bird watching activities at the site, used for the *physical accounts*.

Monetary values for benefit transfer were identified through a literature review:

- A 2021 study reporting the economic value of recreational fishing in Queensland estimated the average trip expenditure per angler per fishing day for fishers in the Cairns region[58], to establish the *monetary account*.
- The same 2021 study[7] also reported the consumer surplus per angler per fishing day, used to estimate *consumer surplus*.
- A 2022 study revealed the average expenditure per visitor per daytrip[59],used to estimate exchange values for the *monetary account*.
- A 2019 study reported average travel cost for birdwatching per trip[60] applied to estimate *consumer surplus*.

To estimate the contribution to welfare values from East Trinity's restored habitats, beyond the recreational services provided we consider the existence value associated with the restored site. There are no primary studies that estimate this value for site, and therefore we rely on benefit transfer to estimate its value. As noted by Whiteoak and Binney[61] (2012), "...it would appear that insufficient work has been done to develop a representative and transferable set of ecosystem services values [for wetlands] to be used to support a policy agenda." (p.45) and the position has not advanced significantly over the intervening period.

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[58] Kandulu, J., Bailey, H. & Magnusson, A., BDO. (2021). Economic contribution of recreational fishing by Queenslanders to Queensland: A Report for Fisheries Queensland. Fisheries Queensland.

[59] Steven, R. (2022). Bird and Nature Tourism in Australia. KBAs in Danger Case Study Report. Report prepared for Birdlife Australia. A. Carlton.

[60] Carnell, P. E., Reeves, S. E., Nicholson, E., Macreadie, P., Ierodiaconou, D., Young, M., Kelvin, J., Janes, H., Navarro, A., Fitzsimons, J. & Gillies, C. L. (2019). Mapping Ocean Wealth Australia: The value of coastal wetlands to people and nature. The Nature Conservancy, Melbourne.

[61] Whiteoak, K. & Binney, J. (2012). Literature Review of the Economic Value of Ecosystem Services That Wetlands Provide. Final Report Prepared for the Department of Sustainability, Environment, Water, Population and Communities.

Results

Note that the opening account assumes there is no supply of recreational services from the East Trinity site given that pre-restoration, the site was disconnected from the estuary and consisted of poor-quality habitat that had been degraded as a result of the transition to agriculture, and the subsequent decline in water and soil quality.

Post-restoration results are provided below. These results should be interpreted as indicative-only, noting that estimates are based on anecdotal visitation rates and are not accurate.

Recreational fishing services from the restoration activities are estimated to have contributed:

- 9,125 fishing trips per annum;
- $187,063 AUD annually in exchange value;
- $474,500 AUD annually in welfare value.

Recreational birdwatching services from the restoration activities are estimated to have contributed:

- 180 bird watching trips per annum;
- $17,712 AUD annually in exchange value;
- $31,446 AUD annually in welfare value.

Additionally, other non-market values associated with existence of the restored habitats are estimated to have contributed $22,932 AUD annually in welfare value.

Reflection relative to the Guide

The ability to implement the advice provided in the Guide has been challenging in this case study application primarily due to scarcity of relevant data. Some of the specific challenges are:

- Visitation data was based on anecdotal evidence from managers and other key informants in the field, which does not allow for a more precise understanding of visitation including seasonal variations.
- Without site-specific visitation data, there is also an absence of data about the socio-demographics of visitors, which reduces the ability to make adjustments of secondary data used in benefit transfer, leading to further reduced accuracy.

The guide provides explicit recognition that the quality of outcomes is determined by the level of investment that is available to generate primary data. Where that is not possible, the use of benefit transfer to provide estimates of the monetary values is the only path possible. The quality of benefit transfer is determined by the availability of existing studies, and the degree to which the context and metric of valuation in those studies aligns with the case study. Recreational fishing is extensively studied, although the majority of that is related to boat-based fishing, where expenditure and values may differ to the land-based fishing experience relevant here. The valuation approach could also be broadened by including welfare values which can be estimated using both market and non-market valuation techniques.

Photo by Through The Looking Glass Studio - http://looking-glass.com.au

Context

Wetlands in estuarine and coastal ecosystems are some of the most heavily used natural systems supporting several ecosystem services that provide important cultural and other benefits to humans[62,63,64]. They are crucial in supporting fisheries both for commercial and recreational uses[65]. Recreation services are part of cultural[66] ecosystem services, which are defined as various non-material benefits people obtain from nature[67].

Referring to the Common International Classification of Ecosystem Services (CICES), examples of cultural services that wetlands may provide include services that imply use of the wetland such as recreation or aesthetic benefits, and services that may not require use of the wetland such as the benefits derived from the knowledge the wetland exists (existence value). Use-related services are relevant for developing accounts, as these imply an exchange has taken place. At East Trinity, recreation services are the most relevant direct use-value services for beneficiaries which needs to be properly accounted for. Both use and non-use related services are relevant for estimating welfare values.

The Common International Classification of Ecosystem Services (CICES) describes nature-based recreation as, "using the environment for sport and recreation; using nature to help stay fit" and "watching plants and animals where they live; using nature to de-stress"[68]. In the SEEA EA, recreation-related services are defined as "the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment" (United Nations[69], 2021, p. 133). Coastal wetland ecosystems such as mangroves, salt marshes, and seagrasses provide a number of recreational activities including recreational fishing, birdwatching, boating, and kayaking of local and non-local visitors[70,71].

Australia's coastal wetlands form recreational hotspots that offer opportunities for recreational fishing and nature-based tourism[76]. Recreational fishing is a popular interaction with coastal and marine environments where most of the recreational fishers link participation to sport and

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[62] Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C. & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. Ecological Monographs, 81(2), 169-193. https://doi.org/10.1890/10-1510.1

[63] Huang, B., Young, M. A., Carnell, P. E., Conron, S., Ierodiaconou, D., Macreadie, P. I. & Nicholson, E. (2020). Quantifying welfare gains of coastal and estuarine ecosystem rehabilitation for recreational fisheries. Science of The Total Environment, 710, 134680. https://doi.org/10.1016/j.scitotenv.2019.134680

[64] Gaylard, S., Waycott, M. & Lavery, P. (2020). Review of Coast and Marine Ecosystems in Temperate Australia Demonstrates a Wealth of Ecosystem Services [Review]. Frontiers in Marine Science, 7, https://doi.org/10.3389/fmars.2020.00453

[65] Webley, J., McInnes, K., Teixeira, D., Lawson, A. & Quinn, R. (2015). Statewide Recreational Fishing Survey 2013–14. Technical Report. State of Queensland, Brisbane, Queensland.

[66] The term "cultural services "is not implied that culture itself is a service, rather it is a collective label intended to capture the variety of ways in which people connect to, and identify with, nature and the motivations attributed to these connections (United Nations, 2021 p.130)".

[67] Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-being: Biodiversity Synthesis. W. World Resources Institute, DC.

[68] Haines-Young, R. & Potschin, M. B. (2018). Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure

[69] United Nations. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. https://seea.un.org/ecosystem-accounting

[70] Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C. & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. Ecological Monographs, 81(2), 169-193. https://doi.org/10.1890/10-1510.1

[71] Carnell, P. E., Reeves, S. E., Nicholson, E., Macreadie, P., Ierodiaconou, D., Young, M., Kelvin, J., Janes, H., Navarro, A., Fitzsimons, J. & Gillies, C. L. (2019). Mapping Ocean Wealth Australia: The value of coastal wetlands to people and nature. The Nature Conservancy, Melbourne.

relaxation with a significant benefit on health and well-being[72]. A national survey shows that about 4.2 million adult Australians were estimated to participate in recreational fishing each year generating a significant economic contribution[73]. For instance, recreational fishers in Queensland spent about $630 million annually between 2019 and 2020[74]. About 73% of Queensland's recreational fish catch come from coastal ecosystems (estuaries and coastal wetlands)[75]. The most common recreational fish species caught include Whiting, Yellowfin Bream, Dusky Flathead, Pikey Bream, and Snapper along with Mud-crab and Blue Swimmer Crab[24].

However, these wetland systems have been rapidly degraded resulting from agricultural development in the coastal zone, for example, through accumulation of acid sulphate soils adversely impacting water quality and fish biomass and leading to serious negative effects in commercial and recreational fishing[76]. Different remedial activities have been implemented to restore these resources.

The remediation activities have resulted in increased bird species and fish abundance[77]. This could be considered as an enabling factor for experiencing selected recreational activities inside and outside the wetland restoration site. In terms of recreational services, this report focuses on recreational fishing and birdwatching activities. Despite some anecdotal data for bushwalking, there is limited evidence about other recreational activities attributed to the restoration site.

In this section, we consider an environmental economic account of recreational services with a focus on recreational fishing and birdwatching. Effective rehabilitation or restoration of Australian wetlands can improve such services[78,79]. The estuary repair works for restoring basic saltmarsh structure through tidal connection are estimated to increase fishery productivity in other nearby locations. For instance, recreational fishing activity in New South Wales[80] and in Tasmania[81] has increased because of similar restoration activities likely linked to increases in fish biomass. In East Trinity, there was a progressive increase

[72] Young, M. A. L., Foale, S., & Bellwood, D. R. (2016). Why do fishers fish? A cross-cultural examination of the motivations for fishing. Marine Policy, 66, 114-123. https://doi.org/10.1016/j.marpol.2016.01.018

[73] Moore, A., Schirmer, J., Magnusson, A., Keller, K., Hinten, G., Galeano, D., Woodhams, J., Wright, D., Maloney, L., FRDC & Abares, U. (2023). National Social and Economic Survey of Recreational Fishers 2018-2021, February. CC BY 3.0. Fisheries Research and Development Corporation.

[74] Teixeira, D., Janes, R. & Webley, J. (2020). 2019–20 state-wide recreational fishing survey. Fisheries Queensland, Department of Agriculture and Fisheries

[75] Webley, J., McInnes, K., Teixeira, D., Lawson, A. & Quinn, R. (2015). Statewide Recreational Fishing Survey 2013–14. Technical Report. State of Queensland, Brisbane, Queensland.

[76] Creighton, C., Boon, P. I., Brookes, J. D. & Sheaves, M. (2015). Repairing Australia's estuaries for improved fisheries production – what benefits, at what cost? Marine and Freshwater Research, 66(6), 493-507. https://doi.org/10.1071/MF14041

[77] Russell, D., Preston, K. & Mayer, R. (2011). Recovery of Fish and Crustacean Communities during Remediation of Tidal Wetlands Affected by Leachate from Acid Sulfate Soils in North-Eastern Australia. Wetlands Ecology and Management, 19, 89–108.

[78] Huang, B., Young, M. A., Carnell, P. E., Conron, S., Ierodiaconou, D., Macreadie, P. I. & Nicholson, E. (2020). Quantifying welfare gains of coastal and estuarine ecosystem rehabilitation for recreational fisheries. Science of The Total Environment, 710, 134680. https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.134680

[79] McArthur, L. C. & Boland, J. W. (2006). The economic contribution of seagrass to secondary production in South Australia. Ecological Modelling, 196(1-2), 163-172. https://doi.org/10.1016/j.ecolmodel.2006.02.030

[80] Creighton, C., Boon, P. I., Brookes, J. D. & Sheaves, M. (2015). Repairing Australia's estuaries for improved fisheries production – what benefits, at what cost? Marine and Freshwater Research, 66(6), 493-507. https://doi.org/10.1071/MF14041

[81] Prahalad, V., Harrison-Day, V., McQuillan, P. & Creighton, C. (2019). Expanding fish productivity in Tasmanian saltmarsh wetlands through tidal reconnection and habitat repair. Marine and Freshwater Research, 70, 140-151. https://doi.org/10.1071/MF17154

in fish species richness, diversity and abundance following the rehabilitation program that started in 2000 using lime-assisted tidal exchange management[82]. A recent survey recorded about 38 species of estuarine and marine fish, including important recreational fishing species such as barramundi (*Lates calcarifer*) and mangrove jack (*Lutjanus argentimaculatu*), in the previously barren creeks of East Trinity[83].

One of the main contributions of the East Trinity is providing suitable habitat for waterbirds. Seasonal wetland communities are now in much better condition than they were in 2002, providing suitable habitat for waterbirds[90]. Studies in Australia suggest that sites where it is possible to see greater numbers of migratory shorebirds attract more birdwatchers and hence are valued higher over sites where birds are less abundant and difficult to watch[84].

A recreational logic chain can be used to describe the logical flow of assets, services, benefits and enabling factors in recreational use of ecosystem services[85]. Adapting the recreation logic chain for East Trinity, we can assume that the ecosystem assets consist of the different wetland habitats, the services are the biotic characteristics required for nature recreation activities; and the benefits include health, recuperation, and enjoyment that people could receive from experiencing recreation (**Figure 4.5**). The restoration of East Trinity could be considered as an enabling factor with positive impacts on recreational services.

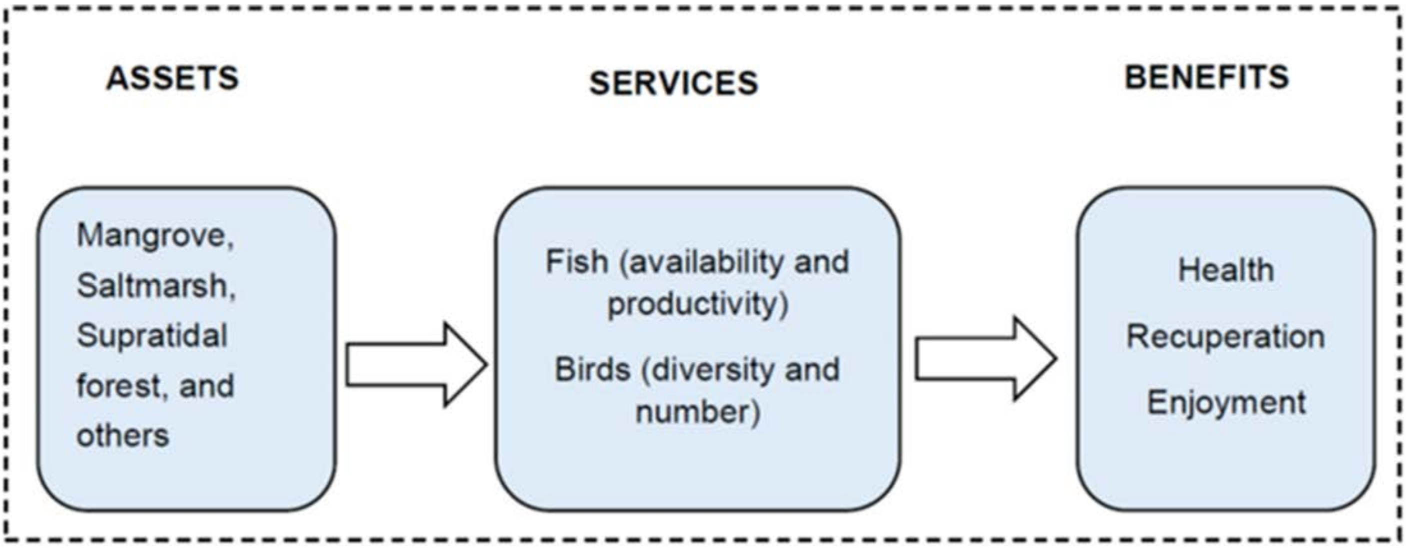

Figure 4.5: A 'logic chain' for recreational services and benefits of East Trinity Inlet wetlands (Adapted from Barton et al., 2019[90]).

[82] Russell, D., Preston, K. & Mayer, R. (2011). Recovery of Fish and Crustacean Communities during Remediation of Tidal Wetlands Affected by Leachate from Acid Sulfate Soils in North-Eastern Australia. Wetlands Ecology and Management, 19, 89–108.

[83] Parks and Forests Queensland Government (2021). Nature, culture and history: Parks and Forests, Department of Environment and science, Queensland Government. https://parks.des.qld.gov.au/parks/east-trinity: Accessed 04/04/2022

[84] Steven, R. (2022). Bird and Nature Tourism in Australia. KBAs in Danger Case Study Report. Report prepared for Birdlife Australia. A. Carlton.

[85] Barton, D. N., Obst, C., Day, B., Caparrós, A., Dadvand, P., Fenichel, E., Havinga, I., Hein, L., McPhearson, T., Randrup, T. & Zulian, G. (2019). Discussion paper 10: Recreation services from ecosystems. Paper submitted to the Expert Meeting on Advancing the Measurement of Ecosystem Services for Ecosystem Accounting, New York, 22-24 January 2019 and subsequently revised. Version of 25 March 2019.

Data availability

The physical and monetary accounts for recreational fishing and birdwatching in East Trinity are developed using anecdotal evidence from key informants. The monetary values are estimated using benefit transfer i.e. based on valuation studies conducted in other similar areas:

- Key informant interviews (experts at the Queensland Department of Environment and Science, traditional owners' group, and tour operators).
- Systematic literature review of recreation valuation studies.
- Reserve Bank of Australia to adjust monetary values using consumer price index (CPI).

Methodology 1: Recreational services data

The objective of the physical accounts for recreational services is to quantify the contribution of the restoration site for outdoor recreational services. The physical unit for recreational services is visitation frequency, i.e. the number of people experiencing recreational activities in the specific study site, or the areas adjacent where services provided by the site are exported to. An actual visitation frequency, (i.e. based on counts of visitors to recreation sites) is needed to develop the physical supply and use tables for accounts of recreational services. Where actual visitation metrics are not able to be provided or estimated, the recreational service account can be described using different metrics including potential visitation, predicted visitation, and other measures based on subjective indicators (e.g. density of social media posts)[39], noting these are not appropriate to directly form the supply and use table.

The restoration of East Trinity has improved the ecosystem's wildlife habitat specifically for fishing and birdwatching activities[86]. However, so far there is no clear documentation about recreational uses in the site, or any increase in those outside the site that can be attributed to the restoration of the site. For example, the Queensland state-wide recreational fishing survey report provides catch and effort data only at large spatial scales of regions and subregions[87], which cannot be disaggregated to a small-scale site-specific data.

Acknowledging that the restoration site might export services to areas outside of the site's boundaries, methods to attribute the proportion of recreational activities occurring as a result of exported services (relative to activities that would have occurred in a location if additional services were not being exported) were also considered. For example, in a case study of the Tomago wetland restoration in NSW, the recreational fishing physical accounts were based on estimations of catch and effort based on the contribution of different ecosystems to fish biomass productivity outside the restoration site. This method is being used for economic valuation of commercial fisheries in estuaries[88,89,90]. However, to implement this method, there should be a quantification of recreational fishing biomass and efforts outside the restoration site and clear scientific evidence on the contribution of the restored ecosystems (mangroves, saltmarshes, seagrass, supratidal swamp forest etc.) to enhance fish productivity. Thus far, no study that shows the East Trinity site's contribution has been found.

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[86] Hanabeth, L., Martens, M. A., Moon, E. M., Smith, D., Ward, N. J. & Bush, R. T. (2017). Ecological restoration of a severely degraded coastal acid sulfate soil: A case study of the East Trinity wetland, Queensland. Ecological Management & Restoration, 18(2), 103-114.

[87] Teixeira, D., Janes, R. & Webley, J. (2020). 2019–20 state-wide recreational fishing survey. Fisheries Queensland, Department of Agriculture and Fisheries

[88] Jänes, H., Macreadie, P. I., Nicholson, E., Ierodiaconou, D., Reeves, S., Taylor, M. D. & Carnell, P. E. (2020). Stable isotopes infer the value of Australia's coastal vegetated ecosystems from fisheries. Fish and Fisheries, 21(1), 80-90. https://doi.org/10.1111/faf.12416

[89] Raoult, V., Gaston, T. F. & Taylor, M. D. (2018). Habitat–fishery linkages in two major south-eastern Australian estuaries show that the C4 saltmarsh plant Sporobolus virginicus is a significant contributor to fisheries productivity. Hydrobiologia, 811(1), 221-238. https://doi.org/10.1007/s10750-017-3490-y

[90] Taylor, M. D., Gaston, T. F. & Raoult, V. (2018). The economic value of fisheries harvest supported by saltmarsh and mangrove productivity in two Australian estuaries. Ecological Indicators, 84, 701-709. https://doi.org/10.1016/j.ecolind.2017.08.044

For this report, actual visitation data for recreational fishing and birdwatching is obtained anecdotally through personal communications with key informants including experts at the Queensland Department of Environment and Science, the Mandingalbay Yidinji Traditional Owners, and tour operators.

Recreational fishing data

According to our key informant from recreational fishing tour operators in Cairns, there has been no increase in fishing activity outside of restoration area, and the quality of fishing in the estuary around the restoration site is poor. Coupled with the absence of other supporting data to attribute proportions of visitation to exported services in areas beyond the site's boundary, we focus only on recreational fishing visitation within the site.

However, based on the information from the key informants, there has been substantial recreational fishing activity within the restoration area (inside the bund wall). Anecdotally, they report seeing about 20-30 fishers per day fishing within the boundary of the restoration site. For our physical account, we take the median value, 25 recreational fishers per day and estimated about 9125 recreational fishers (i.e. fishing days) per annum (for 2022).

Birdwatching data

For bird watching data, our key informant from the Traditional Owners group estimated about 10 to 20 bird observers per month. By taking the median value of 15 per month, this produces an estimate of about 180 birdwatchers per annum at the restoration site (**Table 4.12**).

Table 4.12: **Recreational services of East Trinity based on key informant data.**

Recreational services	Recreational use (key informant evidence)	Annual use (calculated at median use)
Recreational fishing (Fishing days)	20-30 per day (560 a month)	25 fishers per day (9125 per annum)
Birdwatching (Number of visitors)	10-20 per month	15 bird observers a month (180 per annum)

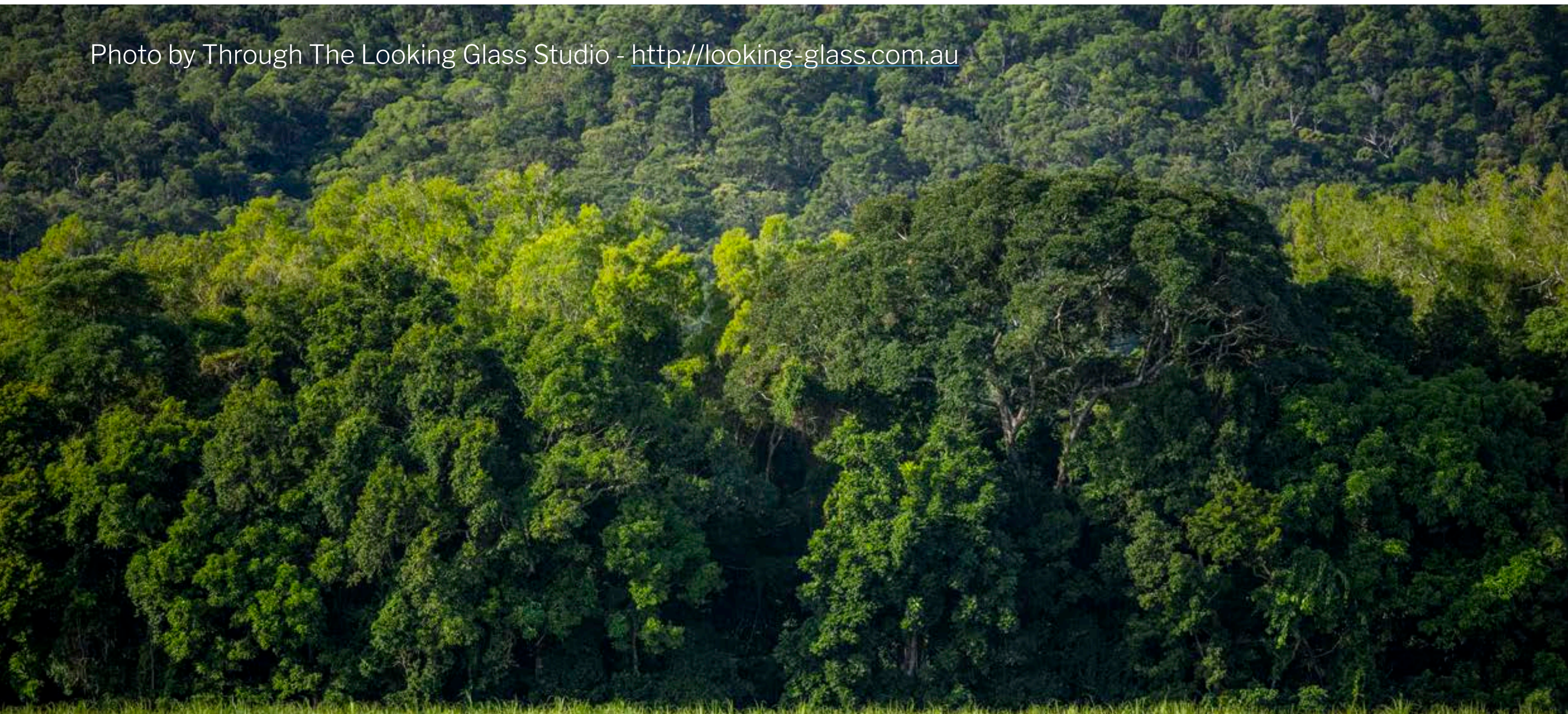

Photo by Through The Looking Glass Studio - http://looking-glass.com.au

Methodology 2: Analysis approach for EEA valuation

According to the SEEA-EA framework, the monetary value of ecosystem flows can be estimated using exchange values. Since recreational services are often non-market uses, the monetary values are often estimated using different valuation methods based on primary survey data. SEEA-EA provides a list of valuation methods and the preferred orders of them to estimate the non-market values of ecosystem services including recreational services[91]. Among them is travel expenditure. The travel expenditure includes costs of travelling in the form of transport costs and/or accommodation costs incurred by households or individuals to reach recreational sites. These costs are based on actual expenditures of marketed goods and services and hence can provide an exchange value for recreational services that ecosystems provide to visitors[92]. Travel expenditure data can be collected through primary surveys conducted with people visiting a site.

When primary data collection is not feasible and limited data is available, a more practical (and less expensive) approach is to use a benefit transfer method. This method employs techniques of transferring existing benefit estimates from studies already completed for another location in Australia or elsewhere[93,94,95]. The value transfer method is a low-cost valuation approach that can facilitate valuation in line with SEEA-EA requirements to provide consistent estimates for use in accounts[96].

A potential challenge of applying benefit transfer for developing accounts is that most existing applications related to non-market uses (including recreation services) focus on the estimation of welfare values, rather than exchange values, using economic non-market valuation techniques. These valuation techniques are broadly categorised into two: revealed preference and stated preference approaches[97,98]. In revealed preference methods the values are obtained from observing consumer behaviour where people reveal their willingness to pay for a good or services. Travel cost and the hedonic pricing method are the most widely used methods in this approach. In the stated preference approach, such as choice experiment and contingent valuation studies, values are obtained through consumers' stated behaviour, i.e. by asking individuals about their willingness to pay for environmental goods/services often in a hypothetical market setting.

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[91] United Nations et al., (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. https://seea.un.org/ecosystem-accounting.

[92] NCAVES & MAIA. (2022). Monetary valuation of ecosystem services and ecosystem assets for ecosystem accounting: Interim Version 1st edition. S. D. United Nations Department of Economic and Social Affairs, New York.

[93] Plummer, M. L. (2009). Assessing Benefit Transfer for the Valuation of Ecosystem Services. Frontiers in Ecology and the Environment, 7(1), 38–45.

[94] Richardson, L., Loomis, J., Kroeger, T. & Casey, F. (2015). The Role of Benefit Transfer in Ecosystem Service Valuation. Ecological Economics, 115(51), 58.

[95] Wilson, M. A. & Hoehn J. P. (2006). Valuing Environmental Goods and Services Using Benefit Transfer: The State-of-the Art and Science. Ecological Economics, 60(2), 335–42.

[96] Grammatikopoulou, I., Badura, T., Johnston, R. J., Barton, D. N., Ferrini, S., Schaafsma, M. & La Notte, A. (2023). Value transfer in ecosystem accounting applications. Journal of Environmental Management, 326, 116784. https://doi.org/10.1016/j.jenvman.2022.116784

[97] Rolfe, J. & De Valck, J. (2021). Values for protecting the Great Barrier Reef: A review and synthesis of studies over the past 35 years. Marine Pollution Bulletin, 169, 112531.

[98] Huang, B., Young, M. A., Carnell, P. E., Conron, S., Ierodiaconou, D., Macreadie, P. I. & Nicholson, E. (2020). Quantifying welfare gains of coastal and estuarine ecosystem rehabilitation for recreational fisheries. Science of The Total Environment, 710, 134680. https://doi.org/10.1016/j.scitotenv.2019.134680

Sometimes, non-market valuation studies that generate welfare values report data that can be used as exchange values. For example, travel cost studies might report travel expenditures in addition to the welfare estimates (i.e. willingness to pay for a recreational trip). It can also be possible to estimate simulated exchange values from welfare values if site specific demand can be derived[99].

For this case study report, the monetary values of recreational fishing and birdwatching are estimated based on exchange value estimates using a benefit transfer methodology. Specifically, the value for recreational fishing and birdwatching in the East Trinity restoration site was estimated by applying measures of similar recreational values from related studies conducted in another location. We conducted a literature review using Web of Science, Scopus, and Google Scholar. The literature data consists of studies from peer-reviewed scientific publications, working papers and research reports. Additionally, the search was extended to checking reference lists in reviewed articles for additional studies and related valuation reports. The main targets were the valuation studies that used travel cost expenditure, travel cost methods, contingent valuation, and choice experiments with estimated economic values for recreational fishing or birdwatching in coastal or estuarine wetlands. The search strategy is summarized as follows:

- The searching framework used the following combinations of selected key words focusing on recreational fishing and birdwatching:
- ((“Travel cost” OR contingent OR “choice experiment” OR “discrete choice” OR economic OR valu* OR monetary OR “willingness to pay” OR WTP) AND (mangrove* OR seagrass* OR saltmarsh* OR “salt marsh” OR marine* OR river* OR estuar* OR coastal* OR wetland*) AND (recreat* OR ecotourism) AND (fish* OR angler* OR “Bird watching” OR birdwatching) AND (Australia))
- Because there were only limited valuation studies for birdwatching obtained from the above search terms, we also slightly modified our searching strategy using a combination of additional key terms related to birdwatching as follows:
- ((“Travel cost” OR contingent OR “choice experiment” OR “discrete choice” OR economic OR valu* OR monetary OR “willingness to pay” OR WTP) AND (mangrove* OR wetland*) AND (Bird* OR Birding OR “Bird watching” OR birdwatching OR Avitourism OR twitching) AND (Australia))
- Each paper was screened based on the abstract and then thoroughly reviewed for its relevance based on what it valued (e.g. what recreational services), ecosystem type (where estuarine or wetlands), valuation approach, respondents’ origin, year of study, value measurements such as per person or trip, and so on. Furthermore, context-based information of study site characteristics, fishing mode (boat-based vs shore-based) visitor type and origin were also gathered to help assess whether the study population were comparable on certain socioeconomic and demographic characteristics to undertake any further adjustments.
- The final list of valuation studies identified for our valuation database included 13 for recreational fishing (eight peer reviewed papers and five research reports) and four (two peer reviewed and two research reports) for birdwatching across Australia (from Queensland, Victoria, Northern Territory, and South Australia).

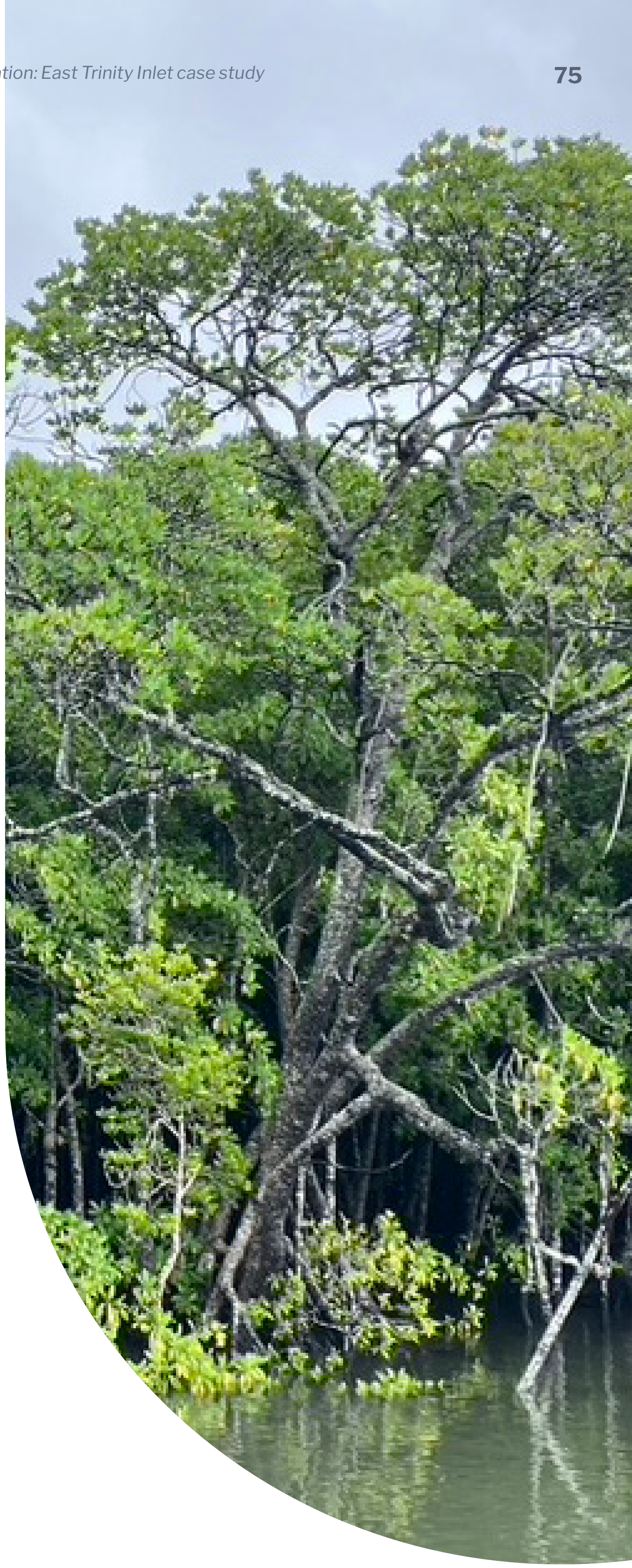
[99] Caparrós, A., Oviedo, J. L., Álvarez, A. & Campos, P. (2017). Simulated exchange values and ecosystem accounting: Theory and application to free access recreation. Ecological Economics, 139, 140-149. https://doi.org/10.1016/j.ecolecon.2017.04.011

- The valuation data were recorded into a spreadsheet database and prioritized for suitability for the benefit transfer method. Additional context-based information of study sites was included to help assess the comparability, quality of the sites for recreation, availability of nearby substitutes and whether the study population are comparable on certain socioeconomic and demographic characteristics.

Values for recreational fishing

The valuation data on estimates of expenditure was compiled from Australian studies. There were six studies based on expenditure survey methods for recreational fishing in coastal saltwaters (**Table 4.13**).

The study by Kandulu[100] et al. (2021) is identified as suitable for value benefit transfer to East Trinity because the methodology used is consistent with the SEEA-EA in that travel expenditure is directly related to recreational services to approximate exchange values for that service (**Table 4.15**). The study provided travel cost expenditure estimates (per trip per angler) of recreational fishing for different regions and subregions in Queensland (including Cairns) using the 2019/20 state-wide recreational fishing survey. The value estimate for the Cairns region was selected with further calculations to obtain travel (trip) cost per angler per day given Cairns is the region where the East Trinity Inlet is situated.



[100] Kandulu, J., Bailey, H. & Magnusson, A., BDO. (2021). Economic contribution of recreational fishing by Queenslanders to Queensland: A Report for Fisheries Queensland. Fisheries Queensland

Table 4.13: List of selected studies for recreational fishing valuation based on travel expenditure.

Study	Year valued	Habitat	State/ Region/ location	Valuation method	Value measurement (per trip or per day)	Estimated value (AUD$)
Kandulu et al., 2021	2019	Queensland Saltwaters	Cairns, Queensland	Expenditure (trip costs)	per angler per day	18.6
Pascoe[101] et al., 2014	2013	Multipurpose coastline	Moreton Bay, Queensland	Expenditure (Fuel cost only	per angler per trip	36
				Expenditure (average car travel cost)	per angler per day	92
Prayaga[102] et al., 2010	2010	Coastal beaches	Capricorn Coast, Queensland	Expenditure	per angler per trip	196
Farr and Stoeckl[103], 2018	2012	GBR coast catchment	Townsville, Queensland	Expenditure	per angler per trip	66
McLeod and Lindner[104], 2018	2018	Saltwaters	Western Australia	Expenditure (Boat fuel, parking, bait & other trip related costs)	per angler per trip	123
				Average expenditure (Weighted mean)	per angler per trip	147
McIlgorm and Pepperell[105], 2013	2012	Saltwaters	NSW	Average travel expenditure (car and related)	per angler per trip	96
				Average trip expenditure (including travel, fishing tackle and other equipment)	per angler per trip	141

[101] Pascoe, S., Doshi, A., Dell, Q., Tonks, M. & Kenyon, R. (2014). Economic value of recreational fishing in Moreton Bay and the potential impact of the marine park rezoning. Tourism Management, 41, 53-63. https://doi.org/10.1016/j.tourman.2013.08.015

[102] Prayaga, P., Rolfe, J. & Stoeckl, N. (2010). The value of recreational fishing in the Great Barrier Reef, Australia: A pooled revealed preference and contingent behaviour model. Marine Policy, 34(2), 244-251. https://doi.org/10.1016/j.marpol.2009.07.002

[103] Farr, M. & Stoeckl, N. (2018). Overoptimism and the undervaluation of ecosystem services: A case-study of recreational fishing in Townsville, adjacent to the Great Barrier Reef. Ecosystem Services, 31, 433-444. https://doi.org/10.1016/j.ecoser.2018.02.010

[104] McLeod, P. & Lindner, R. (2018). Economic dimension of recreational fishing in Western Australia: Research report for the recreational fishing initiatives fund. Department of Primary Industries and Regional Government and Recfishwest.

[105] McIlgorm, A. & Pepperell, J. (2013). Developing a cost-effective state-wide expenditure survey method to measure the economic contribution of the recreational fishing sector in NSW in 2012. A report to the NSW Recreational Fishing Trust, NSW Department of Primary Industries, November 2013. Produced by the Australian National Centre for Ocean Resources and Security (ANCORS). University of Wollongong.

Values for birdwatching

For birdwatching recreational services, only four valuation studies were identified from Australia based on the literature search. Two studies implemented expenditure surveys to be used for exchange values (**Table 4.14**). Studies relevant for welfare analysis are given in Appendix B (**Table B.1**).

The monetary value of birdwatching in estimated using the study by Steven (2022)[100], which estimated the economic value of birdwatching using data of domestic birdwatchers', who listed birdwatching as one of the outdoor activities for a daytrip made in Australia in 2019 (**Table 4.15**). This valuation estimate included the expenditure (with no accommodation) incurred for travelling to the site, which is in line with the SEEA-EA approach on monetary valuation for recreational services[108]. The study used actual visitation data of the domestic population, with trips dominated by those travelling for less than 100 kms to the recreational site[100].

Table 4.14: List of selected studies for recreational fishing valuation based on travel expenditure.

Study	Year valued	Habitat	State/region	Valuation method	Value measurement	Estimated value (AUD$)
Steven, 2022[106]	2019	Key Biodiversity Areas (KBAs)	National, Australia	Travel expenditure	per day (with no accommodation)	89
Steven, 2022	2019	Key Biodiversity Areas (KBAs)	National, Australia	Travel expenditure	per person per trip expenditure with overnight stay (inc. accommodation)	717
Callaghan et al., 2020[107]	2020	Old Bar, New South Wales	NSW	Expenditure (including travel time)	per person per trip	624
Callaghan et al., 2020	2020	Old Bar, New South Wales	NSW	Expenditure (excluding travel time)	per person per trip	532

[106] Steven, R. (2022). Bird and Nature Tourism in Australia. KBAs in Danger Case Study Report. Report prepared for BirdLife Australia. A. Carlton.

[107] Callaghan, C. T., Benson, I., Major, R. E., Martin, J. M., Longden, T. & Kingsford, R. T. (2020). Birds are valuable: the case of vagrants. Journal of Ecotourism, 19(1), 82-92. https://doi.org/10.1080/14724049.2019.1614010

[108] NCAVES & MAIA. (2022). Monetary valuation of ecosystem services and ecosystem assets for ecosystem accounting: Interim Version 1st edition. S. D. United Nations Department of Economic and Social Affairs, New York.

Table 4.15: Valuation studies selected for benefit transfer (expenditure based).

Title	Ecosystem services measured	Information used for the case study	Adjustments needed	Suitability to Benefit Transfer	Reference
Economic contribution of recreational fishing by Queenslanders to Queensland: A Report for Fisheries Queensland	Recreational fishing	Average travel expenditure to Cairns $18.6/day/ angler	The final estimate is $20.5 (adjusted to 2022$ value) based on Australian consumer price index (CPI)	East Trinity Inlet within the Cairns region	Kandulu et al., 2021
Bird and Nature Tourism in Australia	Birdwatching	Travel expenditure for daytrip, on average $89 per trip	The final estimate $98.4 (adjusted to 2022$ value) based on Australian consumer price index (CPI)	'Birdwatching' was listed as nature and outdoor activities in the survey	Steven 2022

Results

Recreation services (fishing and birdwatching) use accounts

The physical account for the selected recreational services of the East Trinity Inlet is presented in **Table 4.17** below. The total supply (and use) of recreational fishing is estimated at 9,125 fishing days per year. The site is also visited for birdwatching – with an estimate of about 180 bird observers per annum. This information is available for the whole site of the study area boundary and not disaggregated by ecosystem type.

Monetary account for recreational fishing and birdwatching

Monetary values are estimated by multiplying the physical flow of the service recorded in the physical account (**Table 4.16** and **Table 4.17**) by relevant values for each service (in **Table 4.15**) that reflect their exchange values per unit. The estimated recreational values from the literature have been adjusted to 2022 AUD values using the Australian consumer price index (CPI) . The monetary account (i.e. estimated monetary terms of the supply and use tables) for the two recreational services is presented in **Table 4.19**. As shown in the table, recreational fishing is estimated at $187,063 per annum. Birdwatching is estimated at about $17,712 per annum.

[109] Reserve Bank of Australia. https://www.rba.gov.au/calculator/

Table 4.16: Physical account: annual supply and use of recreational services in 2000/01 (pre-restoration).

	Units of measurement	Economic units				Ecosystems						
		Industry	Government consumption	Household consumption	Total use by economic units	Mangroves MFT1.2	Saltmarsh MFT1.3	Supratidal forests MFT1.2	Intertidal seagrass M1.1	Mudflats MT1.2	Other land covers T7.1	Total supply
Supply												
Recreational fishing (trips)	Number											***0***
Birdwatching (visitors)	Number											***0***
Use												
Recreational fishing (trips)	Number				***0***							
Birdwatching (visitors)	Number				***0***							

Table 4.17: Physical account: annual supply and use of recreational services in 2022 (post-restoration).

	Units of measurement	Economic units				Ecosystems						
		Industry	Government consumption	Household consumption	Total use by economic units	Mangroves MFT1.2	Saltmarsh MFT1.3	Supratidal forests MFT1.2	Intertidal seagrass M1.1	Mudflats MT1.2	Other land covers T7.1	Total supply
Supply												
Recreational fishing (trips)	Number											**9,125**
Birdwatching (visitors)	Number											**180**
Use												
Recreational fishing (trips)	Number			9,125	***9125***							
Birdwatching (visitors)	Number			180	***180***							

Table 4.18: Monetary account: annual supply and use of recreational services in monetary terms in 2000/01 (pre-restoration) ($, 2022 base year).

	Units of measurement	Economic units				Ecosystems						
		Industry	Government consumption	Household consumption	Total use by economic units	Mangroves MFT1.2	Saltmarsh MFT1.3	Supratidal forests MFT1.2	Intertidal seagrass M1.1	Mudflats MT1.2	Other land covers T7.1	Total supply
Supply												
Recreational fishing (trips)	Number											*0*
Birdwatching (visitors)	Number											*0*
Use												
Recreational fishing (trips)	Number				*0*							
Birdwatching (visitors)	Number				*0*							

Table 4.19: Monetary account: annual supply and use of recreational services in monetary terms in 2021 (post-restoration) ($, 2022 base year).

	Units of measurement	Economic units				Ecosystems						
		Industry	Government consumption	Household consumption	Total use by economic units	Mangroves MFT1.2	Saltmarsh MFT1.3	Supratidal forests MFT1.2	Intertidal seagrass M1.1	Mudflats MT1.2	Other land covers T7.1	Total supply
Supply												
Recreational fishing (trips)	Number											187,063
Birdwatching (visitors)	Number											17,712
Use												
Recreational fishing (trips)	Number			187,063	187,063							
Birdwatching (visitors)	Number			17,712	17,712							

Interpretation and discussion

The restoration activities of East Trinity are improving the ecosystem and wildlife habitat which in turn contributes to the growing recreational services. The monetary valuation is based on a benefit transfer method using travel expenditure data collected from related studies in Australia. For recreational fishing, the annual monetary estimated value is $187,063 in 2022. The annual value of recreational services from birdwatching totalled $17,712 in 2022. These suggest that restoration programs such as that in East Trinity Inlet can generate substantial societal benefits through recreational activities.

It is important to recognise the limitations of the monetary value estimates considering the lack of primary data. All the data in the accounts tables in particular stems from the anecdotal evidence of visitation rates provided by key informants. While it is reasonable to assume that the observations from the key informants are reliable for the days they have spent in the field, there has not been a structured sampling and data recording mechanism in place that would allow for observation of seasonal variations in visitation, including changes during peak periods (e.g. weekends, holiday periods) or weather events.

In the absence of survey-based data collection, there is also no information provided about the socio-demographic characteristics of visitors to the site. This precludes the ability to adjust the value estimate being transferred based on any differences in visitor characteristics between the original study site (from where the data is drawn) and case study site (where the data is being applied). Not having robust visitation data poses various challenges that mean the account tables prepared here are indicative only. They can reliably be interpreted as demonstrating a positive trend in terms of provision of recreational services. However, the confidence in the data used is extremely low, and the information in the account's tables cannot be taken as an accurate estimation of the magnitude of supply, use, or monetary value of the recreational services provided.

Clearly, the accuracy of the data reported will be questionable when practitioners must rely on anecdotal evidence and secondary data for visitation rates and values. Accuracy will improve if primary data is collected on visitation and for calculating exchange values. In this instance, given the retrospective development of the accounts, it was unfortunate that no historical observations had been recorded for visitation. Resources also did not permit for primary data collection through surveys of visitors, and as flagged above, may not have successfully revealed the true visitation rate given the likely trespassing that occurs.

For future wetland restoration projects, there will be a trade-off between accuracy and cost of data used to establish recreational service accounts. If project resources permit, primary data should be collected, with considerations given to the feasibility of being able to reveal truthful responses through survey-based primary data collection if there are certain access constraints in place for some services (as for the recreational fishing inside the East Trinity site).

If project resources do not permit primary data to be collected through survey-based mechanisms (which will be the main mechanism to collect data on trip expenditure) or if illegal activities are likely to make surveys ineffective, we recommend prioritising data collection for visitation through alternate, more cost-effective means. Alternate approaches could include, for example, a stratified approach by field-work officers recording visitation observations. Field-work activities would be allocated to be undertaken at different times of the year, week, and day, and a spreadsheet provided to record data on number of visitors, group sizes, estimated age/gender, activities undertaken, and time spent at the site. For projects that are already established and/or do not need regular presence by field-work officers, CCTV-style cameras (or people counters, which are frequently used by National Parks) could be installed at common entry/exit points, which would allow for ongoing recording of visitor numbers.

The cost of implementing these alternate approaches may be justified relative to the improved accuracy of the visitation data that will be made available, if developing recreational service accounts is an objective of the restoration project, but consideration has to be made on the overall importance of the use within total values. Providing at least some level of robustness in the visitation data is critical, as the magnitudes of reported values in recreational accounts will be meaningless without this.

While having accurate exchange value data is also important, the accuracy of values estimated through benefit transfer is likely to be improved through provision of more accurate visitation data. For example, for activities such as recreational fishing, there is usually data available at the regional or State-wide scale on fishing effort and trip expenditure, which can be applied with reasonable accuracy if visitation rate is known.

Welfare values of cultural services (using consumer surplus)

There are multiple frameworks that can be used to identify the value associated with the ecological services provided by an asset and hence the value of the asset. The exchange value approach outlined above is consistent with the national accounting framework but does not include values that do not pass through markets. As outlined in the Guide, an alternative approach is to estimate the welfare values associated with use and non-use.

In economic terms, well-being is commonly described in terms of welfare and utility, for which the economic values are measured using consumer surplus. Consumer surplus for recreational services can be estimated with the use of non-market valuation methods such as revealed preference and stated preference techniques. The travel cost method (which is commonly used in the case of recreational activities, including fishing and bird watching) estimates the economic value based on people's behaviour to reveal their willingness to pay for a good or service, while choice experiment, a stated preferences approach, is based on people's hypothetical preferences for the good or bundle of services that the ecosystem provides[110]. Where primary studies are not feasible, benefit transfer of values from similar studies can be employed.

Welfare value of recreational fishing services

For this case study, a benefit transfer of values from a similar non-market valuation study conducted elsewhere was carried out. A study by Kandulu[111] et al. (2021) that estimated the economic values of recreational fishing for the Cairns region using Queensland statewide recreational fishing surveys was selected for two reasons. Firstly, it specifically focuses on in the Cairns region where this case study is located. Secondly, this recent study estimated consumer surplus for the number of fishers per day, which aligns to the anecdotal data we have on visitation rate (number of fishers per day). The consumer surplus estimated value in this study was $47 per angler per day for the year 2019. Thus, the values can be transferred to our case study area, which aims at valuing the recreational benefits after adjusting values for 2022 ($52/ angler/ day) using the Australian consumer price index (CPI).

Welfare value of birdwatching services

For birdwatching, Carnell[112] et al. (2019) estimated the economic value of birdwatching using welfare value estimates by birdwatchers travelling to view birds to the coastal ecosystem of Port Phillip, Victoria. This valuation estimate included the cost of time spent travelling to the site, which is in line with SEEA-EA approach on monetary valuation of recreational services[113]. The estimated consumer surplus for birdwatching in 2019 was $158 AUD – which is adjusted to $174.7 for the 2022 base year (**Table 4.20**).

Based on the standardized values, the annual consumer surplus from recreational fishing and birdwatching is estimated at about $474,500 and $31,446 AUD, respectively (**Table 4.21**).

[110] Rolfe, J. & De Valck, J. (2021). Values for protecting the Great Barrier Reef: A review and synthesis of studies over the past 35 years. Marine Pollution Bulletin, 169, 112531.

[111] Kandulu, J., Bailey, H. & Magnusson, A., BDO. (2021). Economic contribution of recreational fishing by Queenslanders to Queensland: A Report for Fisheries Queensland. Fisheries Queensland

[112] Carnell, P. E., Reeves, S. E., Nicholson, E., Macreadie, P., Ierodiaconou, D., Young, M., Kelvin, J., Janes, H., Navarro, A., Fitzsimons, J. & Gillies, C. L. (2019). Mapping Ocean Wealth Australia: The value of coastal wetlands to people and nature. The Nature Conservancy, Melbourne.

[113] NCAVES & MAIA. (2022). Monetary valuation of ecosystem services and ecosystem assets for ecosystem accounting: Interim Version 1st edition. S. D. United Nations Department of Economic and Social Affairs, New York.

Table 4.20: List of selected literature with consumer surplus values used for value benefit transfer for welfare estimates.

Title	Ecosystem services measured	Information used for the case study	Adjustments needed	Suitability to Benefit Transfer	Reference/ link
Economic contribution of recreational fishing by Queenslanders to Queensland: A Report for Fisheries Queensland	Recreational fishing	Estimated values using travel cost method ($47per day per angler, 2019 value)	The final estimate is $52 (adjusted to 2022$ value) based on Australian consumer price index (CPI)	East Trinity Inlet within the Cairns region	Kandulu et al., 2021
Mapping Ocean Wealth Australia: The value of coastal wetlands to people and nature.	Birdwatching	Estimated values using travel cost/ choice modelling ($158 per visit)	The final estimate is $174.7 (adjusted to 2022$ value) based on Australian consumer price index (CPI)	Birdwatching in states is dominated by domestic visitors	Carnell et al., 2019

Table 4.21: Economic valuation using welfare values (consumer surplus): annual supply and use of recreational services in monetary terms ($, 2022 base).

Ecosystem services	Number of fishers/visitors in 2021	Annual consumer surplus (AUD)
Recreational fishing	9,125	474,500
Birdwatching	180	31,446

Welfare value of other non-use services

As noted in the Guide, welfare values are not limited to those that arise through use. Existence values reflect t that people may value nature not because they use or intent to use it but for its mere existence[114]. As such, people may have an existence value for wetlands and enjoy an increase in welfare as a result of the remediation of the site. This value will depend on both the change in extent of the wetlands, and the improvement in the condition of the wetlands. Although these measures may be readily identified for the remediation site, linking these values to the metrics used in valuation studies is more problematic, where often the approach is to define an improvement in quality in ways that the public can easily interpret (i.e. fish populations, water quality). This goes to an issue raised by Xu[115] et al (2020) on the need for unified wetland ecosystem services indicators. In the absence of primary data or wetland valuation studies specific to East Trinity wetland, we derive values based on a benefit transfer approach. We have conducted a systematic review of studies on non-use (existence) valuation of wetlands in Australia. After screening and reviewing abstracts, six studies were identified to be relevant. Among them, MacDonald & Morrison (2010)[116] provides

[114] Davidson, M. D. (2013). On the relation between ecosystem services, intrinsic value, existence value and economic valuation. Ecological Economics, 95, 171–177. https://doi.org/10.1016/j.ecolecon.2013.09.002

[115] Xu, X., Chen, M., Yang, G., Jiang, B., & Zhang, J. (2020). Wetland Ecosystem Services Research: A Critical Review. Global Ecology and Conservation, 22, e01027. https://doi.org/10.1016/j.gecco.2020.e01027

[116] MacDonald, H. D. & Morrison, M.D. (2010) Valuing biodiversity using habitat types. Australasian Journal of Environmental Management, 17(4), 235-243.

estimates of WTP (willing to pay) for an increase in the size and improvement of the quality of wetlands in South Australia based on surveys in Adelaide, Upper South East, and State-wide respondents. The study is best suited to our case study in terms of the valuation scope with WTP for wetland conservation. The WTP at State level is AUD 1.36 per 1000 hectare per household for a maximum of five years.

The original value of WTP Is adjusted to the 2022 price level using CPI and by household income level for Cairns residents in Queensland, to AUD 1.79. Since the WTP in the original study is defined as the amount that respondents would pay per year for a 5-year period, this needs to be converted into a NPV value, and then an annuity value. We do this using a 7% discount rate[117]. The 5 years of payments is equivalent to an NPV of AUD 7.35, and the equivalent annuity of AUD 0.51 per year per household, for a restored area of 1000ha. In determining an existence value, the appropriate population needs to be defined i.e. which community is benefited by the restoration. As a relatively small area, it is assumed that it is of relevance to the population of Cairns only. The welfare value is estimated based on the consumer surplus corresponding to the size of restoration area multiplied by the total household population of Cairns which is about 60,318[118]. Therefore, the existence value for East Trinity restoration site is estimated at about AUD 22,932 per year (in 2022 value, Table 4.22). This is the significance of restoration of the site for the Cairns residents in addition to the use-value of ecosystem services.

Interpretation and discussion of welfare values

This report also establishes the monetary account based on welfare estimate values for the two recreational services. Given the benefits are attributed to the East Trinity Inlet site, the values can reflect the positive impacts of the restoration in enhancing wildlife habitat. The monetary valuation is based on a benefit transfer method using consumer surplus estimates from Australian studies. Recreational services flow in monetary terms are estimated by multiplying the physical flow of the service by relevant consumer values for each service. Based on this, for the annual monetary value based on anglers' willingness to pay for the recreational fishing is **$474,500 AUD** in 2022. For birdwatching, bird watchers' willingness to pay estimate is **$31,446 AUD** in 2022. This estimate is substantially higher than the value estimated using exchange value for birdwatching. Note that these two measurements are conceptually different and estimated using different approaches.

We note that the challenges regarding accuracy of visitation rates discussed above for exchange values are relevant here for welfare values also. They are perhaps even more pronounced when attempting benefit transfer of consumer surplus estimates given that economic theory acknowledges the role that scarcity plays in demand for services: the more accessible that a service becomes, the less people are willing to pay for each access occasion, while the less that a

Table 4.22: Economic valuation using welfare values (consumer surplus): annual supply and use of recreational services of Tomago in monetary terms (AUD, 2022 base).

Study	Original WTP estimate (AUD per 1000ha/year/household in 2010)	Adjusted WTP (AUD/1000ha/year/household in 2022)	Present value WTP (AUD/1000ha/year/household in 2022)	Total consumer surplus (AUD/year)
MacDonald & Morrison (2010)[110]	1.36	1.79	0.51	22,932

[116] MacDonald, H. D. & Morrison, M.D. (2010) Valuing biodiversity using habitat types. Australasian Journal of Environmental Management, 17(4), 235-243.

[117] McLiesh, C. (2017). NSW Government Guide to Cost-Benefit Analysis: Policy and Guidelines Paper (Issue March). www.treasury.nsw.gov.au

[118] Australian Bureau of Statistics (2021 census). https://www.abs.gov.au/census/find-census-data/search-by-area

service is able to be accessed, the more it is worth per occasion. For example, Kandulu[119] et al. 2021, provide an estimated expenditure of $47 AUD per angler per day, and 4.48 average fishing days per year. They equate the annual consumer surplus to $210 AUD per angler, reflecting the value per day and the number of days fished throughout the year.

Reflection relevant to the Guide

The ability to implement the advice provided in the Guide has been challenging in this case study application primarily due to scarcity of relevant data. Specific challenges are documented below.

- Establishing the causal link between management action, ecological change, behavioural change has been challenging as not all parts of this causal chain have been researched and reported.
- Most visitation or other use-related data is required for the onsite location, rather than the values that may arise off site. A complication here is that much of the recreational use is illicit, and not formally allowed. Quantifying this is therefore difficult. Furthermore, although illegal activity is part of the record in national accounts, and hence EEA, the status of welfare values associated with illicit activity is perhaps less clear.
- The 'export' of services from the site to the broader area (in the form of fish biomass and hence values for recreational fishing elsewhere) was not established for this site, although anecdotal evidence suggested that it was not high.
- Assumptions necessarily relied on the anecdotal evidence from researchers/ managers in the field, which does not allow for a more precise understanding of visitation including seasonal variations.
- Without site-specific visitation data, there is also an absence of data about the socio-demographics of visitors, which reduces the ability to make adjustments of secondary data used in benefit transfer, leading to reduced accuracy.
- For bird watching there were no locally relevant studies available to provide suitable monetary estimates for benefit transfer. Instead, national data had to be used for extrapolation leading to reduced accuracy.

In this case study application, the resources did not permit for primary data collection, hence the challenges above. However, if one assumed resources were available to allow this for other restoration projects, the ability to conduct primary research that would reliably enable estimation of monetary (exchange or welfare) values would be highly dependent on the available samples of people using the site (i.e. there would need to be sufficient sample available to statistically estimate travel expenditures or consumer surplus measures with confidence).

The availability of visitation numbers is more dependent on primary data: there are not sufficient studies to be able to 'transfer' use associated with a site, unless one has closely aligned models (i.e. local site visitation models that can be used to infer use based on ecological characteristics of the new site). Here we use 'anecdotal' estimates of use based on key informants familiar with the site. Our task here was made easier by the fact that one could assume no values before restoration, given the nature of the site.

In the terminology of EEA, there may be "export" of services to areas geographically separate from the restoration site itself e.g. improved fishing elsewhere. This compounds the difficulties: change in usage as a result of restoration requires quantification over a broader, possibly ill-defined area, where that change needs to be linked to an understanding of the export of ecological services that may not be well understood/quantified. Our informal understanding is that there has been little discernible impact on recreational fishing outside of the restoration area, so this information was not required, but it would have proven to be a challenge.

[119] Kandulu, J., Bailey, H. & Magnusson, A., BDO. (2021). Economic contribution of recreational fishing by Queenslanders to Queensland: A Report for Fisheries Queensland. Fisheries Queensland

Other relevant economic indicators (such as the number of jobs created) could also be reported to better understand the economic contribution of recreational services. However, estimates of such indicators would require a robust estimate of supply, use, and exchange values than we have available in this case study. So, primary data collection would be ideal to integrate such indicators in reports.

Moving forward, it may be useful to improve data collection on visitation rates – before and after restoration – for project sites. This requires structured sampling for objective data to be recorded but is technically feasible to implement even for small/infrequently visited sites.

Broadening of the associated non-market valuation literature could then focus on estimating exchange and welfare values for case study sites where the relevant human populations are large enough to allow for a reliable analysis to take place, and ensuring that sites are targeted to build a representative database of non-market values for restored wetland ecosystem services to use in benefit transfer (i.e. supporting extrapolation of monetary values to those sites were primary data collection is infeasible).

4.3 Regulation and maintenance

4.3.1 Carbon stocks, sequestration & emissions

Intent of work

This section details an integrated approach for quantifying two related but distinct accounts associated with greenhouse gas regulation service provision: *carbon abatement* and *carbon stocks*. The carbon abatement account integrates estimates of changing greenhouse gas emissions and sequestration through the life of the East Trinity restoration project (including adjacent mangrove forest) so far (2002 to 2022) to determine the net outcomes of carbon abatement of tidal restoration actions at this site. Both physical and financial accounts are included.

In contrast, the carbon stock account provides snapshots of the amount of carbon stored in aboveground biomass and soil carbon (to 1m depth) pools within the East Trinity Inlet study area, estimated at two timepoints: a pre-restoration timepoint (2002) and a post-restoration timepoint (2022). No financial account has been estimated for *carbon stocks* as this would represent double-counting of values which are already considered in the *carbon abatement* account.

Approach taken

Two complementary approaches were selected for carbon accounts of East Trinity Inlet based on data availability and suitability. These approaches include:

A. a 'nationally-consistent' approach, which uses nationally-available datasets only

B. a 'hybrid' approach, which uses the same mapping products as above with implementation of available setting-specific tidal range and carbon cycling parameters.

The Blue Carbon Accounting Model (BlueCAM) calculator is a foundational tool in the development of physical accounts for both carbon abatement and carbon stocks under each of the above approaches. Tables provided in the detailed sections below outline the inputs that have been used in each version (tier) of BlueCAM calculator operation. The delineation of specific Carbon Accounting Areas within a project area and their parameterization in BlueCAM is an important step in this process. Details are also provided on how BlueCAM outputs were compiled to derive final accounts for carbon abatement (physical account plus financial account) and carbon stocks (physical account only).

Results

The outcomes of carbon abatement and carbon stock accounts are presented at the scale of individual Carbon Accounting Areas, and at the overall East Trinity project scale. Comparison of carbon abatement and carbon stock accounts derived through the two approaches shows variation among methodologies. Overall abatement estimates were 74 % higher, and overall stock change 30% higher in the 'hybrid approach' (B) relative to the nationally-consistent approach (A).

Depending on the accounting approach taken, estimates of carbon abatement volume across the 20 years since tidal restoration at East Trinity Inlet range from 81,615 to 141,688 t CO_2e. This volume of abatement equates to the annual electricity emissions of approximately 15,880 to 27,569 households, or 1.35 – 2.34 million tree seedlings grown for 10 years.

The carbon stock accounts demonstrate the substantial amount of carbon stored within the coastal wetlands of the East Trinity Inlet restoration site and adjacent mangrove forests. Stock estimates were very high (>640,000 t CO_2e) in both baseline (2002) and project (2022) accounts under both approaches and were as high as 1.56 million t CO_2e in the highest case project scenario. These stock estimates equate to the annual electricity emissions of approximately 126,000 to 304,000 households, or the amount of carbon sequestered by growing 10.7 to 25.8 million tree seedlings for 10 years. This finding demonstrates the carbon-rich nature of the East Trinity Inlet setting, and the significant amount of carbon which may be at risk of emission to the atmosphere if the site is disturbed or restoration practices are reversed.

Reflection relevant to the Guide

The lack of suitable high-resolution extent mapping for the East Trinity Inlet case study highlights the significance of such products for detailed carbon service accounts. While this imposed high uncertainty for the East Trinity Inlet case study, the incorporation of a hybrid approach with multiple site- and setting-specific carbon parameter estimates highlighted the tendency of nationally-consistent approaches (without setting-specific data) to underestimate carbon abatement and carbon stock outcomes at a project-level. While setting-specific parameters for some land types and some specific carbon cycling parameters were available for the East Trinity Inlet case study, there remains some data gaps across all ecosystem/land cover types and across all carbon parameters (i.e. biomass, soil carbon, CH_4 and N_2O fluxes), which prevented more accurate determination of the true abatement and stock outcomes of the tidal restoration project. Finally, this case study documents the carbon abatement outcomes associated with tidal restoration activities (including associated land cover changes) but does not incorporate greenhouse gas emissions or abatement associated with the production, transport, or application of lime as part of the management of acid-sulphate soils.

4.3.2 Carbon stocks, sequestration & emissions Supplementary Information

Context

This section details an integrated approach for quantifying two related, but distinct accounts associated with greenhouse gas regulation service provision:

- *Carbon abatement* (avoided emissions, emissions and sequestration): Physical AND financial accounts
- *Carbon stocks* (aboveground biomass stocks, soil carbon stocks to 1 m): Physical accounts only

Accurate estimation of the carbon abatement outcomes of a restoration project requires consideration of multiple greenhouse gas fluxes related to the activity over a relevant time period. These greenhouse gas fluxes include any emissions which would have been expected from the project area if the restoration project had not occurred (termed 'avoided emissions'); any direct or indirect emissions resulting from the restoration activity itself; and any additional sequestration in biomass and soil carbon pools resulting from the restoration activity. Accurate estimation of the overall carbon abatement outcome of a restoration project therefore needs to consider the net direction and magnitude of these combined fluxes over the entire accounting period.

Accurate estimation of the carbon stock outcomes of a restoration project requires consideration of any change in significant carbon pools (in this instance: aboveground biomass carbon pool, and soil carbon pool to 1m depth) resulting from the restoration activity, over a relevant time period.

The geographic extent of carbon abatement and carbon stock estimation may change over time due to the dynamic nature of coastal ecosystems and the potential for both eustatic sea-level rise and any modification of engineering controls to alter inundation footprints and therefore the spatial extent of physical and biotic controls on carbon cycling. Blue carbon projects under the Australian Carbon Credit Units (ACCUs) would typically be required to account for carbon abatement not only within contemporary project boundaries, but also over land that will be within the intertidal zone in 100 years (i.e. land that is within the elevation envelope of the highest astronomical tide with anticipated levels of sea level rise). As the current project seeks only to quantify carbon abatement over the period 2002-2022, the East Trinity Inlet restoration project area extent identified in **Section 3** is suitable for EEA purposes, and is therefore used for consistency with other service accounts.

Data availability

Two complementary approaches were selected for carbon accounts of East Trinity Inlet on the basis of the availability and suitability of available datasets. These approaches integrate carbon abatement and carbon stocks and range from low to moderate site-specificity, as detailed in **Table 4.23**.

While multiple vegetation surveys were conducted for the site in the early stages following tidal restoration, these were not considered of a suitable timeframe (i.e. at or near 2022) and/or were not available in formats required for carbon accounts. These limitations, combined with the lack of a detailed-approach for extent accounts for the site, hindered the application of a 'detailed-approach' for carbon services as outlined in the Guide. Site-specific datasets of soil surveys conducted under baseline impacted and reference sites (1999) and mid-project restoration sites (2009) made significant contributions to the hybrid approach, which is provided in the absence of a truly detailed approach.

Table 4.23: Summary of two tiers of approach demonstrated in the East Trinity Inlet restoration project case study for both *carbon abatement* and *carbon stock* accounts.

Approach	Datasets used	Expected outcome
(A) Nationally-consistent approach	– Nationally-consistent extent accounts (Section 3.1) – Nationally-consistent tide gauge approach – Nationally-available elevation dataset – Modified version of BlueCAM calculator with additional outputs for EEA projects	Low site-specificity - less reliable account
(B) Hybrid approach: nationally-consistent with limited setting-specific inputs	– Nationally-consistent approach extent accounts (Section 3.1) – Site-specific tide gauge approach – Nationally-available elevation dataset – Site-specific (East Trinity Inlet) and setting-specific (Cairns region) blue carbon datasets, from published and unpublished sources – Modified version of BlueCAM calculator with additional outputs for EEA projects	Moderate site-specificity - moderately reliable account

Methods

Blue Carbon Accounting Model (BlueCAM) calculator:

The Blue Carbon Accounting Model (BlueCAM) calculator is a foundational tool in the development of physical accounts for both carbon abatement and carbon stocks under this Guide. The methodology for both approaches (A and B in table above) utilises the BlueCAM calculator, and these approaches broadly follow the requirements of the following BlueCAM guidance documents and scientific outputs:

- ACCU Method guide
- Blue Carbon Accounting Model (BlueCAM) Guidelines
- Blue Carbon Accounting Model (BlueCAM) Technical Overview

In some instances, minor variations from these guidance documents are implemented in the East Trinity Inlet EEA case study, for the following reasons: (1) provide greater simplicity for higher level EEA assessments (i.e. as opposed to ACCUs); (2) ensure consistency with other physical and financial accounts quantified in the case study; and (3) enable use of setting-specific datasets in the hybrid approach. The rationale for such variations from BlueCAM guidance is provided below.

Note: A single file of the publically available BlueCAM calculator file can be used to generate all required outputs for the carbon abatement account. This public version of the calculator, however, does not provide the outputs required for the carbon stock account – in this instance an additional, modified version of BlueCAM for EEA purposes is required.

BlueCAM inputs:

Operation of BlueCAM for both carbon abatement and carbon stock accounting purposes requires two types of data inputs: (1) project level parameters; and (2) Carbon Estimation Area (CEA) parameters. Project level parameters include project accounting timeframes, the tidal range of the project site, and quantification of any fuel use associated with the project. The source of these project level parameter inputs, and rationale for their use for the East Trinity Inlet restoration project is detailed in **Table 4.23**.

Accurate carbon abatement accounting may require the stratification of the project area into sub-units (termed Carbon Estimation Areas or CEAs in BlueCAM). For BlueCAM, CEAs may need to be delineated within a project area on the basis of different land-uses, vegetation types and levels of land elevation (relative to Australian Height Datum or m AHD) – factors which may all change for a given parcel of land over the life of a project. While ACCU projects are typically required to monitor and delineate CEAs at multiple intervals (e.g. every five years) over the life of a project, carbon abatement accounting for the East Trinity Inlet EEA project utilises a simplified approach. That is, CEAs are delineated on the basis of two timepoints: a CEA baseline land type based upon status prior to 2002; and reporting period (post-restoration) status in 2022. The source of CEA parameter inputs, and rationale for their use for the East Trinity Inlet restoration project is detailed in **Table 4.24**. Further guidance on the definition of CEA land types is provided in ACCU technical documents.

Spatial analyses were undertaken to determine the number, type and extent of each CEA, with separate analyses required for both the national approach (A) and (B) hybrid approach (were completed together). The nationally-consistent extent map for baseline conditions (land type in 2002) and post-restoration conditions (land type in 2022) were used as inputs in a 'change detection analysis'. This returned a new raster layer depicting the extent of each category of land type change within the project area. As the land types defined by the extent account approaches do not align perfectly with the prescribed land type inputs available in BlueCAM, a harmonization process was required whereby input land classes were converted to the most suitable BlueCAM value based upon knowledge of the site's management history (**Table 4.25**).

The elevation of a CEA operates as a modifier of some carbon cycling parameters in BlueCAM. To determine the elevation of each CEA, a further spatial analysis was undertaken. That is, the land type change raster described above was first converted to multipart polygon files, and a zonal statistics tool was used to compute central estimates of elevation for each polygon/CEA, using a high-resolution digital elevation model (**Table 4.24**). Both median and mean elevation values for each CEA are reported in **Table 4.26**, with the median value used in BlueCAM to minimize the influence of any elevation outliers.

Finalised Project level parameters and CEA input parameters were entered into a 'Tropical humid' BlueCAM worksheet following specifications outlined for nationally-consistent (A) and hybrid (B) approaches in **Table 4.23** and **Table 4.24**. A further process was undertaken for the hybrid approach (B) to replace generic BlueCAM model parameters with site- and setting-specific parameters identified in published literature and available, unpublished datasets (**Table 4.28**). These new values (and the BlueCAM values they replace) are detailed in **Table 4.29**.

BlueCAM outputs (physical accounts)

Carbon abatement: Two sets of outputs were derived from BlueCAM calculator to populate carbon abatement accounts tables. There are: (1) estimates of carbon abatement parameters for each individual CEA (populated from BlueCAM calculator rows AC, AG and AM and reported in **Table 4.30**), and (2) whole-of-project abatement estimates (populated from BlueCAM calculator cells AQ3: AT3 and reported in **Table 4.32**). Note that BlueCAM automatically applies at 5 % reduction on the overall abatement estimate (i.e. Net abatement amount (Ar)) within the BlueCAM calculator (i.e. cell AT3). This discount is a specific requirement of projects seeking carbon credits under the tidal restoration method of the Australian Carbon Credit Untis, but is less relevant to EEA projects which are not operating under this framework. For this reason, **Table 4.32** includes an additional row 'Net abatement amount (Ar-adj): ACCU discount removed', whereby Ar-adj is the net sum of values EA, CP and Efk (i.e. no 5% discount applied).

Carbon stocks: Four carbon stock values were derived separately for each of the approach levels (nationally-consistent and hybrid). These stocks, and the way in which they were derived from BlueCAM files are defined in **Table 4.30**.

Financial accounts (Carbon abatement only)

BlueCAM net abatement estimation outputs (i.e. columns AQ:AT in BlueCAM worksheet, plus the $A_{r\text{-}adj}$ value described above) are used to populate the overall physical account estimates for carbon abatement in **Table 4.32**. Each of these high-level physical account estimates – in Tonnes CO_2e and calculated over the life of the restoration accounting period (i.e. 2002 to 2022) were also used to calculate related financial accounts. Two financial account approaches are demonstrated. The first approach applies an Australian Carbon Credit Unit spot price value of $30.75 per Tonne of CO_2e abatement, as reported by the Clean Energy Regulator in the Quarterly Carbon Market Report – September Quarter 2022. A second approach using a financial multiplier of $150 per Tonne of CO_2e abatement was applied to reflect the expectation that carbon credits generated in Blue Carbon projects are likely to attract a premium market value (relative to other carbon credits) due to their multiple co-benefits and high market demand.

Table 4.24: Project-level BlueCAM input parameters, their descriptions and rationale for use East Trinity Inlet carbon service accounting. Further guidance on each BlueCAM parameter is provided in ACCU technical documentation. *Continued over page.*

Project Information Parameter	Input Description / Rationale		Source / Links
	(A) Nationally-consistent approach	(B) Hybrid approach	
Climatic zone	Climate: BlueCAM uses climatic regions aligned with the Australian Government's Natural Resource Management (NRM) regions approach for projecting the influence of climate change to estimate regionally specific abatement. The East Trinity remediation site is positioned within the Wet Tropics cluster, and is therefore considered 'Tropical humid' in the application of BlueCAM.		Link: NRM regions
Reporting period start date (day/ month/year)	Baseline (pre-restoration) date assumed to be 01/01/2002		
Reporting period end date (day/ month/year)	Project (post-restoration) reporting period assumed to be 31 December, 2022 As defined in the guide, EEA projects can select a project accounting period of either 25 years or 100 years. Projects with a permanence period of 25 years (and projects with a 100 year permanence period which are subject to the project area discount) are subject to a 25% reduction in carbon abatement estimates, which is applied automatically by BlueCAM. A project accounting period of 100 years, with no project area discount has been selected for the East Trinity EEA as this EEA case study is concerned with a short-term (pre 2002-2022) accounting period, and therefore should not be subject to estimate reductions associated with longer-term ACCU projects.		
Apply project area discount?	**Input = 'No'** A project accounting period of 100 years, with no project area discount has been selected for the East Trinity EEA as this EEA case study is concerned with a short-term (pre 2002-2022) accounting period, and therefore should not be subject to estimate reductions associated with longer-term ACCU projects.		

Table 4.24: Cont.

Project Information Parameter	Input Description / Rationale (A) Nationally-consistent approach	Input Description / Rationale (B) Hybrid approach	Source / Links
Enter the tidal range (m)	The distribution of coastal wetland types, their carbon cycling parameters, and responses to anticipated sea-level rise are influenced by tidal inundation parameters.		National approach: 2022 QLD Tidal Planes summary
	Tidal range data for the nearest public tidal gauge (Cairns).	Tidal range data for the East Trinity restoration site have been compiled from as minimum and maximum values reported across multiple sources	Detailed approach: Johnston et al. 2012
	LAT = -1.74 m AHD	LAT = -0.48 m AHD[120]	Hybrid approach: Smith et al. (2016)
	HAT =1.83 m AHD	HAT = 1.5 m AHD[121]	
	Input value = 3.57 m	**Input value = 1.98 m**	Tidal range calculated from HAT and LAT estimates
Fuel consumed during reporting period	A general principle in many carbon accounting frameworks is that carbon pools or emissions which represent less than 5% of overall project abatement may be considered 'de minimis'. For the purpose of EEA reporting, fuel consumption may be assumed to be zero for project activities (where it is reasonable to assume these emissions represent). Fuel consumption is assumed 'de minimis' for project activities associated with the East Trinity restoration site and therefore accounted as zero in BlueCAM.		
Carry over net abatement from the previous reporting period	There were no previous reporting periods (i.e. a single reporting period was used for EEA estimation purposes), therefore no value is entered here.		

[120] Johnston, S. G., Keene, A., Burton, E., Bush, R. (2012). Quantifying alkalinity generating processes in a tidally remediating acidic wetland. *Chemical Geology*, 304, 106-116.

[121] Smith, C. D., Manders, J. A. & Brough, D. M. (2016). East Trinity Acid Sulfate Soil Remediation Project–Changes in Soil Properties after 13 years of Remediation. *Department of Science, Information Technology and Innovation, Queensland Government, Brisbane (2016).*

Table 4.25: Carbon Estimation Area (CEA) BlueCAM input parameters, their descriptions and rationale for use in East Trinity Inlet carbon service accounting. *See also **Table 4.26** for BlueCAM replacement parameters with site- and setting-specific values utlised in the (B) Hybrid approach. *Continued over page*.

CEA Parameter	Input Description / Rationale: (A) Nationally-consistent approach	Input Description / Rationale: (B) Hybrid approach*	Source / Links
CEA area (ha)	Area of each unique change (pre-restoration to post-restoration) class, as determined from national extent mapping approach **Input values in Table 4.24**		**Section 3.1** **Table 4.24**
Elevation of CEA (m AHD)	Median elevation value of all pixels within CEA, as derived from nationally-available, high resolution DEM **Input values in Table 4.24**		Elvis **Table 4.24**
Tidal introduction in CEA?	**Input = 'Yes'** for all CEAs as they are within the limits of the restoration extent mapping and all CEA median elevation estimates are within the range of national approach LAT to HAT values in **Table 4.21**	**Input = 'Yes'** for all CEAs as they are within the limits of the restoration extent mapping and all CEA median elevation estimates are within the range of hybrid approach LAT to HAT values in **Table 4.21**	Restoration extent maps (**Figure 1.1**) Tidal range and tidal plane (LAT, HAT) estimates (**Table 4.21**); CEA median elevation estimates (**Table 4.24**)
New CEA or first reporting period?	**Input = 'Yes'** for CEAs which experienced a change in land type: N2-N4; N6-N7; N9-N18 **Input ="N"** for CEAs which remained the same land type: N1, N5, N8, N19		**Table 4.24** **Table 4.24**
CEA baseline land type	Derived from pre-restoration national extent account approach. Extent account land type harmonized approach with BlueCAM-specific land types as per **Table 4.23** Input values in **Table 4.24**		**Section 3.1** **Table 4.23** **Table 4.24**
Land type for CEA: last reporting period end	N/A (only one reporting period used)		
Land type for CEA: current reporting period end	Derived from pre-restoration national extent account approach. Extent account land type harmonized approach with BlueCAM-specific land types as per **Table 4.23** **Input values in Table 4.24**		**Table 4.23** **Table 4.24**

Table 4.25: Cont.

CEA Parameter	Input Description / Rationale		Source / Links
	(A) Nationally-consistent approach	(B) Hybrid approach*	
Age of blue carbon vegetation in previous reporting period (years)	Age of vegetation at baseline (2002). **Input = 20** years for all CEAs. Assumed value to be representative of carbon stocks of mature vegetation		Table 4.24
Age of blue carbon vegetation in current reporting period (years)	Age of vegetation at reporting period (2022). **Input = 21** years (age assumed; post restoration timeframe) for CEAs which experienced a change in land type: N2-N4; N6-N7; N9-N18 **Input = 41** years for blue carbon vegetation CEAs which remained same land type (age assumed; 20 year assumed baseline age + 21 year post restoration timeframe): N1, N5, N8, N19		Table 4.24
Excavation area within CEA (hectares)	Assumed zero		

Table 4.26: Harmonisation of land type extent classes and BlueCAM prescribed land type input classes for East Trinity Inlet case study. Both the nationally-consistent and hybrid approaches alculatd the same input maps and calculated on approach.

	Extent account land type	BlueCAM land type
Pre-restoration extent classes	Mangrove	Mangrove
	Saltmarsh	Saltmarsh
	Supratidal forests	Supratidal forest
	Waterbodies/mudflats	Flooded agricultural land, managed wet meadow or pasture
	Other land covers	Other use land
Post-restoration extent classes	Mangrove	Mangrove
	Saltmarsh	Saltmarsh
	Supratidal forests	Supratidal forest
	Waterbodies/Mudflats	Saline waterbodies
	Other land covers	Other use land

Table 4.27: BlueCAM input values for specific Carbon Estimation Areas (CEAs) derived from classification of land type changes as determined from nationally-consistent extent account. Note: Median elevation estimate was used in preference over mean elevation, with the latter included here for reference only.

CEA ID	CEA baseline land type	Land type for CEA: current reporting period end	CEA Area (ha)	CEA elevation (m AHD): median of all pixels	CEA elevation (m AHD): mean of all pixels
N1	Mangrove	Mangrove	358.4	1.04	1.10
N2	Mangrove	Supratidal forests	0.1	0.02	0.03
N3	Mangrove	Saline waterbodies	8.6	-0.07	0.09
N4	Mangrove	Other use land	1.7	-0.04	0.07
N5	Saltmarsh	Saltmarsh	5.0	1.05	1.05
N6	Supratidal forests	Mangrove	0.2	-0.02	0.06
N7	Supratidal forests	Saltmarsh	4.3	0.51	0.53
N8	Supratidal forests	Supratidal forests	235.5	0.64	0.67
N9	Supratidal forests	Waterbodies/mudflats	34.0	0.04	0.13
N10	Supratidal forests	Other use land	7.5	0.73	0.78
N11	Flooded agricultural land, managed wet meadow or pasture	Mangrove	0.6	-0.39	-0.30
N12	Flooded agricultural land, managed wet meadow or pasture	Supratidal forests	0.7	0.00	0.09
N13	Flooded agricultural land, managed wet meadow or pasture	Saline waterbodies	15.8	-0.11	-0.04
N14	Flooded agricultural land, managed wet meadow or pasture	Other use land	1.0	0.10	0.29
N15	Other use land	Mangrove	0.5	-0.32	-0.20
N16	Other use land	Saltmarsh	5.6	0.84	0.95
N17	Other use land	Supratidal forests	154.4	0.84	0.85
N18	Other use land	Saline waterbodies	6.4	0.06	0.08
N19	Other use land	Other use land	274.9	1.15	1.26

* Note: the replacement value reported in this table needs to be multiplied by the CEA area estimate and project timeframe in BlueCAM (i.e. replacement value x row K [CEA area] x cell AV3 [years]).

Table 4.28: Context and source of published and unpublished carbon parameter estimates which were used in place of BlueCAM parameters in the (B) Hybrid approach. Source letters are footnotes for values supplied in Table 4.29.

Parameter	BlueCAM column #	Data context	Replacement value and units	Source	Ref
Baseline avoided emissions of CO_2 (EB,CO_2) (tonnes CO_2)*	*V**	Site-specific estimate of CO_2 emissions from East Trinity Inlet based upon comparison of soil carbon stocks in drained and undrained. A single value is reported for the project by Hicks et al. (1999)[128] this has been conservatively applied only to replace BlueCAM values only in CEAs which are likely to have changed from oxic conditions in the baseline scenario to a land type where conditions are expected to be significantly less oxic in the project scenario.	33 $tCO_2e\ ha^{-1}\ yr^{-1}$	***a***	122
Soil C accumulation (t $CO_2e\ ha^{-1}$)	*BK*	Setting-specific dataset for mangrove. Mean of six surface soil carbon accumulation estimates derived from cores collected in undisturbed mangroves of the Cairns regions (external to East Trinity Inlet restoration site)	1.8 $tCO_2e\ ha^{-1}\ yr^{-1}$	*b*	123
Soil C stock (t $CO_2e\ ha^{-1}$)	*BL*	Site-specific dataset for mangrove. Mean of two undrained mangrove sites (1 mid intertidal, 1 upper intertidal) in 1999. Stocks were calculated to 1m depth and applied to all CEAs with a mangrove baseline.	1579.9 $tCO_2e\ ha^{-1}$	*a*	7
Soil C stock (t $CO_2e\ ha^{-1}$)	*BL*	Site-specific dataset for supratidal forest. Single estimate of drained/cleared land with Melaleuca forest in 1999. Stocks were calculated to 1m depth and applied to all CEAs with a supratidal forest baseline.	1535.2 $tCO_2e\ ha^{-1}$	*a*	7
Soil C stock (t $CO_2e\ ha^{-1}$)	*BL*	Site-specific datasets for"flooded lan". Mean of two flooded (sub-tidal) sites in 2009 (profiles D, E) from Burton et al. (2011). Soil carbon stocks were calculated to 1m depth, and are applied to CEAs with the baseline land type"flooded lan").	450.7 $tCO_2e\ ha^{-1}$	*c*	124
Soil C stock (t $CO_2e\ ha^{-1}$)	*BL*	Site-specific datasets for"other land us". Mean of two drained settings (cleared Imperata cylindrica grassland; cleared saline flat with salt couch grassland) from Hicks et al (1999) and three upper intertidal restored settings (profiles A, B, C) from Burton et al. (2011). Soil carbon stocks were calculated to 1m depth, and are applied to CEAs with the baseline land type"other land use").	461.8 $tCO_2e\ ha^{-1}$	*a* *c*	7 11

* Note: The replacement value reported in this table needs to be multiplied by the CEA area estimate and project timeframe in BlueCAM (i.e. replacement value x row K [CEA area] x cell AV3 [years])

[122] Hicks, W. S., Bowman, G. M. & Fitzpatrick, R. W. (1999). *East Trinity acid sulfate soils Part 1: Environmental hazards*.

[123] P. Macreadie et al. (unpublished data) Soil carbon accumulation rates for mangrove of Cairns airport site.

[124] Burton, E. D., Bush, R., Johnston, S., Sullivan, L. & Keene, A. (2011). Sulfur biogeochemical cycling and novel Fe–S mineralization pathways in a tidally re-flooded wetland. *Geochimica et Cosmochimica Acta*, 75(12), 3434-3451.

Table 4.29: Details of setting-specific published and unpublished estimates which have been used to replace input and/or calculation parameters of the BlueCAM calculator. Replacement values have been determined on the basis of each CEA, and include datasets collected within the East Trinity Inlet site and/or nearby locations. Note: CEA area and project timeframe multipliers have been incorporated as needed. Source letters refer to entries in **Table 4.28**. *Continued over page.*

		BlueCAM parameters											
		Baseline avoided emissions of CO_2 ($E_{B,CO2}$) (tonnes CO_2)	Baseline avoided emissions of CH_4 ($E_{B,CH4}$) (tonnes CO_2e)	Baseline avoided emissions of N_2O ($E_{B,N2O}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CO2}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CH4}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,N2O}$) (tonnes CO_2e)	ETR emissions from baseline vegetation (40% AGB for 1 year) (t CO_2e ha^{-1})	ETR emissions from blue C wetlands (40% AGB for 1 year) (t CO_2e ha^{-1})	AGB (t CO_2e ha^{-1})	BGB (t CO_2e ha^{-1})	Soil C accumulation (t CO_2e ha^{-1})	Soil C stock (t CO_2e ha^{-1})
CEA ID	BlueCAM row/cell:	V	W	X	Y	Z	AA	BB	BC	BI	BJ	BK	BL
N1	BlueCAM value	0	376.50	538.54	0	358.38	512.63	0.0	0.0	158.2	50.6	73.1	990.0
	Setting-specific replacement value											**141.8**	**1579.9**
	Source											*b*	*a*
N2	BlueCAM value	0	0.09	0.14	0	0.00	0.00	244.9	0.0	0.0	0.0	0.0	990.0
	Setting-specific replacement value												**1579.9**
	Source												*a*
N3	BlueCAM value	0	9.08	12.98	0	0	0	2116.2	0.0	0.0	0.0	0.0	403.3
	Setting-specific replacement value												**1579.9**
	Source												*a*
N4	BlueCAM value	0	0.2912	4.1602	0	0.2912	4.1602	0.0	0.0	5.0	0.0	37.0	495.0
	Setting-specific replacement value												**878.2**
	Source												

Table 4.29: Cont.

		BlueCAM parameters											
		Baseline avoided emissions of CO_2 ($E_{B,CO2}$) (tonnes CO_2)	Baseline avoided emissions of CH_4 ($E_{B,CH4}$) (tonnes CO_2e)	Baseline avoided emissions of N_2O ($E_{B,N2O}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CO2}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CH4}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,N2O}$) (tonnes CO_2e)	ETR emissions from baseline vegetation (40% AGB for 1 year) (t CO_2e ha^{-1})	ETR emissions from blue C wetlands (40% AGB for 1 year) (t CO_2e ha^{-1})	AGB (t CO_2e ha^{-1})	BGB (t CO_2e ha^{-1})	Soil C accumulation (t CO_2e ha^{-1})	Soil C stock (t CO_2e ha^{-1})
CEA ID	BlueCAM row/cell:	V	W	X	Y	Z	AA	BB	BC	BI	BJ	BK	BL
N5	BlueCAM value	0	0.2912	4.1602	0	0.2912	4.1602	0.0	0.0	5.0	0.0	37.0	495.0
	Setting-specific replacement value												**878.2**
	Source												
N6	BlueCAM value	0	0	0.00	0	0.18	0.2575	0.0	0.0	149.6	47.9	73.1	0.0
	Setting-specific replacement value	**124.8**										**141.8**	**1535.2**
	Source	*a*										*b*	*a*
N7	BlueCAM value	0	0	0.00	0	0.24	3.46	0.0	0.0	5.0	0.0	37.0	0.0
	Setting-specific replacement value	**2995.3**											**1535.2**
	Source	*a*											*a*
N8	BlueCAM value	0	0	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Setting-specific replacement value												**1535.2**
	Source												*a*
N9	BlueCAM value	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Setting-specific replacement value	**23588.2**											**1535.2**
	Source	a											*a*
N10	BlueCAM value	0	0	0.00	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Setting-specific replacement value												**1535.2**
	Source												*a*

Table 4.29: Cont.

		BlueCAM parameters											
		Baseline avoided emissions of CO_2 ($E_{B,CO2}$) (tonnes CO_2)	Baseline avoided emissions of CH_4 ($E_{B,CH4}$) (tonnes CO_2e)	Baseline avoided emissions of N_2O ($E_{B,N2O}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CO2}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CH4}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,N2O}$) (tonnes CO_2e)	ETR emissions from baseline vegetation (40% AGB for 1 year) (t CO_2e ha^{-1})	ETR emissions from blue C wetlands (40% AGB for 1 year) (t CO_2e ha^{-1})	AGB (t CO_2e ha^{-1})	BGB (t CO_2e ha^{-1})	Soil C accumulation (t CO_2e ha^{-1})	Soil C stock (t CO_2e ha^{-1})
CEA ID	BlueCAM row/cell:	V	W	X	Y	Z	AA	BB	BC	BI	BJ	BK	BL
N11	BlueCAM value	0	107.62	55.20	0	0.66	0.95	7.7	0.0	149.6	47.9	73.1	233.6
	Setting-specific replacement value											**141.8**	**450.7**
	Source											*b*	*c*
N12	BlueCAM value	0	122.99	63.08	0	0.00	0.00	7.7	0.0	0.0	0.0	0.0	233.6
	Setting-specific replacement value												**450.7**
	Source												*c*
N13	BlueCAM value	0	2690.4	##	0	0.00	0.00	7.7	0.0	0.0	0.0	0.0	233.6
	Setting-specific replacement value												**450.7**
	Source												*c*
N14	BlueCAM value	0	169.11	86.74	0	0	0	7.7	0.0	0.0	0.0	0.0	233.6
	Setting-specific replacement value												**450.7**
	Source												*c*
N15	BlueCAM value	0	0	0.00	0	0.5673	0.8115	0.0	0.0	149.6	47.9	73.1	114.9
	Setting-specific replacement value	**374.4**										**141.8**	**461.8**
	Source	a										*b*	*ac*
N16	BlueCAM value	0	0	0.00	0	0.33	4.69	0.0	0.0	5.0	0.0	37.0	114.9
	Setting-specific replacement value	**3869.0**											**461.8**
	Source	a											*ac*

Table 4.29: Cont.

		BlueCAM parameters											
		Baseline avoided emissions of CO_2 ($E_{B,CO2}$) (tonnes CO_2)	Baseline avoided emissions of CH_4 ($E_{B,CH4}$) (tonnes CO_2e)	Baseline avoided emissions of N_2O ($E_{B,N2O}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CO2}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,CH4}$) (tonnes CO_2e)	Coastal wetland emissions ($E_{CW,N2O}$) (tonnes CO_2e)	ETR emissions from baseline vegetation (40% AGB for 1 year) (t CO_2e ha^{-1})	ETR emissions from blue C wetlands (40% AGB for 1 year) (t CO_2e ha^{-1})	AGB (t CO_2e ha^{-1})	BGB (t CO_2e ha^{-1})	Soil C accumulation (t CO_2e ha^{-1})	Soil C stock (t CO_2e ha^{-1})
CEA ID	BlueCAM row/cell:	V	W	X	Y	Z	AA	BB	BC	BI	BJ	BK	BL
N17	BlueCAM value	0	0	0.00	0	0	0	0.0	0.0	0.0	0.0	0.0	114.9
	Setting-specific replacement value												**461.8**
	Source												*ac*
N18	BlueCAM value	0	0	0.00	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	114.9
	Setting-specific replacement value	**4430.6**											**461.8**
	Source	*a*											*ac*
N19	BlueCAM value	0	0	0.00	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	114.9
	Setting-specific replacement value												**461.8**
	Source												*ac*
	Projection duration (yrs)	21.01											

Table 4.30: Summary of carbon stock accounting approach, including instruction for application of equations to BlueCAM calculator files in Excel.

Stock account	BlueCAM input file(s) used	Equation applied to BlueCAM file for each CEA*
Aboveground biomass carbon stock (2007) [$AGB_{baseline}$]	BlueCAM file used for carbon abatement account	$AGB_{baseline}$ = *BBx**2.5**Kx*
Soil carbon stock to 1m (2007) [$Soil_{baseline}$]	BlueCAM file used for carbon abatement account	$Soil_{baseline}$ = *BLx***Kx*
Aboveground biomass carbon stock (2022) [$AGB_{project}$]	New (additional) BlueCAM file with all 'New CEA or first reporting period?' inputs entered as 'Yes' Note: $AGB_{baseline}$ parameter derived as per carbon abatement file above	$AGB_{project}$ =$AGB_{baseline}$+*BIx***Kx*-*ABx*
Soil carbon stock to 1m (2022) [$Soil_{project}$]	Same BlueCAM file as used for carbon abatement account Note: $Soil_{baseline}$ parameter derived as per carbon abatement file above	$Soil_{project}$ = $Soil_{baseline}$ + *AMx*

* where italicised letters (e.g. K, AB, BB) refer to BlueCAM Excel columns and 'x' refers to the Excel row number for a given CEA)

Results

Table 4.31 details the carbon abatement outcomes over the entire restoration accounting period (2002 to 2022), as well as baseline (2002) and project (2022) carbon stock accounts for all carbon estimation areas under nationally-consistent and hybrid accounting approaches. The same outcomes are reported at a higher level (i.e. as the sum of all CEAs) in the physical account columns of **Table 4.32** for carbon abatement and **Table 4.33** for carbon stocks.

Inspection of the individual CEAs shows that areas mapped as mangrove forest which stayed mangrove forests (i.e. CEA N1) represented the vast majority of abatement associated with both the nationally-consistent (96 % of total abatement) and hybrid account (73 % of total abatement). Three of the nineteen CEAs experienced negative abatement outcomes under both approaches – these were all associated with areas mapped as mangrove in the baseline extent map which changed to other land types (i.e. CEAs N2, N3, N4) and experienced negative carbon abatement outcomes overall (**Table 4.31**).

Comparison of carbon abatement and carbon stock accounts derived through the two approaches shows variation among methodologies. Overall abatement estimates were 74 % higher and overall stock change 30% higher in the 'hybrid approach' (B) relative to the nationally-consistent approach (A). There was similarity between estimates of change in carbon stock (2022 stocks minus 2002 stock) and carbon abatement estimates integrated across the entire accounting period (2002 to 2022) under the nationally-consistent approach (both ~81,000 t CO_2e). This was not the case in the hybrid approach however, where estimated carbon abatement was more than 35,000 t CO_2e higher than the associated estimate for change in carbon stock.

Trends in financial accounts among the two different approaches for carbon abatement follow those of the physical accounts (**Table 4.32**) because simple financial multipliers were applied in each circumstance.

Table 4.31: BlueCAM output values for each Carbon Estimation Areas (CEAs) over the period 2002-2022, derived from classification of land type changes as determined from nationally-consistent and hybrid approaches for the East Trinity Inlet restoration case study. *Continued over page.*

			Carbon abatement			Carbon stocks			
CEA ID	CEA baseline land type	Land type for CEA: current reporting period end	CEA total emissions avoided ($E_{A,i}$) (tonnes CO_2e)	CEA total carbon sequestered in vegetation ($C_{v,i}$) (tonnes CO_2e)	CEA total carbon sequestered in soil (tonnes CO_2e)	Vegetation biomass carbon stocks - baseline AGB tCO_2e	Vegetation biomass carbon stocks - project AGB tCO_2e	Soil carbon stocks - baseline tCO_2e	Soil carbon stocks - project tCO_2e
	(A) Nationally-consistent approach								
N1	Mangrove	Mangrove	44	52,385	26,204	219,448	276,142	354,796	381,000
N2	Mangrove	Supratidal forests	-22	0	0	55	33	89	89
N3	Mangrove	Saline waterbodies	-2,094	0	0	5,291	3,174	8,554	8,554
N4	Mangrove	Other use land	-414	0	0	1,047	628	1,693	1,693
N5	Saltmarsh	Saltmarsh	0	25	183	62	86	2,450	2,633
N6	Supratidal forests	Mangrove	0	36	13	0	27	0	13
N7	Supratidal forests	Saltmarsh	-4	22	160	0	22	0	160
N8	Supratidal forests	Supratidal forests	0	0	0	0	0	0	0
N9	Supratidal forests	Waterbodies/ mudflats	0	0	0	0	0	0	0
N10	Supratidal forests	Other use land	0	0	0	0	0	0	0
N11	Flooded agricultural land, managed wet meadow or pasture	Mangrove	156	124	46	12	102	147	193
N12	Flooded agricultural land, managed wet meadow or pasture	Supratidal forests	181	0	0	14	8	168	168
N13	Flooded agricultural land, managed wet meadow or pasture	Saline waterbodies	3,949	0	0	303	182	3,679	3,679
N14	Flooded agricultural land, managed wet meadow or pasture	Other use land	248	0	0	19	11	231	231

Table 4.31: Cont.

			Carbon abatement			Carbon stocks			
CEA ID	CEA baseline land type	Land type for CEA: current reporting period end	CEA total emissions avoided ($E_{A,i}$) (tonnes CO_2e)	CEA total carbon sequestered in vegetation ($C_{v,i}$) (tonnes CO_2e)	CEA total carbon sequestered in soil (tonnes CO_2e)	Vegetation biomass carbon stocks - baseline AGB tCO_2e	Vegetation biomass carbon stocks - project AGB tCO_2e	Soil carbon stocks - baseline tCO_2e	Soil carbon stocks - project tCO_2e
N15	Other use land	Mangrove	-1	107	39	0	81	62	102
N16	Other use land	Saltmarsh	-5	28	206	0	28	641	848
N17	Other use land	Supratidal forests	0	0	0	0	0	17,736	17,736
N18	Other use land	Saline waterbodies	0	0	0	0	0	734	734
N19	Other use land	Other use land	0	0	0	0	0	31,584	31,584
	TOTAL		**2,037**	**52,726**	**26,852**	**226,251**	**280,525**	**422,565**	**449,417**
	(B) Hybrid approach								
N1	Mangrove	Mangrove	44	52,385	50,802	219,448	276,142	566,217	617,019
N2	Mangrove	Supratidal forests	-22	0	0	55	33	142	142
N3	Mangrove	Saline waterbodies	-2,094	0	0	5,291	3,174	13,651	13,651
N4	Mangrove	Other use land	-414	0	0	1,047	628	2,702	2,702
N5	Saltmarsh	Saltmarsh	0	25	183	62	86	2,459	2,633
N6	Supratidal forests	Mangrove	124	36	26	0	27	276	302
N7	Supratidal forests	Saltmarsh	2,992	22	160	0	22	6,632	6,792
N8	Supratidal forests	Supratidal forests	0	0	0	0	0	361,576	361,576
N9	Supratidal forests	Waterbodies/mudflats	23,588	0	0	0	0	52,226	52,226
N10	Supratidal forests	Other use land	0	0	0	0	0	11,468	11,468
N11	Flooded agricultural land, managed wet meadow or pasture	Mangrove	156	124	89	12	102	284	373
N12	Flooded agricultural land, managed wet meadow or pasture	Supratidal forests	181	0	0	14	8	324	324

Table 4.31: Cont.

			Carbon abatement			Carbon stocks			
CEA ID	CEA baseline land type	Land type for CEA: current reporting period end	CEA total emissions avoided ($E_{A,i}$) (tonnes CO_2e)	CEA total carbon sequestered in vegetation ($C_{v,i}$) (tonnes CO_2e)	CEA total carbon sequestered in soil (tonnes CO_2e)	Vegetation biomass carbon stocks - baseline AGB tCO_2e	Vegetation biomass carbon stocks - project AGB tCO_2e	Soil carbon stocks - baseline tCO_2e	Soil carbon stocks - project tCO_2e
N13	Flooded agricultural land, managed wet meadow or pasture	Saline waterbodies	3,949	28	206	0	28	2,577	2,783
N14	Flooded agricultural land, managed wet meadow or pasture	Other use land	248	0	0	19	11	446	446
N15	Other use land	Mangrove	373	107	77	0	81	249	326
N16	Other use land	Saltmarsh	3,864	28	206	0	28	2,577	2,783
N17	Other use land	Supratidal forests	0	0	0	0	0	71,284	71,284
N18	Other use land	Saline waterbodies	4,431	0	0	0	0	2,951	2,951
N19	Other use land	Other use land	0	0	0	0	0	126,939	126,939
	TOTAL		**37,419**	**52,726**	**51,542**	**226,251**	**280,525**	**1,229,494**	**1,281,036**

Table 4.32: Physical accounts and financial accounts of Avoided Emissions and Carbon Sequestration outcomes of the East Trinity Inlet restoration project over the period 2002-2022, as estimated from two approaches: (A) a low-resolution but nationally-consistent approach; (B) a hybrid approach of low-resolution mapping products combined with setting-specific carbon and tidal range parameters. Net abatement amount ($A_{r\text{-}adj}$) is the net sum of values EA, CP and Efk (i.e. 5 % discount off ACCU projects removed).

		(A) Nationally-consistent approach			(B) Hybrid approach		
		Physical account (Tonnes CO_2e)	Financial account (AUD) - ACCU SPOT	Financial account (AUD) - Premium	Physical account (Tonnes CO_2e)	Financial account (AUD) - ACCU SPOT	Financial account (AUD) - Premium
BlueCAM outputs	Reporting period emissions avoided (E_A)	2,037	$62,645	$305,585	37,419	$1,150,649	$5,612,921
	Reporting period C sequestered in vegetation and soil (CP)	79,578	$2,447,023	$11,936,696	104,268	$3,206,255	$15,640,268
	Emissions from fuel consumed during reporting period (E_{fk})	0	$0	$0	0	$0	$0
	Net abatement amount (A_r): BlueCAM calculator output	77,636	$2,387,316	$11,645,446	126,475	$4,196,591	$20,471,176
Net abatement amount ($A_{r\text{-}adj}$): ACCU discount removed		**81,615**	**$2,509,667**	**$12,242,280**	**141,688**	**$4,356,904**	**$21,253,189**

Table 4.33: Physical accounts of baseline (2002) and end of accounting period (2022) carbon stocks of the East Trinity Inlet restoration project (5.34) over the period 2002-2022, as estimated from two approaches: (A) a low-resolution but nationally-consistent approach; (B) a hybrid approach of low-resolution mapping products combined with setting-specific carbon and tidal range parameters.

		(A) Nationally-consistent approach	(B) Hybrid approach
		Physical account (Tonnes CO_2e)	Physical account (Tonnes CO_2e)
BlueCAM outputs	Vegetation aboveground biomass carbon stocks - baseline	226,251	226,251
	Vegetation aboveground biomass carbon stocks - project	280,525	280,252
	Soil carbon stocks - baseline	411,565	1,229,494
	Soil carbon stocks - project	449,417	1,281,036
	Total carbon stocks - baseline	648,816	1,455,745
	Total carbon stocks - project	729,942	1,561,561
	Net carbon stock change (project - baseline)	**81,126**	**105,816**

Interpretation and discussion

Carbon abatement (Physical and Financial accounts):

Depending on the accounting approach taken, estimates of carbon abatement volume across the 20 years since tidal restoration at East Trinity Inlet range from 81,615 to 141,688 t CO_2e. This volume of abatement equates to the annual electricity emissions of approximately 15,880 to 27,569 households, or 1.35 – 2.34 million tree seedlings grown for 10 years[6].

Inspection of accounts at the level of individual CEAs (Table 10) demonstrates the significance of areas mapped as mangroves in the East Trinity Inlet carbon accounts. CEA N1 (areas of mangrove in 2002 which were also mapped as mangrove in 2022) represents the largest of all the CEAs, and was responsible for the overwhelming majority of abatement under the nationally-consistent approach (96 % of abatement), and to a lesser extent in the hybrid approach (73% of abatement).

This CEA also includes areas both within the direct footprint of tidal restoration (i.e. behind the bund wall), as well as areas which may have been influenced indirectly or not at all by tidal restoration (i.e. mangrove forests outside the bund wall). It is therefore likely that the carbon estimates reported here overestimate abatement outcomes due solely to tidal restoration actions at East Trinity Inlet. Instead, the carbon estimates reflect the combined outcomes of restoration actions and the continued protection and preservation of adjacent mangrove forests.

A significant outcome of this case study was the extent to which carbon abatement accounts varied among the two methodologies, even though they are derived from the same extent mapping product. This variation is driven largely by two pieces of information which were added in the hybrid approach. First, the application of Hicks et al's (1999) estimate of CO_2 emissions to selected CEAs resulted in an 18-fold increase in avoided emission estimates relative to the nationally-consistent approach. Second, soil C accumulation data specific to mangroves of the Cairns region also led to a less conservative estimate of soil carbon sequestration than default BlueCAM values for CEAs which were mapped to maintain or transition to mangrove forest. It is important to note that while these setting-specific inputs had a strong influence on abatement and stock estimates, similar datasets were not available for the majority of carbon parameters, including those relevant to biomass carbon and non-CO_2 emissions most instances. Therefore, generic BlueCAM values still populated most of the inputs for the 'hybrid' approach (**Table 4.29**). The collection of new site- and setting-specific data to populate missing parameters (or update existing literature values) may lead to further refinement of the tier C detailed accounts, though the direction and magnitude of these changes cannot currently be known.

Overall, we conclude that the substantially higher carbon abatement estimates derived using setting-specific data highlight the conservative nature of the generic BlueCAM approach in this carbon-rich and data-rich setting. On this basis, we recommend, that where setting-specific data is available or can be collected through the life of a restoration project, then this approach is advisable to reduce accounting uncertainties. Such data collection may also be useful to future refinements of carbon accounting mechanisms, including BlueCAM.

Carbon stocks (physical account only):

The carbon stock accounts demonstrate the substantial amount of carbon stored within the coastal wetlands of the East Trinity Inlet site. Stock estimates were high (>640,000 t CO_2e) in both baseline (2002) and project (2022) accounts under both approaches and were as high as 1.56 million t CO_2e in the highest case project scenario (**Table 4.33**). These stock estimates equate to the annual electricity emissions of approximately 126,000 to 304,000 households or the amount of carbon sequestered by growing 10.7 to 25.8 million tree seedlings for 10 years. This finding demonstrates the carbon-rich nature of the East Trinity Inlet setting, and the significant amount of carbon which may be at risk of emission to the atmosphere if the site is disturbed or restoration practices are reversed.

Carbon stocks within the surface 1 m of soils exceeded estimates of carbon stock with the aboveground biomass pool, particularly under the hybrid approach where site-specific soil stock data, but not biomass data, were available (**Table 4.33**). This disparity highlights the conservative nature of the generic BlueCAM approach for estimating soil carbon stocks in settings (such as East Trinity Inlet) where local data reveal large carbon stocks.

The dissimilarity in the hybrid approach between the change between carbon stock opening year and closing year accounts (105,816 t CO_2e) and the carbon abatement account calculated over the entire accounting period (141,688 t CO_2e) provides an example of why a simple stock change approach may represent a poor measure of carbon abatement outcome. The primary cause of this discrepancy is that carbon abatement accounts (such as BlueCAM) incorporate the significant volume of CO_2 emissions avoided when tidal restoration commenced. A stock change approach does not account for these avoided emissions and therefore underestimates the overall abatement outcome.

We also re-iterate that no financial account was estimated for carbon stocks (or change in carbon stock), as doing so would lead to double-counting of financial accounts which are already incorporated in the carbon abatement account. Both carbon abatement and carbon stock accounts were constrained by a number of limitations. The most significant of these is the fact that the identification and delineation of CEAs was informed only by coarse-resolution nationally-consistent datasets (maps and elevation datasets). These coarse-resolution extent maps are subject to significant uncertainties, which are apparent when compared against the most recent site-specific vegetation surveys. Completion of high-resolution, up-to-date ecosystem extent maps would provide an opportunity to complete carbon abatement and carbon stock accounts with greater confidence.

The increase in overall carbon abatement and carbon stock accounts when using the more detailed (hybrid) approach highlights the significance of generating and applying setting-specific data. While the East Trinity Inlet case study had access to setting-specific parameters for some carbon cycling parameters, there remain significant data gaps for the majority of data inputs (including biomass and non-CO_2 emissions), which prevented more accurate determination of the true abatement and stock outcomes of the East Trinity Inlet restoration project.

4.4 Water quality

Intent of work

Coastal wetlands can improve water quality by removing nutrients (nitrogen, N, and phosphorus, P) from the water through denitrification, plant uptake, and soil sequestration. Denitrification is the main pathway for N reduction converting nitrate (NO_3^-) to gaseous N_2. Plant uptake is the accumulation of nutrients in wood, and soil sequestration is the accumulation of nutrients through sedimentation. In Trinity Inlet, the restoration initially targeted reducing acidity caused by the disturbance of acid sulphate soils. However, additional water quality benefits from reducing nutrients and suspended sediments were also obtained and quantified.

Approach taken

Denitrification:

Data for dissolved nutrient concentrations were obtained from the closest monitoring station to Trinity Inlet. The relationship between nitrate concentration and denitrification for wetlands in north Queensland was used to determine NO_3^- removal potential per hour of inundation. Flooding frequency was estimated for each vegetation type based on the tidal regime obtained from the closest tidal gauge (Cairns Station). We estimated the number of tides flooding each vegetation type per year and converted them to an annual rate of NO_3^- removal.

Tree uptake:

The removal of nutrients by trees was estimated from the growth rates as biomass of Melaleuca and mangroves in the Wet Tropics region. The biomass accumulation was converted to N from known concentrations in wood (mean of 0.7 %).

Soil sequestration

N removal was obtained from carbon sequestration rates for the region and converted to N from local soil data (mean C:N ratio of 17.2). Retention of total suspended solids (TSS) was calculated in mangroves from its relationship with turbidity. Retention of P in sediments was estimated from the concentration of total phosphate (TP) attached to TSS (mean of 0.007range 0.003 to 0.009 mg/L).

Acidity reduction

The main target of the restoration was to increase water and soil pH to values close to neutral (i.e. 7). We used data from CRC CARE (2018) to obtain the changes in pH and soil acidity (mol H+/t) before and after restoration. Additionally, we analysed water quality data from the Department of Environment and Sciences to assess changes in pH from the creeks that were treated with lime (2001-2016).

Results

The regeneration of supratidal forests and increase in tidal flow connectivity increased the water quality benefits of the wetlands. The increase in area of supratidal forests resulted in a large improvement in NO_3^- removal and an increase in the uptake and storage of nutrients as wood. Also, the new open water lagoons increased sedimentation and deposition of particulate P and N. There was a slight decrease in the mangrove area from 2001 to 2021, which decreased the water quality service from this type of wetland. But overall, benefits of water quality amounted to an annual increase in the removal of 7 tons of N, 1,220 tons of TSS, and 1.1 ton of TP in the soil. These benefits were additional to the reduction of acidity from the site, with soils and water reaching values close to 7 (neutral) at the end of the restoration.

Water quality benefits were additional to the reduction of acidity from the site, with soils and water reaching values close to 7 at the end of the restoration project (**Table 4.37**). Using nitrogen removal values from approved Australian projects, restoration was estimated to provide an additional $119,646 per year in water purification services relative to pre-restoration conditions.

Table 4.34: Water quality provision through NO_3^- removal from denitrification, soil sequestration, total suspended sediment (TSS), TP retention and water acidity before restoration (2000). "-" = not applicable; n.a. = no data available.

2000	Unit	Mangroves	Saltmarsh	Supratidal	Open water
NO_3- removal	kg/yr	11,690	77	2,081	-
Soil TN removal	kg N/yr	29,506	77	10,979	-
Tree TN removal	kg N/yr	8,985	-	7,320	-
TSS removal	Mg	9,466	127	n.d.	464
Soil P removal	kg P	8,211	110	n.d.	403
Soil acidity reduction	mol H+/t			0.11	
Soil pH increase	pH				3.9
Increase in water pH	pH				5.5

Table 4.35: Water quality provision through NO_3^- removal from denitrification, soil sequestration, total suspended sediment (TSS), TP retention and water acidity after the restoration (2021). "-" = not applicable; n.a. = no data available.

2021	Unit	Mangroves	Saltmarsh	Supratidal	Open water
NO_3- removal	kg/yr	11,402	229	2,888	-
Soil TN removal	kg N/yr	28,788	231	15,237	-
Tree TN removal	kg N/yr	8,763	-	10,158	-
TSS removal	Mg	9,233	381	n.d.	1,663
Soil P removal	kg P	8,009	331	n.d.	1,443
Soil acidity reduction	mol H+/t		-	0.01	
Soil pH increase	pH				6.5
Increase in water pH	pH				7.2

Table 4.36: Total water quality provision gains from the restoration through NO3- removal from denitrification, soil sequestration, total suspended sediment (TSS), TP retention and water acidity from the restoration.

2000-2021	Unit	Mangroves	Saltmarsh	Supratidal	Open water
NO_3- removal	kg/yr	-288	153	807	-
Soil TN removal	kg N/yr	-727	154	4,258	-
Tree TN removal	kg N/yr	-221	n.a.	2,838	-
TSS removal	Mg	-6,823.1	7443.4	n.d.	39,698
Soil P removal	kg P	-5.9	6.5	n.d.	34.4
Soil acidity reduction	mol H+/t			-0.10	
Soil pH increase	pH				2.6
Increase in water pH	pH				1.7

Reflection relative to the Guide

To estimate water quality benefits from the restoration of East Trinity Inlet, we relied on monitoring programs that assessed nutrient concentrations from tidal water. Data were available from 2005-2015, but no data existed before restoration (2000). Water quality at the monitoring station was only sampled three times a year; thus, seasonal changes in N concentrations may have been missed. Data on soil N and P was not available, so extrapolations from similar mangroves in the Wet Tropics were necessary. Finally, we were not able to account for TSS deposition in Melaleuca wetlands due to scarcity of data.

Inundation frequency was the most challenging parameter to calculate. Attempts to determine it from satellite images (e.g. Water Observations from Space) were unsuccessful; all products have confounding signals between sites with no water and sites with high tree cover (suggesting tall mangroves have low inundation frequency). Thus, we decided to estimate inundation frequency based on vegetation types (inundation is higher and more frequent in mangroves > saltmarsh > supratidal).

Despite limitations, we were able to obtain a numerical value that we believe fairly represents the water quality improvement value of the restoration project. This methodology could be applied to any location in Australia.

Photo by Through The Looking Glass Studio - http://looking-glass.com.au

Supporting information

Detailed methodology

Denitrification:

Trinity Inlet is mostly inundated by tidal water; thus, we used data for the marine Water Quality Monitoring Program (AIMS, JCU Lønborg et al. 2016), station C8, which is the closest to Trinity Inlet (**Table 4.37**). We used a NO_x- concentrations (mean, 5th and 95th) to estimate potential denitrification based on **Figure 4.6**.

We obtained information of the tide regime from Cairns (Australian Bureau of Meteorology) to convert denitrification potential to N removal. We calculated the height and number of tides above the 50th, 75th and 90th percentile height distribution over a year (**Table 4.38**). The region's tide is semidiurnal, with a maximum height of 3.5 m.

Mangroves are usually flooded at least once daily, while supratidal forests are only flooded during large tides or wet periods. Tidal inundation will occur for at least four hours when tides are high enough to reach the wetlands. We expect that tidal inundation would occur for mangroves only when tides were above the 50th percentile (1.65 m), for saltmarsh when they are above the 75th percentile (2.45 m) and for supratidal wetlands, only during the highest tides, at the 90th percentile (> 2.81 m). This assumption was supported by the Digital Elevation Model (see **Section 3.2**), which showed that most mangroves were at elevations between -0.32 and 1.04 m AHD; supratidal wetlands were between 0 and 0.84 m and saltmarsh was located between 0.51 and 1.05 m. We did not include habitats without vegetation such as open lagoons, as denitrification requires a low water:soil ratio and a source of carbon, usually plants, which are scarce in open water. Finally, we calculated NO3- removal from denitrification rate, wetland area, and inundation time. The results were compared between pre- (2000) and post-restoration (2022).

Table 4.37: Nutrient concentrations from Trinity Inlet estuary (station C8; 2005-2015). Data is from[125], from the long-term Water Quality Monitoring program (AIMS, JCU), Cairns. DIN = dissolved inorganic nitrogen, PN = particulate nitrogen, PP = particulate phosphorus, TSS = total suspended solids.

	DIN (µg/L)	NO_x^- (µg/L)	PN (µg/L)	PO_4^- (µg/L)	PP (µg/L)	TSS (mg/L)
Mean	1.47	0.72	16.54	2.18	4.6	4.27
Median	1.29	0.52	16.68	2.28	4.4	2.88
5th	0.4	0.01	11.17	0.54	2.45	0.73
20th	0.58	0.05	14.01	1.19	3.05	1.83
80th	2.49	1.33	19.33	2.85	5.77	6.25
95th	2.93	1.77	22.29	3.97	7.91	10.9

[125] Waterhouse, J., Lønborg, C., Logan, M., Petus, C., Tracey, D., Lewis, S., Howley, C., Harper, E., Tonin, H., Skuza, M., Doyle, J., Costello, P., Davidson, J., Gunn, K., Wright, M., Zagorskis, I., Kroon, F. & Gruber, R. (2016). Marine Monitoring Program: Annual Report for inshore water quality monitoring: 2014 to 2015. Report for the Great Barrier Reef Marine Park Authority. Australian Institute of Marine Science and JCU TropWATER, Townsville.

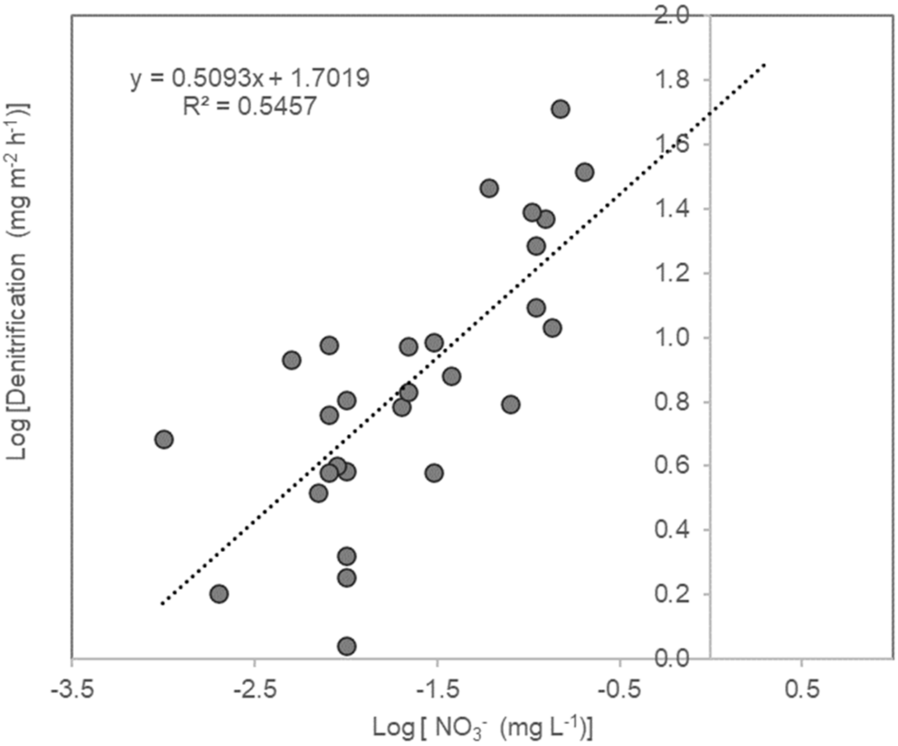


Figure 4.6: Relationship between [log] denitrification potential (mg m^{-2} h^{-1}) and NO_3^- concentration [log+3] (mg L^{-1}) for coastal wetlands in North Queensland. The regression is significant at $R^2 = 0.545$; $F_{1,27} = 31.23$, $p < 0.001$. The red square indicates the ranges of potential denitrification from Trinity Inlet based on the NO_x^- concentrations from the water in the Bay.

Table 4.38: Characteristics of the tidal regime in Cairns (ABM, annual tide predictions for 2024): height (m) and number of tides at that height per year. HAT = highest astronomical tide

Tide	(m)	No tides/yr
HAT	1.74	
Maximum	3.57	
Minimum	0.07	
25th	1.07	1078
50th	1.65	716
75th	2.45	349
90th	2.81	167

Soil sequestration

Rates of soil carbon sequestration in mangroves were from Macreadie (unpublished data), in supratidal forests data was from[126], and saltmarsh was obtained from Serrano et al. (2019)[127]. We used the mean soil carbon sequestration for tropical climates of 1.5 MgC/ha/yr. The rate was converted to N from the C:N ratio of soils samples from the Moresby estuary in the Johnstone catchment south of Trinity Inlet (mean C:N = 22.5 ± 5.8, unpub. data). The sequestration of P and TSS was only possible for mangroves from the relationship between turbidity (NTU) and surface accumulation (mm/month[128]):

Surface accretion (mm/month) = 0.261 + 0.016 (Turbidity, NTU)

Equation 1

Surface accretion was then transformed to aerial accumulation per year using bulk density values from the mangroves (0-5 cm) in the Moresby estuary (0.73 ± 0.16 g/cm³), which were then converted to kg of TSS per hectare, and then converted to kg P using TP/TSS values (**Table 4.35**).

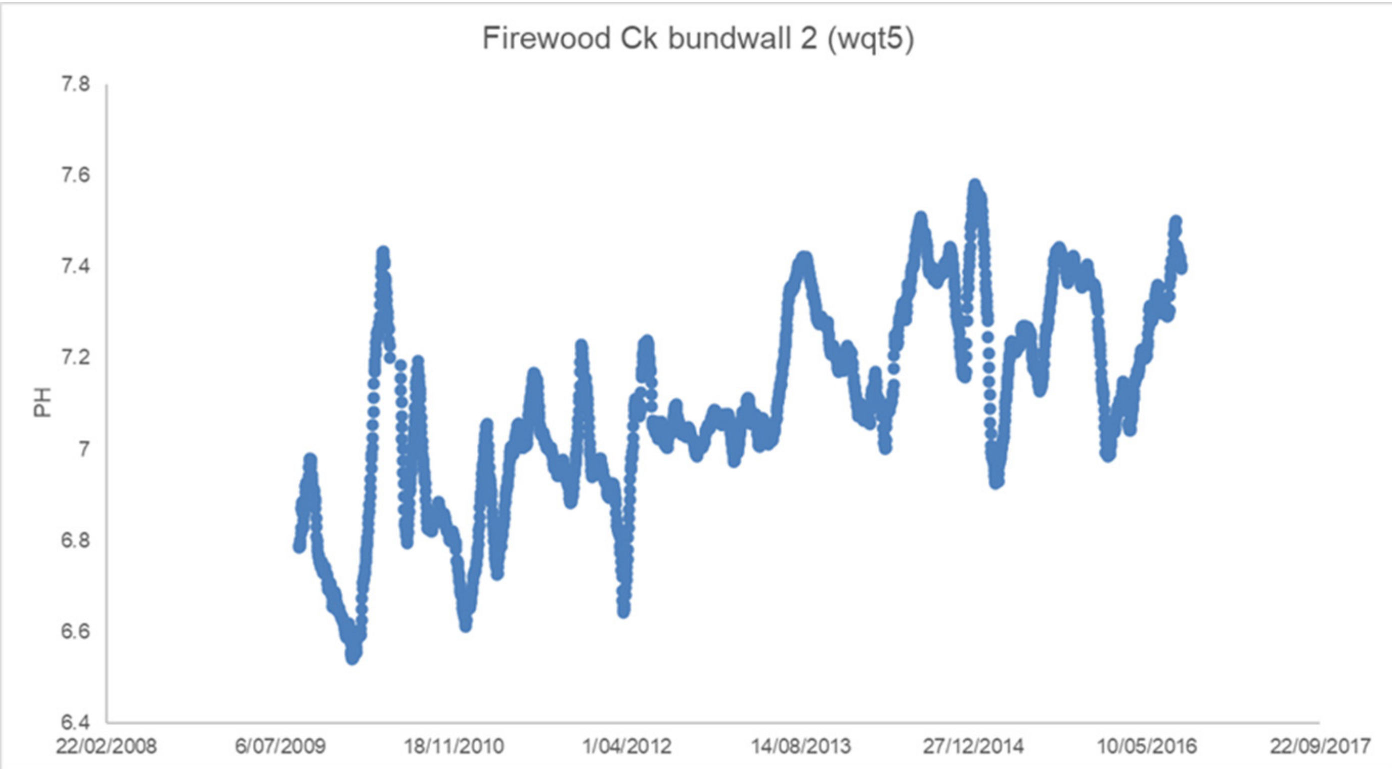


Figure 4.7: Changes in water pH from station at Firewood Ck bund wall from 2009 to 2016. Data is from the Department of Environment and Sciences.

[126] Adame, M.F., Reef, R., Wong, V. N. L., Balcombe, S. R., Turschwell, M. P., Kavehi, E., Rodríguez, D. C., Kelleway, J. J., Masque, P. & Ronan, M. (2019). Carbon and nitrogen sequestration of Melaleuca floodplain wetlands in tropical Australia. Ecosystems, 23, 454–466.

[127] Serrano et al. (2019). https://www.nature.com/articles/s41467-019-12176-8

[128] Lovelock, C.E., Adame, M. F., Bennion, V., Hayes, M., O'Mara, J., Reef, R. & Santini, N. S. (2014). Contemporary rates of carbon sequestration through vertical accretion of sediments in mangrove forests and saltmarshes of South East Queensland, Australia. Estuaries and Coasts, 37, 763–771.

Interpretation and discussion

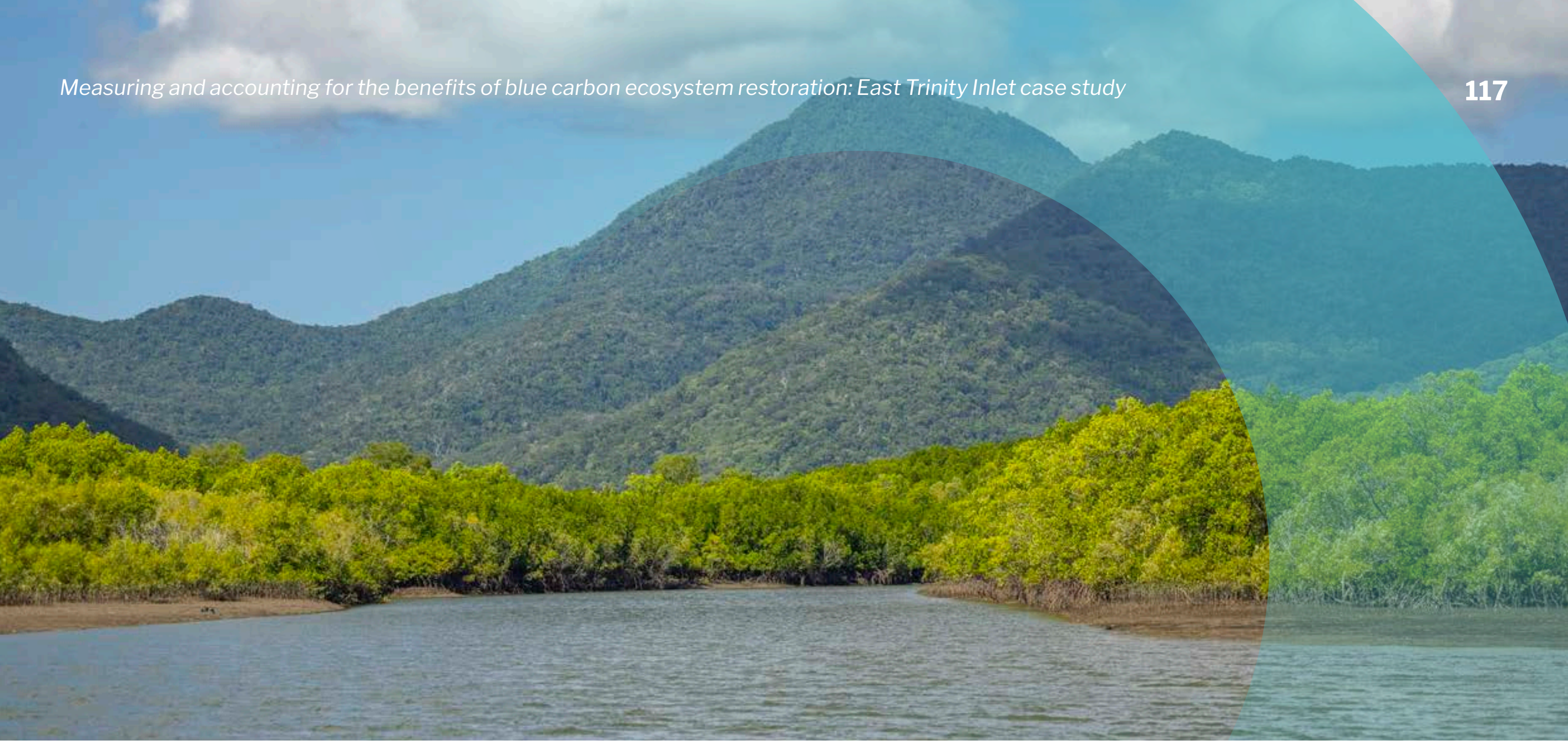
The concentrations of N in the tidal water were relatively low, with NO_x^- values under 2 µg/L (< 0.02 mg/L). Low N concentrations were also confirmed through the Wet Tropics Waterway Health Report[129], which have scored the water in the Bay as "Good" or "Very Good" (2015-2020) for dissolved inorganic nitrogen (DIN or the sum of NO_x^- and NH_4^+). The good water quality appears to have remained stable (2005-2015) with only a slight increase in NOx- concentrations during 2010, probably due to the break of the drought by La Nina event. The low concentrations entering East Trinity Inlet resulted in denitrification rates of 1.1 (0.4- 1.4) mg/m^2/h (or $\log_{10}$ (0.1) m^2/h), which are at the lower end of our measurements in the region is because NO_x^- concentrations drive denitrification (more N- more removal). This case study is typical of what can we find in other locations in Australia, where water quality monitoring data is spatially and temporally patchy. However, the relationship of nitrate concentrations and denitrification applies to all wetlands globally[130]. Thus, nitrate removals can be confidently predicted if there is adequate information of nitrogen entering the restored wetland.

In this case study, the removal of N through sediment accumulation and tree biomass was greater than that due to denitrification. This result can be explained because Melaleuca forests do not get flooded as frequently as mangrove forests. Increases in biomass are relatively easy to measure from field measurements of satellite images, and bark N content is relatively constant. There was also water quality benefits from the creation of open water areas, which are suitable for removal of suspended solids and particulate nutrients. However, sedimentation is not a permanent removal. Relying on ponds to act as sedimentation basins comes with the commitment of managing the site in the future by periodic dredging.

Most of the benefits of water quality measurements are based on the increase in wetland area and wetland type (and thus, inundation frequency). Thus, any error in these parameters will be easily carried on all the estimations. While area is relatively easy to measure, the classification of the wetland type is essential to obtain an accurate analyses of water quality benefits. For this, classification such as the Australian National Aquatic Classification Scheme and Intertidal and Subtidal Ecosystem Classification Scheme (Department of Environment and Science) could be used (https://wetlandinfo.des.qld.gov.au/wetlands/what-are-wetlands/definitions-classification/classification-systems-background/intertidal-subtidal/). In conclusion, there were clear benefits from the restoration of this wetland for water quality. First, the pH of the soil and water was improved by 2.6 pH units, reaching close to neutral values; second through the removal of nitrate through denitrification; third through tree growth, and fourth through accumulation of P and N in the soil.

[129] Wet Tropics Waterways. (2021). Report Card. https://wettropicswaterways.org.au/wet-tropics-report-card/estuaries/trinity-inlet/

[130] Pina-Ochoa, E. and Álvarez-Cobelas, M., 2006. Denitrification in aquatic environments: a cross-system analysis. Biogeochemistry, 81, pp.111-130.



5. Restoration activities

5.1 Restoration activities - physical

Intent and approach

The intent of the physical restoration activities accounts is to document the on-ground works completed onsite to achieve the restoration outcomes. This includes documentation of changes to infrastructure, such as the commissioning, decommissioning or modification of floodgates, the installation or removal of levees, and activities such as planting or lime additions. Details of the works completed have been largely sourced from existing studies, first-hand experience, personnel communication with land managers, and analysis of aerial imagery.

Results

Complete records of restoration activities have been detailed in Luke et al. (2017)[131] and Powell and Martens (2005)[132]. Existing flap gate structures were modified with automated tidal regulators to control daily inundation level in the year 2000. Initially maximum tidal exchange height was limited to 0.5m AHD. Purpose-designed water quality monitoring stations were installed within the site to monitor changes in water parameters.

An automated liming machine that could deploy 1-tonne bags of hydrated lime was installed at Hills Creek. Incoming and outgoing water was supplemented with hydrated lime to ensure exiting water was above pH 6. Incoming waters were only treated with hydrated lime if pH was < 6. As remediation progressed, flap gate structures were again modified in 2009 to increase daily inundation level. By 2016, pH values were consistently above the threshold of 6 and lime supplementation ceased.

[131] Hanabeth, L., Martens, M. A., Moon, E. M., Smith, D., Ward, N. J. & Bush, R. T. (2017). Ecological restoration of a severely degraded coastal acid sulfate soil: A case study of the East Trinity wetland, Queensland. Ecological Management & Restoration, 18(2), 103-114.

[132] Powell, B. & Martens, M. (2005). A review of acid sulphate soil impacts, actions and policies that impact on water quality in Great Barrier Reef catchments, including a case study on remediation at East Trinity. Marine Pollution Bulletin 51(1-4), 149-164.

Header photo by Through The Looking Glass Studio - http://looking-glass.com.au

Reflection relative to the Guide

Completing the physical activities accounts for East Trinity Inlet highlights the need for good records to accurately account for changes that have occurred onsite. In this case, with the accounts being completed retrospectively, it was difficult to access information on works completed nearly two decades ago. We expect that many of these issues would not occur if accounts were completed concurrently or immediately following the on-ground restoration works and annually thereafter.

5.2 Restoration activities (monetary accounts)

Introduction

Remedial of the East Trinity has started soon after the land was purchased by the Queensland government in the year 2000, with 'Acid Sulphate Soil Remediation Action Plan'[133,134,135]. The restoration project involved extensive work including an innovative strategy known as lime-assisted tidal exchange (LATE) to reverse the acidification of the wetland[108,109]. In this section, we provide the over-all costs of the restoration activities based on data from the Queensland Department of Environment and Science.

Data availability

The data for cost of restoration is provided by the Queensland Department of Environment and Science covering the restoration period from 2001/02 to 2022/23. The costs are categorized into employment related, operations, depreciation related, grants/subsidies and capital expenditures on annual basis. The total financial (CPI unadjusted) cost of the restoration activities is about $8 million AUD. Employment related and all capital costs account for about 60% of the total costs, while the operating costs account for about 27 % (see **Table 5.1**).

[133] CRC CARE. (2018). Remediating and managing coastal acid sulphate soils using Lime Assisted Tidal Exchange (LATE) at East Trinity Inlet Queensland. In CRC CARE Technical Report 41 (Issue 41).

[134] Hanabeth, L., Martens, M. A., Moon, E. M., Smith, D., Ward, N. J. & Bush, R. T. (2017). Ecological restoration of a severely degraded coastal acid sulfate soil: A case study of the East Trinity wetland, Queensland. Ecological Management & Restoration, 18(2), 103-114.

[135] Vahedian, A., Aghdaei, S. A., & Mahini, S. (2014). Acid Sulphate Soil Interaction with Groundwater: A Remediation Case Study in East Trinity. APCBEE Procedia, 9, 274–279. https://doi.org/10.1016/j.apcbee.2014.01.049

Table 5.1: Annual cost of restoration by item (in AUD) (Queensland Department of Environment and Science).

Year	Employee related	Operating related	Depreciation related	Grant/ subsidies	Capital	Year total
2001/02	191,074	135,220			264,307	**590,601**
2002/03	131,782	102,954			66,006	**300,742**
2003/04	-	-	-	-	-	**-**
2004/05	-	-	-	-	-	**-**
2005/06	-	-	-	-	-	**-**
2006/07	-	-	-	-	-	**-**
2007/08	-	-	-	-	-	**-**
2008/09	217,741	233,092	82,100	454,495	-	**987,428**
2009/10					40,000	**40,000**
2010/11					52,000	**52,000**
2011/12	-	-	-	-	-	**-**
2012/13	14,361	113,297		170,000		**297,658**
2013/14	-	-	-	-	-	**-**
2014/15	356,642	161,016	47,017			**564,675**
2015/16	372,633	176,205	47,575			**596,413**
2016/17	33,061	323,240	117,495			**473,796**
2017/18	279,752	211,337	46,567		32,000	**569,656**
2018/19	214,756	219,145	36,514		46,000	**516,415**
2019/20	254,645	160,419	28,285		757,000	**1,200,349**
2020/21	194,870	222,271	28,161		692,000	**1,137,302**
2021/22	106,424	151,124	18,313		330,000	**605,861**
2022/23					101,000	**101,000**
Total cost per item	**2,367,741**	**2,209,320**	**452,027**	**624,495**	**2,380,313**	**8,033,896**

Results

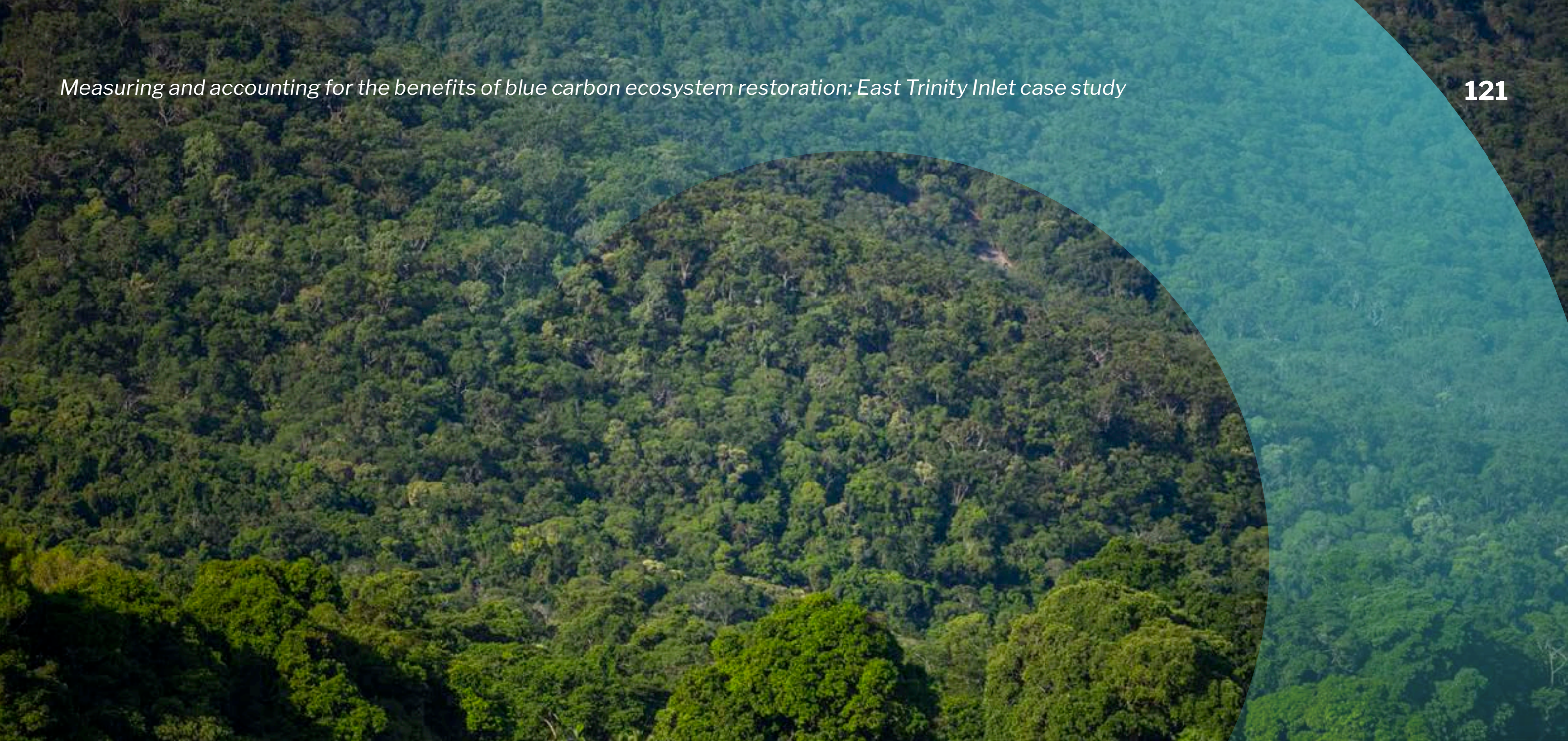
The monetary account for restoration costs is presented in the below in the SEEA-EA central framework[136]. Note that in this report the annual costs are shown for the entire restoration area (and activities). A preferred approach is to show the costs of restoration per ecosystem type when data is available – to associate the improvement of each ecosystem per its restoration cost, but in this case it's not possible to attribute costs to the different ecosystem type in the area. The CPI-adjusted total cost of restoration is $9,881,672 AUD at 2022 price level.

[136] United Nations, European Commission, Food and Agriculture Organisation of the United Nations, International Monetary Fund, Organisation for Economic Co-operaton and Development, & The World Bank. (2014). System of Environmental-Economic Accounting 2012: Central Framework.

Table 5.2: Environmental protection expenditure, 2001-2022 (AUD in 2022)[137].

	Ecosystem asset						
Protection of biodiversity and landscapes	Mangroves	Saltmarsh	Seagrass	Supratidal	Others	Total annual costs (CPI unadjusted)	Total annual cost (CPI adjusted)
2001/02						590,601	1,009,929
2002/03						300,742	499,231
2003/04						-	-
2004/05						-	-
2005/06						-	-
2006/07						-	-
2007/08						-	-
2008/09						987,428	1,372,525
2009/10						40,000	54,400
2010/11						52,000	68,640
2011/12						-	-
2012/13						297,658	375,049
2013/14						-	-
2014/15						564,675	677,610
2015/16						596,413	703,767
2016/17						473,796	554,341
2017/18						569,656	655,104
2018/19						516,415	578,385
2019/20						1,200,349	1,332,387
2020/21						1,137,302	1,251,032
2021/22						605,861	648,271
2022/23						101,000	101,000
Total cost of restoration						**8,033,896**	**9,881,672**

[137] Cost splits by ecosystem are provided to demonstrate SEEA-compliant tables, however, data on ecosystem splits is unavailable and arbitrary allocation may be misleading.



6. General discussion and lessons learned

The implementation of the guide in the East Trinity case study provides an example of the challenges and utility of the SEEA-EA process. Implementation of the case study also provided an opportunity to learn what works in practice, but also what gaps may need to be filled or addressed in future blue carbon ecosystems. Cultural review of the reporting and process of engagement was an important part of the project.

The development of the account tables provided lessons for future application of the Guide. A key challenge for all team members was around the collection, nature of and scale of data needed for each account. For some, data needed to be at a much higher resolution than that which was readily available to undertake analysis and come to meaningful conclusions.

In many cases, data were simply not available. Given the ambition to identify pre and post restoration outcomes, the lack of data, especially pre-restoration, made analysis more challenging. In some cases, as with the condition account, variability across the indicators did not provide enough capacity to provide site-specific assessments. In others, data availability was patchy or temporally inconsistent.

Ensuring that data collected was at a scale that made site-level reporting meaningful and precise is another ongoing challenge. For the carbon account for example, the lack of high-resolution extent mapping led to high uncertainty in reporting. Identifying site boundaries was also an issue. Determining the boundary that was under consideration took some time. For the extent account, clarity on the boundary was crucial, as the site is connected, via waterways, to numerous environments that could be exposed to flow-on effects. For the First Nations account, the ‘boundary’ created some initial confusion, as they defined the area as Country and thus did not differentiate the site as separate from Country.

Time was a factor that would differentiate this case study from a real-world application. This case study was undertaken within a very tight time frame, and as a result much data accessed and work undertaken was virtual. The time available did not allow for multiple on-site visits nor the collection of new data. Specifically, the recreational and existence services as well as the cultural accounts would have benefited from more time for site visits and information collection.

Header photo by Through The Looking Glass Studio - http://looking-glass.com.au

This report reports on how the SEEA-EA Framework, as articulated in the guide, was applied at East Trinity Inlet to develop a series of account tables. Given the variability, paucity of and disciplinary differences between various accounts, integrating them all in a meaningful way was a challenge. The First Nations account highlighted this issue, where the circular and interconnected nature of their account was not captured within the SEEA-EA format. Further, the SEEA-EA approach focuses primarily on what benefits humans derive from ecosystem, and how they can be valued, but the ways in which humans can benefit the ecosystem is not as well articulated. Given caring for country was a core service in the cultural account, there is a need to accommodate this dimension. In the condition account, detailed maps of changes in condition were completed in addition to SEEA-EA account tables to enable reporting of the spatial complexity of changes that occurred within the site.

It is recommended that future applications of the Guide in/to other sites consider how to maximise the availability, historicity, resolution and precision of data at the site as well as how to reconcile cultural and disciplinary differences within the same tables. It is recommended that site boundaries are established upfront. The provision of more time and on ground site visitation to account for knowledge gaps is also suggested as a modus for building consolidated accounts. It is also recommended, that given any site will also always be the Country of a First Nations group, that a cultural account be undertaken and/or partnerships with the relevant First Nations group be established, as well as cultural review processes be written into the project as a first principle.

Overall, this case study demonstrates the value of restoration for blue carbon ecosystems and provides documentation and guides to methodologies that can be used in other areas, including innovative presentation of First Nation accounts within the current SEEA-EA Framework.

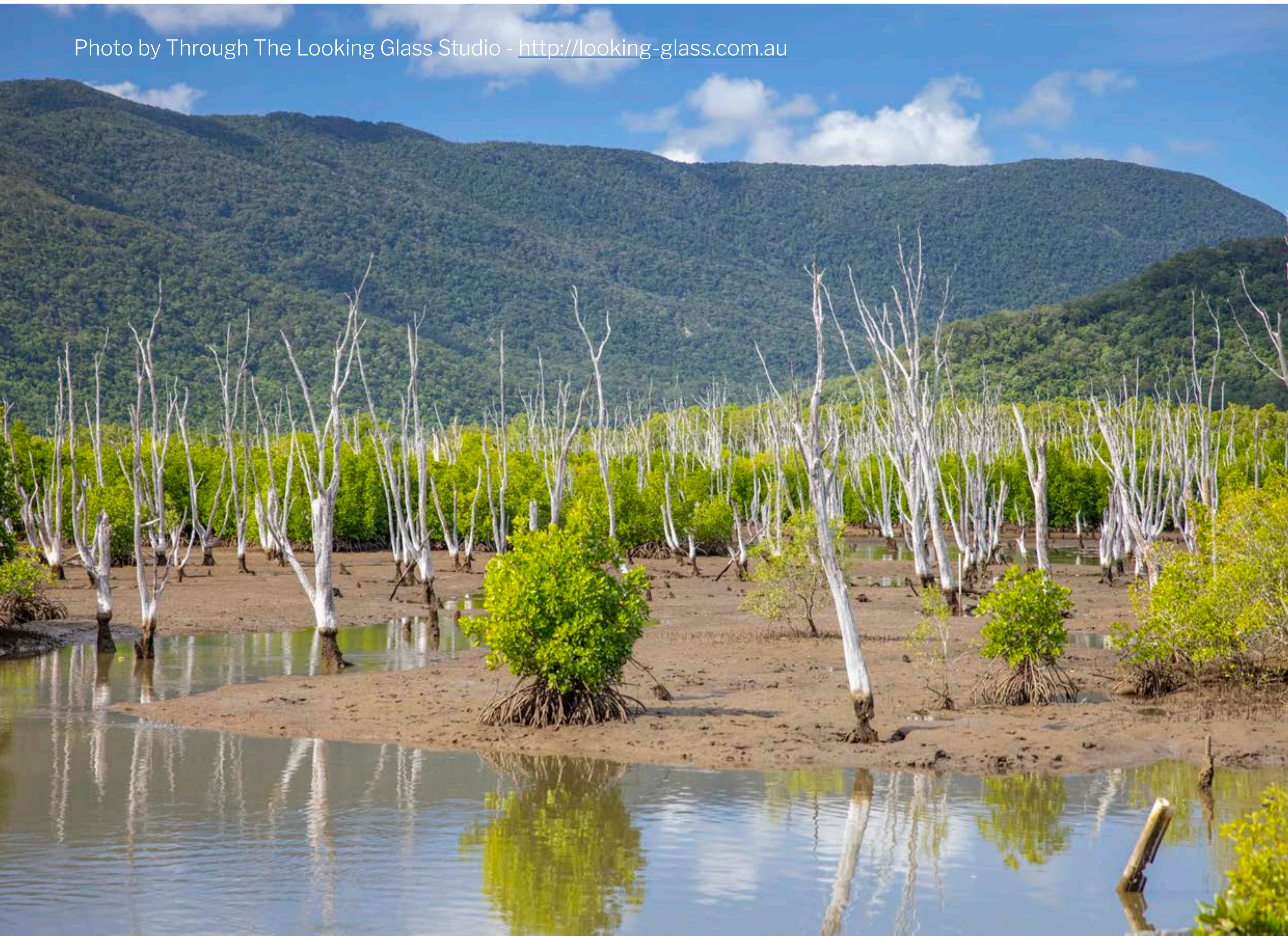


Photo by Through The Looking Glass Studio - http://looking-glass.com.au

7. Glossary

Glossary of relevant Ecosystem Services from SEEA, adapted from SEEA Table 6.3[138]

Ecosystem Service as described in case study	Ecosystem Service		Description
Regulating and maintenance services			
Carbon sequestration & emissions	Global climate regulation services		Global climate regulation services are the ecosystem contributions to reducing concentrations of GHG in the atmosphere through the removal (sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. These services support the regulation of the chemical composition of the atmosphere and oceans. This is a final ecosystem service.
Water quality	Water purification services (water quality regulation)	Retention and breakdown of nutrients Retention and breakdown of other pollutants	Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health. This may be recorded as a final or intermediate ecosystem service.
Cultural services			
Cultural services – recreation and existence values	Recreation related services		Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. This includes services to both locals and non-locals (i.e. visitors, including tourists). Recreation-related services may also be supplied to those undertaking recreational fishing and hunting. This is a final ecosystem service.
Cultural services – First Nations Values	Spiritual, artistic and symbolic services		Spiritual artistic and symbolic services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that are recognised by people for their cultural, historical, aesthetic, sacred or religious significance. These services may underpin people's cultural identity and may inspire people to express themselves through various artistic media. This is a final ecosystem service.

[138] United Nations. "System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA)". (2021). https://seea.un.org/ecosystem-accounting.

Glossary of terms

Term	Definition
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences.
Abiotic	Not from living organisms, only in the physical or chemical realm.
Australian carbon credit units (ACCU)	ACCUs offers landholders, communities and businesses the opportunity to run projects in Australia that avoid the release of greenhouse gas emissions or remove and sequester carbon from the atmosphere.
Acid Sulfate Soils (ASS)	Naturally occurring soils and sediments containing iron sulphides, most commonly pyrite. When ASS are exposed to air the iron sulphides in the soil react with oxygen and water to produce a variety of iron compounds and sulfuric acid. Initially a chemical reaction, the process is accelerated by soil bacteria.
Activities	Activities that occur in or near ecosystems that have impacts on the system, generally with economic benefits (for example, fishing).
Above Ground Biomass (AGB)	Living vegetation above the soil, including stem, stump, branches, bark, seeds, and foliage.
Annual Average Damage (AAD)	Calculated equivalent annual equivalent expense if hazard damages occurred evenly through time.
ArcMap	Main component of Esri's ArcGIS suite of geospatial processing programs, and is used primarily to view, edit, create, and analyse geospatial data.
Annual Exceedance Probability (AEP)	The probability (measured as a percentage) that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Australian height data (AHD)	The Australian Height Datum (AHD) is the official national vertical datum for Australia and refers to Australian Height Datum 1971 (AHD71; Australian mainland) and Australian Height Datum (Tasmania) 1983 (AHD-TAS83).
Assets	An item or service that has value which is measured in the accounts.
Biodiversity	The diversity of life found within an area.
Biomass	The mass of biological matter, generally expressed in kg or t.
Biotic	Produced from living organisms.
Blue Accounting Model (BlueCAM)	A model used to estimate carbon stocks in a wetland ecosystem.
Blue Carbon Ecosystems	Ecosystems that contain blue carbon, which is stored atmospheric or oceanic carbon.
Carbon sequestration	The process of capturing and storing atmospheric carbon dioxide, often mitigating greenhouse emissions.
Carbon Estimation Area (CEA)	A stratum of the Project Area; land which is homogenous for the purpose of abatement calculations, has consistent biophysical characteristics and is established and managed in a consistent way. CEAs may be defined by a single CEA Polygon or, where a specific method allows, more than one CEA Polygon (see Split CEA).
Coastal protection	Physical protection provided by habitats to human developments.
Compositional state	The composition of an ecosystem, usually referring to plant or animal communities and their diversity.
Conceptual model	Simplified flow chart outlining interactions between different factors relevant to the system examined.
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water.
Digital Earth Australia (DEA) sandbox	The Digital Earth Australia (DEA) Sandbox is a learning and analysis environment for getting started with DEA data and our Open Data Cube.
Digital elevation model (DEM)	A Digital Elevation Model (DEM) is a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects.
Ecosystem condition	The quality of the ecosystem measured in terms of its abiotic, biotic and landscape/ seascape characteristics. Successfully restored habitats should see their condition improve.

Term	Definition
Ecosystem conversion	Amount of change in restored habitats before and after restoration activities.
Ecosystem extent	Spatial area covered by an ecosystem, expressed in hectares (Ha), m^2 or km^2. Also 'size of ecosystem asset'.
Ecosystem service	The many and varied benefits to humans provided by the natural environment and from healthy ecosystems. For example, the fish they produce that are then consumed by fisheries.
eCognition	Trimble eCognition software is used by GIS professionals, remote sensing experts & data scientists to automate geospatial data analytics.
Ecotone	A transitional area of vegetation between two different plant communities, for example between saltmarshes and mangroves.
Environmental Economic Accounting (EEA)	A framework for organising statistical information to help decision-makers better understand how the economy and the environment interact.
Environmental economic account	Accounts used to value ecosystems, usually comprised of an ecosystem extent account and an ecosystem condition account.
Environmental economic accounting	Framework used to compile information linking environmental factors to economics.
Emissions trading register (ETR)	An online database that issues, records, and tracks the carbon units that are exchanged within market mechanisms or financed through Results-Based Climate Finance programs.
Fine benthic organic matter (FBOM)	Deposited on the stream bottom (i.e. fine benthic organic matter) can vary greatly between stream habitats (e.g. pools and riffles) and is a key food for deposit feeders (analogous to microphytobenthos).
First Nations ecosystem services	Services provided by natural habitats to First Nations people.
Fisheries biomass provisioning service	The fish product (e.g. fishes and crustaceans) produced from ecosystem services that is caught and sold by fisheries.
Flows	Ecosystem services in environmental accounting, usually between ecosystem assets and economic units.
Food web	A more complicated version of a food chain that includes all feeding interactions between organisms in an ecosystem.
Functional state	The function of the community.
Geographic Information Systems (GIS)	Software systems used to process spatial information, to create maps, for example.
Global climate regulation	Activities, natural or human-caused, that help regulate the climate, generally through lowering atmospheric greenhouse gases.
Habitat maintenance	Services provided by natural habitats to themselves that are required for ecosystem function.
Highest astronomical tide (HAT)	Defined as the highest level which can be predicted to occur under average meteorological conditions and any combination of astronomical conditions.
Indigenous Protected Areas (IPA)	Areas of land and sea Country managed by First Nations groups in accordance with Traditional Owners' objectives.
Hydrodynamic regime	Patterns in water flow within or across an ecosystem, for example tidal patterns.
Indigenous cultural resource management (ICNRM)	ICNRM are activities undertaken by Indigenous individuals, groups and organisations across Australia constituted by caring for Country and which originate from the millennia old relationships between traditional Aboriginal and Torres Strait Islander societies and their Country. Cultural resource management such as hunting, gathering, burning, ceremony, knowledge sharing are actions taken to protect and maintain the health of Country and its people.

Term	Definition
(Australian) Institute of Aboriginal and Torres Strait Islander Studies (IATSIS)	This is a national institute that provides advice on how to engage with Aboriginal and Torres Strait Islander communities, support recognition of ATSI culture, narrative and resurgence. They also provide formal advice on and protocols for how to conduct research with ATSI people.
Landsat	Earth observation satellite system run by NASA (digital remote sensed data).
Lowest astronomical tide (LAT)	Defined as the lowest level which can be predicted to occur under average meteorological conditions and any combination of astronomical conditions.
Light detection and ranging (LiDAR)	Also called 3D laser scanning, LiDAR is a method for determining ranges by targeting an object or surface with a laser and measuring the time for the reflected light to return to the received.
Modified Normalised Difference Wetness Index (MNDWI)	Uses green and short-wave infrared band pixel values to enhance open water features in GIS applications.
Modelling	Extrapolating patterns, either between known data points, or into the future.
Monetary accounts	Accounts that measure the value of ecosystems for society.
Monitoring	Repetitive assessments of habitat condition, usually conducted annually or every 5 years.
Mandingalbay Yidinji Aboriginal Corporation (MYAC)	Under the Native Title determination the Mandingalbay Yidinji Aboriginal Corporation was set up as the Registered Native Title Prescribed Body Corporate which holds the Native Title for National parks, other reserves and state forest areas near Cairns.
Normalised Difference Vegetation Index (NDVI)	The data provides an overview of the status and dynamics of vegetation across Australia, providing a measure the amount of live green vegetation using grids and maps from satellite data. The satellite data comes from the Advanced Very High Resolution Radiometer (AVHRR) instruments on board the National Oceanic and Atmospheric Administration (NOAA) series of satellites that are operated by the US (http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html).
Nearmap	Nearmap is an aerial technology company that provides frequently-updated high-resolution aerial imagery and location intelligence.
Non-market valuation (NMV)	Non-Market valuation is a set of techniques that aims at reflecting the economic value of changes, in the availability or quality, of goods and services that are not intended to be traded in the market.
Nursery population	Role of habitats for assisting the growth of young animals.
Object-based image analysis (OBIA)	A type of image analysis that groups cells into objects (i.e. vectors) based on their spectral, geometrical and spatial properties to partition and classify Earth observation data.
Orthomosaic	The output from a process where a number of overlapping photos (e.g. from a drone or aerial camera) are stitched together with distortions removed to create a complete and continuous image representation or map of a portion of the earth.
Physical accounts	Accounts that measure the physical distribution of ecosystems, for example habitat extent or productivity.
Pools	Components of an ecosystem that can 'store' carbon.
Primary data collection	Information requiring boots on the ground at the site of restoration to assess, data not currently existing elsewhere.
Project scoping	Determining the size of the project, both in time and space.
QGIS	QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, printing, and analysis of geospatial data.

Term	Definition
Ramsar	The Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat is an international treaty for the conservation and sustainable use of Ramsar sites (wetlands). It is also known as the Convention on Wetlands. It is named after the city of Ramsar in Iran, where the convention was signed in 1971.
Reference level	The value of a variable at the reference condition, against which it is meaningful to compare past, present or future measured values of the variable.
Reference sites	Sites with similar habitat at the restoration site, used to assess relative changes as being caused by restoration activities.
Regional multipliers	An expenditure that leads to broader economic benefits, for example the value of 1 kg of prawns caught leads to broader economic benefits from processing, transport etc.
Remote sensing	Process of detecting and monitoring the physical characteristics of an area using aircraft or satellites, without physically interacting with the habitat.
Remotely-piloted aircraft (RPA), or UAV	Aircraft flown without a person on-board, also called "drone" or Unmanned Aerial Vehicle (UAV).
Restoration project	A project aiming to undo damage caused by human activities within a given area, usually trying to revert to conditions pre-human influence.
SEEA	System of Environmental Economic Accounting A formal framework developed by the UN for valuing ecosystem services.
SEEA-EA	System of Environmental Economic Accounting Ecosystem Accounting.
SIMMR	A statistical package in R designed to solve mixing equations for stable isotopic data within a Bayesian framework.
Spatial coverage	Area covered by the project.
Spatial resolution	How easy it is to distinguish two neighbouring structures as separated, higher is usually better but comes at a cost of data maintenance issues. Usually expressed in m or km.
Stable isotopes	Naturally-occurring elements (e.g. Carbon) that do not decay like radioisotopes.
Stakeholder	A stakeholder is either an individual, group or organization that's impacted by the outcome of a project or a business venture. Stakeholders have an interest in the success of the project and can be within or outside the organization that's sponsoring the project.
Statistical	Summarising numbers in a way that is objective.
Stocks	Natural resources or land, such as fish stocks.
Supply and use tables	Record flows of goods and services, including ecosystem services, between economic units and the environment, including ecosystems.
Supratidal forest	Forest occurring on a tidal flat above the level of mean high water for spring tides, 'splash zone'.
Terms of Reference	The prescribed temporal coverage of the Trinity case study was to have two snapshots; one representing the site before intervention, and one after. The ecosystem services to be considered included: Traditional Owner values, Recreational activities, Carbon sequestration and emissions, and Water quality enhancement.
Trophic enrichment factor (TEF)	A parameter reflecting the difference in isotopic ratio between a consumer's tissues and diet, used in isotopic ecology and paleoecology to track dietary habits.
Temporal coverage	Historical time across which data will be collected.
The Guide	A Guide to Measuring and Accounting for the Benefits of Restoring Coastal Blue Carbon Ecosystems, 2023.

Term	Definition
Universal Transverse Mercator (UTM)	A map projection system for assigning coordinates to locations on the surface of the Earth.
Validation	Assessing the accuracy or uncertainty of higher-level remote sensing products with analytical reference data (such as corresponding ground and field measurements or using experts to verify).
Water purification service	Processes that increase the quality of the water, for example often reducing levels of pollutants.
Woody Vegetation Cover Fraction (WCF)	Vertical projection area of vegetation cover index used in remote sensing applications.
World Geodetic System (WGS)	A standard used in cartography, geodesy, and satellite navigation including GPS. The current version, WGS 84, defines an Earth-centred, Earth-fixed coordinate system and a geodetic datum, and also describes the associated Earth Gravitational Model (EGM) and World Magnetic Model (WMM).
Willingness to Pay (WTP)	The maximum price a customer or consumer is willing to pay for a product or service.

8. SEEA-based accounts

Below are a set of SEEA-based account tables that draw upon the analysis done in previous sections, and report in a structure that is broadly consistent with the SEEA-EA reporting structure. Where tables do not have relevant data they have been left blank to illustrate what could be presented (for example, flood mitigation).

8.1 Ecosystem extent account

Table 8.1: Ecosystem extent account

Realm	**Marine-Freshwater-Terrestrial**			**Marine**		**Marine-Terrestrial**		**Terrestrial**	**Freshwater**	
Biome	**MFT1 Brackish tidal**			**M1 Marine shelf**		**MT1 Shorelines biome**		**T7 Intensive land use**	**F3 Artifical wetlands**	
Selected Ecosystem Functional Group (EFG)	Supratidal swamp forest MFT1.2* ha	Saltmarsh MFT1.3 ha	Mangroves MFT1.2 ha	Seagrass MFT1.1 ha	Subtidal sand beds MFT1.7 ha	Muddy shorelines MFT1.2 ha	Sandy shorelines MFT1.3 ha	Other land covers T7.1 ha	Constructed lacustrine wetlands F3.2 ha	**Total ecosystem extent** ha
Opening extent 2005 (pre-restoration)	0	10	10	500	100	130	10	110	50	920
Additions										
Managed expansion	80	60	100	0	0	0	0	0	0	240
Unmanaged expansion	0	0	10	0	50	0	0	0	0	60
Total additions	*80*	*60*	*110*	*0*	*50*	*0*	*0*	*0*	*0*	*300*
Reductions										
Managed reduction	0	0	0	0	0	100	0	100	40	240
Unmanaged reduction	0	10	0	50	0	0	0	0	0	60
Total reductions	*0*	*10*	*0*	*50*	*0*	*100*	*0*	*100*	*40*	*300*
Net change	80	50	110	-50	50	-100	0	-100	-40	0
Closing extent	80	60	120	450	150	30	10	10	10	920

8.2 Ecosystem condition account

Table 8.2: **Ecosystem condition indicator account[139].** *Continued over page.*

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	**Measurement unit**	**Opening value**	**Closing value**	**Change in indicator**
Mangrove	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	04 (0.05)	0.04 (0.06)	0
	Biotic	Structural state	Age since restoration activities	Years	-	21.84 (0)	-
			Vegetation cover	% cover, rescaled (0-1)	0.81 (0.1)	0.79 (0.1)	-0.02
			Above-ground biomass	Mg ha^{-1}	*	*	-
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	0.88 (0.04)	0.9 (0.05)	0.02
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.75 (0.31)	0.75 (0.32)	0
Saltmarsh	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	0.27 (0.02)	0.27 (0.03)	0
	Biotic	Structural state	Age since restoration activities	Years	-	12.16 (7.94)	-
			Vegetation cover	% cover, rescaled (0-1)	0.78 (0.08)	0.68 (0.15)	-0.1
			Above-ground biomass	Mg ha^{-1}	43.84 (82.65)	24.27 (33.04)	-19.57

[139] Opening account year = 2005, closing account year = 2021). Values are mean of all cells in restoration activity boundary, values brackets indicate standard deviation. Comparison area for opening and closing mean values is the mutually inclusive area of the ecosystem type (i.e. where mangrove was present in both pre- and post-restoration activities). *unreliable estimates from datasets and not included.

Table 8.2: cont.

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	**Measurement unit**	**Opening value**	**Closing value**	**Change in indicator**
Saltmarsh	Biotic	Functional state	Vegetation greenness	Spectral index, rescale (0-1)	0.83 (0.05)	0.79 (0.03)	-0.04
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.23 (0.15)	0.23 (0.15)	0
Supratidal forests	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	0.3 (0.03)	0.32 (0.07)	0.02
	Biotic	Structural state	Age since restoration activities	Years	-	14.06 (6.47)	-
			Vegetation cover	% cover, rescaled (0-1)	0.78 (0.14)	0.75 (0.15)	-0.03
			Above-ground biomass	Mg ha^{-1}	61.08 (74.8)	61.92 (67.71)	0.84
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	0.88 (0.03)	0.87 (0.03)	-0.01
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.62 (0.33)	0.62 (0.32)	0
Waterbodies/ mudflats	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	-	-	-
	Biotic	Structural state	Age since restoration activities	Years	-	15.06 (5.22)	-
			Vegetation cover	% cover, rescaled (0-1)	-	-	-
			Above-ground cover	Mg ha^{-1}	-	-	-
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	-	-	-

Table 8.2: cont.

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	**Measurement unit**	**Opening value**	**Closing value**	**Change in indicator**
Waterbodies/ mudflats	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.23 (0.13)	0.36 (0.25)	0.13
Other land covers	Abiotic		Landscape wetness	Spectral index, rescaled (0-1)	0.28 (0.04)	0.28 (0.05)	0
	Biotic	Structural state	Age since restoration activities	Years	-	20.52 (2.95)	-
			Vegetation cover	% cover, rescaled (0-1)	0.31 (0.29)	0.46 (0.25)	0.15
			Above-ground biomass	Mg ha^{-1}	33.44 (68.86)	58.1 (66.8)	24.66
		Functional state	Vegetation greenness	Spectral index, rescaled (0-1)	0.84 (0.04)	0.86 (0.04)	0.02
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.71 (0.33)	0.55 (0.32)	-0.16

Table 8.3: Ecosystem condition indicator account[140]. Values for connectivity of ecosystem are mean of all cells in restoration activity boundary, values brackets indicate standard deviation. Comparison area for opening and closing mean values is the mutually inclusive area of the ecosystem type (i.e. where mangrove was present in both pre- and post-restoration activities. Note that for vegetation cover, biomass, greenness and wetness this is reported as change in hectare area for descriptor (i.e. opening value = area gained or maintained in value of descriptor, closing value = area loss in value of descriptor, change in indicator = net change in area for condition indicator). * unreliable estimates from datasets and not included *Continued over page.*

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	Measurement unit	Increase in indicator value/ Opening value	Decrease in indicator value/ Closing value	Change in indicator
Mangrove	Abiotic		Landscape wetness	Hectares	176	182	-6
	Biotic	Structural state	Age since restoration activities	Years	-	16.93	0
			Vegetation cover	Hectares	160	198	-38
			Above-ground biomass	Hectares	*	*	*
		Functional state	Vegetation greenness	Hectares	290	69	221
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.23 (0.11)	0.23 (0.11)	0
Saltmarsh	Abiotic		Landscape wetness	Hectares	2	3	-1
	Biotic	Structural state	Age since restoration activities	Years	-	10.21 (3.96)	-
			Vegetation cover	Hectares	2	3	-1

[140] Opening account year = 2000, closing account year = 2021. Indicating the change in extent (ha) that has improved or declined in condition. Values for connectivity of ecosystem are mean of all pixels in restoration activity boundary, values brackets indicate standard deviation. Comparison area for opening and closing mean values is the mutually inclusive area of the ecosystem type (i.e. where mangrove was present in both pre and post restoration activities. Note that for vegetation cover, biomass, greenness, and wetness this is reported as change in hectare area for descriptor (i.e. opening value = area gained or maintained in value of descriptor, closing value = area loss in value of descriptor, change in indicator = net change in area for condition indicator). *unreliable estimates from datasets and not included.

Table 8.3: cont.

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	**Measurement unit**	**Opening value**	**Closing value**	**Change in indicator**
Saltmarsh	Biotic	Structural state	Above-ground biomass	Hectares	4	1	3
		Functional state	Vegetation greenness	Hectares	1	4	-3
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.51 (0.31)	0.54 (0.3)	0.03
Supratidal forests	Abiotic		Landscape wetness	Hectares	116	120	-4
	Biotic	Structural state	Age since restoration activities	Years	-	9.88 (5.12)	-
			Vegetation cover	Hectares	104	131	-27
			Above-ground biomass	Hectares	158	77	81
		Functional state	Vegetation greenness	Hectares	109	127	-18
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.47 (0.29)	0.52 (0.32)	0.05
Waterbodies/ Mudflats	Abiotic		Landscape wetness	Hectares	-	-	-
	Biotic	Structural state	Age since restoration activities	Years	-	6.82 (2)	-
			Vegetation cover	Hectares	-	-	-
			Above-ground cover	Hectares	-	-	-

Table 8.3: cont.

SEEA Ecosystem Condition Typology Class			Indicators				
			Descriptor	**Measurement unit**	**Opening value**	**Closing value**	**Change in indicator**
Waterbodies/ mudflats	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0	0.5 (0.31)	0.5
Other land covers	Abiotic		Landscape wetness	Hectares	95	180	-85
	Biotic	Structural state	Age since restoration activities	Years	-	15.73 (1.24)	-
			Vegetation cover	Hectares	220	55	165
			Above-ground biomass	Hectares	242	33	209
		Functional state	Vegetation greenness	Hectares	212	63	149
	Landscape/seascape characteristics		Connectivity of ecosystem	Index, rescaled (0-1)	0.59 (0.31)	0.41 (0.26)	-0.18

8.3 Physical ecosystem service account

Table 8.4: Ecosystem services supply and use account in physical terms – supply table (unpopulated).

							Marine-Freshwater-Terrestrial			Marine		Marine-Terrestrial		Terrestrial	Freshwater		Total
		Industry				Sector	MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands		
SUPPLY	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtidal sand beds	Muddy shorelines	Sandy shorelines	Derived semi-natural pastures	Constructed lacustirine wetlands		
							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.5	F3.2		
Ecosystem services Provisioning																	
Wild fish and other natural aquatic biomass provisioning services																	
Wild animals, plants and other biomass provisioning services																	
Cultural services *Recreation-related services*																	
Visual amenity services																	
Educational, scientific and research services																	
Spiritual, artistic, and symbolic services																	
Wellbeing services																	
Stewardship services																	

8.3 Physical ecosystem service account

Table 8.5: Ecosystem services supply and use account in physical terms – use table (unpopulated).

							Marine-Freshwater-Terrestrial			Marine		Marine-Terrestrial		Terrestrial	Freshwater	
		Industry				Sector	MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
USE	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtitdal sand beds	Muddy shorelines	Sandy shorelines	Derived semi-natural pastures	Constructed lacustirine wetlands	**Total**
							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.5	F3.2	
Ecosystem services Provisioning																
Wild fish and other natural aquatic biomass provisioning services																
Wild animals, plants and other biomass provisioning services																
Cultural services *Recreation-related services*																
Visual amenity services																
Educational, scientific and research services																
Spiritual, artistic, and symbolic services																
Wellbeing services																
Stewardship services																

Table 8.6: Supply and use of recreational services in physical terms – 2001 (pre-restoration).

							Marine-Freshwater-Terrestrial			Marine		Marine-Terrestrial		Terrestrial	Freshwater	
		Industry				Sector	MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	Total
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtitdal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustirine wetlands	
SUPPLY							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Final ecosystem services																
Cultural services																
Recreational fishing	days															0
Birdwatching (visitors)	visitors															0
USE																
Final ecosystem services																
Cultural services																
Recreational fishing	days				0											0
Birdwatching (visitors)	visitors				0											0

Table 8.7: Supply and use of recreational services in physical terms – 2022 (post-restoration).

		Industry			Sector		Marine-Freshwater-Terrestrial: MFT1 Brackish tidal			Marine: M1 Marine shelf		Marine-Terrestrial: MT1 Shorelines biome		Terrestrial: T7 Intensive land use	Freshwater: F3 Artifical wetlands	Total
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtitdal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustirine wetlands	
SUPPLY							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Final ecosystem services																
Cultural services																
Recreational fishing	days															9,125
Birdwatching (visitors)	visitors															180
USE																
Final ecosystem services																
Cultural services																
Recreational fishing	days				9,125											9,125
Birdwatching (visitors)	visitors				180											180

8.4 Monetary ecosystem service account

Table 8.8: Supply and use of recreational services in monetary terms – 2001 (pre-restoration).

		Economic units						Ecosystem type									Total
		Industry			Sector			MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Imports/Exports	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtidal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustirine wetlands	
SUPPLY								MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Final ecosystem services																	
Cultural services																	
Recreational fishing	AUD$																0
Birdwatching (visitors)	AUD$																0
USE																	
Final ecosystem services																	
Cultural services																	
Recreational fishing	AUD$				0												0
Birdwatching (visitors)	AUD$				0												0

Table 8.9: Supply and use of recreational services in monetary terms – 2022 (post-restoration).

		Economic units						Ecosystem type									Total
		Industry				Sector		MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Imports/Exports	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtidal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustrine wetlands	
SUPPLY								MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Final ecosystem services																	
Cultural services																	
Recreational fishing	AUD$																187,063
Birdwatching (visitors)	AUD$																17,712
USE																	
Final ecosystem services																	
Cultural services																	
Recreational fishing	AUD$				187,063												187,063
Birdwatching (visitors)	AUD$				17,712												17,712

8.5 Regulation and maintenance

Table 8.10: Carbon asset account table.

Realm	**Marine-Freshwater-Terrestrial**			**Marine**		**Marine-Terrestrial**		**Terrestrial**	**Freshwater**	
Biome	**MFT1 Brackish tidal**			**M1 Marine shelf**		**MT1 Shorelines biome**		**T7 Intensive land use**	**F3 Artifical wetlands**	
Selected Ecosystem Functional Group (EFG)	Supratidal swamp forest MFT1.2* tonnes C	Saltmarsh MFT1.3 tonnes C	Mangroves MFT1.2 tonnes C	Seagrass MFT1.1 tonnes C	Subtidal sand beds MFT1.7 tonnes C	Muddy shorelines MFT1.2 tonnes C	Sandy shorelines MFT1.3 tonnes C	Annual cropland T7.1 tonnes C	Constructed lacustrine wetlands F3.2 tonnes C	**Total ecosystem extent** tonnes C
Opening stock 2002 (pre-restoration)	630,369	2,512	808,552	0	0	0	0	212,502	0	1,653,935
Additions										
Managed expansion										
Unmanaged expansion										
Total additions										
Reductions										
Managed reduction										
Unmanaged reduction										
Total reductions										
Closing stock 2021 (post-restoration)	687,088	14,122	894,400	0	0	0	0	145,303	93,605	1,834,518
Net change	56,719	11,610	85,848	-	-	-	-	(67,199)	93,605	**180,583**
Closing extent	9%	462%	11%					-32%		11%

Table 8.11: **Climate regulation supply and use account in physical terms - pre-restoration (2002).**

		Economic units						Ecosystem type									Total
		Industry			Sector			MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Imports/Exports	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtidal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustirine wetlands	
SUPPLY								MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Regulating and maintenance																	
Global climate regulation services																	
Sequestration	tonnes $CO_2e\ yr^{-1}$							4,979	33	5,999					0		11,011
Storage	tonnes CO_2e							630,369	2,512	808,552					212,502		1,653,935
USE																	
Regulating and maintenance																	
Global climate regulation services																	
Sequestration	tonnes CO_2eyr^{-1}				11,011												11,011
Storage	tonnes CO_2e				1,653,935												1,653,935

Table 8.12: Climate regulation supply and use account in physical terms - post-restoration (2022).

		Economic units						Ecosystem type									
		Industry			Sector			MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	Total
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Imports/Exports	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtidal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustrine wetlands	
SUPPLY								MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Regulating and maintenance																	
Global climate regulation services																	
Sequestration	tonnes $CO_2e\ yr^{-1}$							6,910	100	5,816					0	0	12,826
Storage	tonnes CO_2e							687,088	14,122	894,400					145,303	93,605	1,834,518
USE																	
Regulating and maintenance																	
Global climate regulation services																	
Sequestration	tonnes CO_2eyr^{-1}				12,826												12,826
Storage	tonnes CO_2e				1,834,518												1,834,518

Table 8.13: Water filtration services, supply and use table in physical terms – pre-restoration (2002). *Continued over page.*

							Marine-Freshwater-Terrestrial			Marine		Marine-Terrestrial		Terrestrial	Freshwater	Total
		Industry				Sector	MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtitdal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustirine wetlands	
SUPPLY							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Water filtration services																
NO_3^- removal	kg yr^{-1}						2,081	77	11,690						-	13,848
Soil TN removal	kg N yr^{-1}						10,979	77	29,506						-	40,562
Tree TN removal	kg N yr^{-1}						7,320	-	8,985						-	16,305
TSS removal	mg yr^{-1}						n.d.	127	9,466						464	10,057
Soil P removal	kg P						n.d.	110	8,211						403	8,724
Soil acidity reduction	mol H+/t						0.11								0	0
Soil pH increase															4	4
Increase in water pH															6	6

Table 8.13: Cont.

							Marine-Freshwater-Terrestrial			Marine		Marine-Terrestrial		Terrestrial	Freshwater	Total
		Industry				Sector	MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtidal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustrine wetlands	
USE							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Water filtration services																
NO_3^- removal	kg yr^{1}					13,848										13,848
Soil TN removal	kg N yr^{1}					40,562										40,562
Tree TN removal	kg N yr^{1}					16,305										16,305
TSS removal	mg yr^{1}					10,057										10,057
Soil P removal	kg P					8,724										8,724
Soil acidity reduction	mol H+/t					0										0
Soil pH increase						4										4

Table 8.14: Water filtration services, supply and use table in physical terms – post-restoration (2022). *Continued over page.*

							Marine-Freshwater-Terrestrial			Marine		Marine-Terrestrial		Terrestrial	Freshwater	Total
		Industry				Sector	MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtitdal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustirine wetlands	
SUPPLY							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Water filtration services																
NO_3^- removal	kg yr^{1}						2,888	229	11,402						-	14,519
Soil TN removal	kg N yr^{1}						15,237	231	28,788						-	44,256
Tree TN removal	kg N yr^{1}						10,158		8,763						-	18,921
TSS removal	mg yr^{1}							381	9,233						1,663	11,277
Soil P removal	kg P							331	8,009						1,443	9,783
Soil acidity reduction	mol H+/t						0.01									0.01
Soil pH increase															6.5	6.5
Increase in water pH															7.2	7.2

Table 8.13: Cont.

							Marine-Freshwater-Terrestrial			Marine		Marine-Terrestrial		Terrestrial	Freshwater	
		Industry				Sector	MFT1 Brackish tidal			M1 Marine shelf		MT1 Shorelines biome		T7 Intensive land use	F3 Artifical wetlands	
	Units of measure	Agriculture, forestry and fishing	Other industry	Total industry	Households	Government	Supratidal swamp forest	Saltmarsh	Mangroves	Seagrass	Subtidal sand beds	Muddy shorelines	Sandy shorelines	Other land covers	Constructed lacustirine wetlands	Total
USE							MFT1.2*	MFT1.3	MFT1.2	M1.1	M1.7	MT1.2	MT1.3	T7.1	F3.2	
Water filtration services																
NO_3^- removal	kg yr[1]					14,519										14.519
Soil TN removal	kg N yr[1]					44,256										44,256
Tree TN removal	kg N yr[1]					18,921										18,921
TSS removal	mg yr[1]					11,277										11,277
Soil P removal	kg P					9,783										9,783
Soil acidity reduction	mol H+/t					0.01										0
Soil pH increase						6.5										7
Increase in water pH						7.2										7

9. Appendices

Appendix A1. Data enquiry from Key Informants (Recreational fishing)

We were aiming to gather information on: (a) fishing activities and fishers in the restoration site (e.g. annual report/survey or observational/judgemental/anecdotal evidence) (plus number of trips, duration of recreation, travel origin) before and after restoration; or (b) data on recreational fishing and fishers in adjacent areas (which can be directly linked to the restoration activity), (c) data related to recreational activities (e.g. preferred locations, seasonality of fishing, multi-site recreation). Data enquiry was framed using the following list of questions:

1. Did people recreationally fish at the site, or adjacent areas prior to restoration (and if so, how many per annum)?
2. How many people have been fishing at the site, or adjacent areas in a recent 12-month period (e.g. 2020 or 2021)?
3. Has there been an increase in fish numbers, biomass, or species present (relevant to the recreational fishery) since pre-restoration (2006/7) to now (~2020/21)? Did any increase in fishing activity begin immediately after restoration began, or grow over time?
4. f there has been an increase in rec fishing activity in adjacent areas since restoration, is there clear link/evidence that this is driven by the restoration site (i.e. from producing more fish that travel to the adjacent areas to be caught)?
5. Were there particular sites preferred for rec fishing in the general area prior to restoration? Are the same sites still preferred? Are there new sites also preferred now?
6. Is there particular season for observing fishing activities and seasonal variation of visit frequencies of recreational fishing by anglers or residents? (We would also appreciate getting any information regarding the travel of recreation fishers – local, regional, national, tourist)
7. Do fishers typically visit only the East Trinity site when going on a fishing trip, or do they usually make multiple stops at different fishing sites?

Appendix A2. Data enquiry from Key Informants (Birdwatching)

We were aiming to identify whether there has been (a) an increase in the amount of birdwatching occurring at the restoration site and data sets/reports that exist recording the number of bird observers that visit the site or surrounding areas (or in lieu of that through observation/ judgement/ anecdotal evidence provided by managers and/or coordinators of the bird watching club); (b) if there has been an increase in birdwatching occurring in nearby areas that can be attributed to the environmental improvements made at the restoration site. The Key Informants were requested to provide us some information to the following questions (or point us to another contact):

1. Are there any new bird species; and an increase in the number of birds using the East Trinity site since start of restoration (2006/7) to now (~2020/21)?
2. Did any bird observers visit East Trinity before the restoration project i.e. 2006/7 (and if so, how many)?
3. How many bird observers visited East Trinity in a recent 12-month period (e.g. 2020 or 2021)?
4. Has the number of bird observers in the general area (e.g. including nearby wetlands) increased over the last ~15 years? And if so, is this increase linked to the restoration of East Trinity (which has improved the quality of saltmarsh)?
5. Were there particular sites preferred for bird observing in the general area prior to restoration? Are the same sites still preferred? Are there new sites also preferred now?
6. Is there a particular season for birdwatching activities (e.g. linked to migratory birds) and data showing seasonal variation in the number of bird observers?
7. Do bird observers typically visit only the East Trinity site when going on a bird watching trip, or do they usually make multiple stops at different fishing sites?

Appendix A3. Thematic findings 'in-depth' for First Nations values

The case study fieldwork for the First Nations account resulted in detailed information via workshops and interviews that were too lengthy to include in the main text. However, a summary of the thematic analysis, with verbatim quotes is provided below. In this way, the voices of First Nation participants can be heard directly and will offer deeper nuance and insight into the results and findings described in the chapter in the main body.

The sections below reflect synthesis and examples derived from both document analysis and first-person accounts:

Examples from Interviews

The following section describes the key cultural services or values resulting from restoration of the East Trinity site as expressed by participants during interviews. There are three main theme groupings. These main theme groupings are including: 1) enhanced identity on Country, 2) enhanced environmental stewardship, and 3) improved socio-economic capacity. Within each of these groupings, several dimensions of a theme are presented. The significance of cultural services is considered for individuals and the community with a focus on how these services have arisen or changed as a result of the restoration. Example quotes are provided to illustrate the meaning of themes and the way they were expressed by participants.

1. Enhanced identity on Country

For the Mandingalbay Yidinji people who provided input to this case study, Country is valued fundamentally, as a part of themselves, whether or not there is restoration. However, important cultural benefits and services have indeed arisen from the restoration and these have enhanced the people's experience of culture on Country in a number of ways.

Speaking of sharing cultural perspectives with her young son, one ranger described what she teaches her young son about the important relationship between her people's identity, wellbeing, and the landscape;

[75] "When we're out on Country like I'll sit down and I'll talk as much knowledge that I know of and, the importance of the Mandingalbay clan, you know, as a custodian, we don't own the land, the land owns us. We have to look after our Country or else we're going to get sick. If Country gets sick, we get sick. And yeah, so all those kind of stuff I touch on with him. So not just the cultural values, but also the environmental values." p.2

This ranger also elaborated on the positive effects for her own mental wellbeing, explaining that she enjoys being able to work and spend time at the site becuase it is a relaxing and healing place to be;

[75] "And it's also about my social and emotional well-being and that's what that place has done and, and I must admit East Trinity, like apart from [Yarrabah], which is where we grew and spent our childhood. But East Trinity for me has been a big healing place for me because every time I go down there, I leave there de-stressed, relaxed." p.4

Accounts of the Mandingalbay Yidinji cultural identity benefiting from restoration of the East Trinity site were also spoken of with reference to specific physical activities. The participants explained that being able to practice traditional activities like hunting and using medicinal plants not only provided physical health benefits through access to fresh local food, but also provided spiritual benefits throughthrough greater engagement with culture and continuing the traditions of their ancestors. A sense of identity was apparent in comments about these activities, for example, , one older ranger linked the activities to the concept of 'our people';

[64] "...our people, they've ventured all the way through the East Trinity Reserve... hunting mussels, crab, fish, prawns, you name it. shellfish, you know, even, some of the birds, you know, if you're lucky. You know, we used to eat seagulls.... It's an area of significance to a lot of our people because it's just like a big fruit, food bowl." p.15

Another younger ranger, specifically named the Mandingalbay people when talking of the variety of uses for different resources around the site, and the traditional activities related to them. This younger man appreciated that he was still in the process of learning about the significance of the site for his people;

[52] "Well within that seven years, I've been able to pick up the significance of the park itself, not only because of the acid sulphate, but because of the importance of that it brings for its culture... of the Mandingalbay people as a - as a supermarket, as a as a chemist... as a hardware store. So from digging tools to hunting tools to just everything all around." p.1

These natural resources available at the restoration site were described as having improved as a result of the restoration with more wildlife present and improved ecological condition. Crabs were a healthier colour compared to pre-restoration when crustaceans at the site were discoloured. The fact that the restoration has been successful with regard to creating a healthier ecosystem also translated to enhanced cultural identity in the way the people are seen and esteemed by others.

2. Enhanced esteem

The fact that this environmental restoration is a success story has contributed to the Mandingalbay Yidinji identity as they work on the site, demonstrating their involvement in the ongoing success and sharing this experience with site visitors. Tourists and students visit the site from around the world, as do some high-level decision makers. The participants expressed that this was important for them because these visitors can see their pro-active environmental and business management. For example, one ranger spoke of international tourists coming and seeing their ongoing work at the site and rethinking assumptions about indigenous groups;

[29] "we've got people from America, France and that, and they think we're just, you know... in a way they think that we will more or less go - we're losing our identity or something, and then and then when we tell them that our stories and our landmarks and all that, it's a real eye opener for them." p.4

The participants valued this public profile for enhancing their esteem as a people, and because it helped to address negative stereotypes about Aboriginal peoples, showing the wider Australian community that they are an active culture, with autonomy and agency. Another ranger recounted a visit from a government minister, who was able to see the independence and capabilities of the local rangers and tour operators;

[93] "...actually [he] took one of our tours and came over and he, yeah, he was real... It was an eye-opener for him for, for an Indigenous organisation like us that's actually run and like owned and run locally without outside influence or without any non-Indigenous influence." p.7

This public profile is also an important factor in the stewardship role that is valued by the Mandingalbay Yidinji people, when it comes to wildlife and conservation on the global stage.

Intergenerational connection

A key factor in the enhancement of cultural identity at the restoration site was the role of current generations of Mandingalbay Yidinji people in carrying out the vision of those who had gone before. One ranger recounted her personal connections with these visionaries, and saw her work at the site as vital to continue their legacy;

[75] "...Pop, Vince passed away. 2006 we got our native title determination of like the East Trinity area and where we are now... then 2008, they did the Strategic Plan to start the Ranger program. 2008, we lost another uncle that was very dear, Uncle Alfred Mundraby. And oh 2010,

March 23rd, they wrote the Ranger program opened up for about two weeks like the Rangers actually started. My dad passed on. So when my cousin described, "Just remember, you're doing this for your pop and your dad," it was a reflection of yeah, you know what I mean, this is the legacy that they've left that they've worked hard for." p.5

In practical terms, the site remediation has improved physical condition of the site, making construction projects safer and more practicable. In addition, the natural environment and wildlife is becoming richer and therefore more enticing as a destination for visitors. These factors support the viability of businesses and visions for the site and thereby support the people in their purpose of continuing the vision of community leaders who have passed away. This value was echoed by other rangers, as one father reflected on how his young daughter was inspired by his work. He described how the importance of the work at the site bridged the future with the past by carrying on a family legacy;

[29] "So it's not just for our future generations, it's also for our past, the people that left us so, They built something for us, for our future. Now we've got to build, keep building on that." p.9

Intergenerational connection is not only enhanced by the activities carried out at the site but by the wildlife that benefit from the improved environment. This is because wildlife is a part of the identity of the Mandingalbay Yidinji people.

3. Improved socio-economic capacity

Socio-economic capacity lies at the intersection between stewardship of Country and the people's engagement with wider economic systems. Socio-economic capacity is about more than income. In the context of this case study, socio-economic capacity relates to the accessibility of the site, resource use at the site, the business potential of the site, and how these factors feed into the future capacity of people to improve their standard of living and financial independence. Each of these aspects of cultural service have been improved by restoration.

Viability of business ventures

The ecotourism project at the site was the focus of many comments by interviewees. They appreciated that it provides jobs currently, but also has capacity to expand and supply more jobs, training and opportunities for the community into the future. Talking about the current infrastructure for the ecotourism venture, one ranger highlights the plans for growth;

[29] "That's only stage one. We got three stages. I think the next stage is boardwalks. And the third stage is towers, that we're going to be having. In a way we can be flying foxes from one tower to another... And that was dad's vision before he left." p.3

This potential is seen as directly influenced by the restoration of the site. An elder pointed out that pre-restoration, East Trinity would not have been attractive to visitors;

[88] "no-one wants to pay money to come along and have a look at, you know, destructive environment. ...They haven't – but it joins hands with the environmental value as well as the cultural value. So they're interlinked." p.3

Proximity to Cairns and easy access by a boat are now strengths of the business. By making the land viable for ecologically sensitive development, the restoration has created commercial opportunity for Traditional Owners. A ranger who is among the longest serving at the site pointed out that proximity made the experiences they offered accessible to people from all walks of life, a factor that was appreciated by visitors too;

[93] "And where we're situated it's just only a five-minute boat ride... that's why we get good feedback from a lot of the participants that actually take the tour as well. And we get people from all walks of life." p.17

Supplementary harvesting

The final aspect of socio-economic benefit to be considered is the value of supplementary harvesting at the site. While the Traditional Owners are not dependent on food or other resources from the site, these resources are useful. Harvesting or resource use was more often talked about in the context of the value of cultural traditions rather than economic benefits. Still, there is value in people being able to supplement either their diet or their recreational expenses with harvesting of naturally occurring resources. As a result of the remediation, the most commonly mentioned useful resources at the site were in fact weeds including guava and pond apple, which are harvested as fresh fruit;

[16] "yeah so whilst that's a weed species, it's nutrient, sustenance for us... bush tucker. As with the guavas have taken over areas, but still the guavas – yeah a lot of substance for us." p.2

Shellfish were also described as having improved in quality since the remediation. Previously, this seafood was discoloured because of the acidity, but is now looking healthy. One elder said;

[88] "What's also visibly noticeable is that the crustaceans, crabs and prawns are coming back, but they're not red like they've already been cooked." p.3

Through bush-tucker being incorporated into tours, there is potential for the resources described above to add value to future experiences. Deadly Dinners as a bush-tucker experience were paused because of the pandemic, but are likely to continue in the future. Events like these are opportunities to make further use of the resources that have either increased or improved due to the site's remediation. While such opportunities are prospective, rather than of actual current value, it is worth considering the wellbeing effects of such possibilities. As a result of the remediation, the Mandingalbay Yidinji people have successes to build on and a range of possibilities to look forward to in their future. Against the backdrop of a very challenging past, this positive outlook has very real wellbeing value.

The Maningalbay ecotourism venture incorporates bush tucker, storytelling and other performance arts to share cultural knowledge with visitors and community members. Dale Mundraby describes some of these activities when speaking with a news journalist;

"We've infused bush tucker into the menu, working with the head chef from Ochre. There's also traditional storytelling, dancing and an international harpist as part of the entertainment." [142]

A key aspect of cultural value evident in the published literature was the many collaborations arising between the cultural custodians of the East Trinity site and external sectors like universities, government departments and independent businesses. For example, Djunbunji Land and Sea Rangers are collaborating with experts in anthropology to locate, map and record significant sites, some of which were almost lost to recent memory. This is an ongoing Cultural Heritage Project[143]. Knowledge development like this connects the local community with wider communities and sectors, and empowers the Traditional Owners to re-construct stories and tell new stories into the future. These documents highlight the culture's focus on the future. For example, the following excerpt[144] shows the value of the work for cultural knowledge for future generations;

'The P3DM project has encouraged us to share stories about our Country and people, and most importantly to educate our young ones. It helped us to draw out important knowledge, to speak about it and to highlight how much knowledge remains within the minds of Mandingalbay Yidinji people.'

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[142] Cluff, R. (2021) New Cairns Indigenous eco-tour project set to open. TropicNow, https://www.tropicnow.com.au/2021/july/1/new-cairns-indigenous-eco-tour-project-set-to-open

[143] Djunbunji Land and Sea Program. (2023). Cultural Heritage Project, http://www.djunbunji.com.au/ranger-program/cultural-heritage-project/.

[144] Mandingalbay Yidinji Traditional Owners. (2014). Participatory 3 Dimensional Modelling. Sydney.

3. Enhanced environmental stewardship

The relationship described so far between the condition of the landscape and the wellbeing of the people has been recounted with an identity-focused or inward-looking aspect of the cultural value of this site. But there is also an outward-looking aspect, particularly that related to environmental stewardship. Stewardship can be considered outward-looking, because it focuses attention on the wildlife and habitat. As the site is surrounded by globally significant conservation areas, it has a high ecological value, which is recognised by these people. When asked about the value of the area for him, one ranger spoke of its ecological value, describing the site as a unique intersection of several different habitat types;

[16] "For the untouched vegetation is in the northern-eastern area, black mangrove forest so it's real hard mangrove wood and the ecosystem neighbouring that is a rainforest, and then within that is a palm forest as well as a melaleuca forests and also like…tea tree forests all in this one location, which is we said is unique. So many ecosystems that are so close together and supporting each other in the growth."' p.1

Environmental stewards as teachers

Another ranger describes the area as a large 'science lab' through which the Mandingalbay Yidinji people can collaborate with other stakeholders. The site is seen as a source of learning about interactions between the site's remediation and ecology;

[52] "'Before all the, the land got destroyed, it was one of the main food bowls, food sources for the - people to gather their seafood and shell foods and hunting materials down in that park itself. And then obviously when the acid sulphate came back it wiped everything out basically from fish habitats to migration birds so it's obviously one of the biggest migration paths within the far north. The Cairns region. And in saying that it's become one of the biggest science labs as well… with all these different soil people, acid people, all coming together and then I guess putting Western science and indigenous knowledge together to create this beautiful outcome." p.1

Stewardship and discovery

Participants treasured the return of wildlife and expressed the sense of discovery that came with seeing rare or elusive species. One young ranger described the site as special, because of the unusual wildlife. He was taken aback seeing a large Jabiru for the first time;

[29] "Just some birds that you don't really see often. They're down in the reserve, and they're nowhere else. Like, you wouldn't see them up here at the ranger base. You go down inside the swamp lands just to see them. Like the Jabiru…. they're big and, I'm a big person, but that really freaked me out because I was down there on – by myself and I just had heard the wings flap," p.5

Another ranger who has worked at the site for about seven years recounts seeing an increasing number of saltwater crocodiles move into the area and even start using the site for breeding since he has been there;

[52] "…so when I first started, we would only see one big guy now we're seeing like three, four of them on each different ponds of the park so obviously something's been right… And there's actually a few months ago we've seen little [crocodile] hatchlings probably like this [gestured about 40cm] swimming around." p.6

An elder described how he values seeing the ecological functioning of the area improve and the importance of this for wildlife. He describes the regrowing mangroves as the 'lungs of the reef', which benefit many other species by providing food and habitat;

[88] "I think that as a result of the restoration, remediation, that one of the noticeable things because a lot of growth and different plant species and the mangroves because the mangroves are the lungs right of the reef. There's not- you know, it's a filtering system in itself. It's also a nursery ground for like the food source for turtles. So, for example, jellyfish." p.12

This stewardship role reflects the worldview that Country and people are one.These examples suggest that the value of the site is as much about the people's contribution to it, as it is about what the landscape offers to them. In accounting for cultural value of the site, our study acknowledges the role of stewardship, which goes beyond the 'receiver of benefits' to include a giving or devotional role. The most direct expression of this devotional role is that of a protector.

Stewards as protectors

Besides teaching visitors, a valued part of the stewardship role is the ability to protect the area from those who do not understand or value it in the same way. Rangers spoke of 'weekend warriors' during interviews. They valued the capacity to instruct people about appropriate behaviours onsite and how to report those who do not behave responsibly. This ranger described the kinds of activities that took place;

[64] "...we call them weekend warriors they find access into the East Trinity Reserve and the access is illegally...and we tried to shut off access but, you know, people always find a way through and you know, especially they've got shovels on board, they got changed, you know, to cut away the fallen trees over the road." p.14

Another ranger explained how they proceed to educate people and appeal to reason, and then take further action if they need to;

[52] "We say, 'You can come fishing in here buddy just leave the car outside.' I'm just going to have to take a photo of your car and that's when they really panic and don't come back again. And so basically with that compliance ticket is we can take… address and phone number and name. If you don't that's an offence and then basically cops can get involved" p.12

The role of monitoring wildlife and the ecological processes within the site is valued, and this role extends to the wider community through teaching, collaborations, and public education. In summary, the sense of stewardship, of being able to protect and advocate for the habitat and wildlife of the site, is fundamental to its cultural value for indigenous people.

Challenges for delineating benefits of restoration from other changes

External factors can enhance or detract from the cultural services derived by restoration. In our case study, it became apparent during interviews that other human and environmental factors have influenced the cultural value of the site during the same time as the restoration. In response to this complexity, interview questions and document analysis focused on cultural values directly linked to restoration. However, in the following paragraphs, we discuss examples of extrinsic factors influencing change and influencing the values of the site. Implications are considered in cultural accounting for environmental restoration projects.

Land tenure and accessibility

The administrative status of the site and adjacent land influences the cultural value that is experienced from the restoration. This is mainly because it affects access to the site, and determines how the site must be managed. The World Heritage status of nearby regions influences the priorities at the site, while Native Title adjoins the site assists the Traditional Owners with access to it. The status of the site as an Indigenous Protected Area (IPA) enhances the autonomy and agency of the Mandingalbay Yidinji people. The value of the site restoration is enhanced by access and empowerment afforded by this legislation, as one elder explains;

[88] "what we do with, you know, hunting crabs or fishing and those cultural activities but knowing back in the day before they, when, you know, prior to 1992 when the Native Title Act came into play, a lot of these areas were not accessible because of the fact that we're pretty much locked out." p.2

"...Even though we don't have native title over East Trinity but we have surrounding East Trinity exclusive and non-exclusive native title and that's why we put the IPA at the top of it for its cultural and natural values." p.4

The cultural services experienced because of the remediation would not be as great were it not for the access afforded by these administrative tools.

But access would not result in the same benefits, were it not for the restoration. Therefore, these contextual details, while important, do not change the value accounting for the restoration.

Other external influences on cultural value

External factors in environmental change at the site range from cyclones to human uses such as illegal pig hunting. When considering change over time, and how change translates to value in remediation, not all change is due to the remediation. For example, one ranger attributed some change in structure of mangroves at the site to a cyclone;

[64] "…but with the cyclones and stuff over time, you know, those trees would have fell down with the cyclone break off and died. And now the different mangroves that come through, in their place." p.3

In further conversation, this ranger talked about habitat use by different species, and how a change in structure of various sections of the mangrove can have advantages and disadvantages, depending on the species. Such effects may be complimentary to the habitat improvement arising from the restoration. Questions as to whether an event adds to or detracts from the values derived by a restoration, need to be considered, but teasing such effects apart completely would be difficult.

An increase in wildlife due to habitat restoration, along with raised public awareness about the wildlife in the area, may have some negative effects. Feral predators including cats and dogs, have been observed by rangers, and may be attracted if there is more food. For example, an observation of increases in both native and non-native wildlife were made by this ranger;

[93] 'I've seen a significant change over the last 16 years…when the restoration or the remediation took place… it reintroduced marine life, bird life, even, you know, wildlife in a sense such as well pretty much a lot of feral animals such as pigs, dingoes, some feral cats, but yeah, dogs and stuff. p5

While feral animals attracted to the site can be considered a disservice, they also represent employment and an increase in transferable skills for the rangers, who are working to control them or mitigate their impacts. One elder also commented during a site visit that pig hunters occasionally bring their dogs into the region, and these dogs are a serious threat for large birds. The pig hunters also have firearms, which are a safety concern. Hence increasing public awareness about the site may bring challenges, but in this case study such challenges are context for consideration, or risks to be managed, rather than disservices from the remediation.

Walls and weeds

Although the bund wall was originally installed as a part of the former sugar plantation, the bund wall around the site is now valued by the Mandingalbay Yidinji people. The wall serves as an access road around the site not usually affected by tides. The Traditional Owners appreciate that the bund wall was useful in controlling inundation of the site during remediation, and still prevents tides from making areas of the site inaccessible. All these benefits were mentioned at different times by the study participants. As one ranger said pointing to sections of the site map;

[52] "…if the bund wall wasn't there, all this would have been in, underwater. So, it's quite special little spot there." p.12

Weeds and pest species are a mixed issue for cultural value attribution in this restoration site. Elders report that weeds have increased in the area during the remediation, and ranger activities include weed control. Yet while outside observers may consider the weeds a 'disservice' - they are not viewed that way by the Traditional Owners. For example, this elder said that weeds were a positive sign that plant growth in general was increasing at the site;

[16] "…most of it's full of weeds but that's a good thing because things are growing. Just how we combat the weeds through a weed program. Spraying, and burning. Doing mosaic burns…" p.1

A ranger also made specific mention of a species, known as the 'pond apple' which was considered a weed by others, but valued as a resource by his people. He made further comment that other weeds were serving to protect the banks from erosion, which he noted as an important benefit in the face of sea level rise and extreme weather events;

[52] "Yeah and then I only found out recently that the pond apple that's a- the scientists were saying it's a bad weed for our riverbanks and whatnot. But then again, my elders utilised that fruit in the sense of for their cooking.... [scientists] were saying it wasn't [native] but my old people used it. My one of my... great aunts came out and said, "No that's our traditional food." ...But these non-Indigenous [people] said they're weeds... no, it's what it's doing, it's fine. Okay. So basically, what it does is just, just clusters the riverbanks so all the natives can't grow along. But then again, because of sea level rising and floods and whatnot, it's actually holding the banks together, so it's got that balance of good and bad." p.4

The topic of 'weeds' is an example of the importance of asking the people themselves how they experience and see various events, objects and phenomena related to a site. When it comes to cultural services and values in environmental accounting, it is after all, the services and values - as experienced by those people - that is the point of a study.

Appendix B

Table B.1: List of identified recreational services valuation studies conducted based on welfare estimates for Australian coastal and marine wetland ecosystems. As an alternative to the use of exchange values, these studies can be used for BT to the economic valuation of recreational fishing and birdwatching in coastal wetland ecosystems in Australia (based on systematic literature review). *Continued over page.*

Study ID	Study Author	Year valued	Habitat	Region/location	What is valued	Valuation method	Value measurement	Estimate (AUD)	Remark
1	Pascoe[145] et al., 2014	2013	Multipurpose coastline	Moreton Bay Marine Park, Queensland	Recreational fishing	TC	per trip/angler	58.23-60.58	Using "marginal cost only" (lower and higher trip assumption)
1	Pascoe et al., 2014	2013	Multipurpose coastline	Moreton Bay Marine Park, Queensland	Recreational fishing	TC	per trip/angler	105-108	Using "Total cost" (lower and higher trip assumption)
1	Pascoe et al., 2014	2013	Multipurpose coastline	Moreton Bay Marine Park, Queensland	Recreational fishing	TC	per trip/group	128.91-134.1	Using "marginal cost only" (lower and higher trip assumption)
1	Pascoe et al., 2014	2013	Mutipurpose coastline	Moreton Bay Marine Park, Queensland	Recreational fishing	TC	per trip/group	232.68-239.15	Using "Total cost" (lower and higher trip assumption)
2	Windle[146] et al., 2017	2016	Harbour area, beaches	Gladstone Harbour, Queensland, Australia	Recreational fishing	TC	per trip/person	143	
3	Huang[147] et al., 2020	2016	Seagrass	Port Phillip Bay, Victoria	Recreational fishing	CM	per trip/angler	0.39-1.22	Welfare gains from seagrass rehabilitation (10 and 30%)

145 Pascoe, S., Doshi, A., Dell, Q., Tonks, M. & Kenyon, R. (2014). Economic value of recreational fishing in Moreton Bay and the potential impact of the marine park rezoning. Tourism Management, 41, 53-63. https://doi.org/10.1016/j.tourman.2013.08.015

146 Windle, J., Rolfe, J. & Pascoe, S. (2017). Assessing recreational benefits as an economic indicator for an industrial harbour report card. Ecological Indicators, 80, 224-231. https://doi.org/10.1016/j.ecolind.2017.05.036

147 Huang, B., Young, M. A., Carnell, P. E., Conron, S., Ierodiaconou, D., Macreadie, P. I. & Nicholson, E. (2020). Quantifying welfare gains of coastal and estuarine ecosystem rehabilitation for recreational fisheries. Science of The Total Environment, 710, 134680. https://doi.org/10.1016/j.scitotenv.2019.134680

Table B.1: Cont.

Study ID	Study Author	Year valued	Habitat	Region/location	What is valued	Valuation method	Value measurement	Estimate (AUD)	Remark
3	Huang et al., 2020	2016	Seagrass	Port Phillip Bay, Victoria	Recreational fishing	CM	per trip/angler	2.27-7.35	Welfare gains for 10 and 30% increase in seagrass cover
3	Huang et al., 2020	2016	Seagrass	Western Port, Victoria	Recreational fishing	CM	per trip/angler	5.49-19.57	Welfare gains from seagrass rehabilitation (10 and 30%)
3	Huang et al., 2020	2016	Seagrass	Western Port, Victoria	Recreational fishing	CM	per trip/angler	19.18-85.55	Welfare gains from (10 and 30%) increase in seagrass cover
4	Prayaga[148] et al., 2010	2010	Coastal beaches	Capricorn Coast, Queensland	Recreational fishing	TC	per trip/angler	167	
5	Farr and Stoeckl[149], 2018	2012	GBR coast catchment	GBR World Heritage, Queensland	Recreational fishing	TC	per trip/angler	441	
6	Rolfe and Dyack[150], 2021	2021	GBR	GBR, Queensland	Recreational fishing	TC	per trip/angler	295	
7	Rolfe[151] et al., 2011	2011	GBR	GBR Marine Park, Queensland	Recreational fishing, boating and sailing	TC	per trip/angler	183	
8	Kandulu[152] et al., 2021	2021	Saltwaters	Different regions and subregions, Queensland	Recreational fishing	TC	per trip/angler	183	

[148] Prayaga, P., Rolfe, J. & Stoeckl, N. (2010). The value of recreational fishing in the Great Barrier Reef, Australia: A pooled revealed preference and contingent behaviour model. Marine Policy, 34(2), 244-251. https://doi.org/10.1016/j.marpol.2009.07.002

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[150] Rolfe, J. & De Valck, J. (2021). Values for protecting the Great Barrier Reef: A review and synthesis of studies over the past 35 years. Marine Pollution Bulletin, 169, 112531.

[151] Rolfe, J., Gregg, D. & Tucker, G. (2011). Valuing local recreation in the Great Barrier Reef, Australia (Environmental Economics Research Hub Research Report 102. Canberra

[152] Kandulu, J., Bailey, H. & Magnusson, A., BDO. (2021). Economic contribution of recreational fishing by Queenslanders to Queensland: A Report for Fisheries Queensland. Fisheries Queensland

Table B.1: Cont.

Study ID	Study Author	Year valued	Habitat	Region/location	What is valued	Valuation method	Value measurement	Estimate (AUD)	Remark
8	Kandulu et al., 2021	2021	Saltwaters	Different regions and subregions, Queensland	Recreational fishing	TC	per trip/angler	56-76	
9	McLeod and Lindner[153], 2018	2018	Saltwaters	Western Australia	Recreational fishing	BT	per day/angler	178	
10	Carnell[154] et al., 2019	2019	Mangroves and Saltmarsh	Port Phillip, Victoria	Recreational fishing	CM	per trip/angler	13	
10	Carnell et al., 2019	2019	Mangroves and Saltmarsh	Western Port, Victoria	Recreational fishing	CM	per trip/angler	85	
11	Pascoe[155], 2019	2017	Coastal beach	Sydney, NSW	Recreational fishing	TC	per trip/angler	23.75	Recreational fishing as one of the of travel activities
12	Steven[156] et al., 2017	2016	Multiple birding sites	Conservation sites, Australia	Birdwatching	CM	per trip/person	105-135	Amount of bird diversity (medium 20-60 species and high >60 species) by quantity driven birders

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[153] McLeod, P. & Lindner, R. (2018). Economic dimension of recreational fishing in Western Australia: Research report for the recreational fishing initiatives fund. Department of Primary Industries and Regional Government and Recfishwest

[154] Carnell, P. E., Reeves, S. E., Nicholson, E., Macreadie, P., Ierodiaconou, D., Young, M., Kelvin, J., Janes, H., Navarro, A., Fitzsimons, J. & Gillies, C. L. (2019). Mapping Ocean Wealth Australia: The value of coastal wetlands to people and nature. The Nature Conservancy, Melbourne.

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[156] Steven, R., Smart, J. C. R., Morrison, C. & Castley, J. G. (2017). Using a Choice Experiment and Birder Preferences to Guide Bird-Conservation Funding. Conservation Biology, 31, 818–27.

Table B.1: Cont.

Study ID	Study Author	Year valued	Habitat	Region/location	What is valued	Valuation method	Value measurement	Estimate (AUD)	Remark
12	Steven et al., 2017	2016	Multiple birding sites	Conservation sites, Australia	Birdwatching	CM	per trip/person	18-36	Amount of bird diversity (medium 20-60 species and high >60 species) by special birders
12	Steven et al., 2017	2016	Multiple birding sites	Conservation sites, Australia	Birdwatching	CM	per trip/person	31-45	Number of threatened spp (medium, 1-3 and high, >3) by special birders
12	Steven et al., 2017	2016	Multiple birding sites	Conservation sites, Australia	Birdwatching	CM	per trip/person	18-66	Number of endemic spp (medium, 1-6; high >6 species)

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