Blue and Teal carbon potential in the Coorong, Lower Lakes and Murray Mouth

Task 1.1: Final report on stocktake, knowledge gap identification and metadatabase

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Sophie Russell, Alice R. Jones, Elliese Judge, Jade Teigeler and Sabine Dittmann

The CLLMM Research Centre has the objective of developing and delivering locally driven, innovative, and impactful research that reflects community and First Nations priorities to provide an evidence base to address critical needs of the CLLMM region. The CLLMM Research Centre will also bring together our First Nations, local community and scientists to create and share knowledge, and support our well-informed and engaged community and empower our future generations to be part of the solution.

The Goyder Institute for Water Research Coorong, Lower Lakes and Murray Mouth (CLLMM) Research Centre, based in Goolwa SA, was established in 2023 through funding by the Australian Government.

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Title page photo credit: Saltmarsh on Tauwitchere Island looking across to the Younghusband Peninsula (S. Russell 2025).

Enquiries should be addressed to: CLLMM Research Centre
Level 1, 92 Barrage Road
Goolwa, SA 5214
e-mail: info@cllmmresearchcentre.org

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Executive Summary

The blue and teal carbon project is a flagship research initiative within the Coorong Lower Lakes and Murray Mouth Research Centre's climate mitigation theme. This report documents the findings of Task 1, Objective 1.1 of the project, which involved a stocktake of existing knowledge, available data, and maps concerning the blue and teal carbon ecosystems in the CLLMM region. The stocktake also investigated the environmental drivers and threats impacting blue and teal carbon ecosystems in the region, and identified key knowledge gaps. The materials discovered through the stocktake, along with the resulting metadatabase and geospatial database, will support the remaining tasks being undertaken as part of the blue and teal carbon project.

Blue carbon ecosystems (e.g., saltmarsh and supratidal forest) and teal carbon ecosystems (e.g., freshwater wetlands) are crucial for mitigating climate change by sequestering and storing carbon. These ecosystems also provide extensive co-benefits, including supporting biodiversity and fisheries, protecting shorelines, and maintaining cultural significance for First Nations communities. The broader aims of the blue and teal carbon project are to establish the carbon abatement potential of these ecosystems in the CLLMM region, which include saltmarsh, supratidal forests, coastal sedges, and reed beds.

The stocktake compiled and assessed existing knowledge and spatial data relevant to the location of blue and teal carbon ecosystems, above or below-ground carbon stocks, sequestration rates, or ecosystem restoration within the CLLMM region. Data was sourced through expert elicitation, Google searches for grey literature, and a Web of Science search.

The stocktake discovered a total of 83 documents and 43 spatial data files, which were examined and summarised. The information was entered into a metadatabase (Excel file), and the spatial data was compiled into a geodatabase in ArcGIS Pro. The majority of information sources originated from state government or council reports, with relatively few sources derived from published scientific literature. The most consistent and long-term data available is from The Living Murray initiative's Lower Lakes Vegetation condition monitoring program (2008-2023 included here, but monitoring is ongoing as part of TLM program), which is focused on aquatic vegetation (i.e. teal carbon ecosystem) monitoring.

The stocktake identified 55 different vegetation habitats, grouped into 18 categories, including Reedbeds, Saltmarsh/Samphire shrublands, and various types of Wetlands. Though there is little existing data on soil organic carbon, what exists suggests that the highest concentrations occur within the surface sediments of the Coorong, and that poorly flushed parts of the system, such as the Coorong South Lagoon and Lake Albert, tend to have high carbon accumulation. There is no existing information on teal carbon stocks.

The project identified 42 threats, summarised into 29 classes, with the most commonly mentioned threats to blue and teal carbon ecosystems being altered hydrological regimes, salinity changes, and invasive species. The geodatabase contains 43 geospatial datasets, with the majority (23 layers) focused on soil properties that may influence carbon storage.

Despite extensive research conducted in the CLLMM region, particularly after the Millennium Drought, no targeted blue or teal carbon studies have yet been undertaken. Key data deficiencies that prevent reliable carbon stock estimation include significant spatial gaps in soil organic carbon sampling coverage across the region and a lack of above-ground biomass data for many species. The absence of targeted carbon studies and specific above-ground biomass data means that ecosystem-based carbon stock estimates cannot currently be made. To generate robust, fine-scale, region-wide estimates of future carbon opportunities, updated vegetation mapping and future projections of vegetation extent under varying conditions (e.g., sea-level rise and changing hydrology) are necessary. The new targeted data collection planned by this project is intended to address some of these gaps and lay the foundations for realising blue and teal carbon wetland restoration in the CLLMM region.

Acknowledgements

We acknowledge the cultural connections to the land and connected waters, as well as the cultural significance of waterbirds that exist between people of the Ngarrindjeri and Boandik Nations across the Coorong, Lower Lakes, and Murray Mouth region. We recognise that First Nations peoples' spiritual, social, cultural, and economic practices come from their lands and waters, and they continue to maintain their cultural heritage, economies, languages, and laws which are of ongoing importance. We are committed to fostering and nurturing ongoing relationships with First Nations communities in the CLLMM region as we collectively work toward healthy, resilient and thriving lands, waters, ecosystems and communities across the region.

This project was funded by the Goyder Institute for Water Research's CLLMM Research Centre, which is funded by the Australian Government. We thank the CLLMM Research Centre staff for project initiation, support and management. We thank the Goyder Institute for Water Research, Research Advisory Committee and two anonymous reviewers for constructive feedback on the report.

We would like to acknowledge the support of staff and students in the Future Coasts Lab at the Adelaide University, particularly Ashleigh Keneally. We are extremely grateful for the time and information provided by scientists working in the region and as part of the broader project team (especially Jason Nicol and Kerri Muller) and local experts, and restoration practitioners who provided reports and information. In particular, we would like to thank Richard Owen (Kumarangk Hindmarsh Island Landcare), Monika Rhodes (Alexandrina Council), Caroline Taylor (Landscape Hills and Fleurieu), Samantha Blight (Coorong District Council), Ben Taylor (Nature Glenelg Trust) and Sam Hardy (Murraylands and Riverland Landscape Board).

1 Introduction

The CLLMM Research Centre aims to investigate the impacts of climate change on the Coorong, Lower Lakes and Murray Mouth region with four main research themes: Climate adaptation, climate mitigation, ecosystem services, and threatened species and biodiversity. The Blue & Teal Carbon project is one of the flagship research projects under the climate mitigation theme and will also inform other themes.

Blue carbon ecosystems, like saltmarsh and supratidal forest, as well as teal carbon ecosystems, such as freshwater wetlands, can help mitigate climate change by sequestering and storing carbon. Additionally, these ecosystems offer a wide range of benefits, including supporting biodiversity and fisheries, protecting shorelines, and holding cultural significance for First Nations communities. The project aligns with strong community and management interests in wetland restoration and carbon offset opportunities.

The CLLMM region contains areas of both blue and teal carbon ecosystems, primarily saltmarsh, supratidal forests, coastal sedges, reed beds and other aquatic vegetation in freshwater wetlands. This project will establish the carbon abatement potential of these ecosystems and explore the further benefits of wetland restoration for people and nature through a combination of desk-top work, field investigations, workshops and training. Outputs will include an inventory and metadatabase of knowledge and data, maps, and reports. The outcomes from the project will lay the foundations for realising blue and teal carbon wetland restoration in the CLLMM region and adjacent wetlands.

The blue and teal carbon flagship project focuses on four main tasks:

1. **Task 1: Blue and teal carbon as a nature-based solution to climate change** – This task includes taking stock of available knowledge and existing data, identifying key vegetation types, detecting main environmental drivers enabling carbon sequestration in blue and teal carbon ecoystems, measuring carbon stocks at key sites, using space-for-time substitution, and identifying sites with the highest potential for carbon restoration outcomes.
2. **Task 2: Values and benefits of blue and teal carbon for First Nations Peoples** – This task will be managed and delivered through the CLLMM Research Centre in partnership with First Nations representatives.
3. **Task 3: Co-benefits from blue and teal carbon conservation and restoration** – To determine co-benefits, this task will evaluate the biodiversity of blue and teal carbon ecosystem sites in the CLLMM region with different ages of restoration or management history. A further co-benefit that will be assessed is shoreline and coastal protection by blue and teal carbon ecosystems, through comparisons of sediment accretion and wave attenuation.
4. **Task 4: Opportunities for blue and teal carbon** – This task will integrate the data and information from other tasks to identify blue and teal carbon opportunities in the CLLMM region. This assessment will also consider connectivity and the effects of sea level rise from climate change on blue and teal carbon ecosystems.

This is the final report for Task 1, objective 1.1: A stocktake of existing knowledge of blue & teal carbon in the CLLMM region and adjacent wetlands, available data and maps, and identification of key knowledge gaps.

2 Stocktake methods

2.1 Scope statement

For this stocktake, we compiled and assessed existing knowledge, data, and spatial data on blue and teal carbon in the CLLMM region and adjacent wetlands. We identified key vegetation types, habitats, and sites of carbon storage; determined the main environmental drivers and threats to these ecosystems; and highlighted knowledge gaps and priority areas with high potential for restoration to enhance blue and teal carbon outcomes.

The following criteria were used to constrain the information included in the stocktake.

Criteria for inclusion:

1. Studies must be focused on specific blue and teal carbon ecosystems within scope (e.g. reedbeds, saltmarsh, swamp paperbarks) in the CLLMM region
2. Studies must contain information or data relevant to above or below ground carbon stocks or sequestration (e.g. soil stocks/sequestration rates, vegetation biomass, distribution of vegetation, GHG flux)

OR

3. Studies must contain information relevant to the restoration of focal ecosystems in the CLLMM region (restoration methods used and areas restored, type of vegetation restored, etc.)

Data and information were discovered through expert elicitation (contacting known scientists, local and state government agencies and local restoration practitioners in the region for relevant information and contacts); Google searches for grey literature; and a Web of Science search of published scientific literature. The Web of Science search was last updated on 20/08/25 and used the following search terms:

(Wetland* OR swamp* OR saltmarsh* OR samphire* OR paperbark* OR reedbed*) AND (carbon OR blue-carbon OR CO2) AND (stock* OR sequestration-rate* OR accumulation OR capture) AND (Coorong OR Lower lake* OR Murray mouth OR southeastern australia)

The final Web of Science search produced 285 results, of which only one met the criteria for inclusion. In total, all searches acquired 83 documents and 43 spatial data files that were further examined.

2.2 Description of metadatabase

Documents identified during the stocktake had relevant information extracted and entered into the metadatabase (supplied as an Excel file named 'Appendix_1_ CLLMM_BTC_Task1_metadatabase'). The extracted information included details of the focal area, ecosystem and species in the source, as well as methods used and insights into threats, environmental drivers and knowledge gaps identified (Table 1).

Table 1:Summary of information extracted from documents included in the metadatabase.

COLUMN NAME	DESCRIPTION
Study ID	Unique identifier, number of documents in the metadatabase
Report/Resource title	Title of the document
Author/s	List of authors
Organisation/Institute	The organisation or institution that produced the document
Date of Publication	The document's date of publication
Dates of data collection	Dates of data collection, if relevant/mentioned
Location/s	Location of the study/data collection
Project Interest - Relevance to Blue and Teal Carbon research in the CLLMM region	How the document is relevant to understanding blue and teal carbon in the CLLMM region
Category	The category the topic of the document is relevant to (e.g. Plants, birds, soil, hydrology, etc.)
Methods	Methods of data collection/analysis
Threats mentioned	Threats to blue and teal carbon ecosystems or storage potential identified in the region
Environmental drivers	Environmental drivers which affect blue and teal carbon ecosystems or storage potential are identified in the region.
Vegetation types and habitat	Categories of blue and teal carbon were identified in the region
Species of interest	Notes on particular species mentioned or studied
Key findings	Summary of key findings in the document
Knowledge gaps/ Further research recommended	Any knowledge gaps identified or further research suggested in the document.
Associated spatial dataset	Number of an associated spatial dataset from or relating to the document, listed in the 'Spatial datasets' sheet
Reference	Document reference
Comments	Any additional notes/comments about the document
Grouping	Project or insititutional grouping that applies to multiple documents

Spatial datasets were also summarised in the metadatabase (in a separate tab called 'Spatial datasets', as well as being compiled into a geodatabase in ArcGIS Pro 3.5.1. Information extracted from spatial datasets included descriptions of the type and date of data acquisition, as well as identifying uses or interest for the project (Table 2).

Table 2: Summary of information extracted from spatial datasets included in the metadatabase and geodatabase.

COLUMN NAME	DESCRIPTION
Item no.	Number of the dataset in the metadatabase (referred to in the Summary of resources tab for corresponding documents)
Dataset title	Title of the dataset
Group	Grouping variable for the data set used in the map project
Dataset number	Reference number of the dataset externally (e.g. DEW dataset number)
Data type	Type of spatial data (e.g. raster, polygon, point, polyline)
Data description	Description of what the spatial data captures
Data authority	Owner of the dataset
Date last updated	Date that the spatial layer was last updated
Date initially acquired	Date that the underlying data for the spatial data was initially required/date the spatial data layer was created
Coverage	Extent of spatial coverage of the dataset
Project Interest	What relevance or use does the dataset have for the project?
Associated report in the 'summary of resources' tab	Reference number for the associated document in the Summary of resources tab in the metadatabase
Publicly available?	Whether or not the information is available for public download. Y = Yes, N = No

3 Metadatabase summary

3.1 Document summary & emerging findings

Most sources of information on blue and teal carbon ecosystems in the CLLMM region are from state government or council reports, with relatively few sources of scientific literature found within the defined scope of our searches. Information was dominated by studies and reports focusing on plants, with the least information available relating to emissions (Figure 1).

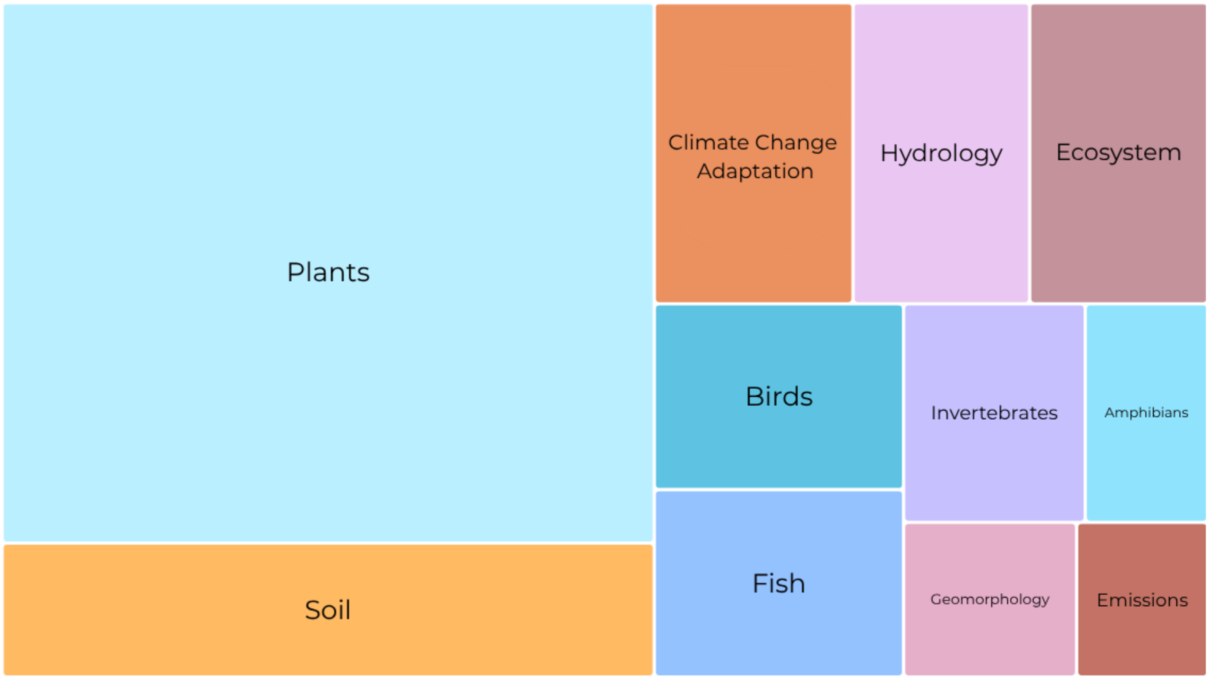

Figure 1: Focal area of information sources discovered through the stocktake. Size of block is proportional to the number of mentions in the metadatabase.

We identified 55 different vegetation habitats mentioned across all sources discovered through the stocktake (see 'Summary Stats tab in Appendix 1). These have been summarised into 18 higher-level groupings and are presented in Table 3. There were 22 environmental drivers identified through the stocktake as having the potential to influence blue and teal carbon ecosystems (Table A 2).

Table 3: List of blue and teal carbon ecosystems and vegetation types identified from the stocktake.

VEGETATION TYPES AND HABITATS - GROUPED
Algal groups
Aquatic and riparian plant communities/riparian and subtidal wetlands
Aquatic macrophytes/aquatic plant communities
Coastal wetlands
Dunes & dune shrublands
Emergents/Emergent freshwater/Emergent plant communities- Sedges/Emergent seed banks
Mudflats
Reedbeds
Saltmarsh/Saltmarsh grasses/Saltmarsh shrublands/Samphire shrublands
Scrublands
Seagrass
Sedgeland
Shrubland
Submergents/submergent freshwater/submergment aquatics/submergent seed banks
Supratidal
Supratidal sedgelands
Wetlands (including types: Ephemeral Brackish, Ephemeral Fresh, Ephemeral Saline, Permanent Brackish, Permanent fresh, Permanent Saline, Seasonal Brackish, Seasonal Fresh, Seasonal Saline) & swamps
Woodland Samphire Swamp

The most consistent and long-term plant data in the region is collected in the Lower Lakes Vegetation condition monitoring program funded by The Living Murray initiative of the Murray-Darling Basin Authority. This program was established in 2008 and has produced 14 annual reports to date from 2009 to 2023 (Marsland et al. 2009; Gehrig et al. 2010; Gehrig et al. 2011; Gehrig et al. 2012; Frahn et al. 2013; Frahn et al. 2014; Nicol et al. 2016; Nicol et al. 2017; Nicol et al. 2019a; Nicol et al. 2019b; Nicol et al. 2020; Nicol et al. 2021; Nicol et al. 2023a; Nicol et al. 2023b). Over the 15 years of vegetation condition monitoring across the Lower Lakes, >167 taxa were recorded, including 77 exotic species and one rare taxon. Vegetation patterns and community composition were strongly influenced by water level fluctuations, salinity, elevation, and management interventions following the Millennium Drought (1996–2010). During this drought period (pre-2010), submergent and aquatic vegetation largely disappeared, replaced by desiccation-tolerant terrestrial and weedy species colonising exposed sediments. The restoration of water levels in 2010 initiated a marked recolonisation of submergent, emergent, and amphibious plant communities, demonstrating substantial regeneration potential. However, species abundances and community structures generally remained below pre-drawdown levels. From 2013 onwards, monitoring showed a gradual and consistent recovery of aquatic vegetation, with an overall increase in native species richness and stabilisation of floristic composition. Recent surveys (2018–2023) indicate little change in composition, suggesting a new post-drawdown equilibrium. Spatial variability persists:

1. **Lake Alexandrina** remains the most species-rich habitat,
2. **Lake Albert** consistently supports the fewest taxa,
3. **Goolwa Channel** displays variable condition scores, likely due to wave action and fluctuating salinity, and
4. **Seasonal wetlands** show variable conditions reflecting hydrological differences.

Melaleuca halmaturorum populations have remained stable overall, with recruitment patterns influenced by elevation, water levels, disturbance, and competition. Overall, the condition of the Lower Lakes vegetation is rated in "Good" condition. There is evidence from the annual monitoring of ongoing gradual recovery since the Millennium Drought, though community composition differs from pre-drawdown conditions and remains sensitive to future changes in water regime and salinity management (Nicol et al. 2023b).

Existing soil organic carbon datasets for the CLLMM region have been compiled by Mosley & Thomas (2020), providing insights into spatial patterns of carbon storage. It remains unclear whether the Millennium Drought had any significant influence on baseline carbon stocks across the region due to a lack of targeted sampling before and after the event. The highest concentrations of organic carbon occur within the surface sediments of the Coorong, while a distinct carbon-rich layer was identified in Lake Albert sediments at depths greater than 50 cm. These findings suggest that poorly flushed systems, such as the Coorong South Lagoon and Lake Albert, tend to accumulate carbon in sediments primarily through organic matter deposition. The presence of peaty layers in certain sediment profiles was found to substantially influence local carbon concentrations, indicating historical periods of high organic matter accumulation. Overall, these data highlight both the potential for significant sedimentary carbon storage within the region's aquatic systems and the need for targeted, standardised sampling to improve understanding of spatial and temporal variability in blue and teal carbon stocks.

Numerous restoration projects have been undertaken in blue and teal carbon ecosystems in the Lower Lakes and Murray Mouth region, particularly focused on reedbeds and swamp paperbark forests (Australian National Parks and Wildlife Service 1984; Coorong District Council n.d.). These projects have primarily been active restoration through plantings and have created restored patches of different age classes, which allow for a space-for-time analysis of both carbon and biodiversity benefits.

There were 42 threats to blue and teal carbon ecosystems identified from the available literature (Appendix 1 – summary stats tab), which have been summarised/grouped into 29 classes in Appendix 2, Table A 1. Key themes that emerged were related to altered hydrological regimes, salinity and invasive species (see Appendix 1 - summary tab). These most commonly mentioned threats all have implications for future blue and teal carbon storage potential and will require significant planning and management to achieve the best possible outcomes for blue and teal carbon and biodiversity into the future.

3.2 Geodatabase summary

The geodatabase that we have generated from the available spatial data consists of environmental data that can be used in predicting carbon stocks in different ecosystem types as shown in Figure 2; as well as locations of existing data and reports, and sites identified as having restoration potential. All the spatial layers are listed in the spatial data tab of the Excel file supplied as 'Appendix 1 - CLLMM_BTC_Task1_metadatabase'.

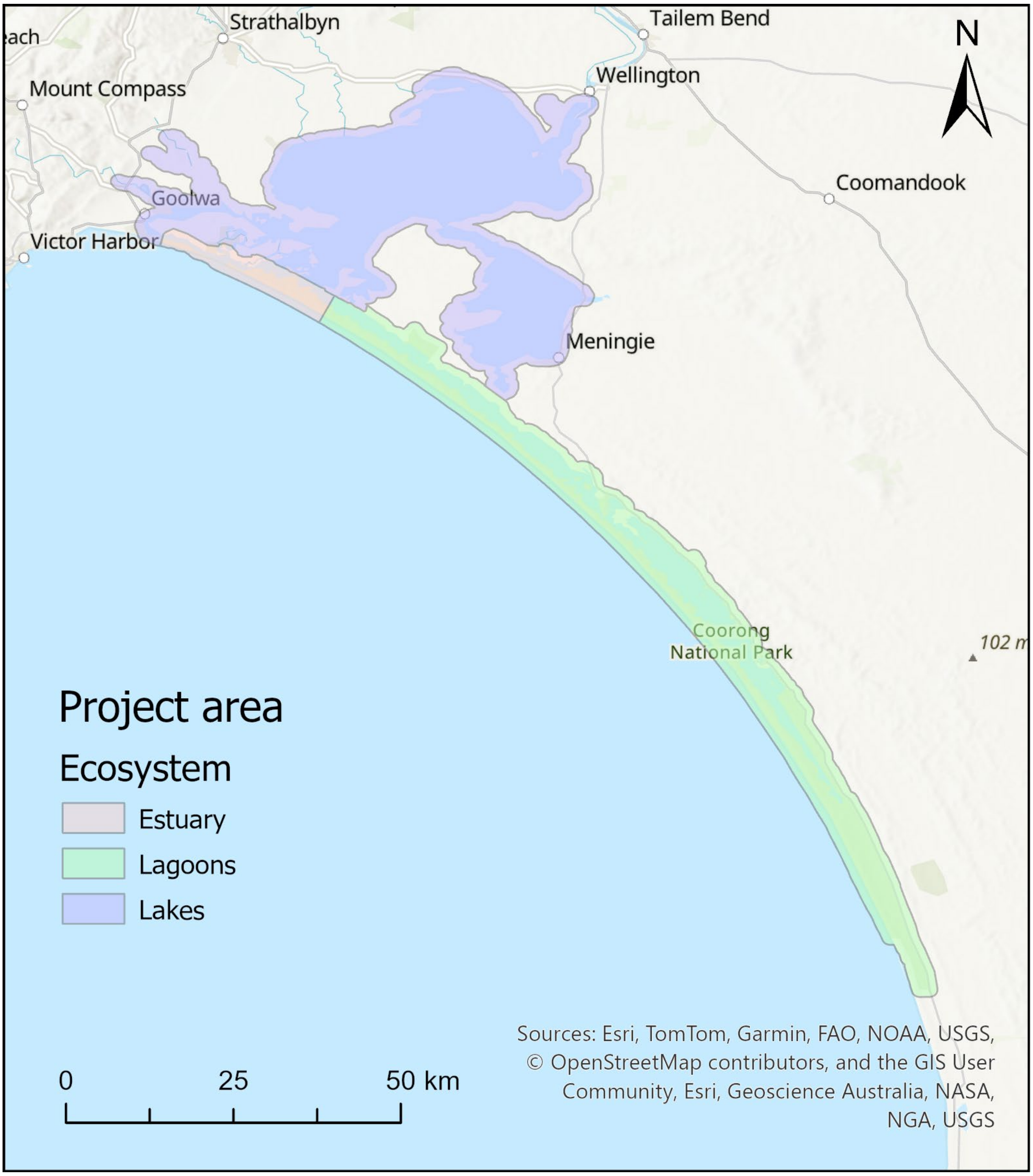

Figure 2: Map of the project area, coloured by broad ecosystem type.

The majority of spatial datasets represent various soil properties that influence carbon storage, either by directly affecting the capacity of organic matter to bind to soil particles or by influencing vegetation growth (Figure 3). Overall, we discovered 22 potential environmental drivers of blue and teal carbon processes through the stocktake (summarised in Appendix 2, Table A 2). We have sourced a total of 43 geospatial datasets related to both the blue and teal ecosystems themselves and the various environmental drivers that may influence them (Appendix 1 – spatial datasets tab). The geodatabase contains 23 layers on soil properties, four vegetation layers, five datasets from past research, including carbon stocks and locations of revegetation, four digital elevation datasets and several administrative and specific project-related layers.

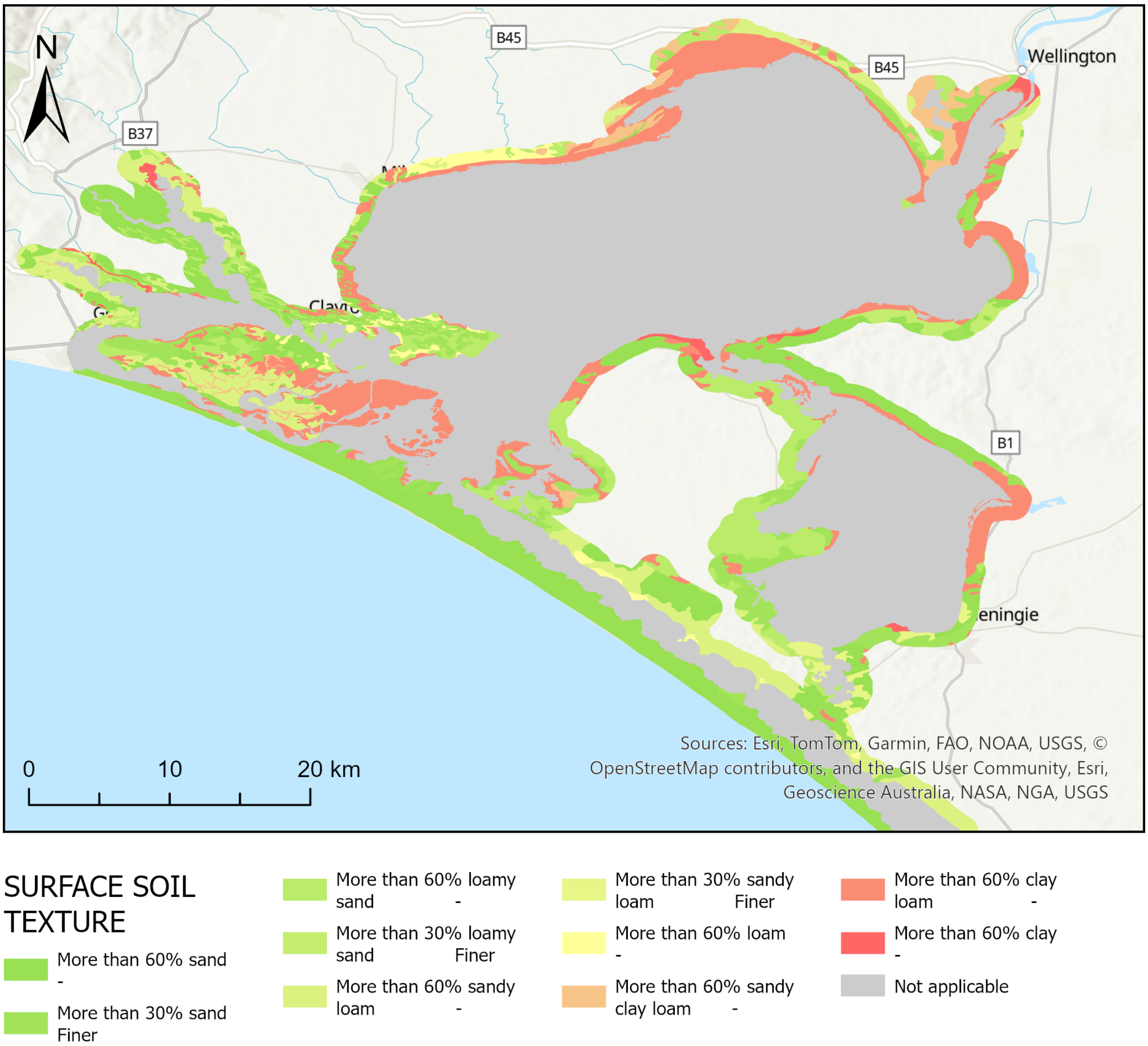

Figure 3: Map of the lower lakes and Murray mouth region showing an example of a dataset included in the geodatabase.

3.3 *Key knowledge gaps*

While extensive research has been conducted in the CLLMM region, particularly following the Millennium Drought and the subsequent increase in funding, no targeted blue or teal carbon studies have been undertaken. Mosley and Thomas (2020) identified significant spatial gaps in soil organic carbon sampling coverage. Above-ground biomass in the region is not available for many species. Without these data, ecosystem-based carbon stock estimates cannot be made, which are required for a region-wide understanding of current stocks and future opportunities. With the new targeted data collection being undertaken by this project, region-wide estimates can be generated using current spatial datasets. However, updated vegetation mapping and future projections of vegetation extent under sea-level rise and changing hydrology will be necessary for producing robust and fine-scale estimates.

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Appendix 1

Please refer to the supplied Excel file titled 'Appendix_1_CLLMM_BTC_Task_1_metadatabase'.

Appendix 2

Table A 1: Summary List of threats to blue and teal carbon ecosystems identified from the stocktake.

THREATS IDENTIFIED – GROUPED
Acid Sulphate Soils
Acidification
Agriculture/agricultural run-off/pesticides/eutrophication/nutrient concentrations, nutrient influx, nutrient load
Algal blooms
Altered hydrological regime, river regulation, management, barrage outflows, reduced freshwater inputs, reduced flow, reduced environmental flow, altered flow patterns, low water levels
Anoxia/anoxic sediments/low oxygen conditions/water quality
Barrage operation
Climate change
Declining groundwater levels
Desiccation
Development
Disconnection
Drought
Dune erosion, dune instability, dune retreat, vehicular dune damage/ wind erosion
Emissions
Erosion
Fire
Grazing
Habitat loss
Heavy metals/toxicity (chloride, boron)
Inundation (depth, duration, frequency)
Invasive emergent vegetation/invasive species
Over-extraction (water)
Salinity, salinization, altered salinity gradients
Sea level rise/seiching
Sedimentation/siltation/turbidity
Soil degradation
Species loss
Vegetation loss

Table A2: List of grouped environmental drivers affecting blue and teal ecosystems identified from the stocktake.

ENVIRONMENTAL DRIVERS IDENTIFIED - GROUPED
Climate, rainfall, temperature, winds
Coastal processes (winds, tides, tidal energy, influence, exchange, prism, wave action, attenuation)
Connection
Dune movement
Fire regime
Food web dynamics
Geomorphology, geomorphological processes
Groundwater levels
Hydrological regime, flushing, flooding, freshwater influence, environmental flows, supplemental flows, levels, depth, frequency, seasonal, evaporation
Littoral drift
Microbial abundance
Ocean flushes
Primary salinity
Sea level
Seasonality
Sediment deposition, organic matter accumulation
Soil type
Storms
Stratification
Succession
Terrestrialisation of shrubs in wetlands
Water quality