Report:

Blue Carbon in the Northern Territory, Australia

A review of the status and potential for blue carbon restoration

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Executive Summary

This literature review contributes to Phase I of the collaborative project 'Investigating blue carbon opportunities in the NT' (CDU, UQ & NAILSMA), which is co-funded by the INPEX operated Ichthys LNG. The objective of this review is to examine the applicability of the recently developed emissions offset methodology (Tidal Restoration of Blue Carbon Ecosystems Method, Australian Government, 2022), and consider additional methods that relate to coastal and freshwater wetland restoration and associated emissions.

The storage of organic carbon within vegetated coastal ecosystems (VCE), primarily seagrass, mangroves, tidal saltmarshes, coastal wetlands (Melaleuca swamps), and associated floodplain environments; and secondarily billabongs and freshwater wetlands, is high in comparison to many terrestrial ecosystems owing largely to their frequent inundation which slows down the oxidation and emission of carbon to the atmosphere. Collectively, these resources are referred to as coastal blue carbon (BC). Extensive (>1000) peer-reviewed papers have been published since 2009 to quantify the magnitude and stability of global BC stores. More recently, research has focused on the potential inclusion of BC in national carbon accounts for inclusion in Nationally Determined Contributions (NDC) arising from the Paris Agreement. Over 150 countries have at least one of the four BC ecosystems noted above, and approximately half of the countries have all four. Where degraded, these ecosystems can be managed to enhance their role as carbon sinks, reduce or avoid future ecosystem degradation thereby reducing emissions, and/or generate recognised carbon offsets that could count towards NDCs.

The Northern Territory (NT) has all three major BC ecosystems as well as Melaleuca swamps, which are considered BC ecosystems in the recently developed *Tidal restoration of blue carbon ecosystems method 2022* under Australia's Emission Reduction Fund. Its coastal areas are largely undisturbed and near pristine. The NT currently has ~40% of Australia's mangrove forests and saltmarshes, but its seagrass ecosystems are relatively less extensive and not well-studied. These BC ecosystems will experience increasing stressors in coming decades due to a combination of pressures including climate change, the impact of invasive species, and those arising from economic development.

We review the current and potential opportunities to manage BC resources in the NT to contribute to improved environmental and economic outcomes, including generating carbon credits. A review of published and grey literature was conducted, complemented by discussions with subject matter experts. While estimates of carbon storage are available, they are highly uncertain due to the limited NT-specific field data and research programs, and many differences in BC resources and management compared to the rest of Australia. Also unknown is the extent of degraded VCEs in the NT. Although the coastline is in good to near-pristine condition with limited degradation there are coastal regions experiencing severe impact and transitions (e.g., coastal Mary River catchment, grazing lands utilising barrages to support dry season grazing, degraded aquaculture sites).

Avoiding disturbance of soils and vegetation and their rehabilitation in coastal wetlands influenced by non-native ungulates is a new blue carbon method that will build on components of the abatement model developed in the "Tidal Introduction Blue Carbon Method." A draft method has been submitted to Australia's Clean Energy Regulator (CER) in August, 2022, and concerns avoiding disturbance of soils and vegetation and rehabilitating soils and vegetation of coastal wetlands influenced by non-native ungulates (Lovelock, 2021). The main activities proposed are removal or exclusion of non-native water buffalo, pigs, and potentially feral cattle to repair coastal wetlands. Avoided disturbance from these feral ungulates would result in reduction of various greenhouse gas emissions including NOx, N_2O, CH_4 and CO_2.

This review presents a contemporary overview of available BC data in the NT and identifies knowledge gaps that are essential for developing a BC market, and for progressing BC in opportunities in the NT. A preliminary review of areas potentially suitable for applying the current approved 'tidal reintroduction' BC method have been included though further research is required to determine their viability. Further investigation in these areas will occur following this review. The funding from this project will support progress in building partnerships with BC stakeholders, e.g., NT government, Aboriginal organisations, the Indigenous Carbon Industry Network, Aboriginal Land Councils, and pastoralists. Specifically, research activities following this review include:

1. Developing an understanding of stakeholder interest in implementing BC projects

2. Trade-off analysis and analysis of accrual of benefits to various stakeholder groups
3. Map areas of degradation and determine levels of anthropogenic vs. natural loss and gain
4. Map carbon hotspots across the coastal ecosystem types
5. Assessing emissions from wetland sites where non-native ungulates have been excluded

Introduction

Reducing global greenhouse gas (GHG) emissions is a major focus of international climate change mitigation efforts (IPCC, 2014). Global-scale action to address climate change and reduce CO_2 and other GHG emissions is coordinated under the United Nations Framework Convention on Climate Change (UNFCCC), which was formally established in 1992. Most recently, the 2015 Paris Agreement, signed by 195 government parties, set out clear and ambitious goals for countries to halt climate change to the maximum extent possible, and adapt to its effects wherever necessary. The conservation and restoration of natural carbon stocks is firmly established as a global priority and integrated into conservation and sustainable development agendas. The conservation of natural carbon stocks is embedded across the Paris Agreement, the 2030 Agenda for Sustainable Development, and the Strategic Plan for Biodiversity adopted under the Convention on Biological Diversity (CBD).

Net carbon emissions from land use change and ecosystem degradation were estimated at one Gigatonne of carbon (1 Gt C) per year between 1980 and 2009 (Ciais et al., 2013). This is the second largest source of CO_2 emissions after the burning of fossil fuels (Ciais et al., 2013), representing approximately 10% of the total anthropogenic carbon emissions. Achieving the 2°C global temperature target will therefore rely on effective planning and implementation of measures to reducing current CO_2 emissions from human activities and protect natural carbon stocks and sinks.

To date the private sector's activities relating to carbon have focused either on developing new technologies for low-carbon production processes, or on reducing direct emissions (Bourgouin, 2014; Climate Action Network, 2013). Despite their significant potential to contribute to meeting the 2°C global target, natural carbon sinks have received limited attention outside of the forestry and agriculture industries. Where they have been addressed, most activities have centred on carbon credits as offsets for GHG emissions (e.g., through national carbon tax models or the Voluntary Carbon Market).

Carbon dioxide is removed from the atmosphere, or 'sequestered', by plants through photosynthesis and stored in both their aboveground and belowground biomass (IPCC, 2006, Box 3). It may in turn be released into the atmosphere through land disturbance (e.g., due to fires, deforestation, or excavation of soils for coastal development for activities such as fish and shrimp ponds, agricultural fields; Denman et al., 2007). Globally, terrestrial ecosystems as a whole store between 2,850 and 3,050 Gt C in living vegetation, dead plant matter, and the top 2m of their soils ("green carbon") (Epple et al., 2016). This is equivalent to between 3.4 and 3.6 times the amount of CO_2 contained in the atmosphere. Mangroves, seagrasses, and saltmarshes together store between 11-25 Gt C. There are further, poorly quantified, carbon stocks in other marine systems (Epple et al., 2016). The physical processes through which CO_2 is sequestered are similar for both green and blue carbon. However, there are differences in the rates at which carbon is accumulated (Figure 1), the amount of time for which CO_2 is stored, and the speed at which it is emitted due to disturbance in terrestrial and marine environments. For example, when degraded, green carbon ecosystems rapidly emit CO_2 into the atmosphere, whereas in blue carbon CO_2 may be held within anoxic sediments. This is due to differences in the way carbon is sequestered – in green carbon, this occurs mainly in aboveground biomass, whereas in blue carbon it is sequestered and stored mainly in sediments.

Green carbon: *Commonly refers to carbon that is contained in living vegetation and soil in forest ecosystems of the terrestrial realm (Mackey et al., 2008).*

Blue carbon: *Carbon stored in coastal and marine ecosystems, such as mangroves,* saltmarshes, *and seagrass meadows (Murray et al. 2011).*

Serrano et al. (2019) investigated organic carbon (C) storage in three vegetated coastal ecosystems (VCE's), mangroves, saltmarsh and seagrass (also known as Blue Carbon Habitats), across Australian climate regions, estimating potential annual CO_2 emission benefits arising from restoration activities (Table 1). Australia VCE's store 5–11% of the C stored in all VCE's globally (70–185 Tg C in aboveground biomass, and 1,055–1,540 Tg C in the upper 1m of soils). Potential CO_2 emissions from current VCE losses are estimated at 2.1–3.1 Tg CO_2-e yr^{-1}, increasing annual CO_2 emissions from land use change in Australia by 12–21%. This demonstrates the gross potential of conservation and restoration of VCEs to contribute to Australia's national policy development for reducing greenhouse gas emissions. The NT coastal estate and ecosystems are unique in that they are extensive (1.48 million ha, Table 1), near pristine, and disturbance from economic development and population pressures are concentrated in a few locations. Saltmarsh and mangrove extent across the NT is 28% and 37% of the national estate, although seagrass communities account for only 5% of the area (Serrano et al., 2019). Similar proportional storage is reported for biomass and soil C storage (Serrano et al. 2019). The distribution of VCEs across the NT is provided in Figure 2.

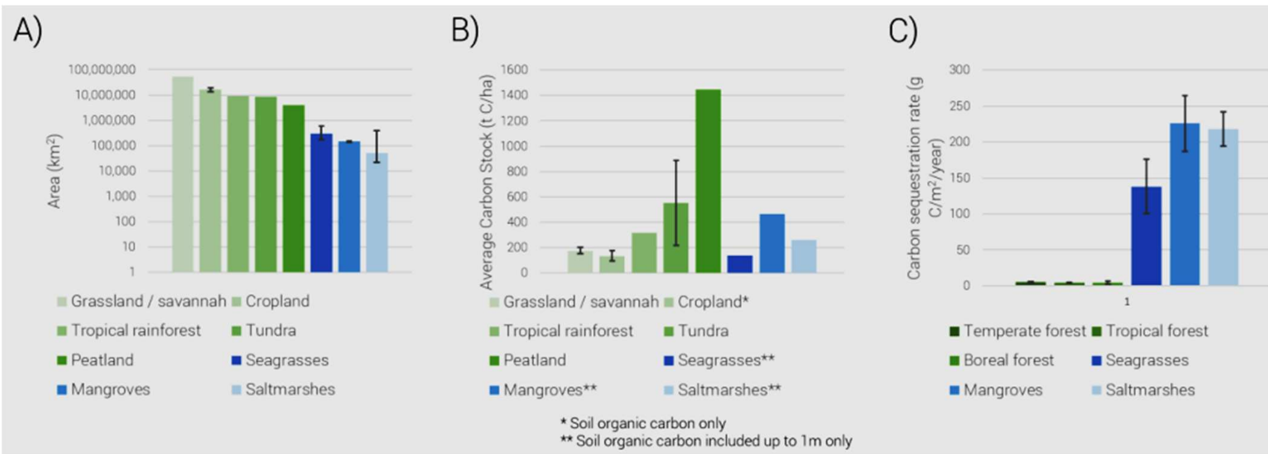


Figure 1. Variation among selected ecosystems important for terrestrial or blue carbon in estimated total global area (A – log scale); average carbon storage per area (B); and carbon sequestration rates (C) Error bars represent the range of estimates for A and B, and standard error for C. Sources: Epple *et al*. (2016) for A and B; Mcleod *et al.* (2011) for C (UNEP-WCMC Technical Briefing Note, 2018)

Aboriginal people own 85% of the approximately 11,000 km of NT coastline as inalienable Aboriginal freehold land (Northern Territory Government, 2019). Approximately 40% of the coast is managed as Indigenous Protected Areas which are voluntarily declared as a protected area for biodiversity and cultural heritage conservation. Most of the remaining coastal and intertidal areas are, or are likely to be, subject to non-exclusive native title land claims (Northern Territory Government, 2018), which mean Aboriginal rights of access and use may coexist with those of other stakeholders. Hence, Aboriginal rights and interests to coastal land are an integral influence on how NT coastal ecosystems will be managed in the future (Northern Territory Government, 2018; Northern Territory Government, 2019). An array of guaranteed rights are discussed in greater detail in the Land Tenure section, including that Native Title and Aboriginal land ownership necessitate that Aboriginal people, communities and their concerns are front and centre in any coastal carbon finance programs.

Table 1. Carbon storage in above-ground and soil pools, estimated sediment C sequestration rate and total area for Vegetated coastal ecosystem of the Northern Territory. Given the uncertainty associated with estimates of below-ground biomass, estimates are not available. Data taken from Serrano et al (2019). Values are Mt C.

Vegetated coastal ecosystem	*NT Area (ha)*	*National fractional - area (%)*	*NT Stock (Mt C)*		*NT Carbon sequestration (Mt C y^{-1})*
			AGB	Soil	Soil
Saltmarsh	428,038	28	4.3	65	0.15
Mangrove	384,679	37	63.5	89.4	0.58
Seagrass	666,629	5	0.34	26.3	0.17

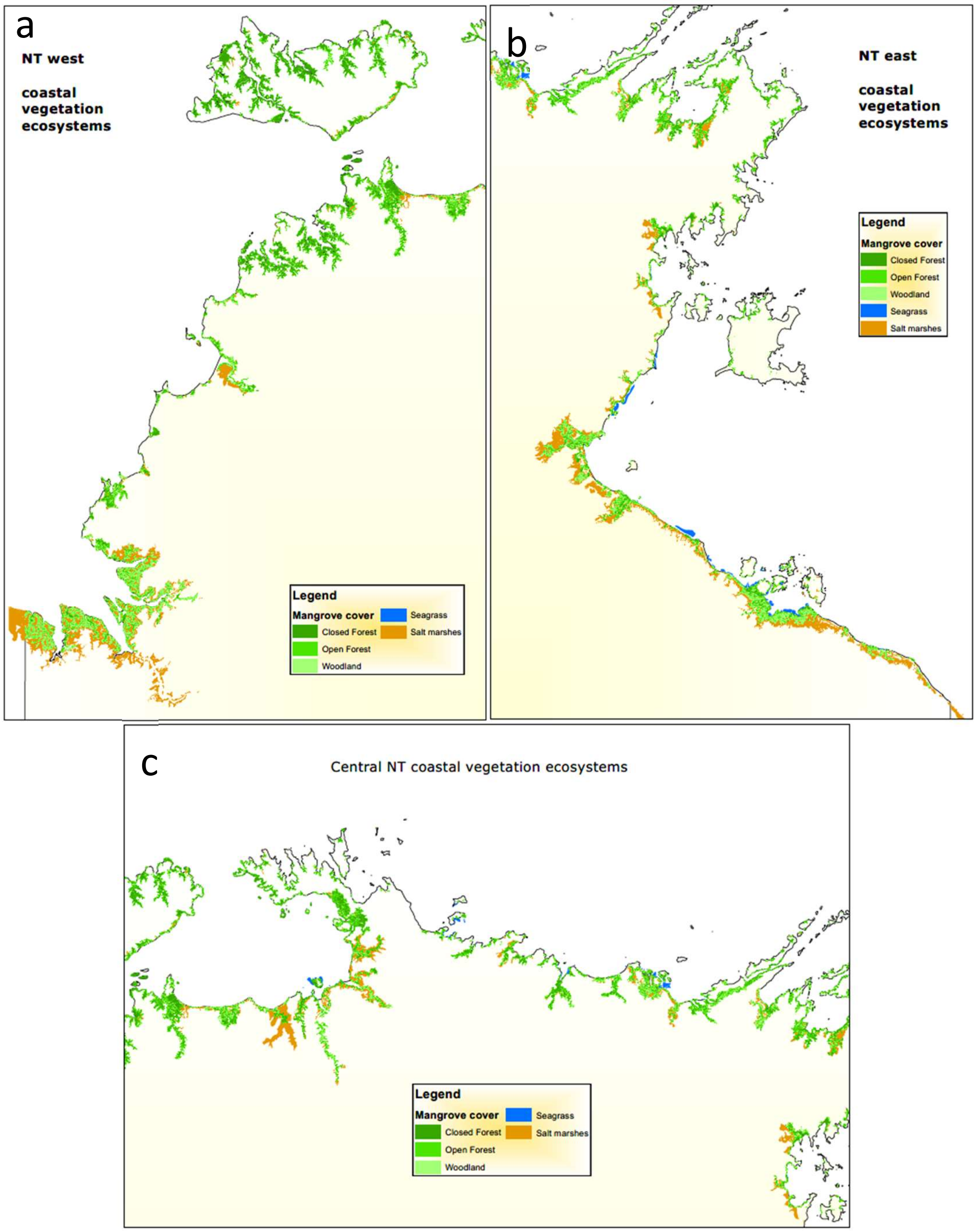


Figure 2. Distribution of vegetated coastal ecosystems across the NT. Panels map VCEs in a) western, b) eastern, and c) central coastal zones. Mangrove stands are stratified into classes (closed forest >80% canopy cover, open forest 50-80%, woodland 20-50%). Spatial data for all VCEs have been integrated into a National Ocean Account, compiled by the Australian Bureau of Statistics (https://www.abs.gov.au/articles/towards-national-ocean-account), and includes data on extent, biomass and estimates of sequestration using the BlueCAM model (Lovelock et al. 2022a,b). For mangroves, cover change and condition over time is also available. Saltmarshes include extensive high intertidal salt flats, or sparsely vegetated saltmarsh.

Objectives of this Review

The objective of this review is to examine the applicability of the recently developed emissions offset methodology (*Tidal Restoration of Blue Carbon Ecosystems Method, Australian Government, 2022*), or the Blue Carbon Method. Also in scope is an appraisal of opportunities associated with additional methods in development that relate to coastal and freshwater wetland restoration and associated emissions. The review provides a first step in the NT BC Project to understand the potential viability of a BC market in the NT and a necessary pathway for research and engagement for a market to develop in the NT.

This literature review contributes to Phase I of the collaborative project '*Investigating blue carbon opportunities in the NT'* (CDU, UQ & NAILSMA). Phase 1 consists of this review, a spatial assessment and identification of potential project sites. That will inform Phase 2 (Trade-off Analysis, Communication and Research Plan) and Phase 3 (Site Prioritisation and Applied Research).

Specifically, the review will:

- Develop an understanding of existing information on BC in the NT
- Determine coastal tenure of BC resources and how tenure interacts with potential projects and their relative risks and opportunities
- Spatially characterise and evaluate BC resources in the NT
- Determine areas of anthropogenic and non-anthropogenic (e.g., climate change) degradation, impacts to BC stocks and potential to implement BC projects.

This project is funded through the Ichthys Project Voluntary Offsets Agreement (IPVOA) between the Northern Territory Government (NTG) and INPEX Operations Australia Pty Ltd on behalf of the Ichthys Joint Venture Partners

Status of Blue Carbon Habitats in the Northern Territory

Mangroves

The mangrove communities of the Northern Territory are vast, totalling 384,679 ha (Table 1) and account for 42% of Australia's mangrove forests. They are floristically diverse containing 33 species of true mangroves and an additional 20+ species of ubiquitous mangrove associates (Duke, 2006; Wightman, 2006; Worthington & Spalding, 2016). The mangroves of the Northern Territory have been stratified into three major types based on hydrological and geomorphological setting: 1) Top End mangroves, 2) Bonaparte Gulf mangroves and 3) Western Gulf of Carpentaria mangroves (Duke, 2006). Of these, the Top End is more biodiverse and carbon-rich due to higher rainfall and largely estuarine locations than the fringing mangroves of the two gulfs (Duke, 2006). Darwin and Bynoe Harbours have the largest extent of the biomass of the Top End Region and are both nationally significant stands that are well studied when compared to other blue carbon communities of the NT (Munksgaard et al., 2019; Staben et al. 2020).

Application of a global biophysical restoration mapping tool depicts 16,003 ha of deforestation and 36,375 ha of degradation between 1996-2016 (Worthington & Spalding, 2016). The tool estimates the carbon stock of NT Mangroves at 5.92 Mt C comprised of 5 Mt C soil carbon and 0.92 Mt C of above ground carbon. These estimates are an order of magnitude lower than those compiled by Serrano et al. (2019) for the NT (Table 1) and highlight the need for region-specific estimates to reduce uncertainty and fill a clear knowledge gap. There are few point-based measures of VCE cover, cover change and biomass in the NT, especially in saltmarsh and seagrass communities.

Mangrove deforestation and degradation in the Northern Territory is small in area (Metcalfe 2007, Staben et al., 2019) and is driven by cyclones, coastal erosion, extreme ENSO events, disturbance from non-native fauna such as ungulates, infrastructure development, and moderate urbanisation with the latter two drivers dominating mangrove loss over the last 20 years (Munksgaard et al., 2019). More recently, losses and gains can be attributed to sea level rise and, above-average rainfall (Asbridge et al., 2016) and a major dieback event which occurred in the Gulf of Carpentaria in 2016 affecting mangroves in both the Northern Territory and Queensland (Abhik et al. 2021; Duke 2022). This die-off event has been attributed to extreme low sea level related to the El Niño Southern Oscillation (ENSO), low precipitation and an incidental "lunar wobble" (Santilan et al., 2022). The mangroves have shown limited signs of recovery and it is postulated that they may not recover, or recovery could be over decadal time scales, due to 1) sea level rise resulting in increased inundations periods at the coastal fringe and limited seed sources, 2) increased intensity of localized storms events, and 3) the threat of future Taimasa[1] low sea level events linked to more severe El Niño and La Niña events (Duke et al., 2022) with these processes potentially further amplified by an 18.61 year lunar cycle that contributes to extremes of the tidal range (Saintilan et al., 2022). The implications of this impeded recovery of mangroves after disturbance events on blue carbon programs is clear, in that it increases risk of failure in reforestation projects.

The ABS (2022) has estimated mangrove carbon stocks for the NT based on multiple attributes. Figure 3 shows the extrapolated estimates of carbon stocks (Million tonnes (Mt C)) and identifies the Darwin-Van Dieman Gulf-Tiwi region as having the highest amount of mangrove BC for the NT coastline. Estimates of stocks for mangrove have been calculated by Young, et al. (2021). These data were used to produce an average value of carbon per hectare of mangrove or seagrass, which was then applied to the extent data to produce spatial estimates of carbon stock (Mt C). Phase 3 of this project seeks to test the validity of the modelled outputs via multiple contrasting plots over a reasonable range of stocks.

[1] Taimasa is a term coined in Samoa describing the stench of dead corals following their prolonged exposure during extended periods of low sea levels that tend occur during El Niño phases (Duke et al., 2022).

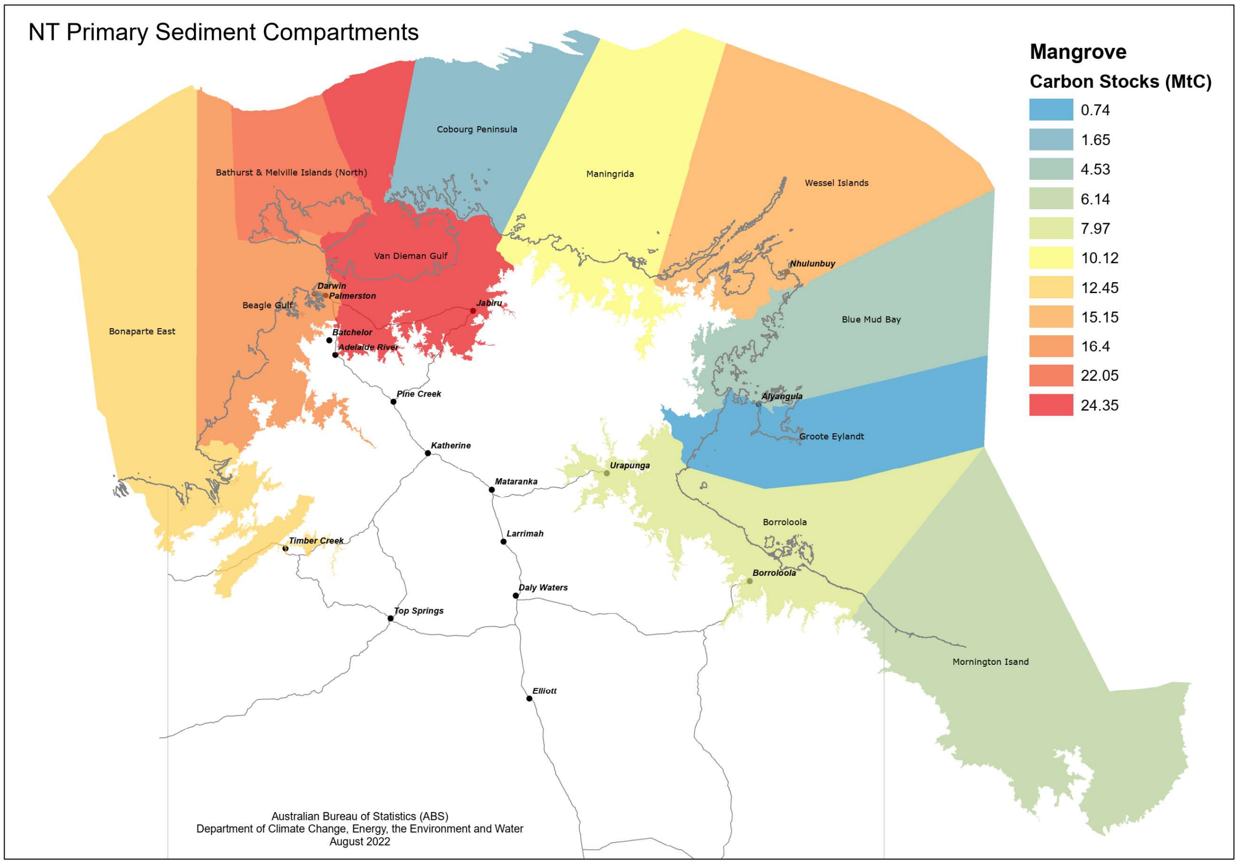
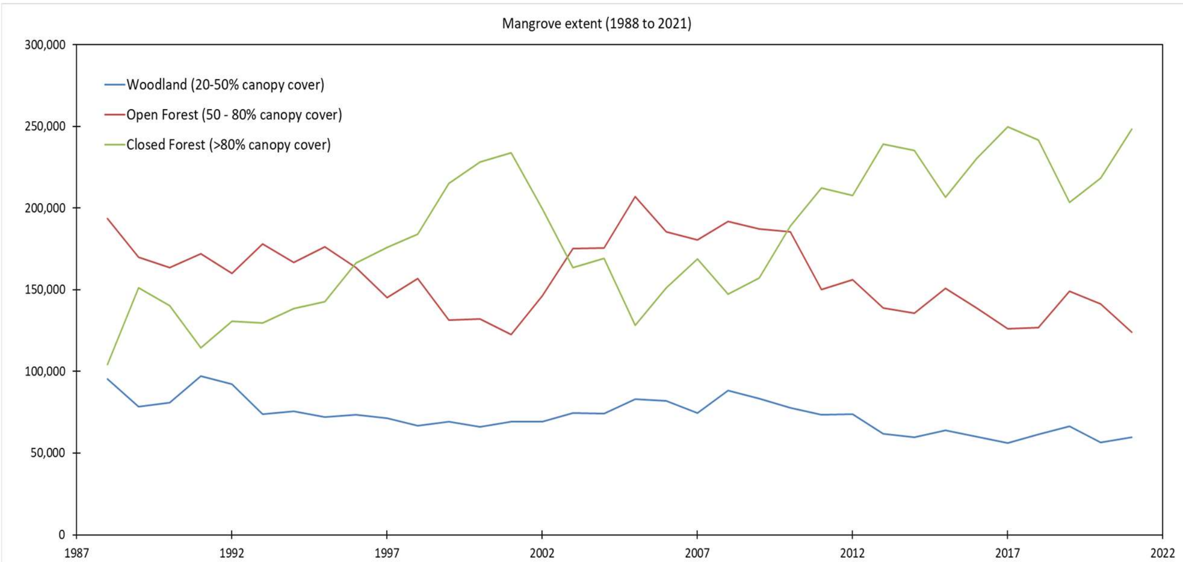


Figure 3. Modelled output of estimated mangrove carbon stocks based on biophysical attributes (e.g., primary sediment components, local geomorphology riverine catchment, aspect). Data derived from the ABS (2022) https://www.abs.gov.au/methodologies/national-ocean-account-experimental-estimates-methodology/aug-2022.

Across the NT coastline, mangrove extent was relatively constant over the last 32 years with a 12% net gain in area (Figure 3), despite the loss of mangroves in significant blocks across the Gulf of Carpentaria (Duke et al., 2022). These trends were derived from Landsat imagery (Lymburner et al. 2020) (Figure 4), although there are no similar data available for saltmarsh and seagrass ecosystems across the NT to examine stability of cover and extent.



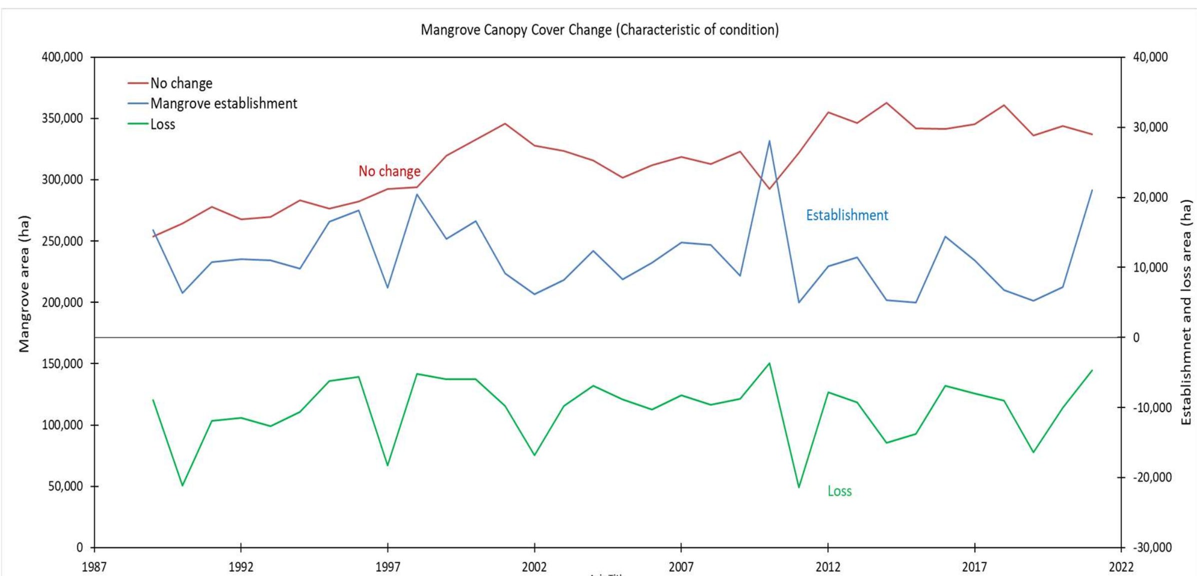


Figure 4. a) Mangrove extent through time partitioned by fractional green canopy cover classes, after Lymburner et al. (2020) that has been incorporated into the ABS database. Panel b) shows the mangrove area that showed no change in cover year to year (LH axis), plus the area of new mangrove establishment and loss (RH axis). The net change was +39,000 ha, ~12% of the estate area in 2021.

Saltmarsh

Saltmarshes occupy the high tide zone and include plants such as sedges, rushes, reeds, grasses, succulent herbs, and shrubs that can tolerate high soil salinity and occasional tidal inundation. Saltmarsh areas have low vegetation cover, often interspersed with bare patches or salt pans. Saltmarshes are important buffers and filters for pollutants and nutrients that enter the estuary, they reduce erosion, maintain water quality, and support a range of faunal species. They are a key component of estuaries and coastal landscapes and provide connectivity between freshwater to brackish to tidal and sub-tidal ecosystems.

The same high resolution of data for mangroves is not available for saltmarsh in the NT and biomass estimates are not yet available.

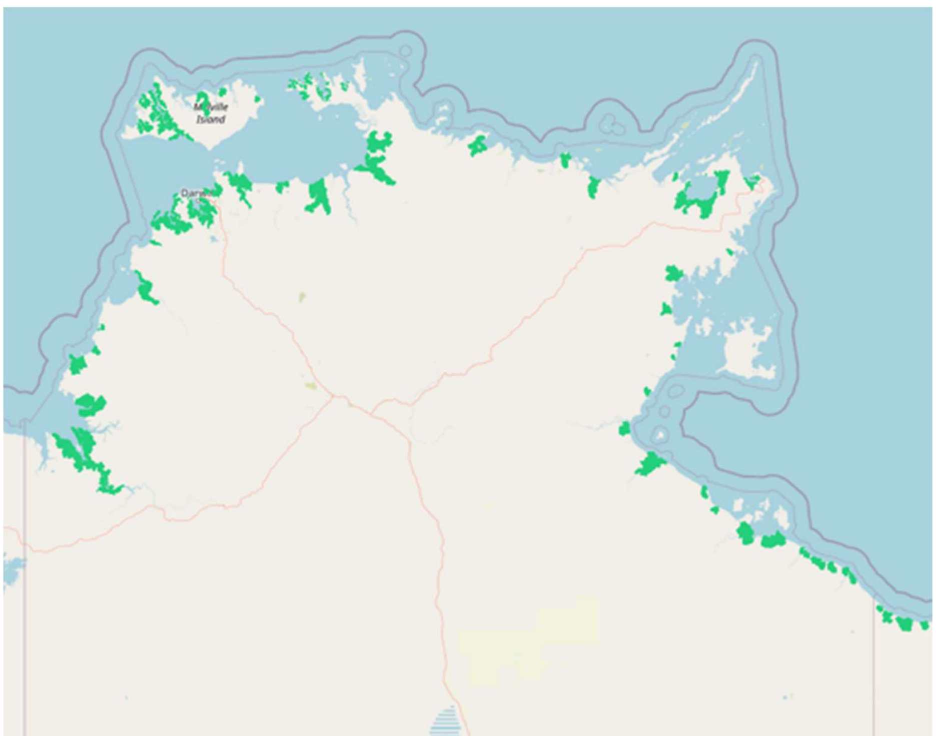


Figure 5. Saltmarsh occurrence across the NT, extracted from a global distribution map of saltmarsh (Mcowen et al. (2017), UN World Conservation Monitoring Centre). Data were collected using low resolution remote sensing and field-based survey methods and are not suitable for temporal analysis.

Australian saltmarshes cover an area of over 13,000 km², most of this coverage of saltmarsh is found in Queensland, Northern Territory and Western Australia, however, there is greater species diversity in Southern Australia. Figure 5 provides the extent of saltmarshes across the NT, an area that represents almost a third of Australia saltmarsh estate (Table 1) and stores ~70 Mt C. Nationally, over 30% of these areas are modified to some degree. It has been estimated that, since 1950, most estuaries in south-east Australia have lost over a quarter of the saltmarsh, with some estuaries losing up to 80 per cent. Recognition of the value of and threats to saltmarshes led to the listing of Subtropical and Temperate Coastal Saltmarsh Communities as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). As a result, any new or expanded development that impacts tidal marsh ecosystems will require an environmental assessment (Wegscheidl et al., 2017). Initially, interest in rehabilitating degraded saltmarsh sites has been motivated by establishing habitat for declining populations of migratory and resident shore and water birds (Purnell et al., 2015). In addition to their roles in filtering nutrients, improving water quality, and moderating flooding, saltmarshes and salt flats are also sources of materials to the nearshore that support fisheries.

Elevation is one of the main factors affecting the distribution of saltmarsh plant species and is an important consideration when determining rehabilitation success (Laegdsgaard, 2006).

Seagrass

Seagrasses are marine flowering plants (angiosperms) with a rhizome root system that anchors the plants into the substrate (as opposed to algae which attach to hard objects on the substrate) with reproduction via flowers during a reproductive season and/or asexually through the rhizomes (Roeloffs et al., 2005). This asexual reproduction can be important for the re-establishment and growth of seagrasses following disturbance (Roeloffs et al., 2005). Like their terrestrial counterparts, seagrasses have perennial and annual species which leads to dynamic communities of seagrass species with variable composition and density. Seagrasses are found in waters of most of the world's coastlines and are a key marine ecosystem in Australia, with large areas of seagrass reported through both tropical and temperate climates. Of the 72 species of seagrasses reported globally, approximately 10 species have been reported from waters of the Northern Territory (Carter et al., 2022; Seagrass-watch, 2022).

Seagrasses are distributed from intertidal waters, estuaries, tidal mudflats, shallow sandy regions to coral reef lagoons. Although most records are from the shallow intertidal zone to approximately 5m depth (the limit of light for photosynthetic activity), they have also been reported from deep water, up to -35m Mean Sea Level (MSL) in the Torres Strait (Carter et al., 2022).

Seagrasses often form meadows, which can be composed of a single species or can be a multi-species community. Within these meadows, the root systems trap sediments like the root systems of mangroves, which stabilises substrates and reduce suspended particulate matter, improving overall water quality. In addition, seagrasses are a critical food source for dugongs and green turtles and provide shelter for a range of animals, including many species of recreational and commercial importance (such as prawns).

Seagrass meadows are important sites of organic carbon sequestration and storage through the trapping and stabilisation of sediments by the root system accumulating soil carbon. Although the available seagrass distribution data is limited, especially within Australia, the prevention of seagrass disturbance and loss, combined with the (re-)establishment of seagrass meadows, could have relatively large impacts on the levels of blue carbon sequestration. A study in Portugal found that non-impacted seagrass meadows had three times the level of fine sediments (mud) within their sediment profiles compared to impacted sites, which led to 1.5 times increase in the level of organic carbon in undisturbed sites (Casal-Porras et al., 2022). Although seagrasses cover less than 0.2% of the ocean floor, it is estimated that they store at least 10% of the oceanic carbon (Duarte et al., 2005; Fourqurean et al., 2012).

Within Australia, known seagrass meadows cover approximately 125,000km^2, which equates to 15-43% of the global seagrass ecosystems (Kelleway et al., 2020), although there are large areas of coastline and deeper waters that have not been surveyed (Carter et al., 2022). Surveys of seagrass distribution in the waters of the Northern Territory have been conducted since the early 1980s, but with mixed methodologies and results (Roeloffs et al., 2005; Carter et al., 2022; Seagrass-watch, 2022). Approximately 75% of surveys for seagrass in the Northern Territory have occurred in shallow water along the coastlines (Commonwealth of Australia, 2007; Carter et al., 2022; Seagrass-watch, 2022), with most of the major Gulf systems (Gulf of Carpentaria and the Joseph Bonaparte Gulf), as well as along the northern coastline and the Arafura Sea, not sampled (or not sampled well). Carter et al. (2022) listed several surveys that have incorporated broad-scale baseline surveys around the Gulf of Carpentaria to targeted mapping and monitoring surveys in particular locations as both one-offs and over several years. Roeloffs et al. (2005; one of the broad-scale surveys listed in Carter et al., 2022) conducted a survey in the Van Diemen Gulf, from Goulburn Island to Castlereagh Bay along the northern coastline of the Northern Territory, and around the Gulf of Carpentaria in 2004. Seagrass-watch (2022) conducted a series of community-based surveys of seagrass in three locations at Mindil Beach, Casuarina Coastal Reserve and Glibb River (Melville Bay). No surveys of seagrasses appear to have been undertaken throughout the Joseph Bonaparte Gulf (Commonwealth of Australia, 2007) or around the Tiwi Islands, except for a mention of seagrasses being present on the northern coastline of the Tiwi Islands by Roeloffs et al. (2005).

The seagrass species within the Northern Territory appear to be dominated by *Halodule uninervis* and *Halophila* spp. (Carter et al., 2022; Seagrass-watch, 2022). Sampling season, however, may impact the composition of species, with annual species not being present during the senescent season (Carter et al., 2022). Additionally, the impact of annual variations, due to levels of rainfall, river flows, salinity, and temperature, is unknown, mainly due to the lack of long-term annual surveys across most of the Northern Territory. The community-based surveys (Seagrass-watch, 2022) conducted at Mindil Beach (2011-2013) and Casuarina Coastal reserve (2012-2013) showed an overall decline in percentage cover of seagrasses from an average of 12.6% to 4.5% and from 3.3% to 0.4%, respectively. The seagrass meadows at both sites were composed of the single species*, H. uninervis*, which increased its canopy height from 6.9cm to 7.4cm and 6.1cm to 7.2cm over the same period. Surveys in 2008 at Glibb River, Melville Bay, near Nhulunbuy, found around 11% cover with *Enhalus acoroides* which has a canopy height of 54.6cm to 69.4cm (Seagrass-watch, 2022). Annual assessments in Weipa, conducted for over 20 years (see Carter et al., 2022) have shown that cycles of daytime tidal exposure can have major impacts on seagrass meadow cover, with an understanding of the recovery responses of different species to various environmental factors unknown.

Extent of seagrass has been calculated using data from both Seamap.org and data from the Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) published on EAtlas. Seagrass data produced by TropWATER and sourced from EAtlas are used in preference to other sources of information. The scope of the TropWATER data includes the Great Barrier Reef, the Torres Strait, and the Gulf of Carpentaria. TropWATER data contains polygons describing the area of shallow water seagrass, as well as point data for deeper water seagrass. As it is not possible to calculate the area of the deeper seagrass from the point data, this has been defined as out of scope for the National Ocean Account. Because of this, the account will necessarily be an underestimation of total seagrass in Australian waters (ABS, 2022). Estimates of carbon stocks in seagrass have been calculated by Young, et al. (2021). These data were used to produce an average value of carbon per hectare of seagrass, which was then applied to the extent data to produce estimates of tonnes of carbon. Figure 6 shows the areas of documented seagrass habitats and their respective modelled Carbon value. The Gulf of Carpentaria is regarded as having the most extensive seagrass habitat in the NT. Other regions remain relatively understudied and unquantified.

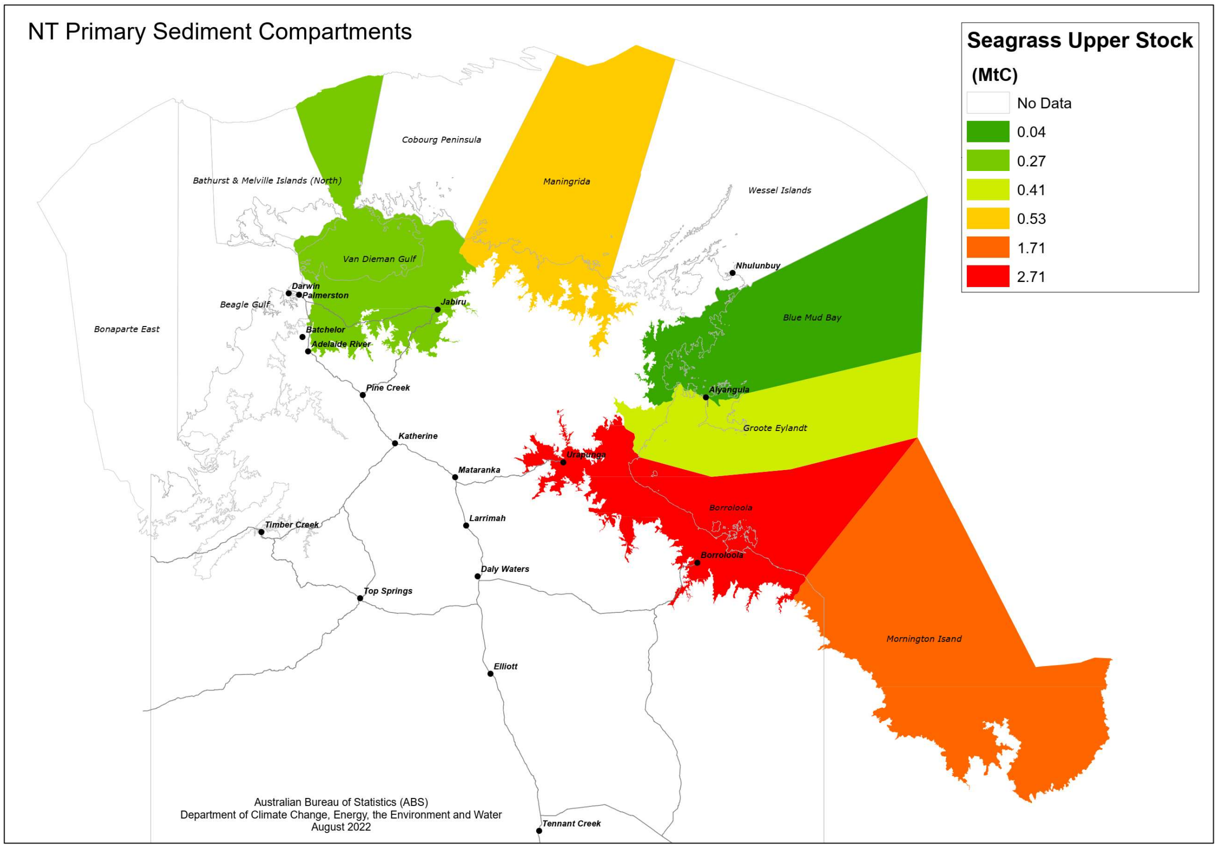


Figure 6. Modelled output of estimated seagrass carbon stocks based on validated seagrass data for the NT. Data derived from the ABS (2022) https://www.abs.gov.au/methodologies/national-ocean-account-experimental-estimates-methodology/aug-2022.ABS (2022)

Supratidal forests (Melaleuca)

Supratidal forests occur adjacent to intertidal saltmarsh and mangrove systems and are dominated by trees and shrubs of species of Melaleuca across northern Australia (UOW, 2022). Although there are over 200 species of Melaleuca, only a few species develop into trees which are known as paperbacks or tea-trees (ABARES, 2019). The restoration of tidal flows to coastal land can increase carbon sequestration through creating conditions that favour the growth and development of blue carbon ecosystems such as mangroves, saltmarshes, seagrasses, and supratidal forests. Supratidal forests are forests that are influenced by interactions among tidal water, groundwater, and rainfall and are typically dominated by Melaleuca and, Casuarina species. Melaleuca forests occur primarily as areas of low woodland forest across estuarine plains and seasonal swamps in the coastal and near-coastal areas of monsoonal northern Australia (ABARES, 2018; ABARES, 2019), with a total of 1 million hectares in the Northern Territory (ABARES, 2019). Within the Northern Territory, almost 81.5% of Melaleuca forests occur on land that is owned, managed or co-managed by Indigenous groups or land that is under native title or Indigenous land-use agreements (ABARES, 2018).

Melaleuca forests trap vegetation and debris deposited in coastal areas during floods and storms, which provides habitats for fish species, retains, and filters water and reduces soil and sediment run-off (ABARES, 2019). Additionally, in combination with the adjacent mangroves, these forests provide habitat (nesting and breeding) for many species, including birds, such as the great-billed heron (ABARES, 2019). The foliage of several species contains essential oils (known as tea-tree oil) that have medicinal and pharmacological uses, as well as some which have germicidal and antibacterial properties (ABARES, 2019). Melaleuca wood is also very durable in water and highly resistant to termites and has historically been used for marine pilings, framing and flooring (ABARES, 2019).

Australian supratidal forested wetlands are locations of high carbon sequestration and storage (Adame et al. 2020) and within the Northern Territory, almost 100% of the carbon calculated to be stored in forests and wood products was within non-productive native forests (in 2016), with 877 Mt C (ABARES, 2018). Non-productive native forests are native forests not available for or subject to forestry industry activity and are generally assumed to be in a state of equilibrium with the atmosphere unless exposed to disturbances and include forests of all species (ABARES, 2018). Soil carbon is the largest pool of carbon in many forests, followed by the living biomass of the trees and then the litter and dead wood above ground (ABARES, 2018). Input to and output from the soil carbon are affected by management activities, especially forest clearing, soil cultivation or wood harvesting, as well as bushfires (ABARES, 2018). Carbon stocks within all forests in Australia have remained relatively stable over the period 2001-2016. Loss of carbon occurred through clearing and conversion of forest land to other land uses, such as agriculture, as well as due to bushfire and drought-induced losses. This was balanced by recovery of carbon through regrowth of areas through expansion of native forests and commercial plantations as well as recovery from bushfires and drought. However, due to the amount of time required for trees to grow and mature, the length of the life cycle needs to be considered for calculating an overall carbon budget (ABARES, 2018).

Billabongs and freshwater wetlands

Billabongs are pools or lagoons of water in or near a creek channel (Finlayson et al., 1994). Although restricted in definition to ox-bow lakes elsewhere in Australia, billabongs in the Northern Territory generally can be any permanent or temporary water body near a creek (Hill & Webb, 1982; Walker et al., 1984; Finlayson et al., 1994). Billabongs and seasonal wetlands in the Northern Territory include many sites of importance to local Aboriginal peoples as well as for recreational fishing. There are generally three types of billabongs recognised in the NT: channel, backflow, and floodplain (Walker et al., 1984; Finlayson et al., 1994). Given these communities are inundated for at least 6 months of the year, they have similar biogeochemical characteristics to VCE in that they are anoxic and occupy low positions in a landscape, accumulating fine sediment over time, with high carbon organic sediment. Methane emissions are typically higher than saline tidal VCEs (Lovelock et al., 2022), and CO2 when sediment is disturbed. Link to ungulate method here as an addendum to the BC method, application in development, needs more RnD before it can be incorporated into the BC method.

Channel billabongs are formed in depressions of flow channels (Finlayson et al., 1994), are deep and have steep banks with coarse sediments and are generally associated with *Pandanus* sp. and *Barringtonia* sp. (freshwater mangroves) (Walker et al., 1984). Backflow billabongs are located on small tributaries of streams and are filled initially by water from the main creek (Finlayson et al., 1994). Backflow billabongs are generally shallow (1.5-2m deep), with shelving banks and fine sediments, and are fringed by Melaleuca forests and sedges (Walker et al., 1984; Finlayson et al., 1994). Floodplain billabongs are generally remnants of deep channels on flood plains (Finlayson et al., 1994) and can range from shallow to deep waters, although generally with steeper banks surrounded by a narrow fringe of woodland (*Pandanus* sp. and *Barringtonia* sp.) (Walker et al., 1984; Finlayson et al., 1994). Floodplain billabongs are characterised by the presence of floating mats which are made up of a mix of grasses, ferns, sedges, and herbs (Hill & Webb, 1982; Finlayson et al., 1994). The edge of the mat closest to the shore can be over 1m thick (Hill & Webb, 1982). Within the waters of the billabongs, different levels of stratification can occur, with some water bodies having anoxic sediments through to levels of continual mixing of dissolved oxygen (Walker et al., 1984). Independent of their source, billabongs are important refuges for a wide variety of animals through the prolonged dry season

(Walker et al., 1984). An example of seasonal swamps and freshwater wetlands are illustrated in the aerial image below (figure 7).

Figure 7. NT tenure and vegetated coastal ecosystems

Some billabongs form in areas below the high tide level and are only separated from potential saltwater intrusion by low natural levees (Hill & Webb, 1982). Over the years there have been dramatic changes in the vegetation associated with billabongs, with a decrease in the surface area of floating mats at the Bullcoin/Boolkine billabong on the Finnis River from 30% in 1963/64 to around 5% in 1978 (Hill & Webb, 1982). This decrease was suggested to be due to impacts from the feral water buffalo which grazed and trampled the edges of the billabongs, destabilising the levee banks (Hill & Webb, 1982). The importance of buffalo as sources of disturbance was supported by the increase in floating mats in billabongs along Magela Creek (Alligator Rivers region) following the removal of water buffalo (Finlayson et al., 1994). A further impact of the removal of buffalo, and increase in the cover of floating mat, was the increase in the level of silt deposition in the billabongs (Finlayson et al., 1994). Inland wetlands are the largest potential store of soil carbon, containing approximately 30% of the global soil pool (Carnell et al., 2016), which may indicate management of billabongs and negative effects of disturbance may have potential in the carbon economy.

Land tenure and governance

Overview

In the Northern Territory there are three types of tenure that exist within the coastal areas. Freehold land covered by the *Land Titles Act NT* also known as Torrens land, Aboriginal Land covered by the *Aboriginal Land Rights Act (Cwth),* and Pastoral Land covered by the *Pastoral Leases Act (NT).* Pastoral land is subject to Native Title. Figure 8 shows the NT coastal land tenure relative to the Vegetated Coastal Ecosystems.

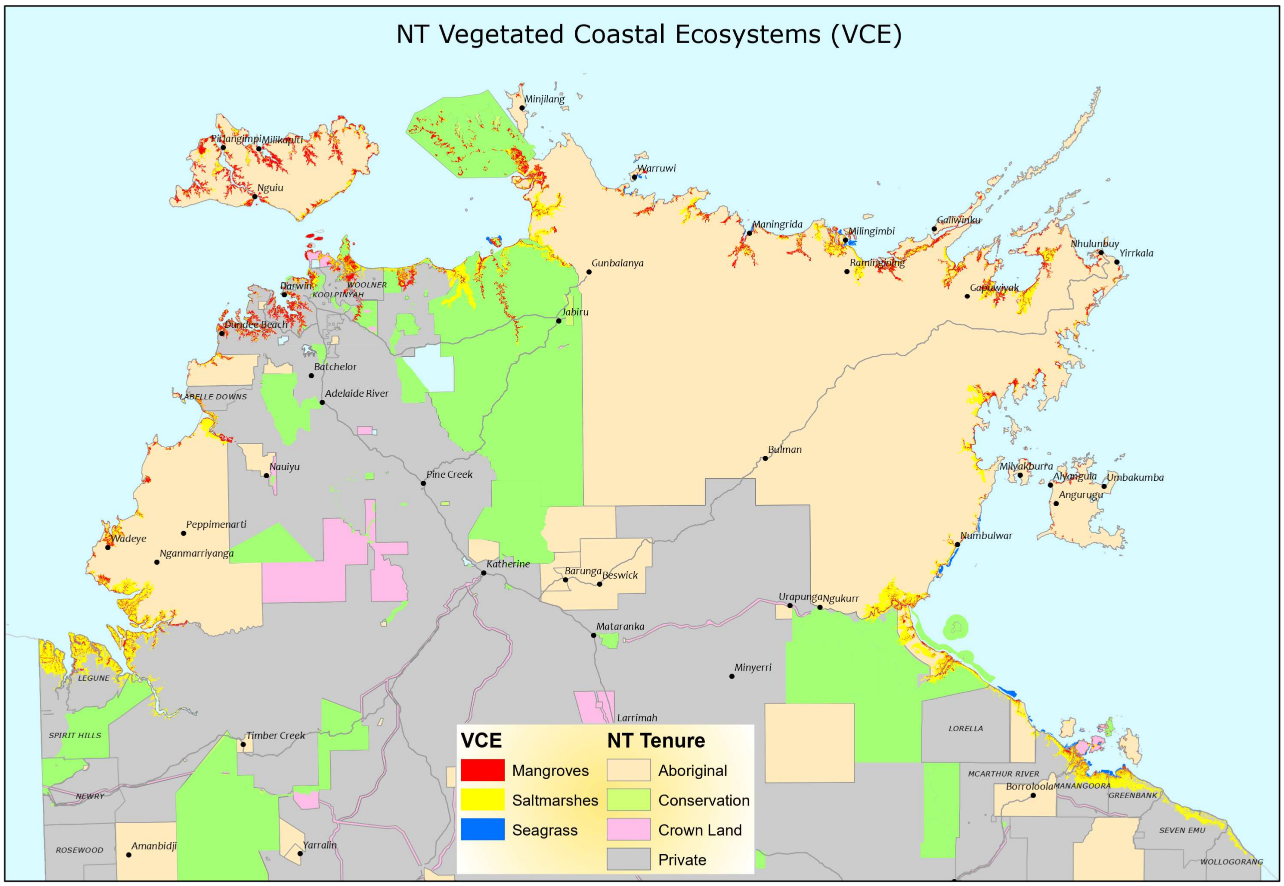


Figure 8. NT tenure and vegetated coastal ecosystems

Legislation and policy

Coastal vegetated ecosystems occupy intertidal, subtidal, and supratidal zones, which are often contested spaces from a legal perspective (Bell-James 2022); for example, mangroves often straddle the boundary between privately owned and state/territory-owned land, and seagrasses can exist beyond exclusive economic zones or within countries where state and national laws conflict. Consequently, in some countries, there is confusion related to land tenure and how it intersects with the blue carbon market, such as who ‘’owns’’ the blue carbon and who has the right to transact carbon credits for a given blue carbon project: the landholder, the project developer, Indigenous groups, or the national/sub-national government.

In Australia, a proponent of a blue carbon project must demonstrate their legal right to carry out the proposed eligible offset project on the sites or assets. This includes obtaining all consents from all eligible interest-holders (i.e., landowners) in the land over which the project will be established. This is discussed in detail in the Indigenous Carbon Industry Network (ICIN), Indigenous Carbon Project Guide (refer to https://www.icin.org.au/indigenous_carbon_projects_guide_downloads).

Native Title

Native Title is governed by the *Native Title Act (1993) (Cth)* and comes in two forms: non-exclusive possession and exclusive possession. The *Native Title Act (Cth)* gives rights to native title holders that are based in traditional laws and customs to the extent of the traditional law or custom, and include land, hunting and gathering, and fishing rights. (*Native Title Act*, s 233). Native title rights do not extend to minerals or petroleum and are limited to traditional resources such as ochre (Western Australia v Ward (High Court)). Native Title holders can create contractual arrangements in native title agreements restricting access to certain areas, (these are called ‘restricted areas’, or ‘no go zones’).

It is likely that an agreement made under the Blue Carbon direction would form the basis of a grant of a permit as an act that will affect native title and be classified as a ‘future act’. Exclusive possession native title rights are valued like freehold title and recognized in other forms of legislation such as *Carbon Credits (Carbon Farming Initiative) Act 2011.*

Native Title Engagement

Where a “future act” is proposed, the “future act” provisions of the Native Title Act must be complied with for that act to be valid. The process can be briefly summarised as requiring notice given to any native title parties. Once notice has been given, the Government, the native title party, and other parties to the agreement, (each a negotiating party), have six months to “negotiate in good faith with a view to obtaining the agreement of each of the native title parties to the doing of the act.” If an agreement cannot be reached within this period, any party negotiating can make an application to the National Native Title Tribunal (NNTT) for the matter to be arbitrated. The NNTT cannot make a determination about the payments that will go to native title holders, which means that native title holders are incentivised to reach an agreement with the other parties in order to secure financial benefits. Native title rights are not extinguished until a grant is made contrary to the rights being asserted, that is a claim to native title can exist over any land and sea country until it is formally extinguished e.g., converted into another type of inconsistent land tenure such as freehold land.

Indigenous Land Use Agreements (ILUA) under the Native Title Act (Cth)

An ILUA is a voluntary agreement between native title parties and other people or bodies about the use and management of areas of land and/or waters. An ILUA can be made over areas where native title has been determined to exist in at least part of the area, a native title claim has been made, or where no native title claim has been made.

While registered, ILUAs bind all native title holders to the terms of the agreement. ILUAs also operate as a contract between the parties (e.g., representatives, government, prescribed body corporate). There are three types of ILUAs, these include area agreements, body corporate agreements and alternative procedure agreements. An ILUA can be about any native title matter agreed by the parties, including settlement or exercise of native title rights and interests, surrender of native title to governments, land management, future development, mining, cultural heritage, coexistence of native title rights with other rights, access to an area, and compensation for loss or impairment of native title.

Land Rights Act

In 1976, the Parliament of Australia passed the *Aboriginal Land Rights (Northern Territory) Act 1976* (Commonwealth) (Land Rights Act). The Land Rights Act set up the first system in Australia where Aboriginal people could make land claims based on their traditional connections to land. Aboriginal land granted under this system was handed back by the creation of Land Trusts.

The Northern Territory coastline measures approximately 11,000 km, split roughly half and half between the coastal mainland and numerous offshore islands. Around 85% of the Northern Territory coast is owned by Aboriginal Traditional Owner groups (NLC, 2022; NTG 2019). Both the intertidal system as well as nearshore seas are important to the livelihoods of Aboriginal people living in remote coastal communities. In addition to the rights confirmed by the High Court in the *Blue Mud Bay* case, Traditional Owners of coastal regions (the traditional 'sea country' as well as adjacent wetlands and saltpan areas) maintain Native Title rights, exclusive access to closed seas, protection of sacred sites and management of Indigenous Protected Areas (NLC, 2022). Native title can exist on land rights land in certain cases. Because native title is about recognising rights and interests that already exist, native title can exist over land even if there hasn't yet been a determination of native title. For native title to be determined to exist, there must be a connection to the land by the native title claimants and there must not have been any 'act' that has extinguished native title.

The Land Rights Act also created land councils to help administer the land claims process and to manage leasing and land use on Aboriginal land. The Land Councils that would be engaged for Blue Carbon projects in the NT include the Northern Land Council (NLC), the Tiwi Land Council (TLC) and the Anindilyakwa Land Council (ALC). The Land Rights Act provides the legal framework for progressing social, commercial, and economic development activities on Aboriginal land on behalf of traditional Aboriginal owners. Most non-mining development activities on Aboriginal land require an agreement under Section 19 of the Land Rights Act. These are commonly referred to as section 19 agreements.

Section 19 Land Use Agreement under the NT Aboriginal Land Rights Act (Cth)

The number of micro-enterprises, private business, Government, and community development activities occurring on Aboriginal land has steadily increased over the last few years. The section 19 agreement process under the Land Rights Act gives traditional Aboriginal owners an opportunity to consider, develop terms and conditions and the right to consent to or reject proposals on their land and seas.

The Aboriginal Land Councils carry out consultations and negotiations on behalf of Aboriginal traditional owners with those interested in carrying out social, commercial, and economic development activities on Aboriginal land and waters. The land councils must ensure that any land use proposal is fair and equitable.

Multi-disciplinary teams within the councils, comprising of land use project coordinators, regional office staff, lawyers, and anthropologists, undertake a rigorous assessment of all land use proposals prior to going to consultation. As required, the councils will also engage external experts to assist with the assessment of land use proposals.

Using this process, Aboriginal traditional owners are given the opportunity to make an informed decision in accordance with their traditional decision-making processes. Affected Aboriginal people and communities are also given an opportunity to express their views in relation to land or water use proposals. Where informed consent is given, the council may direct the appropriate Aboriginal Land Trust to enter into a section 19 Land Use Agreement with the proponent.

Engagement

The time frame for an assessment of a section 19 Land Use Agreement expression of interest and the subsequent consultation with traditional Aboriginal owners can take a minimum of six months to progress if all information is provided in a timely manner. However, the time required to conduct consultations on section 19 Land Use Agreements will vary depending on the type of interest and the region. Third parties that seek an interest or a right to operate on Aboriginal land or waters are expected to bear reasonable costs associated with the delivery of the services associated with their expression of interest.

The Northern Territory Government (NTG) has developed an Aboriginal Land and Sea Action Plan (NT Government, 2019) to better coordinate Aboriginal land and native title matters across the NT, and ensure land and sea ownership delivers on the economic and social aspirations of Aboriginal people in the NT. The Action Plan contains 10 Actions the NTG intends to implement in partnership with Traditional Owners, Land Councils, the Commonwealth Government, and other affected stakeholders, to support natural resource management, economic development, and employment on Aboriginal land, all of which have linkage to potential blue carbon programs.

Sacred Sites

All sacred sites are protected in accordance with the *Northern Territory Aboriginal Sacred Sites Act (1989)*. Many sacred sites are registered in sea country and can be located above or below the water level. Authority certificates are required to permit access within close proximity to a sacred site, and there are strict criminal provisions for interference, desecration of a scared site. (*Northern Territory Aboriginal Sacred Sites Act (NT) 1989*) (NT Government, 2019).

Blue Carbon and land tenure

Under s23 of the *Carbon Credits (Carbon Farming Initiative) Act 2011 (Cth)* ('CFI')) and S13(L) of the Carbon Credits (Carbon Farming Initiative) Rule 2015 ('CFI Rule'), project proponents must demonstrate their legal right to carry out the proposed eligible offset project on the sites or assets and the exclusive lawful right to be credited all ACCUs generated from the project alongside their application to the Clean Energy Regulator (CER). The registration of a project under the Emissions Reduction Fund (ERF) does not establish an approval to undertake the activity. Rather, it simply establishes the eligibility to earn ACCUs in accordance with an approved methodology.

In establishing the legal right to carry out the project, proponents need to consider all stakeholders impacted by the project and obtain all consents from all eligible interest-holders and hold all required regulatory approvals for the project before they can receive ACCUs. In draft commercial agreements with stakeholders, project proponents must be transparent of their intention to undertake an ERF project and the legal right to carry out the project on the sites or assets must exist over a period that is not less than the stipulated duration of the crediting period e.g., 25 years.

Exclusive possession Native Title entails the right to possess and occupy an area to the exclusion of all others. As such, a registered Native Title body corporate can hold legal right on exclusive possession Native Title land. Non-exclusive possession is where Native Title co-exists with nonindigenous property rights such as a pastoral lease. In addition to Native Title rights, Indigenous people may hold other forms of legal interests in the land. These rights can be equivalent to a freehold interest (the Indigenous group owns the land). For example, the *Aboriginal Land Rights (Northern Territory) Act 1976* creates a right to inalienable freehold title based on traditional occupation. Appropriate consent and engagement process for legal right is required for all blue carbon projects.

For a blue carbon project, the two most applicable acts are the *NT Pastoral Leases Pastoral Act (NT)* and the *Aboriginal Land Rights Act (NT)*:

- *Pastoral Leases Pastoral Act (NT*) – a pastoral leaseholder is permitted to implement the following ERF methods: Native forest from managed regrowth, and human-induced regeneration methods, manage the timing and the extent of livestock grazing, manage in a humane manner, feral animals, management of plants not native to project areas, cessation of mechanical or chemical destruction, or suppression, of regrowth, estimating sequestration of carbon in soil using default values method and savanna fire management. If the lessee wants to undertake an activity that is not stipulated, they are required to obtain a non-pastoral use permit from the NT Pastoral Land Board before registering their ERF Project.

- *Aboriginal Land Rights Act (NT)* – all proponents wishing to register an ERF subject to this Act must provide evidence to the CER that legal requirements under the legislation have been satisfied. This includes registration of section 19 agreement negotiated between the proponent, and the relevant indigenous land council for the area, and all land trusts in the agreement.

Currently, there is no CFI Act requirement to obtain the consent of registered Native Title claimants, where the Native Title claim has not yet been decided. However, as a matter of best practice and relationship building, it is preferable to obtain the consent of Native Title claimants as well as Native Title holders before carbon projects are registered, based on the group's applicable decision-making process (ICIN 2020). Failure to engage with registered native title claimants at the time of project registration may present a risk to projects if a claim is later determined while a consent condition under s 28A of the CFI Act is in place on the project declaration.

After project registration under the ERF and the declaration of registration is received, to generate ACCUs the project must be run according to the methodology. In the NT, BC projects will likely occur on pastoral or (more likely) Aboriginal-owned land. To complete a project, permission must be granted by landowners, either from the pastoral board or through people identified through S19 or ILUA. Most of the NT's coast is owned by Aboriginal people which extends to the mean low water mark, this coastal zone is also where all intertidal vegetated coastal ecosystems inhabit which places Aboriginal landowners in a strong position to benefit from BC projects.

Coastal management and NT Aboriginal communities

Coastal Management and Indigenous Protected Areas (IPAs)

Australia has taken a progressive approach to engaging Indigenous communities in coastal management through indigenous-led planning and collaborative governance of "Sea Country," coastal lands and waterways including Indigenous Protected Areas (IPAs) based on the Indigenous concept of "Country" (Commonwealth of Australia, 2019; Rist et al., 2019). This approach has enabled Indigenous People to lead planning and governance of land and sea areas, the control of which was previously limited. For example, national and marine parks exemplified in the Dhimurru IPA in the Northern Territory and Girringun Region IPAs in Queensland (Rist et al., 2019).

Indigenous Protected Areas occur across Australia have steadily grown in recent years and there are now more than 90, including numerous Sea Country IPAs located in northern tropical Australia. The annual cost of Working on Country and IPAs in Australia (approximately $67 million in 2012-13) represents just 0.2% of the estimated $30.3 billion spent by state and territory governments on Indigenous services nationally (SCRGSP, 2014). Despite this relatively small share of funding, Working on Country including Sea Country IPAs are delivering significant social and economic benefits to Aboriginal individuals, communities and the Commonwealth of Australia (van Bueren et al., 2015).

In April 2021, the Australian Government committed $11.6 million under the $100 million Oceans Leadership Package to the Sea Country Indigenous Protected Areas (IPA). The program will operate in 10 Sea Country IPA's across Australia, seeking to increase the area of sea in IPAs to strengthen the conservation and protection of Australia's unique marine and coastal environments, while creating employment and economic opportunities for Indigenous Australians (Australian Government, 2021). Following the 2022 Federal Election, the new Australian Government committed to 'doubling the Indigenous Rangers program, boosting funding for Indigenous Protected Areas by $10 million a year" (Labor, 2022).

On-Country Management (NT)

Being "on-Country" and "Caring for Country" has demonstrated ecological benefit and positive health impacts through healthier diets, more exercise and enhanced family wellbeing and spiritual connection (Burgess, et al. 2009; David et al. 2018; Kingsley et al. 2009; Wright et al. 2021). The *Native Title Act, 1993* and various state land rights and cultural heritage regimes regulate access to, and activities undertaken on, Country and are meant to uphold and protect rights of Aboriginal and Torres Strait Islander peoples, based on their ancestral relationship and traditional customs. Native Title, however, does not provide for other beneficial social and economic development and commercial opportunities, limiting the potential for autonomy and use of Country as the community desires (AHRC 2009; Altman, Buchanan & Larsen 2010).

Despite the ongoing adversity for most Aboriginal communities and ranger groups, there has been extensive efforts to development impactful management plans that represent Aboriginal community values and concerns. Sea country, Healthy Country, and IPA Management Plans provide the framework for on-country implementation of management activities. An example is the Healthy Country Plan 2017-2027 led by Arafura Swamp Rangers who work together across community, clan and language boundaries to protect Aboriginal culture, knowledge and ecosystems across 1.2 million hectares of ancestral lands in East Arnhem Land (ASRAC, 2017). Plans such as the ASRAC's Healthy Country Plan already consider and address issues focal to this literature review such as carbon project development and implementation (fire management) and feral animal management including ungulate control. With regards to non-native ungulate control, participatory eco-cultural research was undertaken in the Southeast Arnhem Land Indigenous Protected Area where Traditional Owners were concerned about feral ungulates trampling and consuming traditional bush food resources and reducing water quality, affecting eco-cultural values of billabongs. Indigenous ecological knowledge (IEK) and Western science were used to investigate the issue, the former revealing that feral ungulates exacerbated disturbance in the dry-season resulting in long term degradation of billabongs (Russell et al., 2021). Over a ten-year period, buffalo populations were reduced by half through musters, culls, and safari businesses, with a local butcher providing cheap, healthy fresh meat for community. Sacred sites (cultural-ecological) are also protected from non-native ungulates such as pigs under the Healthy Country Plan.

There are 18 coastal ranger groups, seven of which are managed by the NLC, one by the Anindilyakwa Land Council, one affiliated with the Tiwi Land Council and other groups are independent (e.g., Dhimurru, Djelk, li-Anthawirriyarra) and emerging. Capacity of Aboriginal and Torres Strait Island ranger groups across northern Australia has increased significantly in the last decade with many groups now leading their own monitoring and management of country. Several groups conduct fee-for-service contracts with state and territory governments and work in partnership with researchers. The management of carbon projects has become core business for many groups. As groups continue to become more empowered with increased capacity, a whole of project management approach is feasible. Supporting groups to engage in the BC industry and acquire ACCU for trading on their terms, beyond fee for service work, would deliver to the on-ground aspirations of many groups.

Indigenous-led climate change adaptation

Extreme environmental events will increase under climate change predictions. There will be multiple adverse impacts on Aboriginal and Torres Strait Islander communities, exacerbating already disproportionate levels of ill health, stress, and hardship. Colonisation created disparities in health and wellbeing between Aboriginal and Torres Strait Islander and non-Indigenous Australians through dispossession of traditional land and waterways, suppression of culture and disempowerment. Climate change is compounding these historical injustices, increasing inequities and feelings of powerlessness as communities despair over the desecration of their land-, water- and sea-scapes (Howitt et al. 2012; Jones 2019; Whyte 2017). Indigenous peoples in Australia exhibit a high level of agency via diverse approaches to climate adaptation (Nursey-Brey et al. 2019) (Table 2).

Table 2. Examples of Northern Territory and Aboriginal and Torres Strait Islander Climate Change and Adaptation Initiatives (adapted from Nursey-Brey et al. 2019)

Examples	Description
Girringun co-leading research network	The National Climate Change Adaptation Network (NCCARF) hosts the Social Economic Institutions Research Network, within which there is a specific Indigenous theme. This theme is co-led by Girringun and encourages the involvement of other Indigenous groups in NCCARF activities.
NAILSMA Climate projects	The Northern Australian Indigenous Land and Sea Management Alliance, develops climate projects for Indigenous groups across northern Australia. It is a wide network that involves researcher, traditional peoples, policy makers in collaborative projects. NAILSMA has been actively involved in a wide range of climate projects.
Torres Strait Climate Change Strategy	The TSRA's Coastal and Climate Change Theme was established in 2007 by the Land & Sea Management Unit (LSMU) and has developed the Climate Change Strategy 2010-2013: "This Torres Strait Climate Change Strategy provides our region with a guiding framework and action plan so we can proactively address current and potential impacts by identifying the range of priority responses required based on sound scientific research and community involvement".
Miriwoong Climate Calendar	The Miriwoong people, Northern Territory, are developing a climate adaptation tool using traditional ecological knowledge based on the weather and observed environmental change. This resulted in an interactive seasonal calendar, showing ongoing and future weather patterns, and help ensure younger generations can adapt to those changes.

Tiwi Climate Science Project	This programme, aimed to increase the engagement of the Tiwi Islander people, Northern Territory (NT) with climate change science; was developed in response to many natural resources being threatened by climate change, upon which Tiwi livelihoods are dependent.
Dhimurru and Yirrkala Ranger outreach activities	Dhimurru and Yirralka Rangers from North-East Arnhem Land have also been working with their local schools to deliver the Learning on Country programme module on understanding climate change and its effects on seasons and the abundance of natural resources. In this programme, Elders take students to some key areas around Nhulunbuy sharing cultural stories about important sites, sea-levels, tides, seasons, and changes to the landscape through song and dance.
Kakadu National Park Climate Change Strategy 2010–2015	And adaptive collaborative management tool co-developed in Kakadu with the Bininj/Mungguy people.

Carbon projects and climate change mitigation and in the NT

The Northern Territory Government has developed a strategy to support the continuation and development of greenhouse gas emissions abatement and carbon sequestration on Aboriginal Land. Australia's carbon markets continue to grow and include national schemes, state and territory government schemes, and the capacity to earn international carbon units (CER, 2022). This rapidly evolving industry relies on the Commonwealth Government providing financial incentives for landowners and businesses to reduce greenhouse gas emissions. The Northern Territory has an advantage over many other jurisdictions as many carbon abatement projects will occur on remote, undeveloped, or under-managed land, with little or no existing infrastructure.

For a carbon offset project to commence, applications must be made to, and accepted by, the Clean Energy Regulator (Bell-James, 2016). For the project to be accepted, the proposer of the project does not need to own the relevant land on which the project is occurring but will need the written consent of any relevant 'eligible interest' holder (Bell-James, 2016). Thus, any potential projects occurring in the Northern Territory on Aboriginal land will require their informed consent under a section 19 land use agreement (nlc.org.au). An additional consideration for the project and consultations will be the length of time over which the project will have to run. The ERF requires carbon offset projects to have a degree of permanence, which relates to the longevity of the carbon stock, which is assumed to be for more than 100 years (Bell-James, 2016). At the time of application, the proposer can choose either a 100 year or 25-year permanence period; if the 25-year period is chosen, the number of credits issued are discounted by 20% (Bell-James, 2016). For both periods, a further discount of 5% is applied as a 'risk of reversal' buffer as a safeguard against potential failure of the project (Bell-James, 2016).

At present there are 47 climate mitigation projects under the ERF currently registered in the NT, with the Savanna Burning methodology the most widely adopted (32 projects). These savanna burning projects provide a net abatement of ~8.4 Mt CO2e yr-1 (CH4 and N2O only). A range of co-benefits are associated with burning projects, ranging from increased patchiness with cooler, early dry season fires that may enhance biodiversity, to engagement of traditional Indigenous burning practices on lands and the development of important revenue streams for regional Indigenous communities (Russell-Smith et al. 2015). It is anticipated that the remediation of BC habitats would also have biodiversity gains, increased resilience for climate change impacts in the coastal zone, e.g., sea level rise, increased severity of storms and cyclones, as well as socio-economic and cultural benefits. Ranger groups in the NT have demonstrated their ability to successfully deliver Savannah Fire Management projects which suggests they would similarly be able to deliver BC projects. There are opportunities for further expansion, especially within BC, although the lack of clarity around 'carbon rights' across the various land tenure and native title arrangements need to be clarified.

Additionally, the role of the voluntary credit market (as opposed to the regulated compliance market hosted by the ERF) needs to be determined; this section is currently undergoing investigation at the Commonwealth level. However, if the voluntary market can continue, it provides the capacity for direct negotiations between the offset providers (the Aboriginal land use groups) and the purchaser (corporations seeking to offset carbon production) at an agreed value that may, in time, better reflect the social, cultural, and environmental benefits of the landowners. In addition to these systems, the Aboriginal Carbon Foundation is a not-for-profit organisation that connects communities who supply carbon credits with organisations seeking to offset their carbon pollution (AbCF, 2022).

The Indigenous Carbon Industry Network (ICIN) has developed over the last decade and is now the peak industry body representing Indigenous owners and operators of carbon projects across Australia. Members include 35 Indigenous organisations which deliver ACCUs with an estimated collective value of around $25 million per annum that contributes to Australia's Emission Reduction Target. The ICIN aims to strategically coordinate and build capacity with their members to engage in the carbon market (including BC) and attain ACCUs and benefit (socially, culturally, environmentally, and economically) from this process.

ICIN have produce significant documents to guide industry conduct including:

- Seeking free, prior, and informed consent from Indigenous communities for carbon projects A best practice guide for carbon project developers (2020)
- Indigenous Carbon Projects Guide (2022)
- Mapping the opportunities for Indigenous carbon in Australia (2022)

Drivers of Blue Carbon Habitat Degradation

Natural

Extreme events (cyclones, ENSO variation in sea level/drought)

Coastal wetlands face further stresses with keeping pace with sea level rise (SLR). Land elevation and the capacity to accrete sediment are key factors when coping with this additional pressure, as well as potential for the landward migration (accommodation space; Adam, 2002; Rogers, 2001). If the ability of coastal wetlands to accrete sediments exceeds the rate of SLR or if the surrounding environment allows for expansion inland (for example, the removal of any man-made barriers or infrastructure), these ecosystems may be able to survive or possibly increase in the future (Adam, 2002; Macreadie et al., 2017). However, Macreadie et al. (2017) found that Australian saltmarsh ecosystems, on average, accrete sediments at a rate of 2.09 ± 0.32 mm yr^{-1}, considerably slower than the global rate of ~3 mm yr^{-1} (Saintilan et al. 2022). It was calculated that a global SLR greater than 7 mm yr^{-1} would likely be greater than some ecosystems' abilities to accrete sediment and increase elevation over this period (Saintilan et al. 2022). In addition, SLR can also have synergic effects with changes in the salinity and inundation conditions which can lead to reduced fitness for some marsh species (Gallego-Tévar et al., 2019). Sediment accretion can be controlled by both the rate of SLR and relative sediment load (Peck et al. 2020). This highlights the importance of incorporating both factors into future studies of coastal BC systems and accounting for this in future BC method. Carbon burial rates, controlled by sediment accretion, will likely increase with future accelerated sea level rise. Figure 9 shows the areas of erosion and accretion around the NT coast as derived from Landsat imagery (Geoscience Australia).

It is highly likely that an extreme ENSO event was the underlying process driving the largest recorded mangrove dieback event on the Gulf of Carpentaria coast in the NT and Qld in late 2015. Mangrove cover was shown to be coherent with the low-frequency component of sea-level height variation related to the El Niño southern oscillation (ENSO) cycle in the equatorial Pacific (Abhik et al., 2020). The sea-level drop associated with the 2015-2016 El Niño was identified as a dominant factor (Duke et al., 2022). Sea-level drop during the austral autumn and winter was greater than previous strong El Niño events and the persistent drop in sea-level height occurred in the late dry season of 2015 exposing mangroves to unprecedented hostile conditions (Sippo et al., 2019). The occurrence of two cyclones across the Gulf during 2018 and 2019 also highlighted the importance of this natural disturbance agent in shaping coastal ecosystems (Duke et al., 2021) with recovery of mangrove stands potentially reset in impacted coastal zones. Recent literature suggests a lunar cycle with an 18.61-year period has mediated the severity of drought impacts in north Australian mangrove stands (Saintilan et al., 2022), in effect amplify the impact of ENSO extremes. The 18.6-year lunar cycle is observed as a modulation in the outer extremes of the moon's monthly range of rising and setting. The 18.6-year lunar-nodal cycle drives changes in tidal amplitude globally, affecting coastal habitat formation, species and communities inhabiting rocky shores, and salt marsh vegetation.

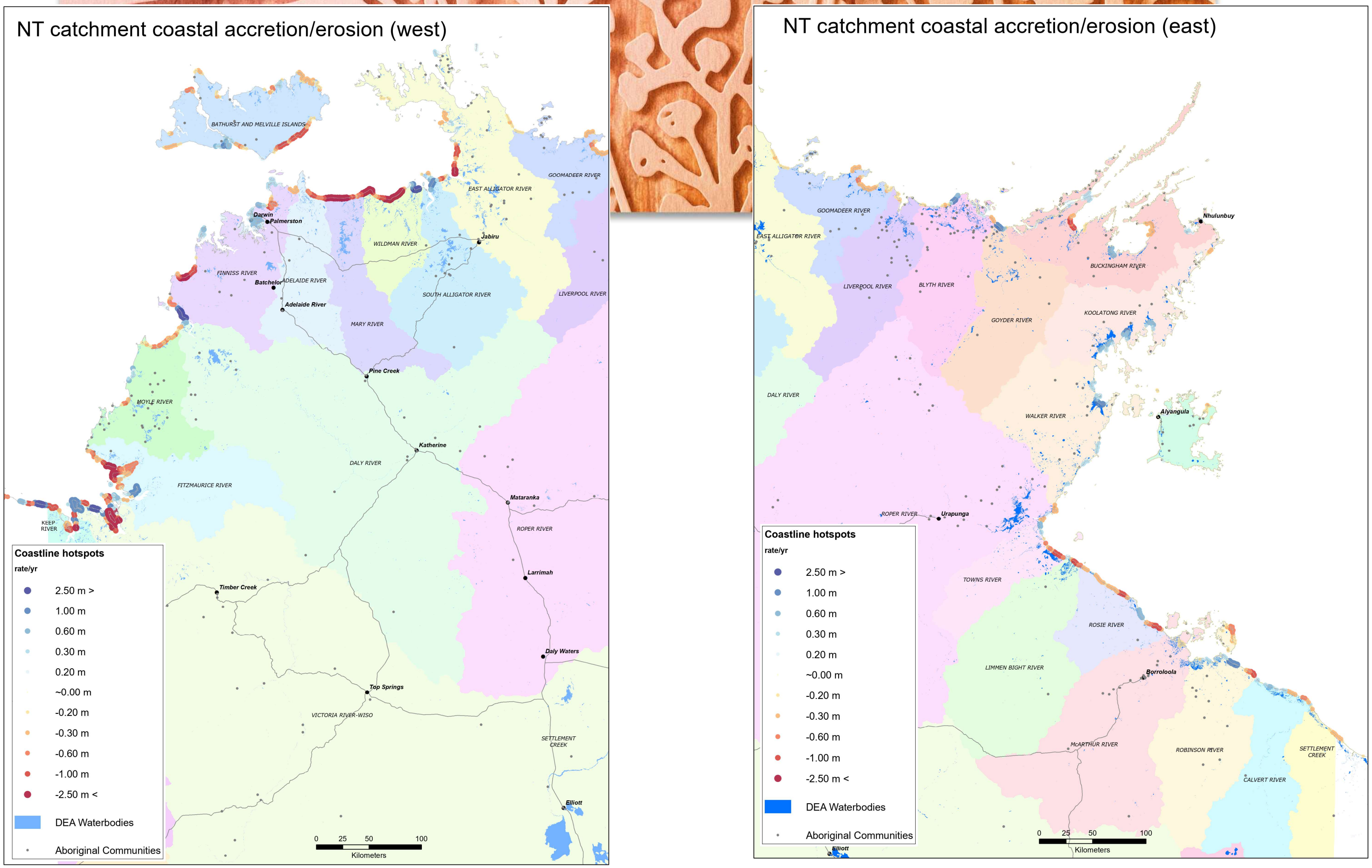


Figure 9. Annual accretion/erosion estimates for western and eastern NT (derived from Geoscience Australia Landsat imagery).

Introduced flora and fauna species

The NT is in a zone with high rates of SLR (6-11 mm y^{-1}, White et al., 2014), rates that are three-fold higher than global SLR. This coupled with extensive, low-lying topography of floodplain and coastal wetlands and the introduction of non-native ungulates is driving significant changes in drainage and coastal erosion rates, saltwater intrusion, and rapid vegetation change. Non-native ungulates occur in high numbers in coastal wetlands in north Australia and there is ample evidence that feral pigs, cattle, buffalo, goats, sheep and other hard-hooved animals cause damage to soils, vegetation and Aboriginal cultural heritage (Negus et al., 2019; Sloane et al., 2021). Non-native ungulates alter hydrological and ecological processes in wetlands in a myriad of ways; increasing evaporation, compacting wetland soils, altering surface and ground-water flows, reducing water quality through increase turbidity which in turn increases temperatures, reduces dissolved oxygen, and exacerbating eutrophication through increased nitrate and phosphate-levels from excrement (Mihailou & Massaro, 2021).

With regards to greenhouse gas emissions, non-native ungulates disturb soils through channelling, pugging and rooting resulting in emissions of CO_2, CH_4 and N_2O as well as reduced carbon accumulation in soils, and they graze (and therefore damage) vegetation (reducing vegetation cover and recruitment) further reducing carbon capture (Christopher N. Janousek, 2021; O'Bryan et al., 2021). There is also evidence of widening of tidal channels, which coupled with sea level rise is resulting in salt-water intrusion, habitat replacement (Melaleuca communities to mangroves) and potentially exacerbated subsidence and erosion of coastal wetlands (Miloshis & Fairfield, 2015).

The NT government conducts aerial surveys over the Top End floodplains (Finniss/Moyle, Adelaide/Murgenalla, Arnhem Land) to establish trends in buffalo and pig populations to target management (Figure 10). Rough estimates for pigs and buffalo for the floodplains including 2022 data (not published) indicate a high degree of spatial variation. For example, the pig numbers for the survey area over the Adelaide/Murgenella (Kakadu region), have increased post their recent dip (driven largely by poor wets in 2018/19, 2019/20). Arnhem Land shows a decline, likely due to the removal of approximately 6,000 pigs (Figure 11). This is a positive change however, populations in surrounding areas should also be managed and continual control on Kakadu National Park to affect any real impacts on environmental damage longer term. Buffalo in Arnhem Land have increased and are possibly at their highest level. They have also increased in the Adelaide/Mugenalla region. The Finniss/Moyle region is trending downward with buffalo presence (Figure 11).

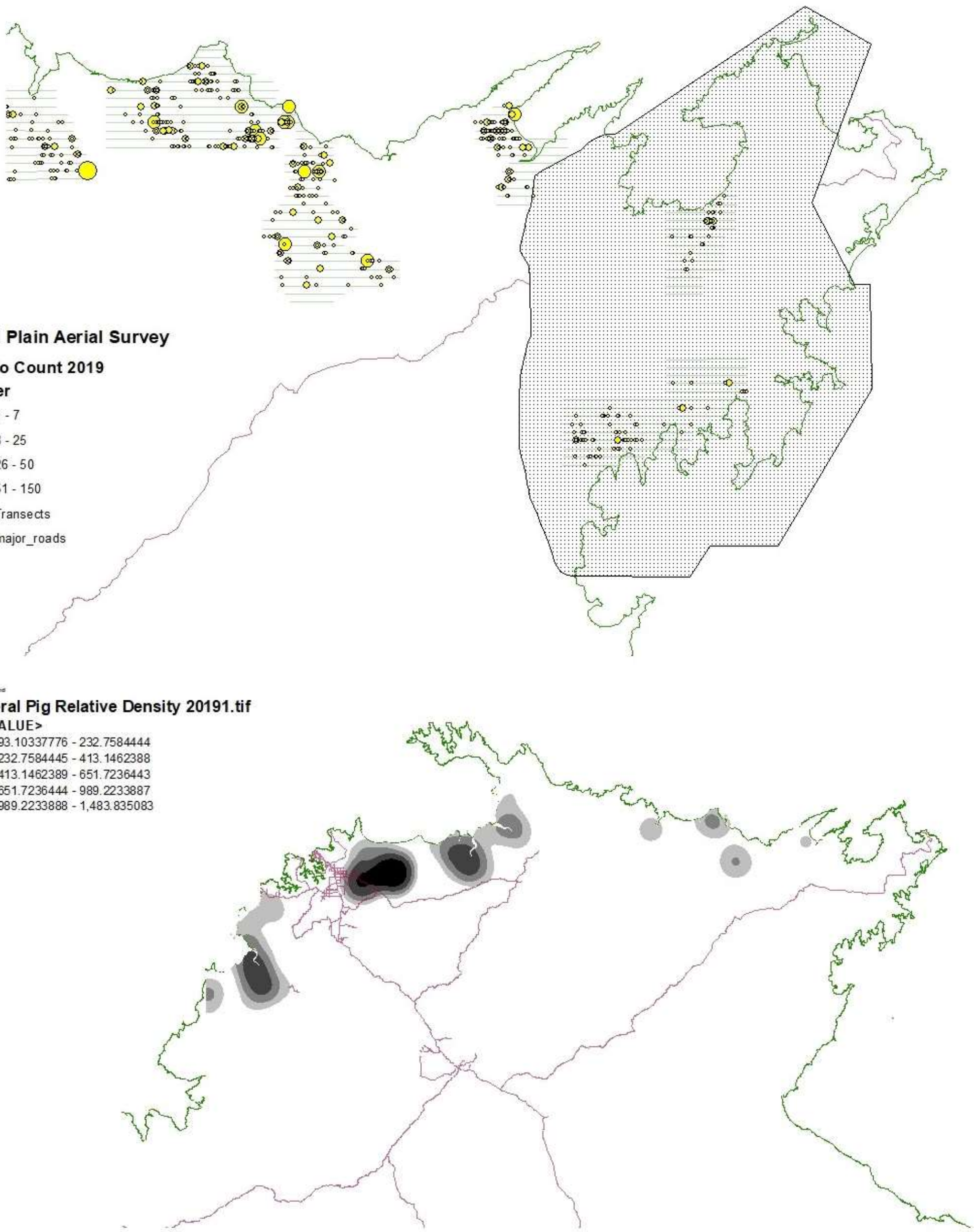
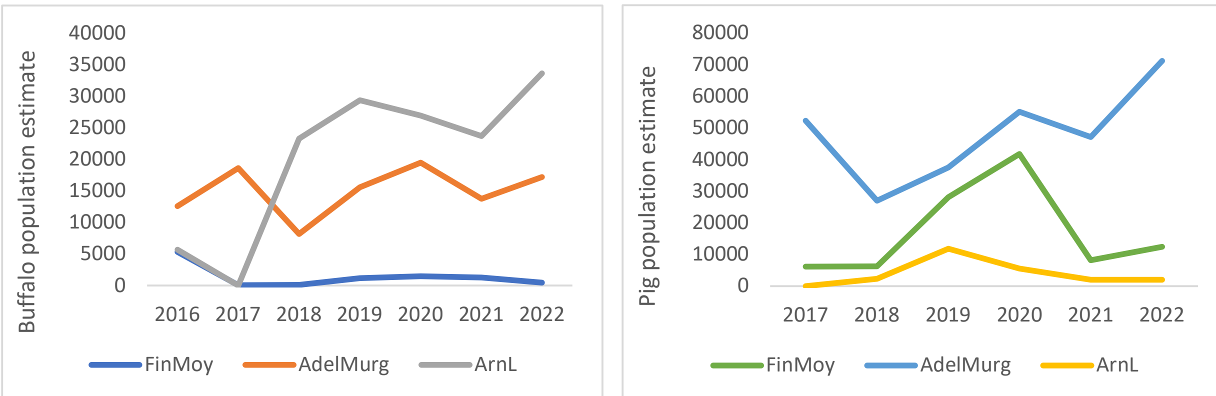


Figure 10. Aerial survey density estimates indicating areas of buffalo (mostly NE Arnhem region) and pig damage mostly west Arnhem region) across the Top End floodplains (NTG, 2019 unpublished data).



A) B)

Figure 11. Population trends of buffalo (A) and pigs (B) by region (Finniss/Moyle, Adelaide/Murgenella and Arnhem Land) in the NT as observed on NT government aerial survey over several years

Anthropogenic drivers

Urban

Urban and agricultural development threaten these wetlands, with many of the vegetated coastal ecosystems becoming lost or changed due to conversion (e.g. port developments, industrial developments) and the construction of artificial barriers (e.g. bunds, roads, culverts and floodgates) as was introduced in the Mary River catchment in the NT during the 1980s (Finlayson and Rea 1999; Abbott et al., 2020).

Infrastructure

Various types of infrastructure development are responsible for degradation and de-vegetation of blue carbon habitats in the Northern Territory, albeit the extent of these disturbances is relatively limited given the low human population density in the NT and the vastness of its blue carbon ecosystems in relation to more developed regions in Australia and world-wide. Roads developed in coastal areas may bi-sect mangroves, saltmarsh and other BC habitats and can serve as stressors where they disturb the exchange of surface waters (Lewis et al., 2016). Most notably, improperly sized culverts can result in extended periods of tidal inundation stressing or causing vegetative mortality in BC systems (Lewis et al., 2016). Settlements and capital infrastructure from energy, transportation and commerce sectors have the additional issue of directly replacing BC habitats. Where these land-use conversions take place, they have traditionally required mitigation in the form of coastal wetland creation or rehabilitation in a different area, equal to or greater than the area replaced. Such mitigation projects have been criticized in the past for resultant wetlands of lower value (productivity, biodiversity, health, etc) than the original system. Shoreline armouring is another form of coastal development intended to protect valuable coastal areas and investments from shoreline abrasion, erosion, waves, currents, and storms. Especially hardscaped "grey" engineering solutions have been criticised in the past for failure as well as "downstream" effects on adjacent shorelines.

Agriculture and other land uses

Conversion of coastal wetlands for agricultural production is common globally (Goldberg et al. 2020). In Australia, agriculture in converted coastal wetlands includes grazing, sugarcane (and other crops) and salt production (Goldberg et al. 2020). Grazing occurs on coastal wetlands across the north of Australia with floodplains providing fodder during the late dry season months (August-October) (Finlayson et al., 1997, 1999).

Social and economic underlying factors

Ponded pastures

One of the main causes of saltmarsh losses in tropical Australia has been the development of ponded pastures where tidal creeks are bunded (blocked) to prevent tidal ingress and bund walls trap freshwater which support pasture growth. Ponded pastures were constructed initially as an attempt to improve cattle grazing carrying capacity. Pasture grasses such as Hymenachne (*Hymenachne amplexicaulis*) and Para grass (*Urochloa mutica*), now both considered to be major weeds, were introduced based on the work of the then CSIRO Division of Tropical Crops and Pastures and its vision of introducing novel pasture species to tropical Australia. Ponded pastures predominate in the drier more extensive tropical catchments of Australia, particularly the dry tropical coast of the Great Barrier Reef and to a lesser extent in the Gulf of Carpentaria, Northern Territory, and tropical Western Australia. Many of the bund works along the Great Barrier Reef coast are unauthorised or were done prior to legislative control, most are on private lands.

Economic value of introduced species (buffalo and pigs)

Buffalo and pigs have economic benefits to landholders where they provide important sources of protein and/or income for landholders from recreational hunting. For example, landholders may partly subsist on cattle on saltmarshes and hunting is also an important recreational activity for buffalo and pigs in the NT. In some places buffalo have become part of Aboriginal cultural practice as a food source and totem (Altman 1982); however, it is likely that the cultural cost of feral ungulate invasion (e.g. on availability of diverse native bush plant and animal foods, access to favoured hunting places or places of cultural significance, likely outweigh the cultural benefits e.g. easy source of meat protein, totems (Robinson et al. 2003; Albrecht et al. 2009; Ens et al. 2016; Sloane et al. 2021; Russell et al. 2020a, b; 2021).

Blue Carbon Methods in Australia

Background on method development

The new Tidal Introduction Blue Carbon Method, came into effect January 2, 2022 under Australia's Emissions Reduction Fund (CER, 2022). This method covers projects that re-introduce tidal flows to anthropogenically degraded blue carbon ecosystems that allow the reestablishment of coastal wetland ecosystems that result in a long-term net reduction in emissions and increased sequestration. Under development includes an additional component linked to emissions from the removal of non-native ungulates from blue carbon habitats, the latter of which may provide the best opportunity for engaging Traditional Owner's in Blue Carbon in the Northern Territory. The Tidal Introduction Blue Carbon Method was appraised by the Emissions Reduction's Accounting Committee (ERAC) before becoming available for public consultation prior to refinement and finalisation. This methodology will help Australia account for blue carbon as a rich form of natural capital and leverage its protection and restoration to provide benefits to coastal communities while contributing to Australia's national and international climate change mitigation and adaptation commitments.

Specific methods

Tidal Restoration

The Tidal Introduction Blue Carbon Method (2022) concerns restoring natural tidal inundation to coastal blue carbon communities to restore vegetation, biomass, and soil carbon stocks. The method also accounts for avoided emissions that arise from the reintroduction of tidal flow (Figure 12). Activities include modifying or removing tidal gates, bund walls or other impediments to tidal inundation (Lovelock et al. 2022a). An ideal project would require biophysical assessment (Kjerfve, 1990; Lewis & Brown, 2014; Worthington & Spalding, 2018), assessment of social, economic, political and governance factors (Thompson, 2018; Lovelock & Brown, 2019; Brown, 2021; Campese et al., 2022), and multi-stakeholder mapping of restoration opportunity (Brown, 2021; IUCN & WRI, 2014). In a carbon-project setting, projections of emissions reductions from intended activities, mapping of defined Carbon Estimation Areas (CEA's), projections of inundation from sea level rise, project risk and risk management are additional priority considerations. Net increases in carbon stocks and avoided emissions (relative to a pre-project baseline) over time are all estimated via the Commonwealth's Blue Carbon Accounting Model (BlueCAM, after Lovelock et al., 2022).

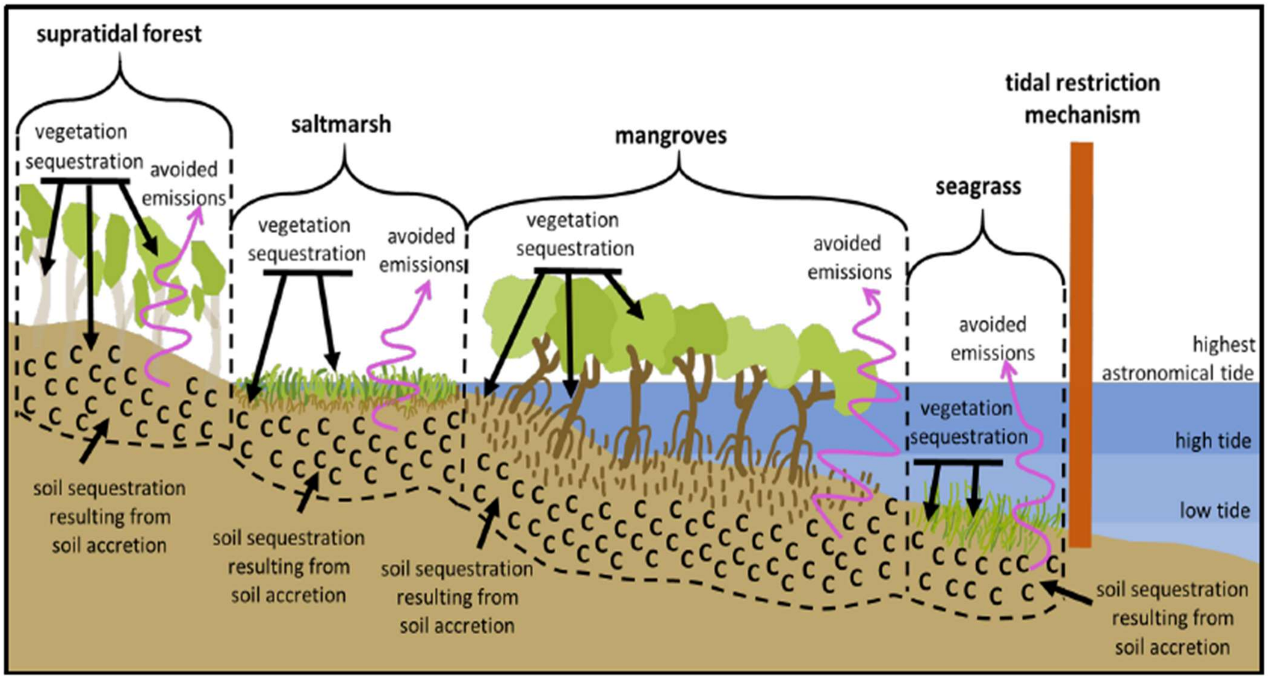


Figure 12. Component processes that underpin the blue carbon method that are instigated following the restoration of tidal flow. These include changes in biomass stock, carbon sequestration in sediment from resultant soil accretion and avoided emissions following the reintroduction of saline tidal water.

Examples of successful hydrological rehabilitation including tidal re-introduction projects in saltmarsh and mangrove habitats in Australia include East Trinity Inlet, Cairns, Queensland (Luke et al., 2017) and Tomago Wetland, Hunter River estuary, Newcastle (Glamore et al., 2021; Negandhi et al., 2019). A non-carbon project which serves as proof of concept has been undertaken at Mungalla Station, in the Boolgooroo lagoon region of North Queensland. Traditional Owners removed a bund wall for weed management, water quality improvement and improved fish biodiversity (Abbott et al., 2020). Project monitoring recorded significant rehabilitation of native freshwater and saltwater wetland vegetation over a period of 4 years.

Ungulate control

Avoiding disturbance of soils and vegetation and their rehabilitation in coastal wetlands influenced by non-native ungulates is a new “blue carbon” method that will build on components of the abatement model developed in the “Tidal Introduction Blue Carbon Method.” A draft method has been submitted to Australia’s Clean Energy Regulator (CER) in August, 2022, and concerns avoiding disturbance of soils and vegetation and rehabilitating soils and vegetation of coastal wetlands influenced by non-native ungulates (Lovelock, 2021). The main activities proposed are removal or exclusion of non-native water buffalo, pigs, and potentially feral cattle to repair coastal wetlands. Avoided disturbance from these feral ungulates would result in reduction of various greenhouse gas emissions including NOx, N_2O, CH_4 and CO_2.

Management of non-native ungulates in coastal wetlands has the potential for large scale carbon abatement in Australia that would enhance biodiversity and provide incomes for coastal landholders, particularly Traditional Owners. The accumulated Indigenous and scientific evidence derived from non-native ungulate exclusion experiments show that exclusion of non-native animals from coastal wetlands results in improved wetland condition and vegetation cover (Ens et al., 2016; Mihailou & Massaro, 2021; Russell et al., 2021; Sloane et al., 2021).

Non-native goats and sheep were successfully eradicated from Dirk Hartog Island, Shark Bay World Heritage Area, Australia from 2005-2017 with long-term funding (Heriot et al., 2019), institutional and expert support, however up-scaling to unbounded mainland landscapes still present significant challenges. Regardless of landscape challenges, care needs to be taken as there are reports that indicate removal of water buffalo alone can lead to increased populations of feral pigs and resultant damage to coastal wetlands (Mihailou & Massaro, 2021).

Other international and proposed Australian methods

The Verified Carbon Standard method for restoration of coastal wetlands (VM0033 and associated modules, https://verra.org/methodology/vm0033-methodology-for-tidal-wetland-and-seagrass-restoration-v2-0/) is broad in the scope of restoration activities permitted compared to the Australian method, which is only for tidal restoration. The VM0033 method requires measurements of carbon stock change through time. Although it is possible to use the method in Australia, issues with double counting that occur with international sale of carbon credits issued (VCUs) result in complexities (i.e., carbon abatement would be recorded in the Australian greenhouse gas inventory but also potentially in the inventory of the nation of the entities that purchased the credits. Therefore, equivalent ACCUs, which have higher $ value than VCUs, need to be retired for the VCUs issued if they are used as international offsets).

Fencing of ungulates from farm dams has been proposed to the ERF as a method to reduce methane emissions, although not yet approved, there is a focus by many disparate groups to pursue this method and attain funding for research to develop robust methods.

The Australian Government has announced their intention to develop Biodiversity Certificates which will be administered by the Clean Energy Regulator. This announcement indicates that all carbon projects may be able to add to their value if there are gains in biodiversity with the project. The Indigenous carbon projects in the NT have the potential to contribute to the policy development as this process progresses.

Status of Blue Carbon projects, Australia

Research projects

Research projects encompassing various aspects of blue carbon have been undertaken by individual researchers, research groups and government-based organisations over several years. Many of these projects have addressed areas where there has been substantial lack of baseline knowledge, such as distribution of seagrass meadows, and are now incorporated into the overall blue carbon research field. As each state and territory creates and promotes the blue carbon economy, further research in this field will grow. The challenge will be to ensure that all research projects are driving towards the same outcomes that allow the development of the relevant methods for assessment of blue carbon in line with the UNFCCC and other international and national policy objectives (e.g., Ramsar, CBD, water quality and hazard reduction plans). Integration of interdisciplinary research, which incorporates science with management and economics, with investment from industry, will ensure the best outcomes in relation to understanding the blue carbon ecosystem with respect to carbon storage as well as additional benefits to the environment for fisheries, biodiversity, and coastal risk reduction.

An example of research within the blue carbon environment is from the National Environmental Science Program (NESP) Marine and Coast Hub (https://www.nespmarinecoastal.edu.au). Overall, the Hub has six major research themes: informing policy and decision making; protected places; threatened and migratory species; people and sustainable use; ecosystem restoration and protection; and knowledge systems. Research into blue carbon topics can cover a number of these themes but is most concentrated in the ecosystem restoration and protection theme. For example, the mapping of the distribution of seagrasses by Carter et al. (2022) was undertaken within this area as is the current project in coastal wetland restoration in northern Australia. Hagger et al. (2022) undertook a quantification of the carbon restoration potential in three locations based in central Queensland, south-western and north-eastern Western Australia. Lovelock (2021) has recently applied for a project to determine the impacts of non-native ungulates (pigs, buffalo) on the potential rehabilitation of wetlands by tidal inundation.

Pilot projects funded by Commonwealth

The Blue Carbon Conservation, Restoration and Accounting Program, run by the Australian Government, has allocated $30.6 million to be invested over the 2021-2025 period for projects that:

- Implement on-ground blue carbon restoration and conservation activities within Australia or overseas
- Apply project-level Environmental Economic Accounting to demonstrate how restoration and conservation activities lead to enhanced climate, biodiversity, and livelihood outcomes
- Enhance collaboration and knowledge exchange in Australia and across the region

Five projects have so far been selected for 4 years funding across the following topics:

Funding recipient	Project	Location	Funding (excl. GST)
Sunshine Coast Regional Council and Partners	Blue Heart – Blue Carbon Wetland Restoration Project Restoration of former farming land (5000 ha in Maroochy River catchment) to coastal wetlands with benefits for carbon sequestration, biodiversity, flood mitigation, recreation, and First Nations engagement. https://www.dcceew.gov.au/water/wetlands/publications/wetlands-australia/february-2021/blue-heart-sunshine-coast	Sunshine Coast, Queensland	$2,036,000
Greening Australia	Mungalla Blue Carbon Project Tidal restoration of former cattle grazing property (~50 ha) with benefits for Indigenous heritage, ecotourism, Great Barrier Reef water quality, and bird and marine biodiversity. Part of a 25-year, $3.74 million collaboration between the Queensland Government and CO_2 Australia Limited.	Ingham, Queensland	$1,779,988

	https://www.accountingfornature.org/afn-proj-co2-09		
The University of Adelaide	Gulf St Vincent Seagrass Restoration Project Seagrass restoration project (20 ha) with benefits for marine diversity, sediment stabilisation, shoreline protection and nutrient processing. https://www.environment.sa.gov.au/topics/coasts/explore-and-learn/seagrass-restoration-in-sa	Port Gawler, South Australia	$1,972,500
Southern Regional Natural Resource Management	Demonstrating Outcomes of Blue Carbon Ecosystem Restoration of Temperate Saltmarsh Cool climate tidal marsh restoration with benefits for coastal resilience, biodiversity, recreational fisheries, and tourism. https://nrmsouth.org.au/blue-carbon-ecosystem-restoration/	Pitt Water-Orielton Lagoon, Tasmania	$793,947
The Nature Conservancy Australia and Partners	South Australian Blue Carbon Ecosystem Restoration Project Tidal marsh restoration (12,400 ha of mangroves and saltmarsh) with benefits for biodiversity, social and cultural values. https://www.natureaustralia.org.au/newsroom/bolder-future-for-blue-carbon/	Upper Gulf St Vincent, South Australia	$2,896,526

Additionally, the Australian Government co-ordinates the Blue Carbon Accelerator Fund, in collaboration with the International Union for the Conservation of Nature, which supports the development of blue carbon restoration and conservation projects in countries outside of Australia. The aim is to establish projects in the hope that they will secure future private sector finance. At the 2022 United Nations Ocean Conference, four projects were announced as recipients of funding:

- Conservation and protection of mangrove forests in Bouche de Roy, Benin.
- Restoration of 2000 ha of mangroves forest in Madagascar
- Protection of mangrove forests in Peru
- Restoration of mangrove forests in the Philippines

Potential NT Project Locations – Applying the Tidal Restoration Method

In the NT, potential locations would be identified based on previous interventions in blue carbon ecosystems. Given the near-pristine condition of large areas of the NT coastline, this could be a limited area but could include degraded ponded-pastures and/or floodplains damaged from overgrazing. Analysis of pastoral leases that incorporate blue carbon communities would be required. Pastoral lands of the Mary River catchment and other stations abutting the coastline, such as Legune Station could serve as locations to assess the potential returns from a blue carbon project. Legune Station includes a significant portion of floodplain country adjacent to the Ord River (Figure 13), with aquaculture flagged as a potential land use on the station (see Project Sea Dragon, Seafarms Group, http://seafarms.com.au/about-project-sea-dragon/).

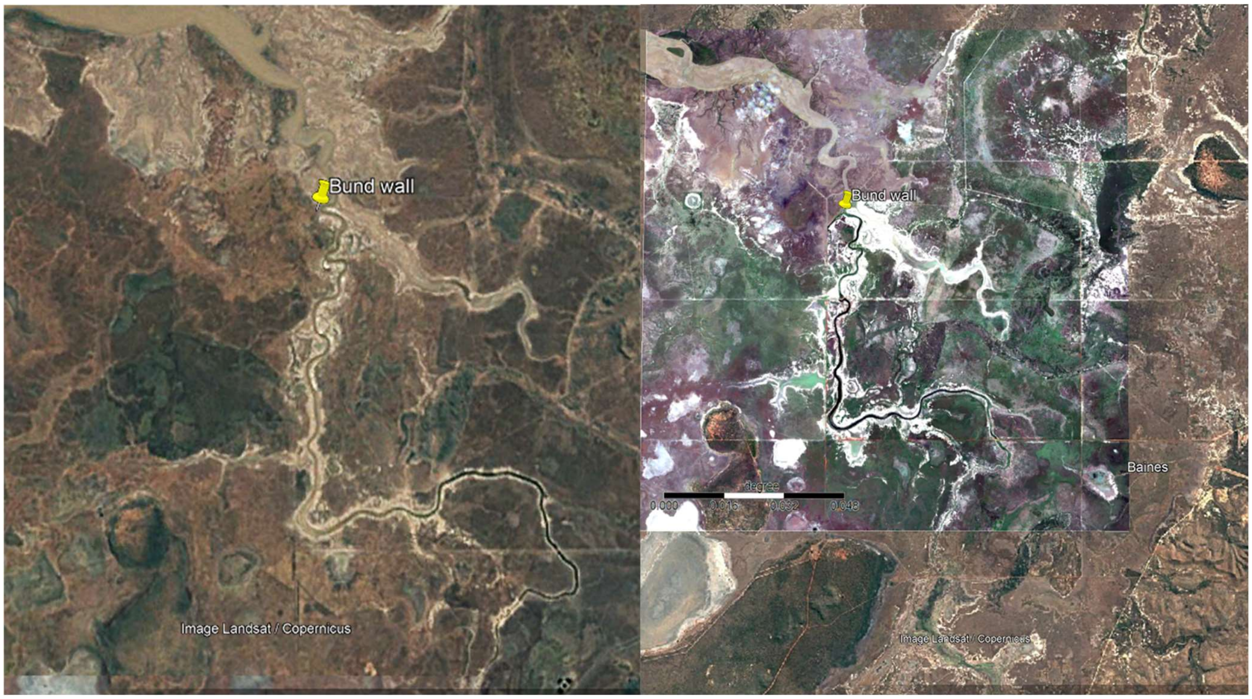


Figure 13. Legune Station floodplain country with infrastructure development in blue carbon communities. The LH panel is from 2001 (Google Earth composite) prior to a track and bund wall construction in 2002/2003. The RH panel is a higher resolution Sentinel-2 image from 2019 with the bund wall potentially altering tidal ingress and ponding of river flow that may be associated with high methane emission. Such a site could be assessed in collaboration with land managers in Phase 2 of this project.

Regulatory issues (tidal introduction)

Since early 2022, the Australian Government has declared that the ERF will credit eligible blue carbon projects that introduce tidal flows to help establish and/or restore wetland ecosystems (cleanenergyregulator.gov.au). Kelleway et al. (2020) found that the mean abatement intensity of organic carbon was highest in areas where tidal flow was (re)introduced resulting in the establishment of mangroves (13-15MgC ha^{-1} yr^{-1}) and tidal marshes (6-8MgC ha^{-1} yr^{-1}).

Much of the Australian coastline has been modified with various structures introduced that modify tidal flows as well as completely or partially inhibit their incursions into wetlands. This has resulted in large areas of coastal vegetation (mangroves, salt marshes and seagrass meadows) reducing and/or completely disappearing. The removal or modification of these tidal restriction mechanisms will allow tidal flow to be introduced into an area which will result in the rewetting of completely or partially drained coastal wetland areas. In some circumstances, the reintroduction of tidal flows will change current freshwater wetlands back to brackish or saline wetlands.

The South Australian Blue Carbon Strategy (Government of South Australia, 2020) outlined a case study which involved the reintroduction of tidal flows to the Dry Creek salt flats in Adelaide. The salt flats had been cut off from the sea for several years to be used as a salt production facility. When the salt flat production ceased, a culvert was constructed to allow tidal flows to return to a small area. Within a few years, the site has been restored with improved soil quality and the presence of vegetation, fish, and invertebrates. Measurements have shown that carbon sequestration has occurred.

Any project that undertakes tidal flow modification must maintain that tidal flow to the project area throughout the project permanence period to ensure that the carbon sequestered in the vegetation and soils is maintained.

The Carbon Credits (Carbon Farming Initiative) Act 2011 (https://www.legislation.gov.au/Details/C2020C00281) and the Carbon Credits (Carbon Farming Initiative – Tidal restoration of Blue Carbon Ecosystems) Methodology Determination 2022 (https://www.legislation.gov.au/Details/F2022L00046) should be consulted. In addition, the Clean Energy Regulator (https://www.cleanenergyregulator.gov.au) provides essential information with respect to eligibility, regulations, and delivery of projects.

Cost-Benefit Analysis to Determine Net Present Value (NPV) of Blue Carbon Intervention

Blue carbon habitats have a high ecosystem value comprised of direct, indirect, options for future uses and intrinsic values (Costanza et al., 1997; Ronnback, 1999; Ranasinghe & Kallesoe, 2006; Barbier et al., 2011; Emerton, 2014). Previously, mangrove and coastal restoration projects were criticized for a lack of empirical data needed to develop robust, transparent economic models of their cost-benefit proposition (Bayraktarov et al., 2016; Lewis, 2001). There are emerging assessments of the potential returns on investment in restoration at a range of scales (e.g., Cameron et al. 2019a,b; Zeng et al. 2021; Hagger et al. 2022). Cameron et al. (2019a), who used the rate of post-restoration mangrove regrowth and avoided deforestation emissions to estimate potential economic benefits from a hypothetical carbon project. The value of sequestered carbon was based on the European voluntary carbon market and approximated restoration costs which yielded a 7% return on investment, equivalent to a moderate to high returning investment portfolio. An analysis of profitability of restoration for blue carbon in the wet tropics, Queensland, revealed around 3,400 ha (of the potential opportunity of 5000 ha) of coastal land would be profitable for blue carbon restoration at a carbon price of $14/tonne CO_2e, and that the area of profitable land would increase to 4,500 ha at a higher carbon price (Hagger et al. 2022).

Prior to developing and financing a blue carbon intervention it will be imperative to perform a thorough cost-benefit analysis to alleviate concerns that a blue carbon intervention may incur high up-front costs and deliver low rates of return (Verdone, 2015). Policy development is shaped by costs of restoration, who pays, who benefits and if there is a more effective way to deliver the same environmental and/or financial benefit.

It is the calculation of internal rate of return (IRR) and the related financial concept of net present value (NPV) which government decision makers, investors, and entrepreneurs use to inform capital budgeting and investment planning to analyse profitability of a projected land-use investment such as mangrove restoration (Tantra, 2016; Verdone, 2015). The concept of NPV quantifies the value of cash inflows (e.g., income or benefits) versus cash outflows (e.g., expenses) over a period of time (Verdone, 2015). Money in the present is worth more than the same amount in the future due to inflation and to earnings from alternative investments that could be made during the intervening time (Gallant, 2020). When NPV is applied to a blue carbon intervention, variables such as interest (discount) rate as well as the growth and performance of the restoration itself are considered to account for the fact that a dollar earned in the future won’t be worth as much as one earned in the present.

The following formula is used to calculate NPV (Verdone, 2015):

$NPV = (\Sigma Bt/(1+\delta)t)-Ct$

where t denotes time in years, Bt is benefit at time t, Ct is total restoration cost at time t, n is the time horizon, δ is the social discount (or interest) rate while (1+δ) is the social discount factor.

A positive NPV indicates that costs incurred to reduce blue carbon emissions are less than their worth and a negative NPV indicates the inverse -- costs to restore blue carbon habitats are greater than the true worth. Because future value usually holds less weight than present value in the decision-making process, the NPV is calculated using one or more discount rates, to account for the lost financial opportunity if funds were invested in alternative projects (Gunawardena and Rowan, 2005). The calculation of NPV can benefit from the development of various scenarios accounting for performance, incremental growth of restored blue carbon habitats and meta-financial conditions represented by social discount rate.

The following guiding research questions are useful for the purposes of calculating NPV for a blue carbon intervention.

- How much do potential blue carbon interventions cost overall and by intervention type?
- What are the values of financial and economic benefits that the blue carbon intervention can deliver over time? Is there a difference in values that accrue to individuals versus those that accrue to society?

- What is the net present value of each blue carbon rehabilitation scenario, considering key variables such as performance, incremental growth, and variable interest rates?
- What are the economic and financial bottlenecks that need to be addressed and overcome to enable the blue carbon intervention?

Literature related to these potential research questions are discussed in the sections below on estimates of blue carbon ecosystem restoration costs, estimates of blue carbon ecosystem values, potential co-benefits from blue carbon interventions and determination of NPV from a blue carbon intervention.

Estimates of Blue Carbon Ecosystem Restoration Costs

Restoring blue carbon habitats requires various inputs including planning, permits, materials and labour (Lewis III and Brown, 2014). Costs are incurred both directly through the physical process of restoration and indirectly through foregone production, stakeholder negotiation, planning and monitoring (Verdone, 2015; Bayraktarov et al., 2016). Although some authors note that there are few studies that estimate costs of coastal restoration (Lewis, 2001; Bayraktarov et al., 2016), it is more accurate to say that most estimates reflect implementation costs alone without considering the entire suite of costs related to a blue carbon ecosystem restoration intervention (Verdone, 2015; Bayraktarov et al., 2016; Buckingham and Kuzee, 2016; Susilo et al., 2017).

Costs of blue carbon habitat restoration should ideally include three components; opportunity costs, transaction costs and implementation costs which are described below (IUCN and WRI, 2014). Opportunity costs represent the tangible goods and services that are foregone during the implementation of the blue carbon method (IUCN and WRI, 2014; Verdone, 2015). In the case of hydrological rehabilitation through tidal re-inundation, opportunity cost could be represented by loss of grazable pasture to livestock owners. In the case of feral ungulate control, opportunity costs may include reduction in available bush-meat available to Aboriginal communities in the case of significant or successful eradication of feral species such as buffalo. Transaction costs represent the cost for relevant stakeholders to identify viable land to restore and negotiate over terms that ensure restoration and other blue carbon emissions reduction strategies meets both local and national priorities (IUCN and WRI, 2014; Verdone, 2015). Transaction costs should be calculated based on recent, proximate, analogous interventions such as blue carbon habitat restoration or feral ungulate control. Implementation costs represent investments in land, labour, and materials and include any expense directly related to the establishment and operation of a blue carbon intervention, including training, design, logistics and purchase of materials (IUCN and WRI, 2014; Verdone, 2015).

Considering lack of holistic intervention costing, Bayraktarov et al. (2016) cautioned that coastal restoration costs may be underestimated by a factor of four. In addition to the need to consider more holistic costs, it is important to use actual costs from previous restoration projects which provides crucial data to estimate these costs once adjusted adjust calculations for inflation (Verdone, 2015; Bayraktarov et al., 2016).

Bayraktarov et al., (2016) undertook a global review of 235 coastal restoration project outcomes with 954 observations of restoration costs across a variety of coastal ecosystem types and country settings and determined that mangrove restoration costs were typically lower than other forms of coastal restoration, including saltmarsh, oyster reef, seagrass and coral reef, the latter two typically being the highest cost types of coastal restoration. Lewis (2001) concurred with this spectrum of costs of coastal restoration, adding that coral reef and then seagrass restoration also incurred the highest risk of failure.

Narayan et al. (2016) reports costs ranging from USD $500 to 54,300 ha^{-1} depending on the degree of site degradation. Spurgeon (1999) also noted a vast range in cost reflecting differential expenses of restoration methods as well as socio-economic settings. Lewis (2001) reported costs from USD $225 - 216,000 ha^{-1} with costs from unpublished data as high as USD $500,000 ha^{-1} due to the high cost of permitting, labour, use of heavy machinery and other inputs in the United States. Similarly, Turek (2015) reports the cost of thin-layer hydraulic sediment spraying in the United States ranging from USD $252,047 - 1,065,022 ha^{-1}. Lewis (2016) elaborates on the differential costs of restoration, ranking the following four methods from least to most expensive; 1) planting alone, 2) hydrologic restoration with or without planting 3) excavation or fill projects with or without planting and 4) experimental erosion control projects.

Hydrological restoration has a wide range of costs depending upon the technique applied, from low-cost strategic breaching of dike walls in aquaculture settings, to expensive basin re-grading and construction of tidal channels. Brown et al. (2014) reported a USD \$590,000 budget to undertake strategic breaching and tidal channel creation in 425 ha site on Tanakeke Island, South Sulawesi, equivalent to USD \$1388 ha^{-1}. This project took place as part of a larger 5-year, USD \$7.7 million project which enabled a high degree of government and community support through investment in sustainable livelihoods development, improved governance, and targeted advocacy (Brown et al., 2014). An additional 100 ha was rehabilitated for a cost of USD \$165,000 demonstrating an economy of scale due to reduced transaction costs (Nurdin & Fadillah, 2016).

In summary, a wide-range of mangrove restoration costs have been reported in the literature, ranging from USD \$100 ha^{-1} to 1,065,022 ha^{-1} depending on socio-economic status of the country/location and techniques applied.

Estimates of Blue Carbon Ecosystem Values and Expected Benefits of Blue Carbon Interventions

Mangrove forests provide valuable goods and ecosystem services some of which are traded in markets, and some of which are not (Barbier et al., 2011; Huxham et al., 2015). A common typology for categorizing ecosystem services is to divide them into 'use' and 'non-use' values, and further divide use values into direct uses and indirect uses (Ranasinghe & Kallesoe, 2006; Smith et al., 2020). Direct uses include goods that are removed from mangrove forests (timber, fisheries products, etc.) and activities that take place in the mangroves (recreational fishing, ecotourism, etc.). Indirect use values are services where values are accrued outside of the mangroves, but which are derived from functions occurring within the mangroves, including fisheries nurseries, protection of infrastructure inland from mangroves and climate maintenance from carbon sequestration. Non-use values include cultural value, options for future uses, and the value that current people get from being able to pass the resource to future generations (Ranasinghe & Kallesoe, 2006; Smith et al., 2020).

It is important to highlight that the value of an ecosystem cannot be substituted for benefit, which needs to include the socio-cultural benefits of ecosystem services for human wellbeing (Russi et al., 2013). It may also prove necessary to disaggregate the proportion of benefits that might accrue to local individuals versus those that might accrue to regional and even global society (Smith et al., 2020). Recent valuations have applied a standard basic value transfer (BVT) approach to ascribe either global or regional estimates of ecosystem value (Smith et al., 2020), while Sangha et al. (2018) added a local trade-off analysis to derive a value for benefit to local stakeholders.

Ecosystem valuations of mangrove systems have been undertaken both regionally and globally, and incorporated direct benefits, indirect benefits, options values, and intrinsic values as outlined above (Ruitenbeek, 1992; Costanza et al., 1997; Ronnback, 1999; Ranasinghe & Kallesoe, 2006; Barbier et al., 2011; Emerton, 2014; Hakim, 2017; Smith et al., 2020). The value of direct benefits alone is "cashable" and can be considered financial values, of greater interest to local stakeholders, primarily landowners, investors, and businesses (Tantra, 2016; Smith et al., 2020). Although the emergence of carbon markets means that ecosystem services including carbon sequestration and greenhouse gas emissions reductions are now cashable, the requisite sharing of benefits to society means that carbon benefits can continue to be characterized as an economic rather than a financial value.

Resultant mangrove ecosystem values range widely from USD 6600 ha^{-1} yr^{-1} (Costanza et al., 1997) to USD 193,845 ha^{-1} yr^{-1} (Brugere & Bosma, 2014). The latter value is dominated by wastewater treatment (USD 162,125), which along with water regulation are vitally important mangrove ecosystem services. Ranasinghe and Kallesoe (2006) conducted a participatory valuation study in Sri Lanka and determined total economic values ranging between USD 8417 – 21,953 ha^{-1} yr^{-1}, and more importantly they concluded that the relative value of mangroves increased for remote and vulnerable communities. The implications of this study are that mangrove restoration benefits are greater the more reliant individuals and communities are upon mangroves for their livelihoods. This type of participatory valuation may be of particular interest in developing blue carbon interventions in partnership with remote communities in the NT.

In a post-restoration context, the value of mangrove ecosystem goods and services (timber value, carbon sequestration, fisheries value, coastal protection, water regulation, tourism, etc.) develops and gains in value over time as the forest matures approaching its pre-disturbance state. This incremental increase in value develops based on biological production functions

(Daily & Ellison, 2012), the rate of which can either be empirically determined or modelled with the use of ecosystem service modelling tools such as InVEST and ARIES (Verdone, 2015).

Biomass accrual was used as a conservative proxy for the return of post-restoration ecosystem function and services such as fisheries value, storm protection, carbon burial. which tend to accrue more rapidly than biomass (Lewis et al., 1985; Wolanski, 2006; Mazda et al., 2007; Salmo & Duke, 2010). The return of a percentage of the value of a mature reference system is hereafter referred to as a functional equivalence value, or FEV (Hubbell, 2005).

Rates for biomass accrual in Indonesian mangrove forests were calculated by Inoue et al. (1999) who developed high and low growth curves for *Rhizophora* spp., based on measurements from Sumatra, Kalimantan, and Papua. This study found that *Rhizophora* attains 50% of above-ground biomass of reference old-growth forests at 25 years after disturbance and 75% FEV after 40 years (Inoue et al., 1999). An assessment of mangrove biomass increments using chronosequence data found that most forests (of 9 global sites) matured in 30-40 years (Lovelock et al. 2022a). A recent assessment of forest structure and biomass regeneration after logging operations in Bintuni Bay, West Papua suggest ecosystem carbon stocks (above and below ground) are returned 25 years after clear-felling (Sasmito et al., 2019).

Again, the literature reveals a wide range of mangrove ecosystem values, from USD 6,600 - USD 193,845 ha^{-1} yr^{-1} which can be used to contextualize the findings of a cost benefit analysis. Such a wide range of potential costs and values undermines investment confidence. More robust and transparent restoration methodologies, costing and management of blue carbon interventions are clearly needed. For the purposes of this literature review, benefits which accrue to individuals will be calculated as financial value (the direct value of monetizable ecosystem goods), while benefit to society will be represented by economic value, which considers direct and indirect value of ecosystem goods and services (Ranasinghe & Kallesoe, 2006; Emerton, 2014). The use of these two ecosystem values to proxy individual and societal benefit can provide rational basis for a discussion on who should pay for restoration.

The following section goes into greater detail over the generation and distribution of co-benefits to relative stakeholders before concluding with a discussion of conducting cost benefit analysis and the determination of net present value (NPV) for a proposed blue carbon intervention.

Potential co-benefits from a blue carbon intervention

Incorporation of a Blue Carbon economy into the Northern Territory will have substantial benefits across several sectors: Aboriginal communities, non-Aboriginal communities, the tourism sector, fisheries, game-hunting, the environment, research, and industry (Pert et al., 2020; Lovelock et al., 2022a,b; Hagger et al., 2022). Improvements in all these sectors will also have benefits for the Northern Territory Government as they could demonstrate leading practice in the establishment of the Blue Carbon economy within Australia, and potentially across the globe.

As most land area that has potential for inclusion within the Blue Carbon ecosystem is on land that is owned, managed or co-managed by Aboriginal land groups, the major immediate benefit will be to Aboriginal communities. Many activities that will be undertaken can be incorporated into the current Caring for Country and Indigenous Ranger Programs that exist. Across Australia, over 120 Indigenous ranger groups already exist who support improvement in the ecology of their local systems through activities such as feral animal control and fire management (Pert et al., 2020). In addition to the immediate environmental benefits, many of these programs have also shown benefits to social, cultural, and economic aspects for the community, as well as improving health and well-being (Pert et al., 2020).

It should be recognised, however, that not all Aboriginal communities will benefit equally from inclusion within this system (Pert et al., 2020). Some Aboriginal communities will not have the environmental resources on hand (e.g., access to large areas of mangroves) to be able to participate in these programs. However, incorporation of these communities and groups into programs based within regions and/or cities – for example, mangrove regeneration in Darwin Harbour – would provide substantial benefit.

Another major benefit from blue carbon projects will be for the environment as regrowth of natural ecosystems will increase and improve habitat for many different types of native species. Increased taxonomic diversity within ecosystems generally lead to systems with greater overall stability and resilience (Hagger et al., 2022). Many of the species that will benefit have commercial value, such as many fish species that utilise mangroves and seagrasses as nursery grounds, as well as prawns. Increases in these stocks will have flow-on benefits to the fishery sector as well as for recreational fishers. The recreational fishing industry already attracts a significant portion of the tourism sector.

Carbon projects that encompass programs for feral animal control to improve ecosystem condition may also have economic benefits beyond carbon (and biodiversity). The addition of feral animal control, possibly through a regulated hunting program, could also have tourism benefits. The Northern Territory is often seen as the "wild" part of Australia, and this could be a major selling point for this aspect.

Additional environmental co-benefits are created through improved water quality due to the increased entrapment of silt and better filtering of the water as well as an increased area of plants to protect the shore from storm events (Hagger et al., 2022).

Throughout the establishment of the Blue Carbon economy, there will be a wide scope for research to be undertaken. This will be across several sectors: environmental/biological/ecological, social/cultural, economic, and within disciplines of coastal engineering.

Methods for Determining Net Present Value of MFLR in Two Landscapes

Once the spatial dimension of one or more blue carbon intervention scenarios are determined, it is possible to calculate predicted costs and benefits represented by the NPV of the intervention. A more transparent approach will enable prediction of whom in coastal communities will accrue benefits, what economic bottlenecks or barriers may impede stakeholder agreements to undertake the intervention, what human resources are required to deliver the intervention and what trade-offs are necessary to enable blue carbon habitat recovery?

In order to determine the net present value of a blue carbon intervention, economic analysis needs to be able to access cost information from analogous interventions such as blue carbon ecosystem restoration or ungulate control, estimate future benefits derived from multiple direct and indirect values of the resultant blue carbon ecosystem, model the growth and post-restoration state of the system and estimate society's willingness to postpone benefit now for the benefit of future generations (IUCN and WRI, 2014; Verdone, 2015).

One approach used to estimate NPV for consideration in Phase 3 of this project uses the following six-step cost-benefit analysis framework adapted from Verdone (2015) and ROAM (IUCN and WRI, 2014), namely:

1. Develop consensus on main blue carbon interventions to be implemented and their spatial extent.
2. Develop reliable estimates of costs broken down into opportunity, transaction, and implementation costs.
3. Monetize and calculate the additional benefits from ecosystem goods and services to be derived per blue carbon intervention scenario. This involves selection of a landscape serving as an analogue for the post-restoration state of the study landscapes, the valuation of their mangrove resources and the application of those benefits to all BC intervention scenarios.
4. Model the incremental increase in benefits over time using variable estimates for intervention performance. This step involves the determination of a timeframe in which full benefits will be achieved and modelling of the annual attainment of those benefits. The second part involves determination of blue carbon intervention performance represented as a percentage of total possible performance.
5. Discount costs and benefits to obtain present values: selecting appropriate discount rates to make streams of future benefits and costs comparable in the present.
6. Calculate the Net Present Value of each scenario. Subtract the discounted stream of total costs from the discounted stream of benefits for each combination of blue carbon intervention performance and discount rate.

Conclusions and Recommendations

The NT is uniquely placed to develop an industry that is built on strong partnerships with Aboriginal landowners, government agencies, industry, and other stakeholders.

Further research is essential to inform new emissions offset methods and their viability across northern Australia. To progress the NT Blue Carbon agenda on the medium term (3-5 years), we suggest the following research and actions the Table below. Underlined activities are those to be addressed (fully or partially) in Phase 2 and 3 of this program. Others listed will be partially supported by this project, e.g., Blue Carbon projects on Pastoral-leased land, baseline distribution and composition data of blue carbon ecosystems.:

Further Research and Actions
Develop a NT Blue Carbon Strategy (as part of this project) with key stakeholders that includes: • <u>Pathways to conserve blue carbon ecosystems and methods to support the market implementation</u> • A clear legislative pathway for stakeholders in the industry in the NT is this required • Identification of Blue carbon projects on Aboriginal and Crown Pastoral-leased land • Integration of Blue Carbon in coastal and marine policy planning and management • <u>Promotion of Blue Carbon research and investment</u> • <u>Understand stakeholder interest in implementing BC projects</u> • Human resource capacity to implement BC projects • <u>Trade-off analysis and analysis of accrual of benefits to various stakeholder groups</u>
Broaden and deepen basic knowledge of Blue Carbon ecosystems to consider: • <u>Baseline distribution and composition data is required for all Blue Carbon ecosystems: seagrass, mangroves, saltmarshes, supratidal forests, and billabongs.</u> • <u>Map areas of degradation and determine levels of anthropogenic vs. natural loss and gain.</u> • Different sequestration rates and storage of carbon both individually and within a community. • Annual cycles of growth and reproduction, as well as die-back. • <u>Map carbon hotspots across the coastal ecosystem types.</u>
Develop new methods for: • <u>Assessing emissions from wetland sites where non-native ungulates have been excluded</u> • Measuring regrowth or establishment of new standing stocks for all ecosystem types at locations where a blue carbon project is found to be feasible. These should be co-created with traditional owners where appropriate. • Measuring the social, cultural, and environmental impacts of blue carbon projects, incorporating the different time frames associated with regeneration and/or re-establishment of each blue carbon ecosystem • Developing port and industry infrastructure that enables tidal inundation and improvement in condition of coastal wetlands while maintaining structural integrity of infrastructure. Modelling and mapping of changes to ocean flow with the removal/modification of infrastructure will need to be undertaken, especially in the Port of Darwin, but also around the other major coastal industrial locations.

Produce mapping outputs that include:

- Map areas of degraded wetlands that are opportunities for restoration and determine levels of anthropogenic vs. natural loss and gain.
- Map carbon hotspots across the blue carbon ecosystem types

While Blue Carbon has gradually been integrated into climate change policy in Australia and into the ERF, it is yet to be mobilised and integrated into the NT's environmental policy and practice. Amongst the challenges identified in this new industry, the opportunities and co-benefits are likely to provide substantial community and biodiversity benefits.

Some legal analysis and policy development is necessary to clarify tenure and appropriate engagement pathways, and royalty matters. This is fundamental for developing a strong governance framework and developing a robust industry. The successful resolution of these issues will pave the way for the inclusion of blue carbon ecosystems in the ERF.

The preparation of methodologies for blue carbon projects can draw upon the now extensive international progress in this area as well as national progress in other carbon market approaches. The issues surrounding legal security may be somewhat more challenging to resolve than in many other parts of Australia. However, there is a committed and growing community willing for this industry to progress and recognise the environmental and community benefits.

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