Mapping Victoria's Blue Carbon

Opportunities for coastal habitat restoration & climate change mitigation

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VICTORIA State Government | Energy, Environment and Climate Action

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Photo credit: White mangroves in Westernport, Credit: Alfred Sin

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it.

We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

DEECA is committed to genuinely partnering with Victorian Traditional Owners and Victoria's Aboriginal community

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Mapping Blue Carbon

Blue carbon is the carbon stored by marine and coastal ecosystems. Habitats such as seagrass, mangrove, and saltmarsh, are recognised for their important role in climate mitigation by their ability to sequester significant amounts of atmospheric carbon. Victoria's environment supports >60,000 ha of blue carbon habitats. The unique characteristics of coastal habitats not only provide climate mitigation benefits but a range of co-benefits from threatened species refuge, coastal protection, improved water quality, to healthy fisheries, recreation, and cultural value.

Purpose statement

The purpose of this report is to describe the method and technical approaches used for mapping blue carbon opportunities across Victoria. This work is underpinned by data provided by Deakin University's Blue Carbon Lab and the *"Mapping the benefits and costs of management actions for coastal wetlands in Victoria"* project (Costa et al. 2022). The Blue Carbon Lab's project outlines methods and information that has been further synthesised and developed into statewide spatial products tailored for a variety of stakeholders, blue carbon investors, conservation groups, catchment and regional planners and state managers.

The outputs will provide key information for supporting the development of blue carbon projects across Victoria as well as informing policy and planning under the *Marine and Coastal Act 2018*.

Marine Habitat Map

The new habitat map represents 24 marine and coastal ecological communities across Victoria's state waters, including blue carbon habitats. Developed from a mosaic of former mapping products, aerial imagery, field observation records, environmental variables and novel machine learning methods that model and predict habitat distributions.

The map aims to provide fundamental ecological information for supporting spatial planning and monitoring. The map includes blue carbon habitats and can be used to support blue carbon management decisions.

Explore the map on:

CoastKit

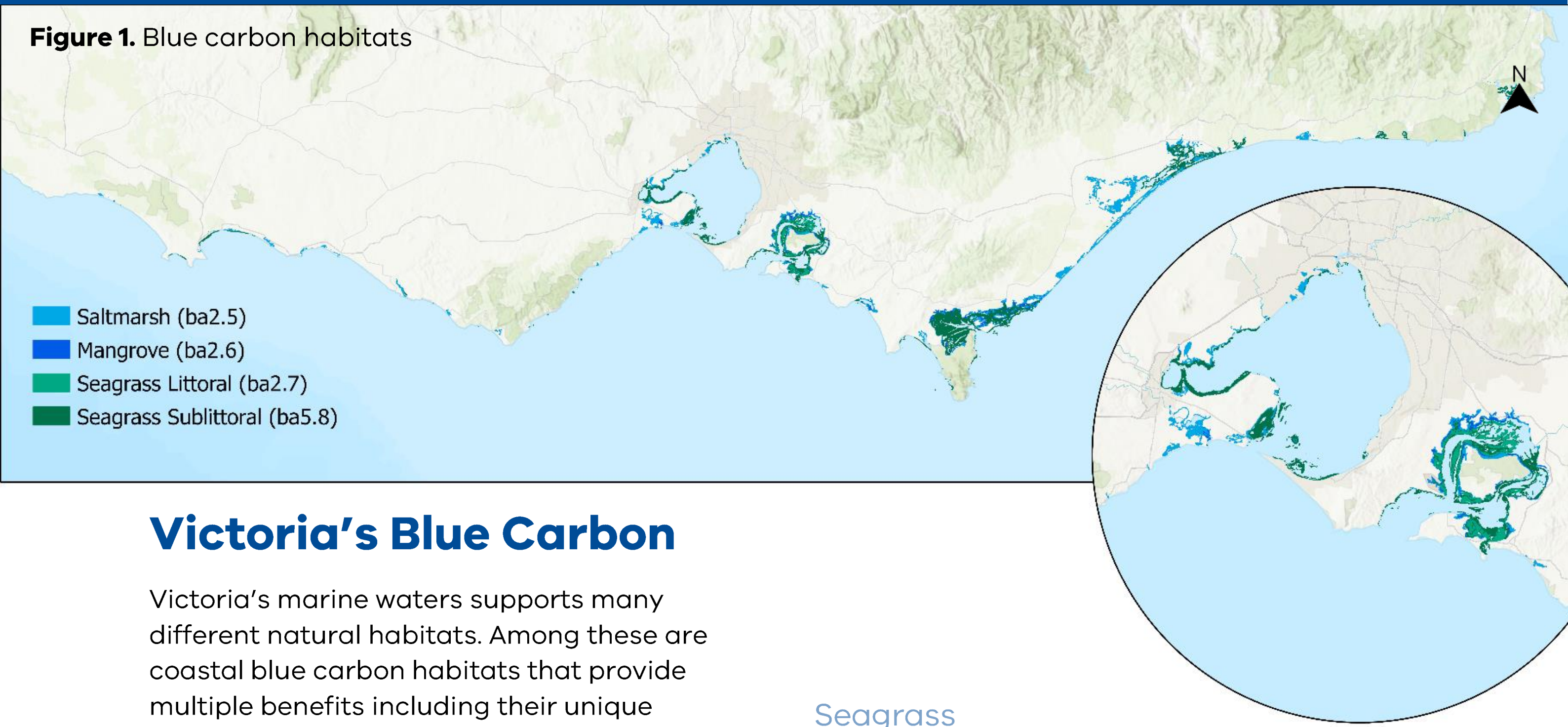


Figure 1. Blue carbon habitats

Victoria's Blue Carbon

Victoria's marine waters supports many different natural habitats. Among these are coastal blue carbon habitats that provide multiple benefits including their unique function in reducing atmospheric carbon. These habitats include saltmarsh, mangroves, and seagrass, which are distributed across the coastal interface and exhibit high ecological connectivity, providing important pathways and ecological functions as part of a larger ecosystem complex.

Saltmarsh

Saltmarsh habitat across Victoria is estimated at 13,286 ha (Mazor et al. 2023) and described by Boon et al. (2011) as 140 taxa within seven floristic and structural units comprising the Coastal Saltmarsh aggregate (Ecological Vegetation Class EVC 9). Saltmarsh habitats incorporate a variety of vascular plants that are recurrently inundated by seawater, such as low shrubs, herbs, grasses, succulents and submerged macrophytes.

Mangroves

Victoria's mangroves are estimated to cover 2,313 ha and located within sheltered bays and inlets in areas associated with saltmarsh habitat. There is only one species in Victoria, the white/grey mangrove *Avicennia marina* (Ecological Vegetation Class EVC 140 Mangrove Shrubland), with the world's most southerly mangrove occurrence at Corner Inlet (Boon et al. 2011). This species is listed under the *Flora and Fauna Guarantee (FFG) Act 1988*.

Seagrass

There is an estimated 42,816 ha of seagrass across Victoria, comprised of 84% sublittoral and 16% littoral seagrass. The dominant seagrass species occurs within sheltered bays and inlets are eelgrasses (*Heterozostera tasmanica, Heterozostera nigricaulis and Zostera muelleri)*, sea nymph (*Amphibolis antarctica*), paddleweed (*Halophila australis*) and the broad-leaved *Posidonia australis* present in Corner Inlet (Ball & Blake 2001). Three species are FFG listed (see Table A1).

1. Habitat Extent

The current extent of blue carbon habitats (see Table A1) was estimated from the Victoria's Department of Energy, Environment and Climate Action (DEECA) statewide marine habitat map (Mazor et al. 2023). Habitats were mapped with a combination of machine learning modelling and a synthesis of former mapping outputs, including mapping initiatives by Boon et al. (2011), Ball & Blake (2007a, b), Deakin Marine Mapping team, and Edmunds & Flynn (2015) and others. Blue carbon extent is predominantly concentrated within bays and inlets across the state, with Port Phillip Bay, Western Port Bay and Corner Inlet supporting the largest habitat extents. Importantly, habitat extent can vary across time, particularly for seagrasses which are ephemeral (seasonal).

2. Habitat Condition

Evaluating habitat condition is important in assessing spatial priorities for restoration. Where habitat is thriving and considered in a "good" or "natural" state, such areas may require protection rather than restoration. Other habitats which are disturbed or threatened will have varying degrees of restoration actions required. Mapping the condition and disturbance level of habitats, helps assess the level of threat as well as the intensity of restoration actions required to improve condition.

The classification and assessment method for condition used available existing literature and historical maps following Costa et al. (2022). Saltmarsh and mangrove habitat were assessed by the change or presence of land modifications such as pasture and grazing, as well as levees. Seagrass was evaluated by persistence, where previous maps (e.g., Dalby et al. 2023) were used to classify the age of seagrass meadows and locations where they have collapsed over time (Carnell et al. 2022b). Seagrass condition in Corner Inlet is understudied but given estimations on habitat loss (Ford et al. 2016) a 'medium disturbance' category was assigned.

The below categories detail how five condition states were assigned to habitat locations.

- **Natural**: Mangroves and saltmarshes that are not impacted by levees limiting tidal exchange and are not within pasture/grazing land; seagrass with persistence (i.e., documented distribution) for >30 years was considered in a stable "natural" state.

- **Low disturbance**: Mangroves and saltmarshes that are within low disturbance pasture/grazing land but are not impacted by levees limiting tidal exchange; seagrass currently present with a persistence between 11-30 years.

- **Medium disturbance**: Mangroves and saltmarshes that are currently impacted by levees limiting tidal exchange but are not within pasture/grazing land; seagrass present with a persistence within 10 years.

- **High disturbance**: Mangroves and saltmarshes that are currently impacted by levees limiting tidal exchange and are within pasture/grazing land; seagrass areas that were previous recorded which have collapsed within the past 10 years.

- **Collapsed**: Mangrove and saltmarsh that were lost and currently under a different land use (historical distribution); seagrass areas that were previous reported which have collapsed within the past 10-30 years (maps from Ball & Blake 2001).

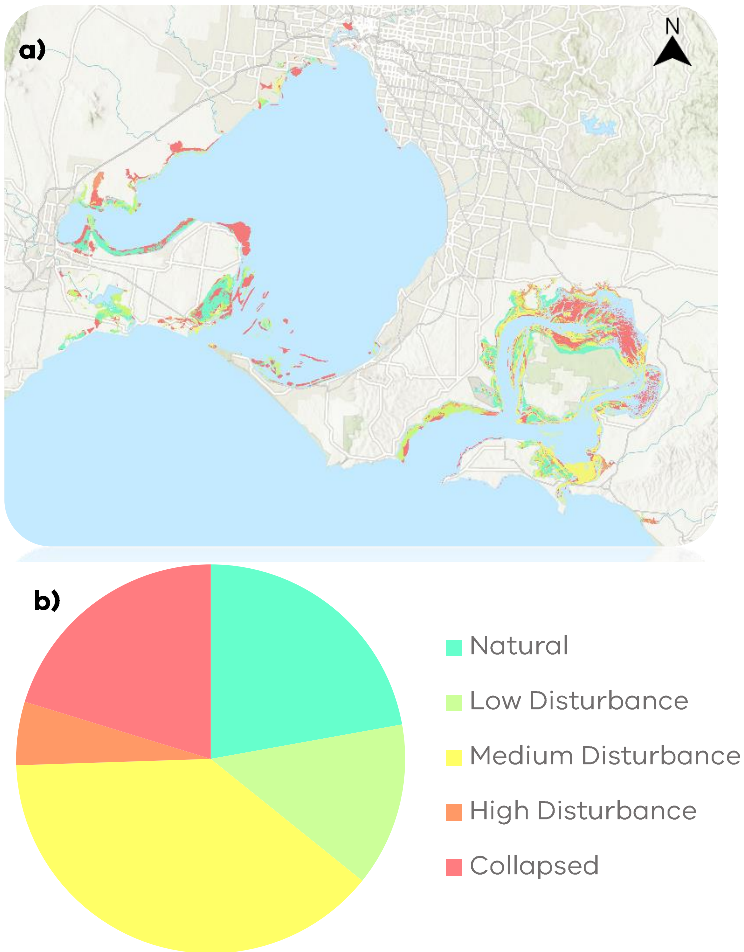


Figure 2. a) Condition of coastal habitats (saltmarsh, mangroves and seagrass) in Port Phillip Bay and Western Port Bay. b) The pie chart indicates the proportion of blue carbon habitat condition across Victoria.

Assessing the condition of blue carbon habitats across the state, approximately 20% of habitats are in a natural state, over half the habitats are in disturbed condition, and 20% in a collapsed state.

3. Benefits

Coastal habitats not only provide nature-based solutions for carbon abatement but also deliver numerous benefits including coastal protection from storms, sea level rise and shoreline erosion, improved water quality, nursey grounds for commercially important fisheries, refuge for endangered marine species, as well as significant cultural and heritage value for Tradition Owners. While spatially refined information is not readily available on all benefits, several benefits have been assessed (described below). When information becomes more spatially refined, the benefit data can be updated to help improve decision making.

Climate mitigation

An important role of coastal habitats is their function in sequestering carbon from the atmosphere. These habitats create a carbon sink, and their potential in climate change mitigation is being recognised. To estimate carbon sequestration Deakin University (Costa et al. 2022) used the spatially explicit coastal blue carbon InVEST model (Sharp et al. 2018) to model sequestration rates (see Table A2).

Biodiversity

Biodiversity benefits were calculated using the Strategic Biodiversity Values (SBV) layer from NatureKit, Victoria's terrestrial biodiversity data tool. The SBV layer ranks all locations across Victoria by their ability to represent threatened vertebrate fauna, vascular flora, and the full range of Victoria's native vegetation on a scale of 0 to 100. These values enable comparison of locations across Victoria based upon biodiversity values. The values were aligned with blue carbon coastal habitats and average values were calculated and assigned. Due to the absence of values for seagrass and their known role in supporting a rich marine biodiversity, a high value (90) was chosen as a surrogate.

Coastal protection

Blue carbon habitats are effective buffers along coastlines, protecting shores from erosion, dissipating wave energy to provide coastal resilience and protection. These natural habitats provide a nature-based solution for a diversity of coastal values and uses (environmental, cultural, social, economic), including infrastructure and coastal populations. As a first-pass assessment of the coastal hazard mitigation benefits provided by coastal habitats at large scales, the number of properties within a 1 km distance from each habitat polygon was calculated (see Costa et al. 2022 for methods).

Fisheries

Coastal habitats provide essential fish spawning and nursery grounds. For example, King George whiting juveniles rely on seagrass beds in Victoria's bays and estuaries during their first four years to reach maturity. Following Costa et al. (2022) annual commercial fish catch biomass enhancement values per habitat were calculated (estimated values from Jänes et al. 2020a, 2020b; Table A2). Recreational fish catch was estimated by finfish and non-fish species for Victoria, with a total catch of 101,509 kg yr-1 (Henry & Lyle 2003). The total catch was divided proportionally by habitat type according to Jänes et al. (2020b). The commercial and recreational catch were then combined into a fisheries benefit value.

Water quality

Coastal habitats play a critical role in water purification, with their ability to sequester nitrogen. Average nitrogen sequestration rates and ranges for each habitat type were calculated and applied to the habitat map according to sampling cores across the state (Costa et al. 2022; Carnell et al. 2022a; Table A2).

Multiple benefits

A measure for multiple benefits was calculated by combining coastal protection, fisheries, water quality, carbon sequestration and biodiversity into one metric. Each benefit (excluding biodiversity, which was an average, as well as coastal protection, which was a 1 km standard radius) was divided by the polygon area (hectares) and standardised between 0-1. All values were then summed with equal weighting (Appendix A). High values across the state represent areas where multiple high benefits occur.

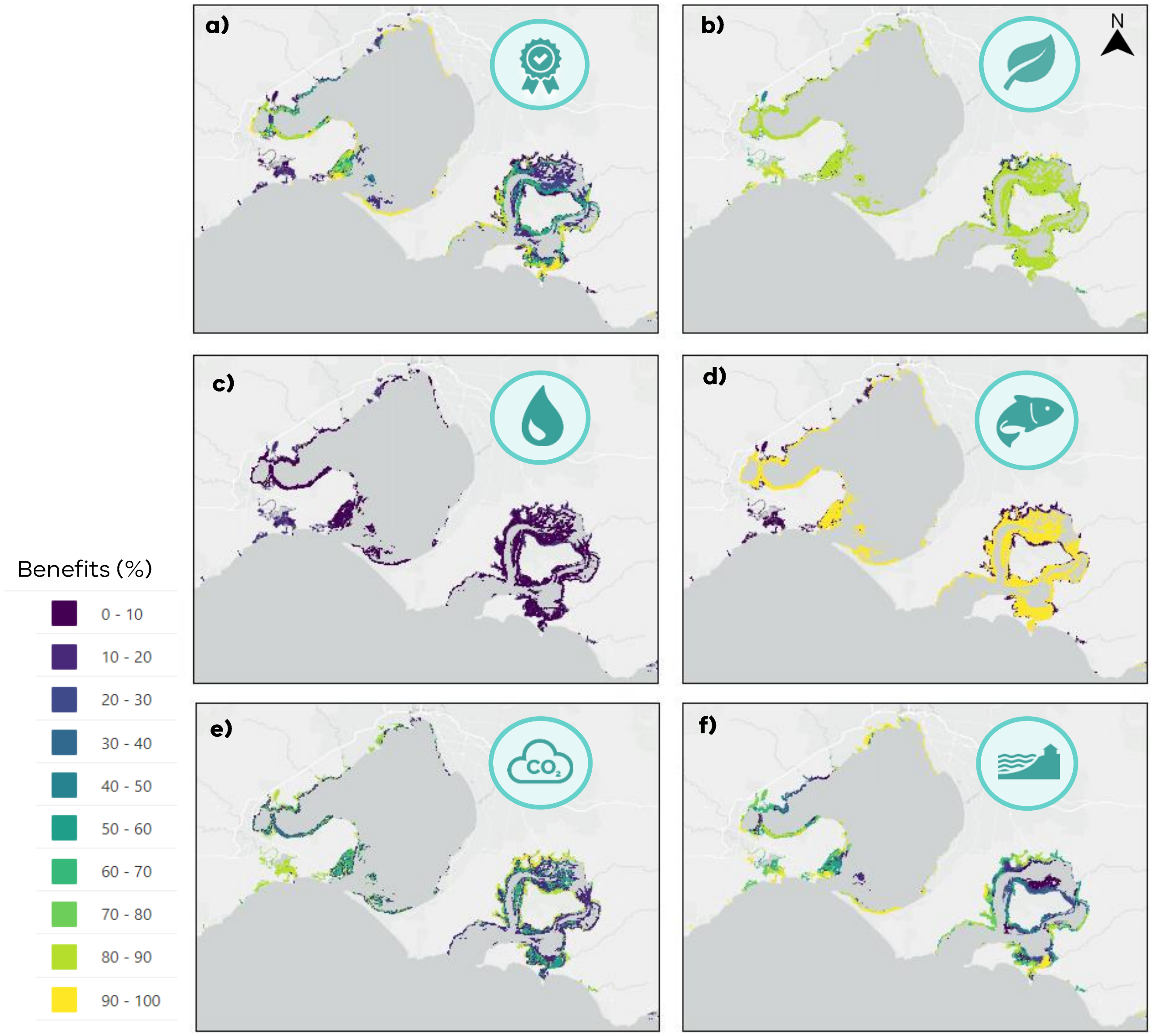


Figure 3. Benefits provided by blue carbon habitats (seagrass, saltmarsh, mangroves) within Port Phillip Bay and Western Port Bay: a) multiple benefits combined (equal weighting; Appendix A), highlighting areas with a wide number of benefits; b) biodiversity benefits, representing areas with high numbers of threatened flora and fauna; c) water quality as represented by nitrogen sequestration rates; d) fisheries benefit across habitats and combined from both commercial and recreational fisheries; e) climate mitigation measured by tonnes of carbon sequestration; f) coastal protection measured by the number of properties.

4. Restoration Potential

Statewide areas with high conservation and restoration potential were mapped for existing blue carbon habitats (Appendix B for method). These areas are coastal habitats that are considered the top 20% ranked (similar to terrestrial SMP methodology) for restoration applying the below criteria:

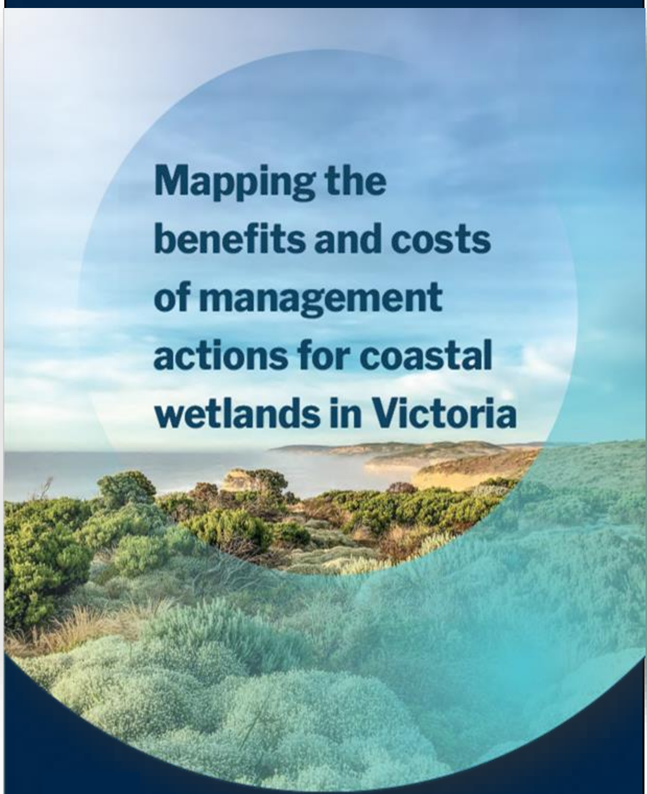
1) Areas with **high carbon sequestration and co-benefits** (fisheries, costal protection, water quality and biodiversity) across the state.
2) Habitats that are of **disturbed condition** (condition map category 2-4), requiring restoration towards a natural state habitat.
3) Equal representation of habitats - **20% of each habitat** extent (seagrass, mangrove, saltmarsh) was included (by area).

These high restoration potential areas provide a large-scale perspective for guiding restoration actions in existing coastal habitats across Victoria. Given the high modification of coastal landscapes over time (e.g. hydrological alterations, changed land-use practises, increased erosion, higher nutrients and pollution inputs) and the unlikelihood in restoring some habitat patches to their previous "natural" state, this assessment also considered land-use areas that are unlikely to be converted back to coastal wetlands (see Costa et al. 2022). These broad areas help guide potential areas for blue carbon restoration actions at large scales (>5 km) but requires further refined data, planning and local scale assessment to be undertaken before on-ground actions occur.

Restoring and/or conserving habitats that are not mapped as a high restoration potential area are still considered important. Some patches of coastal habitats for example could deliver other important co-benefits (e.g., recreational, and cultural values) which have not yet been considered in this evaluation. Likewise, some areas may rank as a high priority if examined within a localised context or with higher resolution information. Existing habitats assessed as 'natural' may also require conservation actions to preserve their current condition from threats.

Ecosystem Accounting

Deakin University's Blue Carbon Lab has led work (Costa et al. 2022) which implemented the new UN System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA) framework to develop a set of accounts for Victoria's coastal habitats.



These accounts provide the metrics and methods used to develop DEECA's statewide blue carbon mapping toolkit. This work assessed the multiple benefits of existing blue carbon habitats as well as evaluated the benefits, costs, and actions of restoring collapsed and new habitat areas.

Blue Carbon Lab
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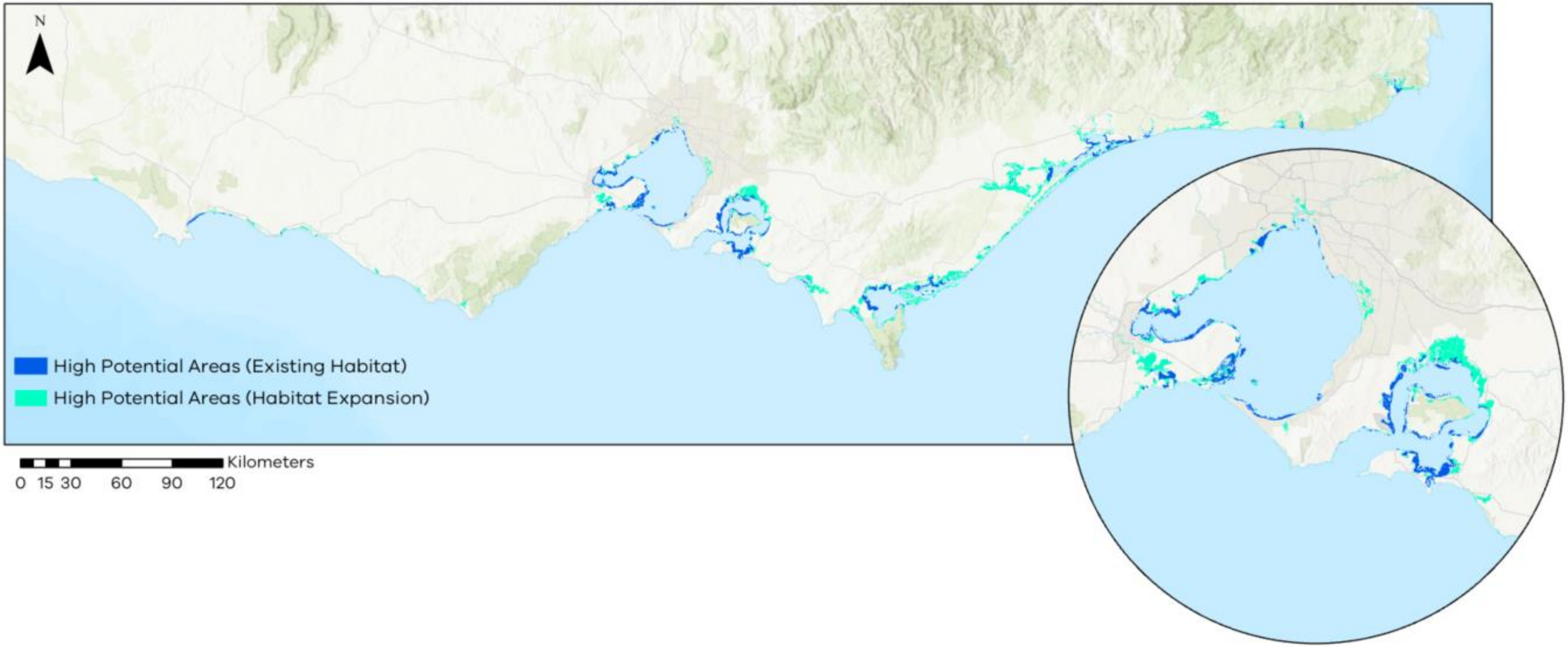
Figure 4. High potential areas for blue carbon restoration including: **a) Existing habitat** – the top 20% of each habitat type (saltmarsh, mangrove and seagrass) which have the highest carbon value and additional benefits (biodiversity, fisheries, water quality and coastal protection), and are in poor condition (disturbed state 2-4), **b) Habitat expansion** – areas that require specific restoration actions (grazing control, tidal restoration, habitat retreat, hydrological intervention) to potentially expand the current habitat extent of saltmarsh and mangroves (seagrass has not been considered) and yield co-benefits (modelling method; Costa et al. 2022).



5. Restoration Actions

Other restoration opportunities exist to expand blue carbon ecosystems areas beyond their current distribution (Figure 4). These opportunities focus on saltmarsh and mangrove habitats (seagrass has not been included) and require specific actions depending on the type of land-use changes that may have occurred over time such as the construction of levees, or agriculture practices. Spatial maps have been developed by Deakin's Blue Carbon Lab (Costa et al. 2022) based on modelling to estimate where actions have the potential to occur across the state (Figure 6). These modelling scenarios are based upon environmental data and have not considered the socio-economic feasibility or the approvals process for relevant land owners or land managers.

Tidal reinstatement

The reintroduction of tidal flows is considered a main management activity identified to have potential application across Australia and Victoria. This action is the first to be developed as a formal Emissions Reduction Fund (ERF), method known as BlueCAM, for acquiring Australian Carbon Credit Units (ACCUs; Clean Energy Regulator 2022). This action assumes removal of a tidal barrier, such as a levee, to enable passive restoration of coastal habitats. The areas mapped for potential tidal reinstatement relied upon levee location data (DELWP 2018).

Grazing Control

This action requires works to restrict livestock and pests from accessing and degrading wetlands. Saltmarshes and mangroves can be damaged by uncontrolled stock and pest animals leading to grazing of native plants, increased soil erosion, vegetation trampling as well as altered nutrient cycling and reduced water quality. The removal of livestock/pests from wetland habitats can see the recovery of saltmarsh and mangroves. The mapped potential locations to undertake this action are based on current land-use and the pre-European distribution of saltmarsh and mangroves (Boon et al. 2011) indicating where these ecosystems existed historically but are currently not present.

Figure 5. Restoration of saltmarsh habitat by grazing control (credit: Deakin Blue Carbon Lab; Melissa Wartman).

Habitat retreat

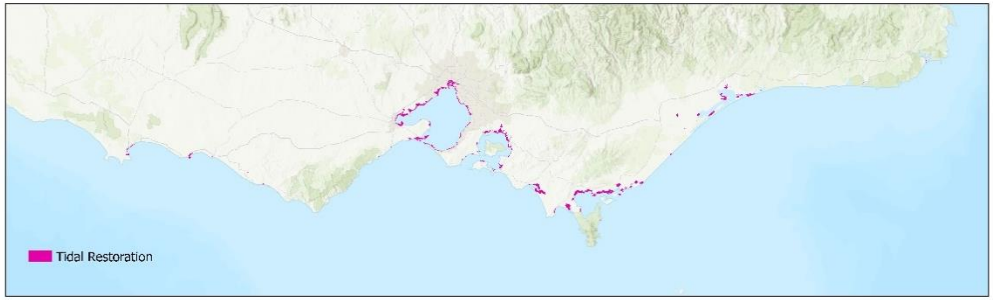
Sea level rise and natural inundation is considered a likely consequence of climate change with projections of an increase in sea levels by 82cm in 2100, from 2009 levels (DELWP 2018). However, this also provides a passive opportunity to expand the habitats of coastal wetlands. Mapped locations for potential habitat retreat were modelled (Costa et al. 2022) based upon sea level rise forecasts to 2100 and historical locations where mangroves and saltmarsh could extend beyond the bounds of the documented historic distribution. These maps apply predictive modelling at large scales and should be used with caution as high-resolution data, local scale mapping, modelling and hydrological assessments are required to improve spatial maps and estimations.

Hydrological intervention

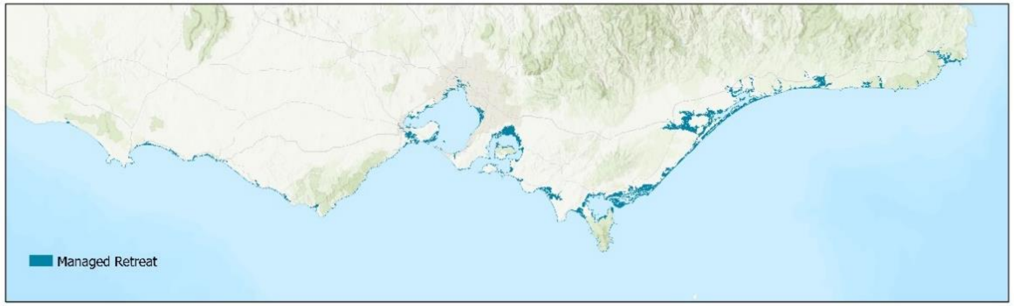
Some locations may require more complicated hydrological interventions. These sites were identified based on local knowledge and the assumption that the presence of two or more levees would require complex hydrodynamic modifications on a specific site. Five sites were identified and mapped in this analysis: Avalon Saltponds, Moolap Saltponds, Cheetham Saltponds, Werribee sewage treatment ponds, Lake Victoria.

Figure 6. Areas across the state for potential blue carbon restoration actions a) tidal reinstatement, b) grazing control, c) habitat retreat (projection for year 2100), d) hydrological intervention. Data presented here are based on large-scale scenario modelling (Costa et al. 2022) and only display estimations of potential restoration areas for mangrove and saltmarsh habitats (seagrass has not been considered). Local scale mapping, modelling and hydrological assessments are required to improve spatial maps and estimations.

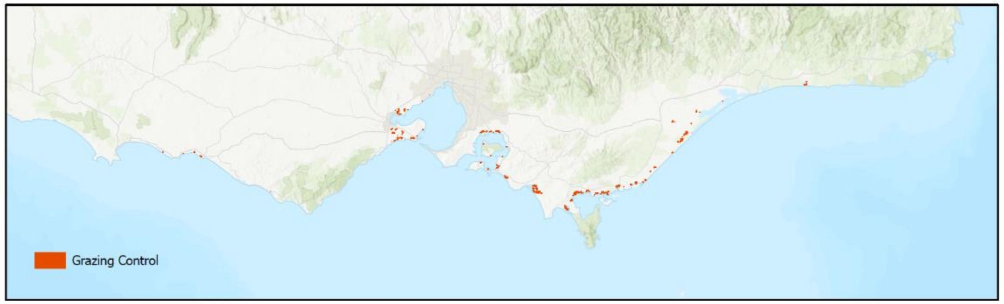
a) Tidal reinstatement



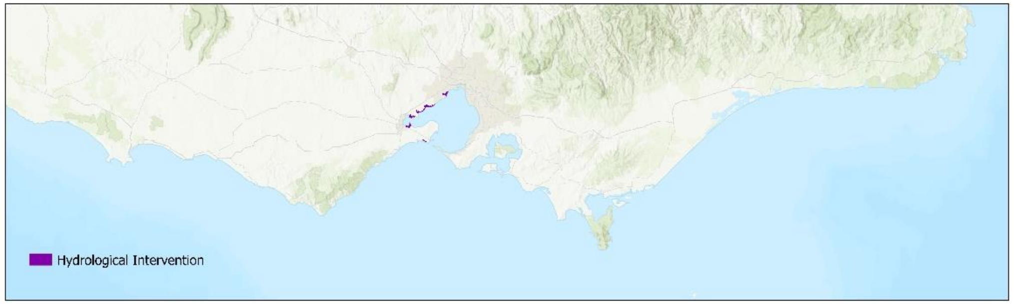
c) Habitat retreat



b) Grazing control



d) Hydrological intervention



6. Blue Carbon Future

Victoria holds opportunities for blue carbon conservation, with two-thirds of current habitat offering restoration potential from a disturbed or collapsed state. These blue carbon areas deliver multiple ecosystem services (or co-benefits) on top of climate change mitigation. The value of blue carbon habitats in Victoria has been estimated to be worth around AUD$120 billion per year (Costa et al. 2022). Despite the clear benefits and value of these habitats, more than 16,000 ha of blue carbon habitat is predicted to be lost to erosion impacts and sea level rise in Victoria (DELWP 2018; Costa et al. 2022). Seagrass is predicted to be the most impacted ecosystem.

The map of high potential areas for blue carbon restoration (of existing and new habitat, Figure 4) was developed to highlight large-scale opportunities where climate mitigation potential aligns with multiple benefits for biodiversity and society. This baseline mapping provides foundational data to build upon with further advanced analytics, integration of high-resolution local scale data and alternative future scenario modelling. These maps aim to help support strategic management decisions, stakeholder engagement and processes to embed Traditional Owner cultural values.

This report provides a statewide scale synthesis of blue carbon habitat mapping of the current extent, condition, and benefits. The intent of statewide mapping is to provide guidance and synthesised information to complement more detailed site-specific assessments that are progressively being undertaken by local governments and land managers, with Traditional Owners actively leading and contributing to blue carbon assessments across the state in a place-based context.

CoastKit

Blue Carbon ToolKit

All statewide maps are available to explore on CoastKit within the "Restoration" theme. The toolkit include options to zoom in and interegate the data showing areas for each different type of benefit, as well as the ability to overlay data with other information available on the CoastKit portal.

References

Ball, D. and Blake, S. (2007a) Shallow habitat mapping at Victorian Marine National Parks and Sanctuaries. Volume 1: Western Victoria, Parks Victoria Technical Series No. 36

Ball, D. and Blake, S. (2007b) Shallow habitat mapping in Victorian Marine National Parks and Sanctuaries, Volume 2: Eastern Victoria. Parks Victoria Technical Series No. 37. Parks Victoria, Melbourne.

Blake, S. and Ball, D. (2001). Victorian Marine Habitat Database: Seagrass Mapping of Port Phillip Bay. Geospatial Systems Section, Marine and Freshwater Resources Institute Report No. 39. Marine and Freshwater Resources Institute: Queenscliff.

Boon, P. I., T. Allen, J. Brook, G. Carr, D. Frood, J. Hoye, C. Harty, A. McMahon, S. Mathews, and N. Rosengren. (2011). Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats, and management.

Carnell, P. E., M. M. Palacios, P. Waryszak, S. M. Trevathan-Tackett, P. Masqué, and P. I. Macreadie. (2022a). Blue carbon drawdown by restored mangrove forests improves with age. *Journal of Environmental Management* 306:114301.

Carnell, P., R. McLeod, M. Young, C. Gillies, C. Obst, P. Macreadie, D. Ierodiaconou, S. Reeves, M. Eigenraam, H. Janes, J. Kelvin, and E. Nicholson. (2022b). Prioritising the restoration of marine and coastal ecosystems using ecosystem accounting. PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-1617940/v1].

Clean Energy Regulator (2022). Tidal restoration of blue carbon ecosystems method. Clean Energy Regulator, Commonwealth of Australia, Available at: https://www.cleanenergyregulator.gov.au/ERF

Costa, M.D.P, Wartman, M., Macreadie, P.I., Ierodiaconou, D., Morris, R., Nicholson, E., Pomeroy, A., Young, M., Carnell, P. (2022). Mapping the benefits and costs of management actions for coastal wetlands in Victoria. Report submitted to the Department of Environment, Land, Water and Planning. Deakin University, Australia. 55pp.

DELWP (2018). Victorian Coastal Inundation Sea Level Rise Storm Tide 2100 (ANZVI0803004733), Victorian Governments Future Coasts Project.

Dalby, O., Pucino, N., Tan, Y.M., Jackson, E.L., Macreadie, P.I., Coleman, R.A., Young, M.A., Ierodiaconou, D. and Sherman, C.D.H. (2023), Identifying spatio-temporal trends in seagrass meadows to inform future restoration. Restor Ecol, 31: e13787. https://doi.org/10.1111/rec.13787

Edmunds, M., Flynn, A. (2015). A Victorian Marine Biotope Classification Scheme. Australian *Marine Ecology Report* No. 545. Melbourne.

Ford, J.R., Barclay K., and Day R.W. University of Melbourne, 2016, Using local knowledge to understand and manage ecosystem-related decline in fisheries productivity, Fisheries Research and Development Corporation Final Project Report, Melbourne, June. CC BY 3.0

Henry, G. W., and J. M. Lyle. (2003). The National Recreational and Indigenous Fishing Survey.

Jänes, H., P. I. Macreadie, E. Nicholson, D. Ierodiaconou, S. Reeves, M. D. Taylor, and P. E. Carnell. (2020a). Stable isotopes infer the value of Australia's coastal vegetated ecosystems from fisheries. Fish and Fisheries 21:80–90.

Jänes, H., P. I. Macreadie, P. S. E. Zu Ermgassen, J. R. Gair, S. Treby, S. Reeves, E. Nicholson, D. Ierodiaconou, and P. Carnell. (2020b). Quantifying fisheries enhancement from coastal vegetated ecosystems. Ecosystem Services 43:101105.

Mazor, T., Watermeyer, K., Hobley, T., Grinter, V., Holden, R., MacDonald, K. and Ferns, L. (2023). Statewide Marine Habitat Map.

Habitat Complex Modelling Method (CBiCS Level 3). The State of Victoria Department of Energy, Environment and Climate Action.

Sharp, R., R. Chaplin-Kramer, S. Wood, A. Guerry, H. Tallis, T. Ricketts, E. Nelson, D. Ennaanay, S. Wolny, N. Olwero, K. Vigerstol, D. Pennington, G. Mendoza, J. Aukema, J. Foster, J. Forrest, D. R. Cameron, K. Arkema, E. Lonsdorf, and J. Douglass. (2018). InVEST User's Guide.

Appendix

Appendix A – Weighted equation for multi benefits

Appendix B - Method for calculating high potential areas:

Figure A1 – Habitat distribution

Figure A2 – Habitat condition

Figure A3 – Priorities for conservation

Figure A4 – Restoration actions

Table A1 – Habitat extent and species

Table A2 – Blue carbon benefits and calculations

Appendix A. Weighted equation used to calculate the multiple benefit metric for each coastal habitat. Each benefit is weighted equally (20%), with the fisheries service divided into 10% for both recreation and commercial fishing.

$$\text{Multi Benefit} = (Recreation\ Fishing * 0.10) + (Commercial\ Fishing * 0.10) + (Coastal\ Protection * 0.20) + (Biodiversity * 0.20) + (Carbon\ Sequestration * 0.20) + (\ Nitrogen\ Sequestration * 0.20)$$

Appendix B. Method for calculating high potential areas:

4

1. Subset dataset for condition values (2-4)
2. Subset dataset for relevant habitats
3. Rank order for carbon sequestration values
4. Rank order for benefits = (biodiversity *0.25) + (fishing *0.25) + (coastal protection *0.25) + (nitrogen *0.25)
5. Combine rank order <- (rank order carbon *0.5) + (rank order benefits *0.5)
6. Order dataset by combined rank order
7. Calculate cumulative percentage of area per order and take top 20% of habitat area as assigned priority.
8. Combine all habitat types and dataset to list priority values

Figure A1. Statewide blue carbon habitat (saltmarsh, mangrove, seagrass) distribution (map from Mazor et al. 2023).

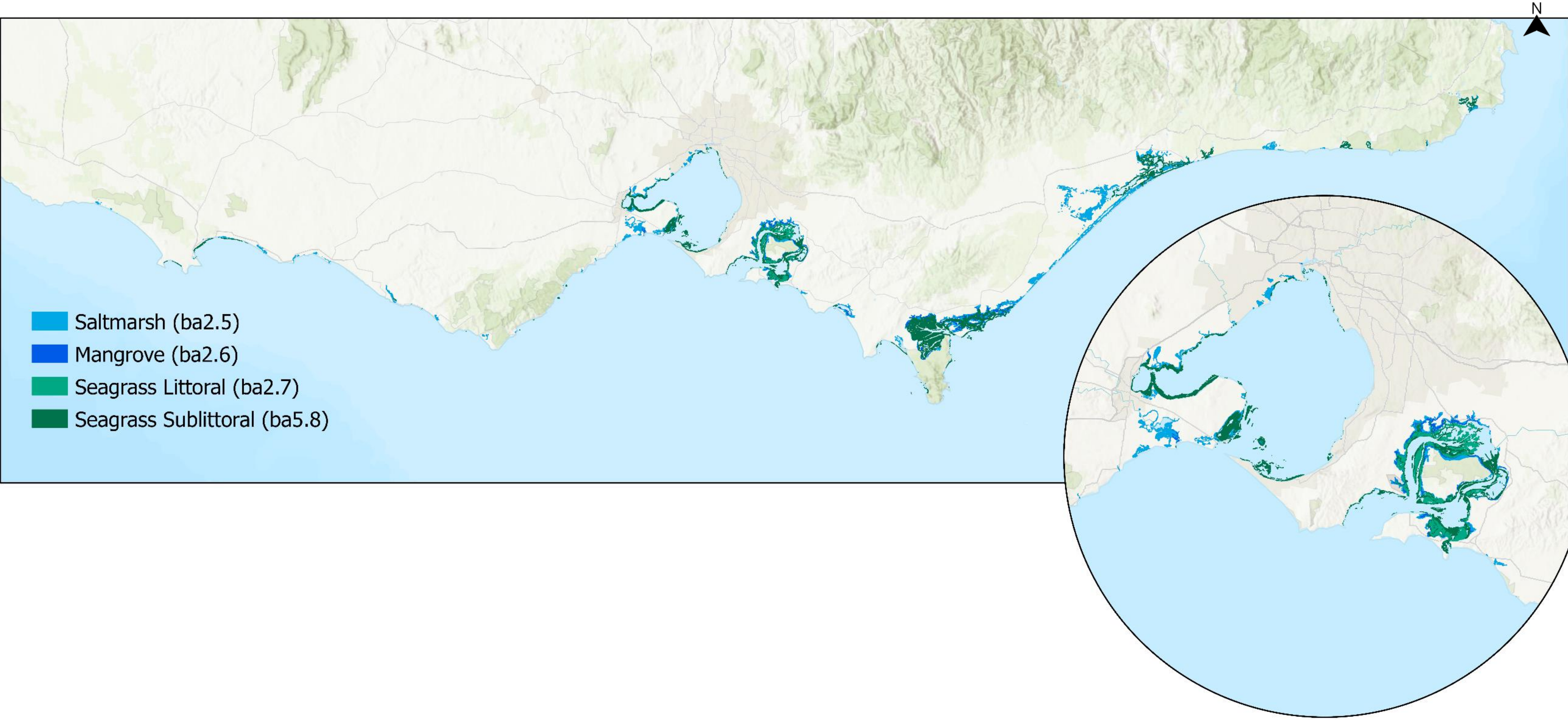
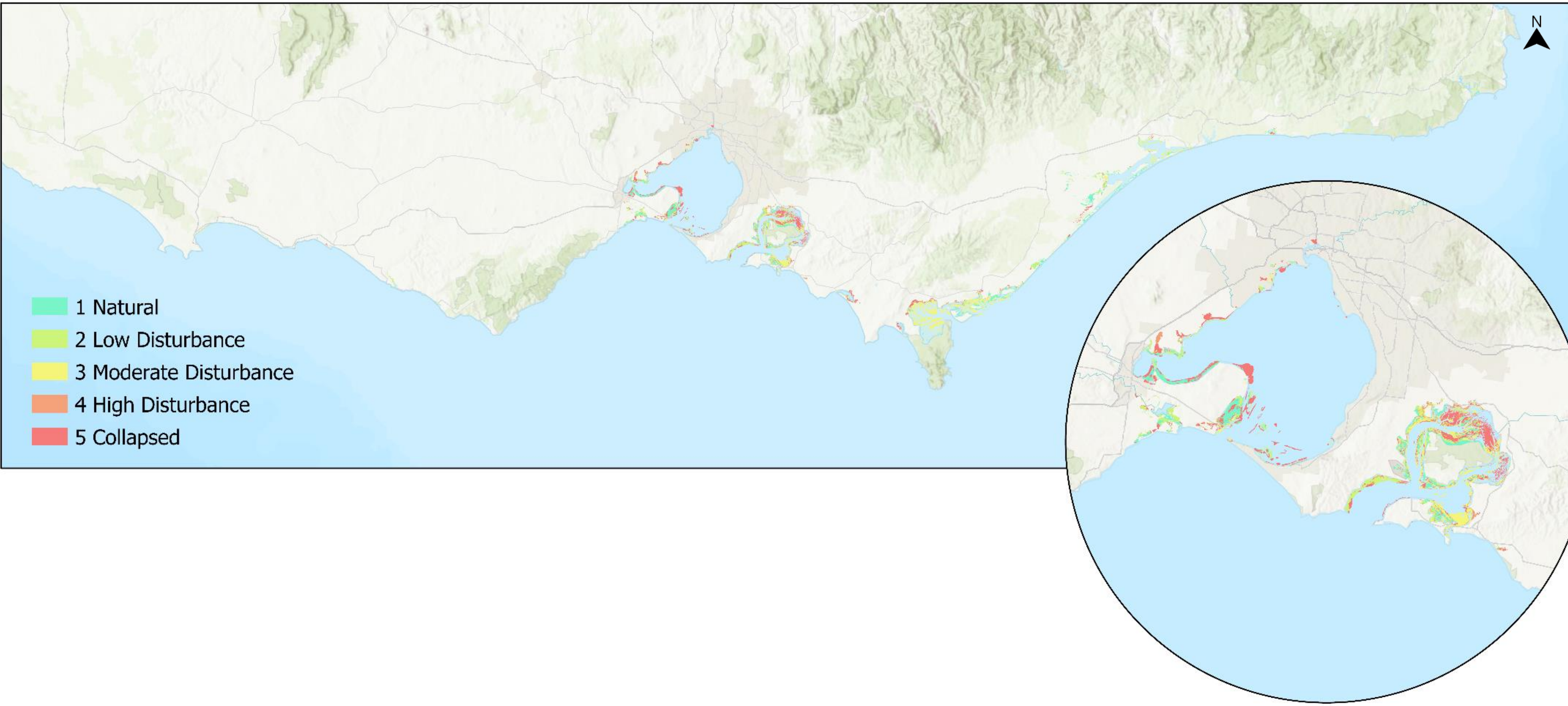


Figure A2. Statewide blue carbon habitat condition.



Appendix A. Weighted equation used to calculate the multiple services metrics for each coastal habitat. Each service is weighted equally (20%), with the fisheries service divided into 10% for both recreation and commercial fishing.

$$\text{Multi Services} = (Recreation\ Fishing * 0.10) + (Commercial\ Fishing * 0.10) + (Coastal\ Protection * 0.20) + (Biodiversity * 0.20) + (Carbon\ Sequestration * 0.20) + (\ Nitrogen\ Sequestration * 0.20)$$

Appendix B. Method for calculating priority areas:

9. Subset dataset for condition values (2-4)
10. Subset dataset for relevant habitats
11. Rank order for carbon sequestration values
12. Rank order for benefits = (biodiversity *0.25) + (fishing *0.25) + (coastal protection *0.25) + (nitrogen *0.25)
13. Combine rank order <- (rank order carbon *0.5) + (rank order benefits *0.5)
14. Order dataset by combined rank order
15. Calculate cumulative percentage of area per order and take top 20% of habitat area as assigned priority.
16. Combine all habitat types and dataset to list priority values

Table A1. Table of blue carbon coastal habitats their relevant Combined Biotope Classification System (CBICS) code, the species comprising the habitat type and the estimate extent of the habitat across the state. *FFG listed

Blue Carbon Habitat	CBICS Code	Species - Scientific name	Species - Common Name	FFG Listing	Estimated extent (ha)
Seagrass	ba2.7 and ba5.8	*Heterozostera tasmanica*	Eelgrass	FFG	42,816
		Heterozostera nigricaulis	Eelgrass / Australian Grass-Wrack	FFG	
		Zostera muelleri	Eelgrass / Garweed		
		Amphibolis antarctica	Sea nymph / Wire weed		
		Halophila australis	Paddle weed		
		Posidonia australis	Fibre-ball weed / Ribbon weed	FFG	
Mangrove	ba2.6	*Avicennia marina*	Grey/White Mangrove	FFG	2,313
Saltmarsh	ba2.5	EVC 9: Coastal Saltmarsh Aggregate*			13,286
		Indicator species:			
		Austrostipa stipoides	Coastal spear-grass		
		Disphyma crassifolium subsp. clavellatum	Rounded Noon-flower		
		Distichlis distichophylla	Australian salt-grass		
		Frankenia pauciflora	Southern sea-heath		
		Gahnia filum	Chaffy saw-sedge		
		Samolus repens	Creeping brookweed		
		Salicornia quinqueflora	Beaded glasswort		
		Suaeda australis	Austral seablite		
		Tecticornia arbuscula	Shrubby glasswort		
		Triglochin striata	Streaked arrowgrass		

*EVC 9: Coastal Saltmarsh Aggregate Description:

Variously low shrubby or herbaceous (to grassy or sedgy) vegetation of salinised coastal soils, in or adjacent to tidally influenced wetland. Coastal Saltmarsh Aggregate can include a number of zones of varying structure and floristics, reflecting the regimen of tidal inundation and substrate character. The potential component EVCs of Coastal Saltmarsh Aggregate include Wet Saltmarsh Herbland (EVC A107), Wet Saltmarsh Shrubland (EVC A108), Coastal Saline Grassland (A109), Coastal Dry Saltmarsh (A110), Coastal Hypersaline Saltmarsh (EVC A111), Coastal Tussock Saltmarsh (EVC A112) and Saltmarsh-grass Swamp (EVC A113). Scattered distribution in sheltered embayments and estuaries along the Victorian coast.

Table A2. Blue carbon benefits and their associated values that were used for spatial mapping.

Co-Benefits	**Coastal Habitat**	**Values**	**Reference**
Commercial fisheries	Saltmarsh	64 kg ha^{-1} yr^{-1}	Methods following Costa et al. (2022) and references within (Jänes et al. 2020a, 2020b, Henry and Lyle 2003).
	Mangrove	265 kg ha^{-1} yr^{-1} (13.5 - 516.9 kg ha^{-1} yr^{-1})	
	Seagrass	4,064 kg ha^{-1} yr^{-1} (530 - 13,800 kg ha^{-1} yr^{-1})	
Recreational fisheries	Saltmarsh	0.13 kg ha^{-1} yr^{-1}	
	Mangrove	0.52 kg ha^{-1} yr^{-1}	
	Seagrass	0.29 kg ha^{-1} yr^{-1}	
Climate mitigation (carbon sequestration)	Saltmarsh	0.66 tonnes C ha^{-1} yr^{-1} (2.42 tonnes CO_2 ha^{-1} yr^{-1}) for natural saltmarshes (Ewers Lewis et al. 2018, 2020) 0.54 tonnes ha^{-1} yr^{-1} (1.98 tonnes CO_2 ha^{-1} yr^{-1}) for restored saltmarshes (Gulliver et al. 2020)	Methods following Costa et al. (2022)
	Mangrove	1.74 tonnes ha^{-1} yr^{-1} (6.38 tonnes CO_2 ha^{-1} yr^{-1}) for natural mangroves (Ewers Lewis et al. 2018, 2020) 2.7 tonnes ha^{-1} yr^{-1} (9.9 tonnes CO_2 ha^{-1} yr^{-1}) for restored mangroves (Carnell et al. 2022a)	
	Seagrass	0.5 tonnes C ha-1 yr-1 (1.87 tonnes CO2 ha-1 yr-1) for natural seagrasses (Serrano et al. 2019)	

Water quality (nitrogen sequestration)	Saltmarsh	Port Phillip Bay 0.051 ± 0.010 Western Port Bay 0.115 ± 0.039 Open Area 0.083	Methods following Costa et al. (2022) and references within (Carnell et al. 2022).
	Mangrove	Port Phillip Bay 0.165 ± 0.076 Western Port Bay 0.013 ± 0.002 Open Area = 0.089	
	Seagrass	PPB 0.012 ± 0.002 WPB 0.008 ± 0.001 Open Area = 0.01	
Coastal protection	Saltmarsh	Number or properties within 1km buffer. The Vicmap property layer "V_PROPERTY_MP" was used to calculate the number or properties.	Methods following Costa et al. (2022)
	Mangrove		
	Seagrass		
Biodiversity benefits	Saltmarsh	The average value that overlay each saltmarsh habitat polygon from the SBV v4.0 raster dataset was calculated and applied.	The Strategic Biodiversity Values (SBV) layer ranks all locations across Victoria for their ability to represent threatened (VROT) vertebrate fauna, vascular flora, and the full range of Victoria's native vegetation on a scale of 0 to 100. It combines information on important areas for threatened flora and fauna, levels of depletion, connectivity, vegetation types and condition to provide a view of relative biodiversity importance of all parts of the Victorian landscape, enabling comparison of locations across Victoria.
	Mangrove	The average value that overlay each mangrove habitat polygon from the SBV v4.0 raster dataset was calculated and applied.	
	Seagrass	Give the unique and highly important value of seagrass habitats for marine biodiversity, and the absence of SBV marine values, the value of 90 was used across all seagrass habitats.	