Coastal carbon opportunities: ecosystem services provided by blue carbon habitats in South Australia
SUMMARY REPORT

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1 Background

Coastal vegetated habitats such as seagrass beds, mangroves and saltmarsh ecosystems are extremely efficient at capturing carbon dioxide from the atmosphere and are considered a carbon 'sink'. Thus, they are useful in combatting climate change. Compared to many terrestrial forests, on a per area basis, coastal vegetated ecosystems can take up carbon dioxide at faster rates and store it for longer periods than terrestrial forests (Mcleod et al. 2011). However, the carbon sequestration is just one of the many benefits derived from these ecosystems.

The benefits that humans gain from healthy functioning ecosystems are often referred to as ecosystem services. Ecosystem services are often grouped into four broad categories, namely:

- Provisioning – services directly obtained from ecosystems, such as the production of food;
- Regulating – benefits obtained from regulation of processes, such as protection of coastal shorelines from erosion and storm damage;
- Supporting – indirect services such as nutrient cycling; and
- Cultural – non-material benefits such as knowledge of country and place or nature-based tourism.

There are however complexities in terms of feedbacks and trade-offs between these services and human benefits.

There has been growing scientific and policy driven interest in ecosystem services, including their understanding, valuation and management largely because of their ability to affect human wealth, well-being and sustainability (Costanza et al. 2014; Polasky et al. 2015). This has gained recognition for economic valuation methods to be used by decision makers in evaluating what society might be prepared to trade off to conserve certain ecosystem services (Himes-Cornell et al. 2018a). Whilst many researchers recognise the importance of ecosystem services, their values have often not been quantified with any precision and can be difficult to measure (Simpson 2011; Mehvar et al. 2018). The total economic value of ecosystem services is extensive (Figure 1) with a range of valuation methods possible (Mehvar et al. 2018). Valuation of ecosystem services can be undertaken using data acquired from field observations and surveys, participatory approaches and stakeholder surveys, all of which can be costly and time consuming. Other means of obtaining data are from existing databases or available literature; these approaches are becoming more common due to time and budget constraints (Mehvar et al. 2018).

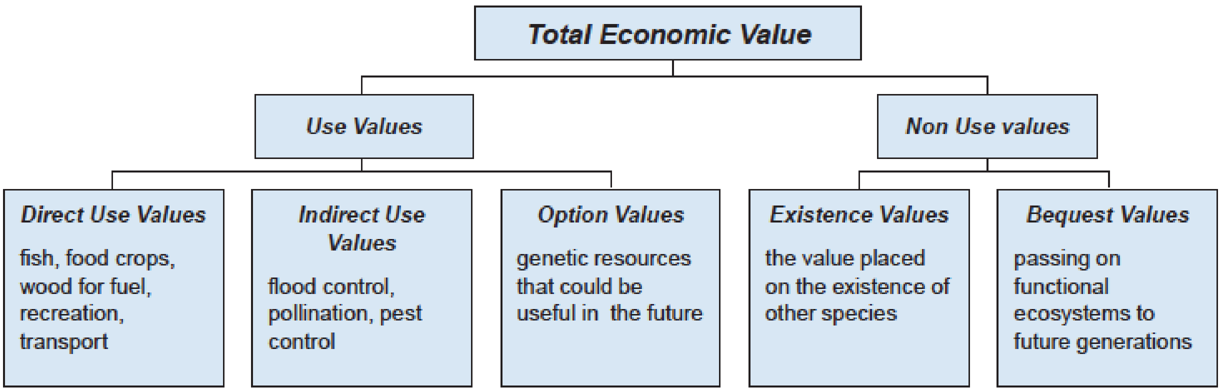

Figure 1. The components of total economic value (source: Department of the Environment 2009).

Our project, 'Coastal Carbon Opportunities' set out to undertake a literature review and meta-analysis of regionally relevant data and literature regarding the potential value of co-benefits provided by coastal carbon ecosystems, namely seagrass beds, mangrove forests and salt marsh. Our original aim was to focus the meta-analysis on the tourism and recreational value of the Adelaide International Bird Sanctuary, the provision of nursery habitat to the State's fisheries, and coastal protection and water quality improvements through reduction in water treatment requirements. However, a lack of available data meant that we were only able to undertake the literature review of ecosystem services provided by the key ecosystems directly relevant to blue carbon. A meta-analysis was not possible, therefore for this component we review we further investigated the few papers that had available data.

For technical details related to this summary report, please refer to Gaylard and Waycott (in review) '*How we value marine and coastal environments. Identification and review of multiple marine and coastal ecosystem services across temperate Australia*' Submitted to Ecosystem Services.

2 What we did

2.1 Review of ecosystem services

A review of the key marine and coastal habitats in temperate Australia identified 10 key habitat types, three of which were directly relevant to blue carbon, namely salt marsh, mangroves and seagrass (Gaylard and Waycott, In review). These are the focus of this report. The broad global distribution, as well as ecosystem services and threats to these three habitats were reviewed focusing in particular on southern Australia. The approach used was a narrative review.

2.2 Meta-analysis of regionally relevant data

A meta-analysis aims to combine data from multiple studies to identify a common trend. Such an approach helps synthesise data in an objective manner. Initially we searched Web of Science (April 2019) for relevant publications using the following search terms: seagrass* OR "salt marsh*" OR saltmarsh* OR mangrove* AND "ecosystem service*" AND "South Australia" where the asterisk acts as a wild card to allow all derivatives of those terms to be included. Based on this search six papers were identified: Wear et al. 2010; Unsworth et al. 2012; Hatton MacDonald et al. 2015; McSkimming et al. 2016; De Falco et al. 2017; Sandhu et al. 2018. A review of abstracts of these papers suggested only two warranted further investigation: Hatton MacDonald et al. 2015; Sandhu et al. 2018. In addition, further literature was added by searching personal libraries to find additional published studies. This resulted in several additional publications that were relevant to either South Australia or southern Australia but only focused on a particular ecosystem service: Scott et al. 2000; McArthur and Boland 2006; Blandon and Ermgassen 2014b. Grey literature, which can be difficult to source, was not included.

We considered applying a Benefit Transfer Model approach, which was the approach of Costanza et al. (1997) and is widely used in blue forest ecosystem service valuations (Himes-Cornell et al. 2018a). Such an approach applies economic values to an ecosystem by transferring information from other regions or contexts to the area of interest with many of the estimates coming from earlier studies (Himes-Cornell et al. 2018a). Although this approach is recognised as cost-effective and can easily and quickly be applied, it has been criticised as it can be inaccurate, and requires broad extrapolations (Himes-Cornell et al. 2018a). Further limiting factors include the limited number of valuations for blue carbon ecosystems globally, and lack of valuations for other areas of Australia that may be transferable (see also below). It is suggested that a better approach would be to collect primary data for use in valuation studies that are appropriate and accurate for the region, habitat and specific ecosystem service of interest.

3 What we found out

3.1 Summary of our review of the ecosystem services provided by blue carbon habitats in South Australia

Blue carbon ecosystems are found throughout much of the world (Figure 2) and are distributed widely throughout coastal areas of South Australia, with seagrass covering the greatest area and mangrove and saltmarshes being limited to relatively narrow strips in the intertidal areas. All three ecosystems are predominantly found in the two gulfs (Gulf St Vincent and Spencer Gulf; Figure 3). Globally, mangroves dominate the intertidal region of sheltered coastlines, mainly between 25°N and 25°S where winter water temperatures are greater than 20°C (Connolly and Lee 2007). However, in Australia they extend beyond these latitudinal limits due to warm oceanic currents. Species richness is greatest in tropical regions and declines rapidly moving south such that only a single species (*Avicennia marina*) occurs in South Australia. Mangroves occupy 164 km^2 in South Australia (Foster et al. 2019). Salt marsh also occurs on similar sheltered shorelines to mangroves with soft sediment and consists of grasses, herbs and shrubs rather than trees (Connolly and Lee 2007). Mangroves occur in intertidal regions, whereas salt marsh occurs from mean tidal to upper astronomical tidal heights. In places like South Australia mangroves may not be inundated except on very high tides or storm surges. Approximately 198 km^2 of salt marsh occurs in South Australia (Foster et al. 2019). Seagrasses occur in subtidal areas down to a maximum depth of ~50 m, being restricted to waters where there are comparatively high levels of light (Ruiz-Frau et al. 2017). Australia has some of the most diverse seagrass ecosystems in the world. Seagrass in South Australia covers around 10,809 km^2 which includes sparse, patchy, medium and dense areas as well as intertidal seagrass; these estimates are from three State mapping datasets[1]. All three ecosystems have suffered a range of threats associated with human activities. There is a dearth of research on ecosystem services in a South Australian context.

Globally, it has been estimated that 50% of saltmarshes, 35% of mangroves and 29% of seagrasses have either been lost or degraded (Ruiz-Frau et al. 2017; Mehvar et al. 2018) and Australia is not exempt from loss and degradation of coastal habitats (e.g. Seddon et al. 2000). With continued degradation of these ecosystems, their ecosystem services – with the possible exception of market or tradable services – also decline (Polasky et al. 2015). A wide range of ecosystem services are provided by blue carbon habitats (Table 1, 2).

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[1] Seagrass estimates were generated by merging all seagrass areas from the State's mapping datasets (SA Marine Benthic Habitats inshore benthic habitat mapping aimed at mapping specific areas of the SA inshore environment; Marine Benthic Habitats mapped as part of a National seagrass/marine habitat mapping program; and Estuarine Habitats of South Australia which contains habitat mapping and outer boundaries for estuaries of SA.

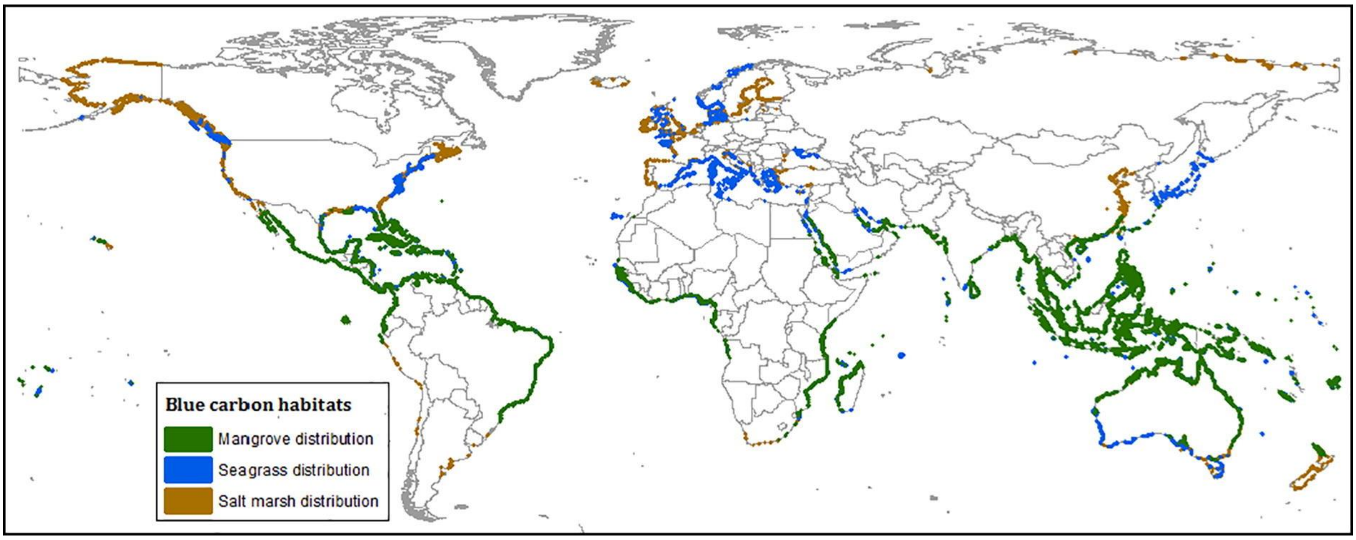

Figure 2. Distribution of blue carbon ecosystems throughout the world (source: Himes-Cornell et al. 2018).

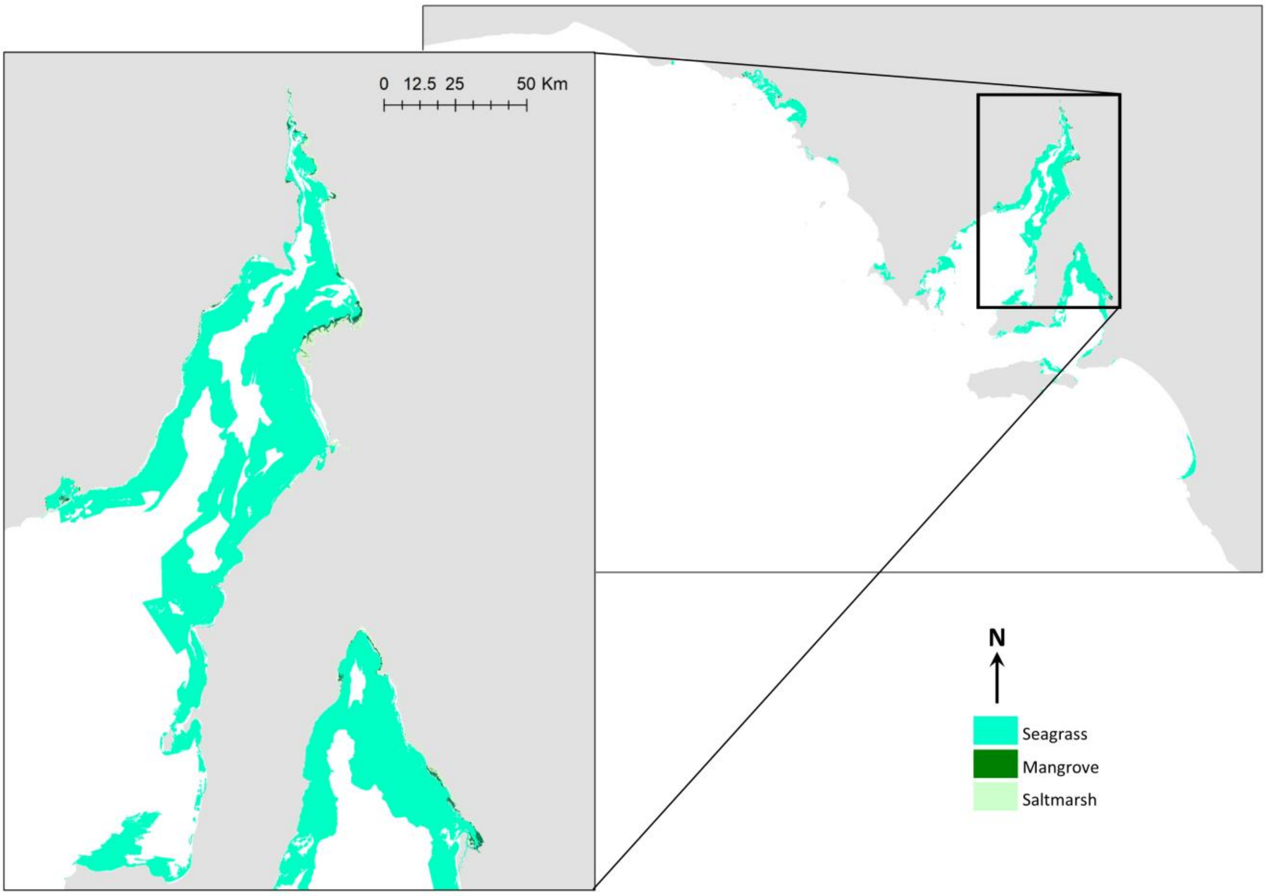

Figure 3. Map of the extent of seagrass, mangrove and saltmarsh ecosystems in South Australia, with inset of the northern Gulf regions that better illustrates the narrow distribution of mangrove and slatmarsh in the intertidal zone.

Table 1. Ecosystem services provided by seagrass, saltmarsh and mangrove habitats. Not all services are provided in all regions of the world (adapted from Mehvar et al. 2018).

Use values		Non-use values
Direct values	**Indirect values**	**Existence & bequest values**
Food, fibre and raw materials provision	Flood control	Cultural heritage & spiritual benefits
Transport	Storm protection, wave attenuation	Resources for future generations
Water supply	Climate change impacts mitigation	Biodiversity
Recreation and tourism	Contaminant storage, detoxification	Enjoyment of recreational & cultural
Wild resources	Shoreline stabilisation & erosion control	
Genetic material	Nursery & habitat for fishes, birds & other species	
Educational opportunity	Nutrient retention and cycling	
Aesthetic	Regulation of water flow, water filtration	
Art	Source of food for organisms	
	Climate regulation, primary productivity as oxygen production & CO_2 absorption, carbon sequestration etc	
	Seed & pollen dispersal	

Table 2. The current condition, trend over the last 5 years, summary of major threats identified and final ecosystem service that can be affected by degradation for the three key blue carbon ecosystems (source: Gaylard and Waycott, In review). Current condition and trend are sourced from Clark and Johnston (2017).

Ecosystem	Current condition	Trend	Major threats	Final ecosystem service affected
Salt marsh	Poor	Declining	Climate change Urbanisation Illegal dumping of rubbish Invasive species Recreational activities	Flood prevention Cultural services Waste treatment/water purification Regulating global climate – carbon sequestration Control of erosion
Mangroves	Good	Stable	Climate change Urbanisation Illegal dumping of rubbish Industrial discharges	Provision of nutrition – wild catch fisheries Regulating global climate – carbon sequestration Cultural services Waste treatment/water purification Flood prevention Control of erosion
Seagrass	Poor	Declining	Nutrient discharges Industrial discharges Physical destruction – dredging Anchoring	Provision of nutrition – wild catch fisheries Regulating global climate – carbon sequestration Waste treatment/water purification Control of erosion Flood prevention

3.2 Outcome of the meta-analysis of ecosystem service values relevant to blue carbon habitats in South Australia

A meta-analysis on coastal ecosystem service value was not possible as there were too few published valuations of these services that were relevant to South Australian coastal systems. However, there have been several papers that have reviewed ecosystem services for coastal ecosystems including mangroves and seagrasses (see Ruiz-Frau et al. (2017); Himes-Cornell et al. (2018a); Himes-Cornell et al. (2018b); Mehvar et al. (2018); Davidson et al. (2019)), which we summarise below. In addition, several studies have focused on valuing either a particular ecosystem service or habitat within South Australia (see McArthur and Boland (2006); Blandon and Ermgassen (2014b); Hatton MacDonald et al. (2015)).

Over half of the total economic value of the biosphere is estimated to come from ocean and coastal ecosystems (Costanza et al. 2014). Recently, Davidson et al. (2019) estimated the value of coastal and inland wetlands at Int$47.4 trillion[1] per year including a value of Int$20.4 trillion per year for

[1] The International dollar is a currency unit to compare the values of different currencies, which have been adjusted to reflect current year's exchange rates, purchasing power parity and commodity prices within each country.

coastal wetlands, which only form ~15% of the global natural wetland area (based on 2011 values). Coastal wetlands assessed in this study included coral reefs, estuaries, seagrass beds, unvegetated tidal flats, salt marshes and mangroves so were more expansive than just coastal blue carbon habitats. Mangroves contributed 13%, seagrasses 11% and saltmarshes 5% of the value of coastal wetlands (Davidson et al. 2019). Eighty six percent of the monetary value of coastal systems was estimated as coming from erosion protection. For natural coastal wetlands, waste treatment and water purification contributed 84% of total monetary value (Davidson et al. 2019).

Himes-Cornell et al. (2018b) undertook a systematic review of ecosystem services from mangrove, seagrass and salt marsh ecosystems and their economic value over the last 10 years. Most studies were conducted in mangroves (n=70) rather than seagrass (n=32) or salt marsh (n=15). There were no ecosystem service valuation studies for Australian mangroves or salt marsh (Himes-Cornell et al. 2018b). The majority of mangrove studies were undertaken in the Asian region, whereas most salt marsh studies were undertaken in North America; mangroves and salt marsh in these two regions are very different to those in South Australia. Four studies were undertaken on Australian seagrasses, two of which were in South Australia (Himes-Cornell et al. 2018b). There was broader global spread of seagrass studies with most ecosystem service valuation studies in either Asia or Europe. Frequently, values used were from earlier time periods with most studies using data that was greater than 4 years old. In addition, few ecosystem services were investigated (range between 1.8 and 4.9) with the number depending on broad geographic region.

Several further studies focused on valuations of ecosystem services provided by mangroves (Himes-Cornell et al. 2018a; Mehvar et al. 2018). Mehvar et al. (2018) reviewed five studies that used different valuation methods including one study (Brander et al. 2012) that used a benefit transfer approach. In contrast, Himes-Cornell et al. (2018a) note that most valuation studies of mangroves use a benefit transfer approach to estimate the value of ecosystem services. Most studies focus on tropical mangroves and have estimated their value between US$177 per hectare (at the 1999 value) (Das and Crepin 2013) and US$12,392 per hectare (Barbier 2007). Two other studies have estimated the value of ecosystem services for coral reef and mangrove ecosystems combined in the Caribbean (see Cooper et al. (2009); Van Beukering and Wolfs (2012)). Overall, of coastal ecosystem services, mangroves and coral reefs are the most frequently valued ecosystems, whereas few studies have focused on seagrass or salt marsh (Himes-Cornell et al. 2018b; Mehvar et al. 2018). Of the ecosystem services investigated, most studies have focused on tourism and recreation services or coastal protection (Mehvar et al. 2018).

Seagrass ecosystem services were recently reviewed by Ruiz-Frau et al. (2017). They found that most studies only included two ecosystem services with regulating services receiving the most attention, followed by supporting services. Cultural services remain understudied for all ecosystems (Ruiz-Frau et al. 2017; Himes-Cornell et al. 2018a; Mehvar et al. 2018). The role of seagrasses in regulating climate through sequestration and storage of carbon is the most widely researched of the regulating services, although the protection of coastal areas through wave attenuation and sediment stabilisation were also researched (see Ruiz-Frau et al. (2017)). The majority of studies focused on ecological assessment rather than economic or social aspects (see Ruiz-Frau et al. (2017)).

Three papers have considered the economic contribution of seagrass to fisheries production in South Australia (Scott et al. 2000; McArthur and Boland 2006; Blandon and Ermgassen 2014b). Scott et al. (2000) constructed a seagrass residency index whereby they used experts to estimate the proportion of time different commercially or recreationally important fishery species and life history stages spent in seagrass. Their index ranged from 0 to 1 (i.e. no time to all time spent in seagrass), being a weighted sum of the averages for the estimated residence time of three life history stages: larval/juvenile, adult/feeding and adult/spawning fish (Scott et al. 2000). Based on this analysis species such as pilchards were seen as having the least association with seagrass and those such as southern calamary and southern sea garfish as having the most association, although the index varied between their two studies (Scott et al. 2000; McArthur and Boland 2006). McArthur and Boland (2006) then estimated the value of seagrass habitats based on their contribution to fisheries for seven commercially important species. For gulf waters of South Australia, they estimated that the economic contribution of seagrass to fisheries was Aus$114 million per annum; however, this value is now almost 15 years old. Using a different approach Blandon and Ermgassen (2014b) estimated the enhancement of juveniles of 12 commercially important species in seagrass in southern Australia. Using growth and mortality models they then estimated the contribution to commercial fish biomass of seagrass. The economic enhancement was estimated at Aus$31,650 ha^{-1} y^{-1}, however the largest contributor to this value was a species that does not occur in South Australia (tarwhine, estimated at Aus$24,863) (Blandon and Ermgassen 2014a; Blandon and Ermgassen 2014b). In addition, it is not clear which year the market data prices were from, but they would now be at least 5 years old. Only two species were included in both sets of studies, King George whiting and southern sea garfish. Applying the prices from McArthur and Boland (2006) to both studies a comparison of the economic enhancement was possible – this showed a dramatic difference between studies with estimates for King George whiting of Aus$6.01 and Aus$298.16 per hectare for McArthur and Boland (2006) and Blandon and Ermgassen (2014a) respectively. Similarly, values for southern sea garfish were Aus$3.93 and Aus$9.16 x 10^{-3} per hectare (Blandon and Ermgassen 2014a).

Coastal water quality along the Adelaide coast has also been valued in terms of what people were willing to pay (see Hatton MacDonald et al. (2015)). Estimates that Adelaide households were prepared to pay more for five additional healthy reef areas ($35.8M) than for a 10% increase in seagrass ($18.9M) or for only 25 rather than 50 turbid water days ($12.4M) (Hatton MacDonald et al. 2015). In this particular study the focus was on provision of habitat and aesthetics of water clarity, although additional benefits associated with supporting and regulating services would also be likely to occur. Such an approach allows policy makers to evaluate potential infrastructure investments against people’s values.

4 What this all means

Saltmarsh, mangroves and seagrass provide a range of ecosystem services including provisioning, regulating, supporting and cultural. The ecosystem services provided vary depending on where the habitat occurs, its condition and the range of threats it faces. One of the key limitations of many studies is the incomplete information of an ecosystem’s value, meaning some ecosystem services are not included largely due to scarcity of data, and the time-consuming nature and high cost of further data collection (Mehvar et al. 2018). The wide range of estimated values for coastal ecosystem services globally reflect discrepancies in how data are collected, the number of services valued, the location of studies and other factors that make studies difficult to compare (Mehvar et al. 2018). These factors also make it extremely difficult and often inappropriate/misleading to use benefit transfer approaches.

Our project, ‘Coastal Carbon Opportunities’ aimed to generate data to fill critical knowledge gaps around carbon in coastal ecosystems, including a review and meta-analysis of coastal ecosystem services that could support the development of South Australian government climate strategies and policies. The results of this task indicate the range of ecosystem services provided by blue carbon habitats are relatively well described (Table 1), both globally and for South Australia specifically. However, there is a significant lack of information that clearly links those ecosystem services to monetary or societal values. The knowledge gaps that we have identified prevent a complete assessment of South Australia’s coastal ecosystem services, including their value. Critical knowledge gaps are listed below, but it should be noted that these gaps are not limited to South Australia, and that it takes a significant effort and investment to generate comprehensive data on geographically relevant ecosystem service valuation.

4.1 Knowledge gaps and recommended ways forward

Primarily, we need to establish direct links between the presence, condition and area of a coastal ecosystem and its value for ecosystem services. In order to fill this knowledge gap, we require:

- Clear demonstrations of the value (economic and social) of areas of blue carbon ecosystems for ecosystem service provisions. This could initially be done through case studies that look at specific services in specific areas of interest. For example, the value of mangroves for nitrogen removal and what this means for water quality, or the value of seagrasses as habitat for key commercially fished species.
- An examination of the link between ecosystem condition and the ability to provide ecosystem services (i.e. are healthier systems more valuable for ecosystem service provision, is this relationship linear, or is there a threshold at which ecosystem service provision is impacted)? Again, this could be done through well-designed case studies.
- Improved maps of the location and condition of mangroves, salt marshes and seagrass in South Australia (particularly seagrasses, as these are the least well mapped of the three). These would enable scaling up of ecosystem service values that are established through case studies.

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