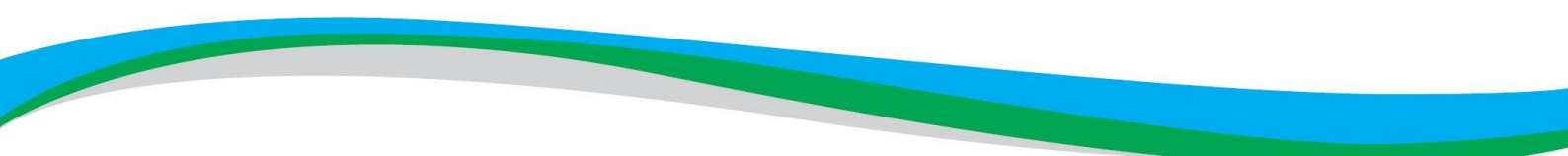


Coastal carbon opportunities: vegetation dynamics at Mutton Cove, a site of recent tidal reconnection

SUMMARY REPORT

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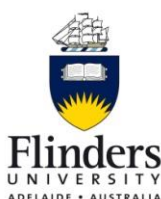
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1 Background

Coastal vegetated ecosystems such as seagrass beds, mangroves and saltmarshes are extremely efficient at capturing and storing carbon and are therefore considered an important carbon 'sink' and a useful tool in combatting climate change (Figure 1). Compared to many terrestrial forests, these coastal vegetation communities can accumulate carbon at faster rates and store it for longer periods (McLeod et al. 2011). Accumulation occurs through both direct uptake of carbon from the atmosphere by photosynthesis, which is turned into biomass (both above and below ground), as well as by trapping carbon in the roots and sediments which quickly gets buried and can be stored for millennia (Nellemann and Corcoran 2009).

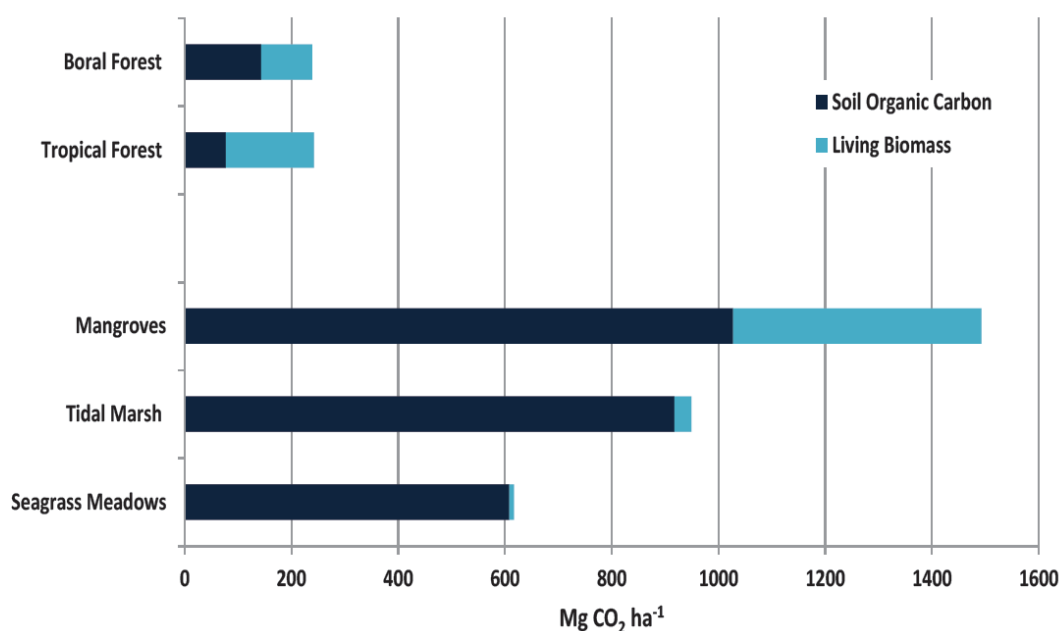


Figure 1. Global average carbon storage rates for blue carbon ecosystems compared to terrestrial forest ecosystems. Figure from The Blue Carbon Initiative (Howard et al. 2014) and based on data from Fourqurean et al. (2012), Pan et al. (2011) and Pendleton et al. (2012).

Our project, 'Coastal Carbon Opportunities' set out to collect and analyse new field data from coastal carbon ecosystems in South Australia (SA), to improve our understanding of the value of the state's coastal environments as carbon sinks. The work summarised in this report are the results from our case study at Mutton Cove (on Port River near Outer Harbour) that demonstrates the impact of degradation, restoration and re-introduction of tidal flows into a tidally restricted saltmarsh area. The outputs of this case study showcase the use of a suite of complementary data sets for investigating site history and vegetation changes, including new applications of drone-based remote sensing for collecting data. The results provide insight into the habitat changes associated coastal management decisions and what the carbon sequestration and storage implications of these may be. This information will be useful for assessing coastal carbon sequestration and emissions abatement opportunities in SA and beyond.

For technical details of the study described in this summary report, please refer to the following report:

Jones, A. R., Raja Segaran, R., Campbell, D., Fernandes, M., Waycott, M., Lavery, P., Serrano, O., Lafratta, A., Gillanders, B. M. (2019) *Coastal carbon opportunities: technical report on vegetation dynamics at Mutton Cove, a site of recent tidal reconnection*. Goyder Institute for Water Research Technical Report Series No. 19/25.

1.1 Why are we interested in how management actions can change coastal vegetation and carbon storage?

International, national and state emissions reduction targets and market incentives (such as carbon crediting frameworks) have sparked growing interest in the potential for carbon sequestration and storage in vegetated coastal ecosystems (Kelleway et al. 2017). Evidence shows that land reclamation and habitat degradation can reduce both carbon stocks by causing emissions of stored carbon, as well as decreasing future sequestration potential by removing vegetation (Ewers Lewis et al. 2019, Ewers Lewis et al. 2017). It is also proposed that habitat protection and restoration can increase the carbon sink value of coastal environments, as well as benefitting the myriad other ecosystem services they provide (Adame et al. 2018, Barbier et al. 2011, Chen et al. 2018). This paradigm is illustrated in Figure 2, which shows the carbon storage and sequestration implications of degradation and restoration.

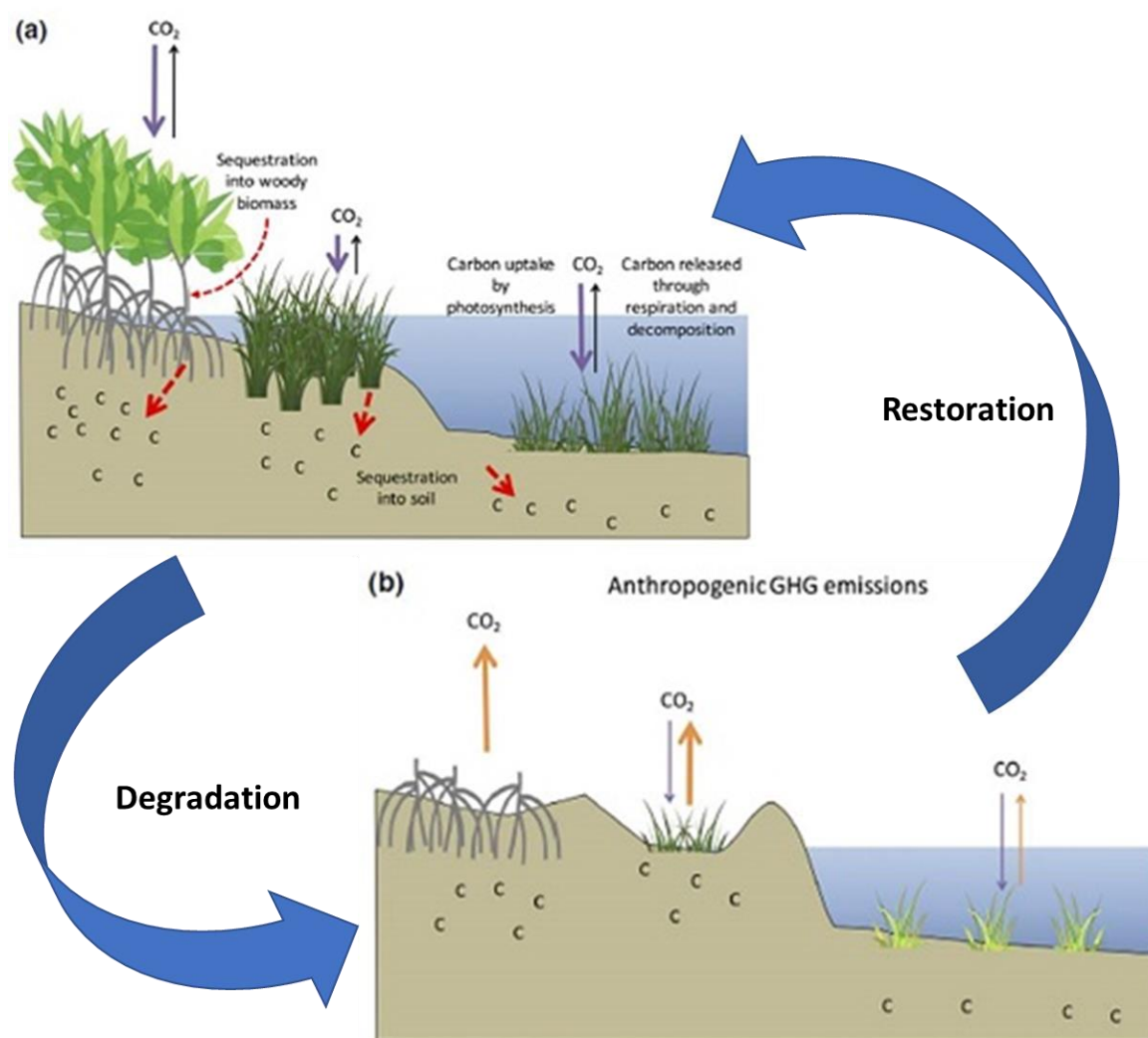


Figure 2. Schematic of the impacts of degradation and restoration on carbon sequestration and storage in coastal vegetated ecosystems. Adapted from Howard et al. (2017).

1.2 Mutton Cove

Mutton Cove is the last remnant area of saltmarsh and mangrove on the Le Fevre peninsula, north of Adelaide in South Australia (Figure 3). Prior to significant land-use change and reclamation along the peninsula, it was an area of mixed mangrove and saltmarsh wetland, like nearby Torrens Island (on the eastern side of Port River). During the development of the peninsula, Mutton Cove was enclosed by a seawall in the early 1970s. As a result, the site became completely cut off from tidal influence and dried out, after which it developed acid sulfate soils leading to significant subsidence behind the seawall (Coleman 2015). Consequently, most of the mangroves inside the seawall died off due to disconnection from tidal flow and only patchy stranded saltmarshes remained, because the site was no longer suitable for colonisation of new plants.

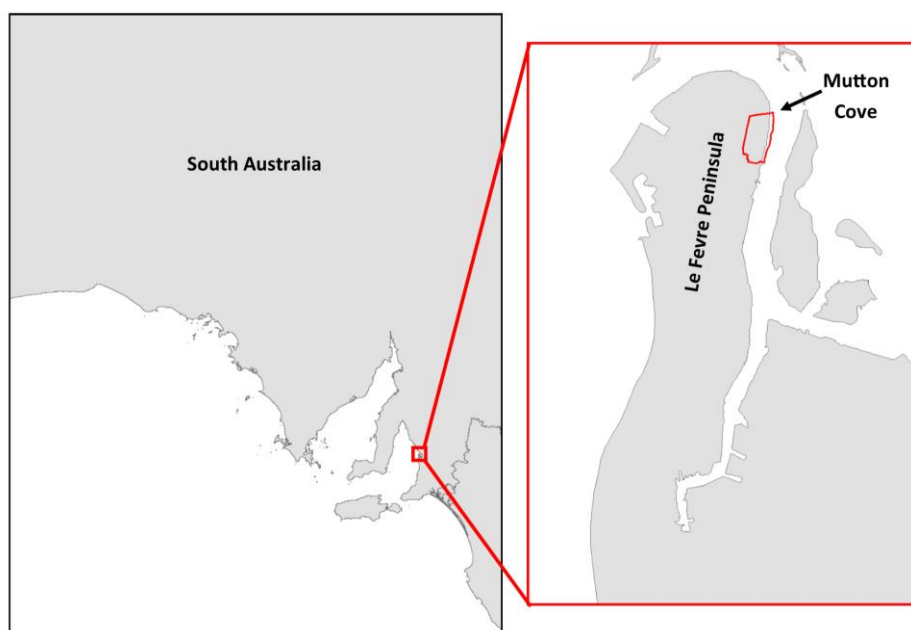


Figure 3. Location map of the Mutton Cove study site, north of Adelaide in South Australia.



Figure 4. Aerial image of Mutton Cove in 2016, shortly before the seawall breach.

A restoration program at the site was initiated in 2003, when pipes in the seawall were repaired to allow controlled tidal flow back into the site. The tidal inflow was limited such that a diversity of coastal wetland habitats was restored, including a range of saltmarshes with differing inundation tolerances. Restoration was achieved through both active re-planting and natural recolonisation of saltmarsh and other supra-tidal vegetation around the boundaries and paths, as well as natural recolonisation of mangroves (from propagules that entered the site through the pipes in the seawall). After 10 years of effort, the site was restored to a mixture of low and mid saltmarsh communities, with mangroves along the creek edges (Figure 4). However, in mid-2016 the seawall was breached and since then the site has been experiencing increasing and uncontrolled tidal inundation.

2 What we did

2.1 Historical aerial photographs

We analysed and digitised aerial images of the site dating back to the 1940s to look at historic changes in the area of mangrove and saltmarsh at the site. These could be linked to carbon sequestration using published literature and data from sediments that we collected at the site (see details in Lavery et al. 2019a). Aerial imagery was provided to us by the South Australian Department for Environment and Water (DEW). On-the-ground vegetation and elevation surveys

2.2 On-the-ground surveys and physical data collection

We collected elevation and vegetation type and condition data along set transect lines, which had previously been survey by DEW in 2015. We also installed sediment elevation tables and water level loggers in the site to record sediment accumulation rates (within the mangroves and at an area of bare sediment) and tidal inundation.

2.3 Drone-based remote sensing

We flew drone surveys over sub-sections of the site with both a standard RGB camera and a multispectral camera (Figure 5). The multispectral camera collects reflectance data from a wider range of light wavelengths than a standard RGB camera, which enables extraction of additional information from beyond the visible light range (e.g. near-infrared and infrared). These data can be used to discriminate between different types of vegetation as well as to map photosynthetic activity and therefore vegetation health. We collected drone survey data on two occasions 1 year apart (Jan 2018 and Jan 2019), which enabled us to look at changes in vegetation over time.



Figure 5. Photograph of drone pilots from the Unmanned Research Aircraft Facility (URAF) at the University of Adelaide flying the drone at Mutton Cove.

3 What we found out

3.1 Historical changes and what these mean for carbon gains and losses at the site

We found that the removal of tidal flow when the seawall was built around the site in the late 1970s led to a drastic decline in mangrove cover and a gradual increase in saltmarsh cover Figure 6. However, the cover of saltmarsh was patchy across the site until restoration attempts began in the early 2000s.

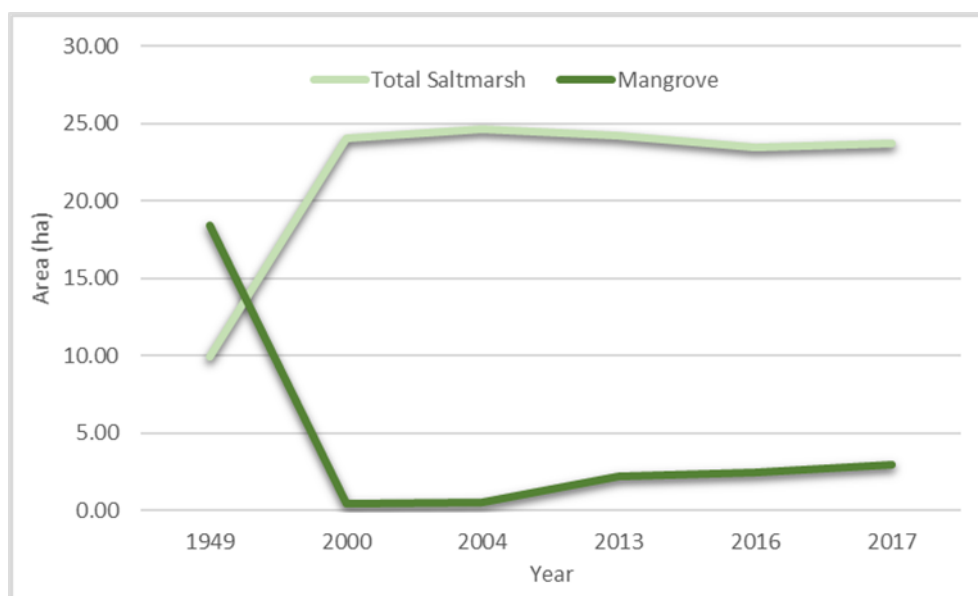


Figure 6. Change in area of mangrove and saltmarsh within Mutton Cove from 1949 to 2017 based on manually digitised aerial photographs. The saltmarsh category includes both area of dense and patchy saltmarshes.

The results from the core samples taken from the site (associated with a different task of the broader Coastal Carbon Opportunities project) show that the building of the seawall and subsequent site degradation led to a significant decrease in sediment carbon stocks and sequestration rates (Lavery et al. 2019a). In addition, the loss of mangroves at the site will have been associated with a decrease in above ground carbon storage (that is the carbon stored in the living biomass of the plants), as this is greater in mangroves than in saltmarshes (Kelleway et al. 2016).

3.2 Recent changes and what these mean for carbon gains

The data from our water level loggers show that, since the breach in the seawall, the tidal regime within Mutton Cove has become more similar to that experienced in Port River (at least in the southern section closest to the breach, where our loggers are). Previous work at the site showed that tidal inundation was restricted, leading to lower high tides and shorter inundation periods (Cook and Coleman 2003), which meant that the site could support saltmarshes at lower elevations than they would normally tolerate. Now that the tide is flowing into the site without restriction, the conditions of these low and mid saltmarsh communities have deteriorated because they are experiencing greater inundation periods and more frequently. The impacts of this are evident from both our on-the-ground vegetation surveys and our drone-based imaging surveys.

In November 2018 we carried out repeat surveys of elevation and vegetation cover/health along transects initially surveyed by DEW in 2015. The results of these show that there has been significant die-off of saltmarsh, especially in lower lying parts of the site Figure 8. A similar loss is shown in the analysis of drone-based images. These indicate losses of up to 60% of live saltmarsh in some areas of the site (i.e. saltmarsh

that has transition from healthy to dead or dying according to our multispectral data). At the same time, we have seen an increase in the area of mangrove across the site, as well as lots of mangrove seedlings. This indicates that in time, with the new tidal regime at the site, the vegetation may eventually return to the mangrove dominated system that was present prior to the seawall being built in the 1970s.

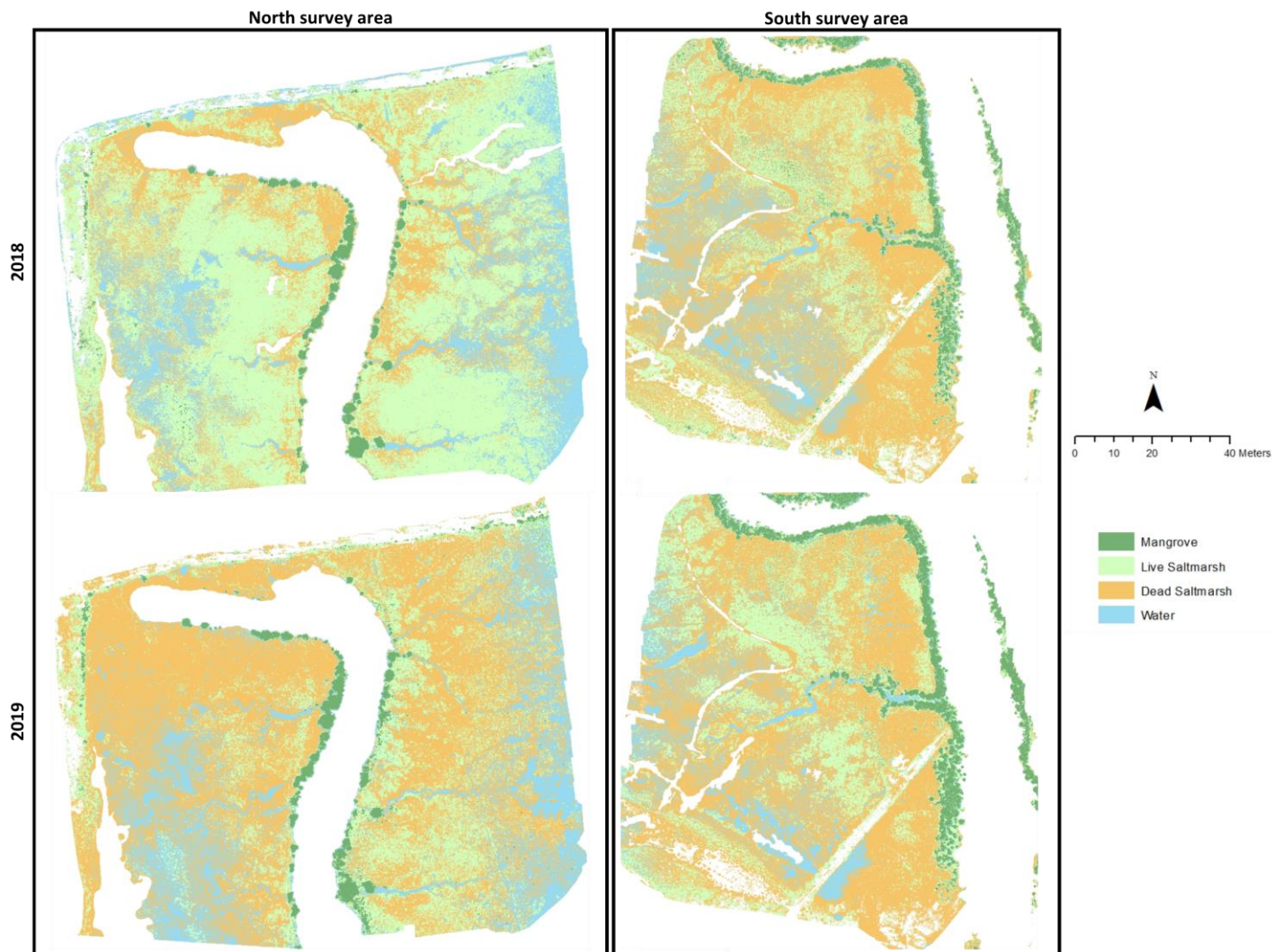


Figure 7. Maps of different types of vegetation cover within the north and south parts of the site. The type of vegetation has been classified based on multispectral data collected using a drone. White areas are either outside of the analysis area boundary or have been masked out of the assessment due to the presence of standing water (which affects spectral reflectance and causes problems with classification).

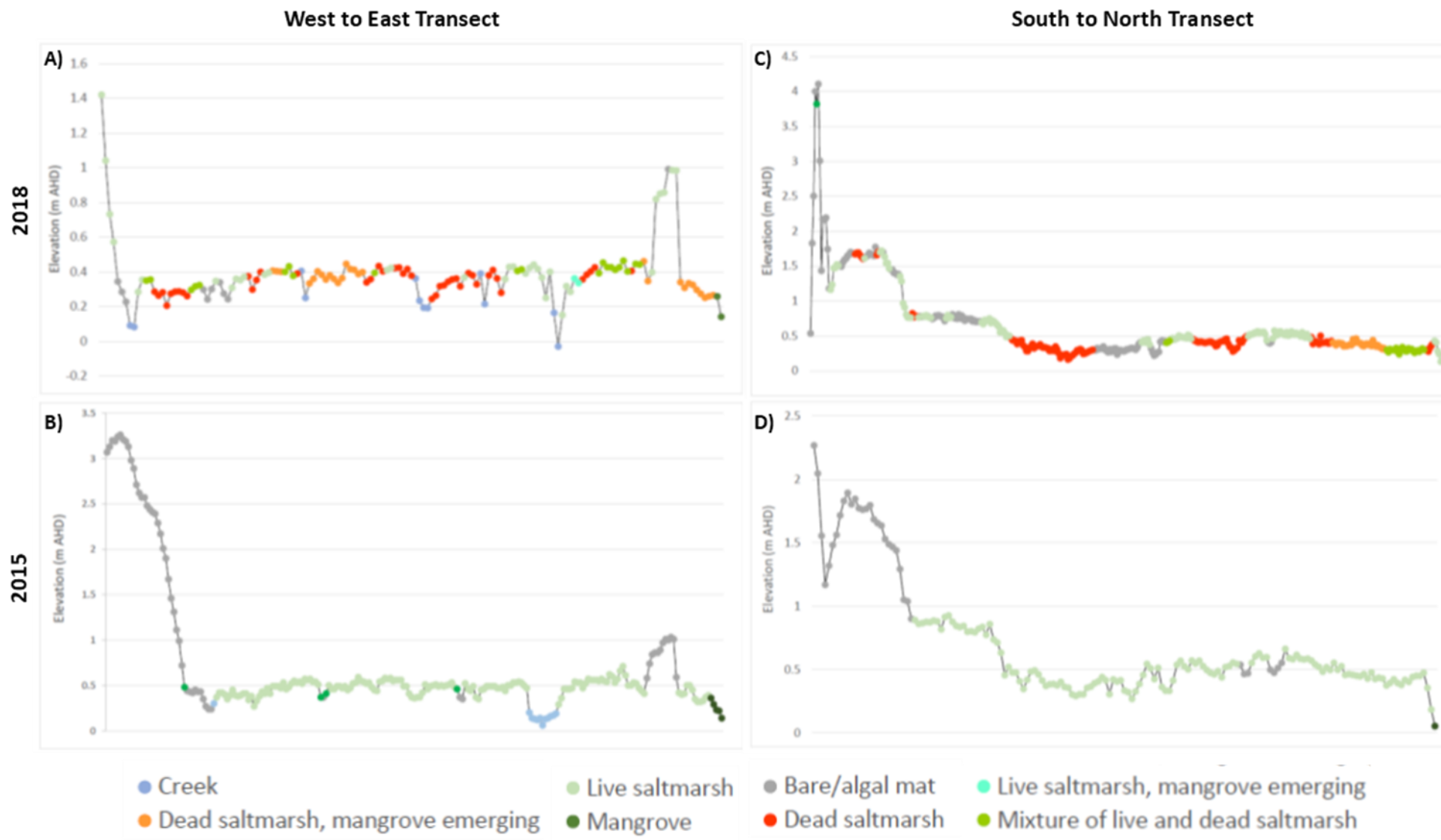


Figure 8. Results from repeated on-the-ground elevation and vegetation surveys at Mutton Cove from 2015 (before the seawall breach) and 2018 (2.5 years after the seawall breach). Surveys were undertaken using RTK-GPS to collect accurate location and elevation data. Point colour shows land cover type. Elevation is shown on the y-axis.

4 What this all means

We have presented a comprehensive history of the vegetation dynamics at Mutton Cove, a site of remnant coastal wetland with a variable management history. The vegetation cover has change from being mangrove-dominated in the 1940s, followed by considerable loss of mangrove after the seawall was built in the early 1970s. This loss of mangrove will certainly have been associated with a loss in above-ground carbon storage (i.e. carbon stored within the mangrove trees themselves), as mangrove systems can store up to 50% of their carbon in the above-ground biomass (Donato et al. 2011), compared to around 10% in saltmarshes (Howard et al. 2014). Therefore, a mangrove area will usually have greater above ground carbon stocks and storage potential than a saltmarsh area of the same size.

The general degradation at the site after construction of the seawall, associated with drying out and subsidence (along with development of acid sulfate soils) is also likely to have led to emissions of carbon from the soil (Donato et al. 2011, Pendleton et al. 2012) and a reduction of the site's sequestration potential going forward (Ewers Lewis et al. 2019). This is supported by the results of Task 1 of the broader Coastal Carbon Opportunities project, which show all of the core samples we collected from within Mutton Cove had significantly lower carbon accumulation rates over the last 70- years (by as much as half) when compared to a nearby undisturbed site on Torrens Island, which has a similar environmental setting (Lavery et al. 2019b). In addition, the cores from Mutton Cove had lower carbon stocks in the top 50 cm (representing ~ the last 70 years) than cores collected from Torrens Island (a nearby undisturbed mangrove site), even though the stocks to 1 m depth were not found to be significantly different (Lavery et al. 2019b). This indicates that the sites had similar carbon sequestration rates and stocks up until a point around 70 years ago, after which the sediments at Mutton Cove experienced either a loss of carbon, or a slow-down in accumulation rate, possibly due to changes in vegetation and inundation regime. It is likely that both of these impacts combined to decrease soil carbon stocks, as we know that the seawall led to widescale drying of the site (causing emissions) and that the density and condition of both mangrove and saltmarsh vegetation cover decreased for decades following seawall construction (which would have reduced the carbon sequestration capacity of the site).

After restoration efforts at the site began in the early 2000s with the reintroduction of controlled tidal flows, the health and cover of both saltmarsh and mangrove increased (Figure 6). However, the dynamics of the site were still very different to what they would be under natural inundation conditions and had been historically (Coleman 2015, Cook and Coleman 2003), leading to a saltmarsh dominated site by 2016. The results from Task 1 (below ground carbon storage) of the Coastal Carbon Opportunities project indicate little difference, on average, in surface soil carbon stocks between mangrove and saltmarsh sites in SA (Asanopoulos et al. (in review); Lavery et al. 2019a). However, loss of vegetation entirely, or a lag-period between the die back of one vegetation type and the colonisation of another, is likely to lead to erosion of sediment and emissions of carbon from the sediment due to disturbance and oxidation/remineralisation of stored carbon (Macreadie et al. 2013, Pendleton et al. 2012).

The various datasets we have collected recently from Mutton Cove all support the same main result; that the seawall breach in mid-2016 led to uncontrolled inundation, which is negatively impacting saltmarsh vegetation whilst benefitting mangroves. An increase in inundation is supported by the data from our water-level loggers, which show that the southern part of the site has a very similar tidal regime to that outside the seawall in Port River and no longer experiences a tidal lag or high-water truncation (Cook and Coleman 2003). The impacts of this increase in inundation are evidenced by the repeat vegetation and elevation RTK-GPS transects that we did in late 2018, which show considerable amounts of dead saltmarsh compared to the same transects surveyed in 2015 by DEW (Figure 8).

Our novel use of drone-based RGB and multispectral imaging of a tidal wetland site has enabled us to demonstrate large losses of saltmarsh at Mutton Cove between Jan 2018 and Jan 2019 (noting that it is likely there had already been some loss prior to Jan 2018, especially in the southern site, closest to the main seawall breach). We show almost 60% dieback in the northern survey zone over this 1-year period (Figure 7).

The restoration efforts in Mutton Cove over the last 15 years and the shorter-term changes in vegetation since the seawall breach in mid-2016 are all too recent to be detected in and resolved by the dating methods

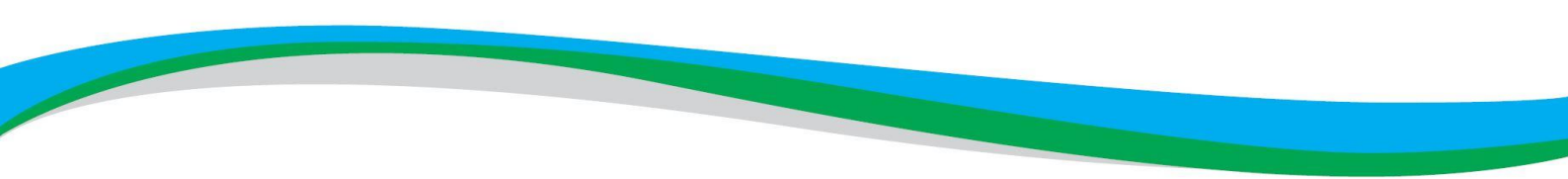
used on the sediment cores samples from the site that were taken as part of Task 1 of our Coastal Carbon Opportunities project (see report by Lavery et al. 2019b). This illustrates the importance of using a suite of data that have different temporal coverage periods and resolutions. The drone-based imaging, combined with on-the-ground surveys, can provide datasets that look at change over relatively short time scales (months to years), compared to what can be resolved from sediment cores (that have a resolution of decades, at-best, but cover periods that can go back millennia) and archived aerial photographs.

The patterns of change that we have documented in the site over the last 18-months are likely to have led to carbon emissions due to potential surface sediment disturbance and removal/die-back of vegetation (Ewers Lewis et al. 2019, Macreadie et al. 2013, Pendleton et al. 2012). However, if the sediment surface remains mostly undisturbed, it is likely that most of carbon stored below ground at the site will be retained, and carbon accumulation rates and stocks will increase again into the future as mangroves colonise areas that were previously covered by saltmarsh. We can already see evidence of this colonisation in the vegetation transect data from 2018, where it is noted that mangrove seedlings are emerging amongst the dead saltmarsh and this tends to be occurring at locations with lower elevation (Figure 8). An increase in the area of mangroves was also detected by our drone-based imagery (Figure 7). Previous studies in the region suggest that mangroves are fast and effective colonisers in muddy intertidal zones (Cann and Jago 2018, Cann et al. 2009). Therefore, within decades we may see Mutton Cove returning to a more mangrove dominated site, as it was prior to the construction of the seawall (Figure 6), with an expectation of associated increases in the above-ground carbon accumulation and stocks (Kelleway et al. 2016).

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