

Coastal carbon opportunities: changes in the distribution of mangrove and saltmarsh across South Australia (1987 – 2015)

SUMMARY REPORT

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Goyder Institute for Water Research
Summary Report Series No. 19/24



www.goyderinstitute.org

Goyder Institute for Water Research Technical Report Series ISSN: 1839-2725

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Citation

Jones, A.R., Foster, N., Waycott, M. and Gillanders, B.M. (2019) *Coastal carbon opportunities: summary report on changes in the distribution of mangrove and saltmarsh across South Australia (1987 – 2015)*. Goyder Institute for Water Research Summary Report Series No. 19/24.

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Acknowledgments

We would like to thank Matthew Miles (Principal Environmental Information) and Matthew Royal (Environmental Knowledge Advisor) from the South Australian Department of Environment and Water and Ramesh Raja Segaran from the University of Adelaide for their input and advice during this study. We would also like to thank Matthew Miles (DEW) and Kenneth Clarke (University of Adelaide) for their independent peer reviews of this report, as well as the members of the Project Advisory Committee established by the Goyder Institute.

1 Background

Coastal vegetated ecosystems such as mangroves and saltmarshes are extremely efficient at capturing carbon dioxide from the atmosphere and trapping organic carbon in the soil. They are therefore considered a carbon 'sink' and a useful tool in abating carbon emissions and combatting climate change. Coastal wetland vegetation is able to trap and store carbon at faster rates and for longer periods than many terrestrial forests (McLeod et al. 2011). They are also the only ecosystems that can continuously store carbon in the soil, because they are constantly trapping sediments and organic matter that is then buried in a low oxygen environment, allowing it to be stored away for thousands of years. This ability to effectively sequester carbon means coastal vegetation habitats are vital environments that need to be monitored and conserved. South Australia, like many other areas in the world, has historically experienced loss of mangrove and saltmarsh, which reduces the capacity of the state's coastal carbon sink. In order to reduce the future loss of these valuable ecosystems, there is a need to effectively monitor the area coverage, change in distribution and condition of mangrove and saltmarsh ecosystems in South Australia.



As part of our project, Coastal Carbon Opportunities, we set out to analyse spatial data on the distribution of saltmarsh and mangrove ecosystems in South Australia and how this has changed over time. The results of this assessment can be used to improve estimates of the capacity of the South Australian coastal carbon sink, as well as identifying changes in the distribution of these two coastal ecosystems. The output can also be used as a starting point for developing maps of saltmarsh and mangrove ecosystem condition and carbon sequestration potential.

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

Alice R. Jones, Ramesh Raja Segaran, Kenneth Clarke, Michelle Waycott, William S. H. Goh, Bronwyn M. Gillanders (in prep). Demonstrating the use of drones for estimating mangrove tree biomass and carbon storage.

1.1 Why do we need to know about changes in the area and distribution of mangrove and saltmarsh in South Australia?

Determining change in area coverage of mangrove and saltmarsh vegetation in South Australia enables better estimates of the carbon stocks and carbon capture potential of these ecosystems. In addition, it allows for the identification of areas where decline has occurred or where there have been changes in vegetation community composition (i.e., conversion from saltmarsh to mangrove) which is relevant to carbon stock inventory. Such changes from saltmarsh to mangrove usually occur when both communities retreat inland because of sea level rise. As saltmarshes move landward they are replaced by mangroves (Saintilan and Williams 1999). However, urbanisation and other coastal land uses (e.g. agriculture) can effectively block the landward migration of saltmarsh causing what is known as a "coastal squeeze" and ultimately loss of saltmarsh ecosystems. Identifying where this is occurring provides an opportunity for interventions (such as tidal reconnection and managed realignment) that allow saltmarsh habitats to increase their range landward and keep pace with sea level rise (Figure 1). Highlighting these opportunities in South Australia could be a vital element in remediating coastal vegetation communities and increasing the carbon sequestration and storage capacity of mangrove and saltmarsh ecosystems throughout the state (Harty 2004).

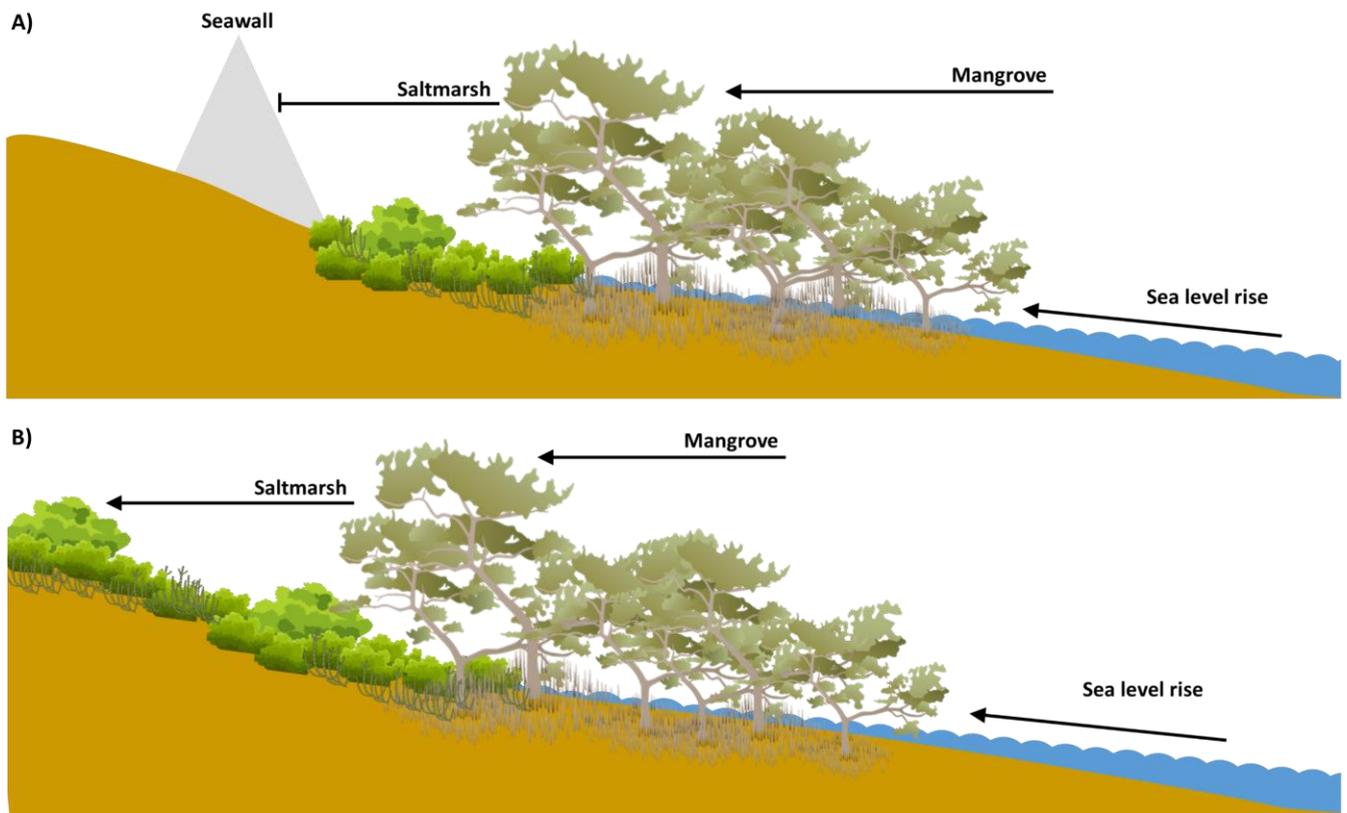


Figure 1. Schematic of the process of inland migration of coastal wetland vegetation with sea-level rise: A) when saltmarsh is blocked by coastal development and protection infrastructure, such as a seawall; and B) when no hard structures block the landward migration of the vegetation.

2 What we did

2.1 Land Cover Layers dataset

The work summarised in this report aimed to use the Land Cover Layers dataset developed by the South Australian Department for Environment and Water (DEW) based on Landsat satellite remote-sensed data, to document state-wide changes in mangrove and saltmarsh vegetation. The Landsat satellites collect multispectral imagery of the earth at a resolution of approximately 25 x 25 m. Multispectral imaging produces information that can be used to classify land use/cover (e.g. natural vegetation cover vs urban) because different types of land use have different light reflectance properties.

The DEW Land Cover Layers dataset is a mapped data product that splits the entire state up into 25 x 25 m grid cells and allocates a specific type of land cover to each of these cells based on the spectral signature from the Landsat multispectral imagery (this is the 'most-likely' land cover class from the Land Cover Layers dataset). The Land Cover Layers dataset covers the period from 1987 to 2015 and is split into six time periods (1987-1990, 1990-1995, 1995-2000, 2000-2005, 2005-2010 and 2010-2015), meaning it can be used to look at change in land cover type across the state through time. For more detail on the generation of the Land Cover Layers dataset see Willoughby et al. (2018). This data layer was clipped to a coastal buffer of 5 km from the mean high-water mark in order to eliminate incorrect classifications of mangrove and saltmarsh further inland. The most likely layer was then used to ascertain changes in mangrove and saltmarsh through time for the whole of South Australia.

There is some uncertainty in the Land Cover Layers most-likely dataset, specifically related to how well it represents the true land cover type at a given location. Some land cover types have very similar spectral (light

reflecting) characteristics and can therefore be difficult to separate with confidence. When looking at change over time, it is important to understand this uncertainty, because apparent changes can be representative of misclassification of land cover types, rather than true change from one land cover type to another. To explore the uncertainty, we carried out an external evaluation of the Land Cover Layers dataset using aerial photography.

2.2 Aerial photos

We obtained aerial photographs from 1987-2015 from DEW and used these to manually map the cover and distribution of saltmarsh and mangrove through time. This dataset acted as an external evaluation of the results from the analysis of the Land Cover Layers. We chose two sites to use for the external evaluation - it was not possible to do this for the entire state due to the amount of time that it takes to manually digitise the photos and the lack of aerial photos of many parts of the South Australian (SA) coastline. The sites we chose were areas that had previously been reported in the literature to have experienced change in the area coverage and/or distribution of saltmarsh and mangrove. The first evaluation site was Torrens Island, where there has been mangrove loss attributed to the Bolivar sewage outflow (Bayard 1992, Coleman 1998) as well as landward encroachment of mangrove into saltmarsh (Coleman et al. 2017, Fotheringham and Coleman 2008). The second site was an area that extended from Port Gawler to Middle Beach which also had documented losses of coastal vegetation (Cann et al. 2009, Coleman et al. 2017). All external evaluation data processing was done in ArcGIS (ESRI 2018), where different land cover types (e.g. saltmarsh, mangrove, water, urban, bare) were manually digitised from the aerial photos by tracing around their boundaries. Finally, the maps generated from the aerial photos were converted to the same data type (raster) and resolution as the Land Cover Layers, so that a direct comparison of the maps for each time period could be made and differences could be investigated.

3 What we found

3.1 DEW Land Cover Layers

Using the Land Cover Layers dataset, we estimated area coverage of 164.2 km² for mangrove and 197.6 km² for tidally influenced saltmarshes in 2015 (Figure 2). We found that there had been relatively small net increases in the area of both saltmarsh and mangrove ecosystems between 1987 and 2015, with a greater increase in saltmarsh (16 km², or an approximately 9% increase since 1987) than mangrove (7.9 km² or a 5% increase since 1987) (Figure 2). There was a small reduction in the area of saltmarsh between 2005 and 2010 and in the area of mangrove area between 2010 and 2015 (Figure 2). There was greater variability in the area of saltmarsh recorded in this dataset from one time period to the next than in the mangrove area. These fluctuations may be due to the dynamic nature of this coastal ecosystem, but could also be attributed to incorrect classification of saltmarsh in the Land Cover Layers dataset (which is relatively poor at classifying saltmarsh compared to other landcover types; White and Griffioen 2016).

It should be noted that a broad scale loss of mangrove and saltmarsh is likely to have occurred prior to the commencement of the Landsat satellite data coverage in 1987 (particularly in urban, industrial and agricultural areas). Therefore, the relatively small increases in area coverage reported here for the period between 1987 – 2015 should be viewed with that in mind.

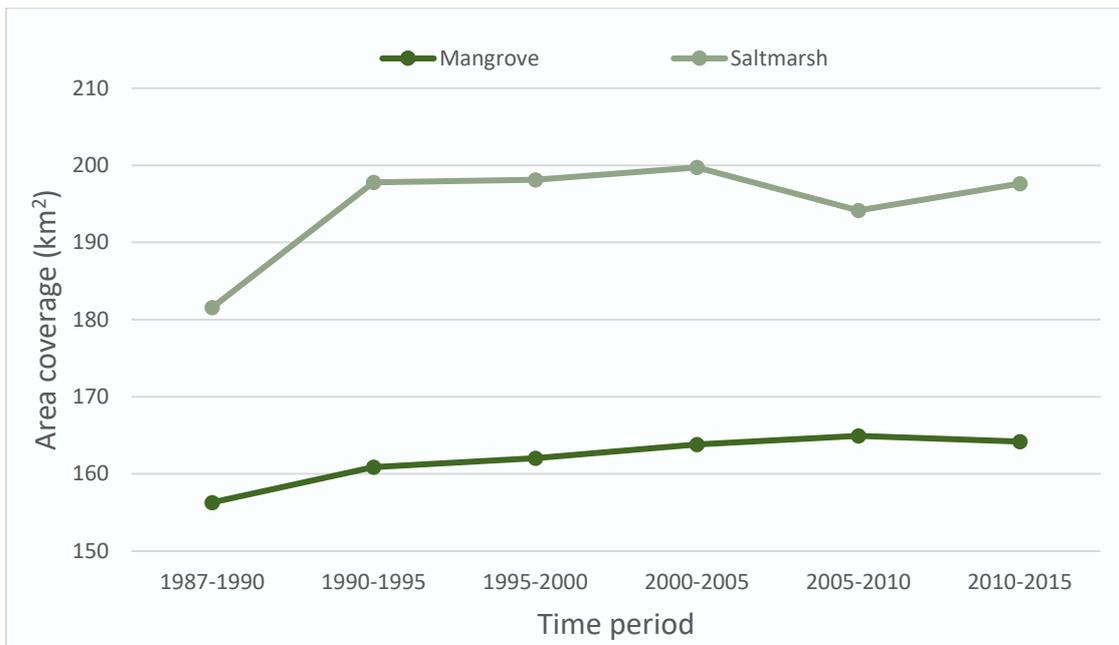


Figure 2. Area coverage through time for saltmarsh and mangrove in South Australia, based on the modelled most likely layer (Willoughby et al. (2018); cropped to the coast using a 5 km buffer).

3.2 Validation with aerial photography

We compared the area coverage estimates and patterns of change in distribution for saltmarsh and mangrove from the Land Cover Layers and the aerial photographs for two areas; Torrens Island and Middle Beach. The results revealed differences between the two methods when assessing the area coverage of each ecosystem and their change over time, for both Torrens Island (Figure 3) and Middle beach (Figure 4). The aerial photography estimates for both mangrove and saltmarsh appeared to better represent the actual area coverage and changes over time.

Closer inspection of the Torrens Island site reveals that the Land Cover Layers data did not accurately detect bare ground, instead incorrectly classifying it as either mangrove or saltmarsh, but this is particularly notable for saltmarsh areas (Figure 3). This misclassification in the modelled Land Cover Layers may have occurred because the ground was wet (due to tidal influence), which can affect the light reflectance characteristics received by the Landsat satellite. Areas of wet sediment may also be covered by algal mats or small photosynthetic organisms (phytoplankton), which again can confuse the spectral signal received by the Landsat satellite, and may prevent correct classification as bare ground. Such misclassification explains why a change from bare ground to mangrove/saltmarsh was observed in the aerial photography data, but no corresponding change was observed in the Land Cover Layers estimates: The modelled Land Cover Layers did not detect colonisation of mangrove or saltmarsh onto bare substrate, because the bare substrate had previously been misclassified as vegetated – so no change was recorded (Figure 3).

For the Middle Beach validation site, aerial photography was again more accurate than the Land Cover Layers, which did not detect the landward progression of mangrove and saltmarsh (Figure 4). In this case, the areas of new vegetation colonisation were incorrectly classified in the Land Cover Layers as ‘woody native’ or ‘wetland vegetation’.

In summary, when we compared the results of the aerial photo analysis with the results from the Land Cover Layers change assessment we found differing area estimates and change trends using the different approaches. We propose that the aerial photograph based assessment is likely to be more accurate and more appropriate for detecting changes relevant to local and regional authority management activities. However, the Land Cover Layers dataset is the best available state-wide mapping product to use for baseline carbon stock assessment and for the identification of broad scale gains and losses in saltmarsh and mangrove ecosystems.

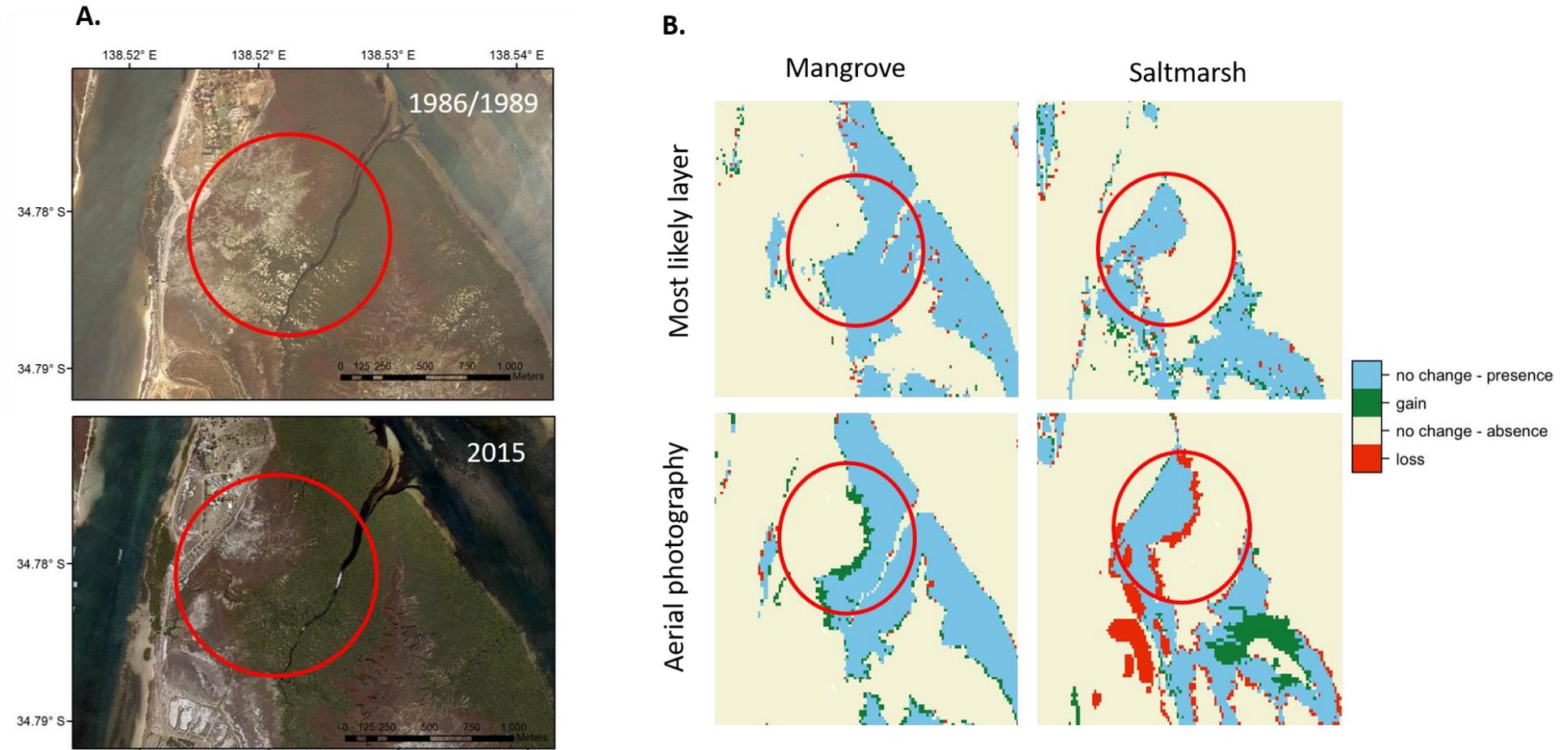


Figure 3. Comparison of estimated change in the cover of mangrove and saltmarsh vegetation over time at the Torrens Island area of interest using different data sets. A) Aerial photography showing clear increase in mangrove and decrease in saltmarsh from 1986 to 2015 within the red circled region. B) Landcover most likely layer and aerial photography change estimates over the same period for the same area as the photos on the left.

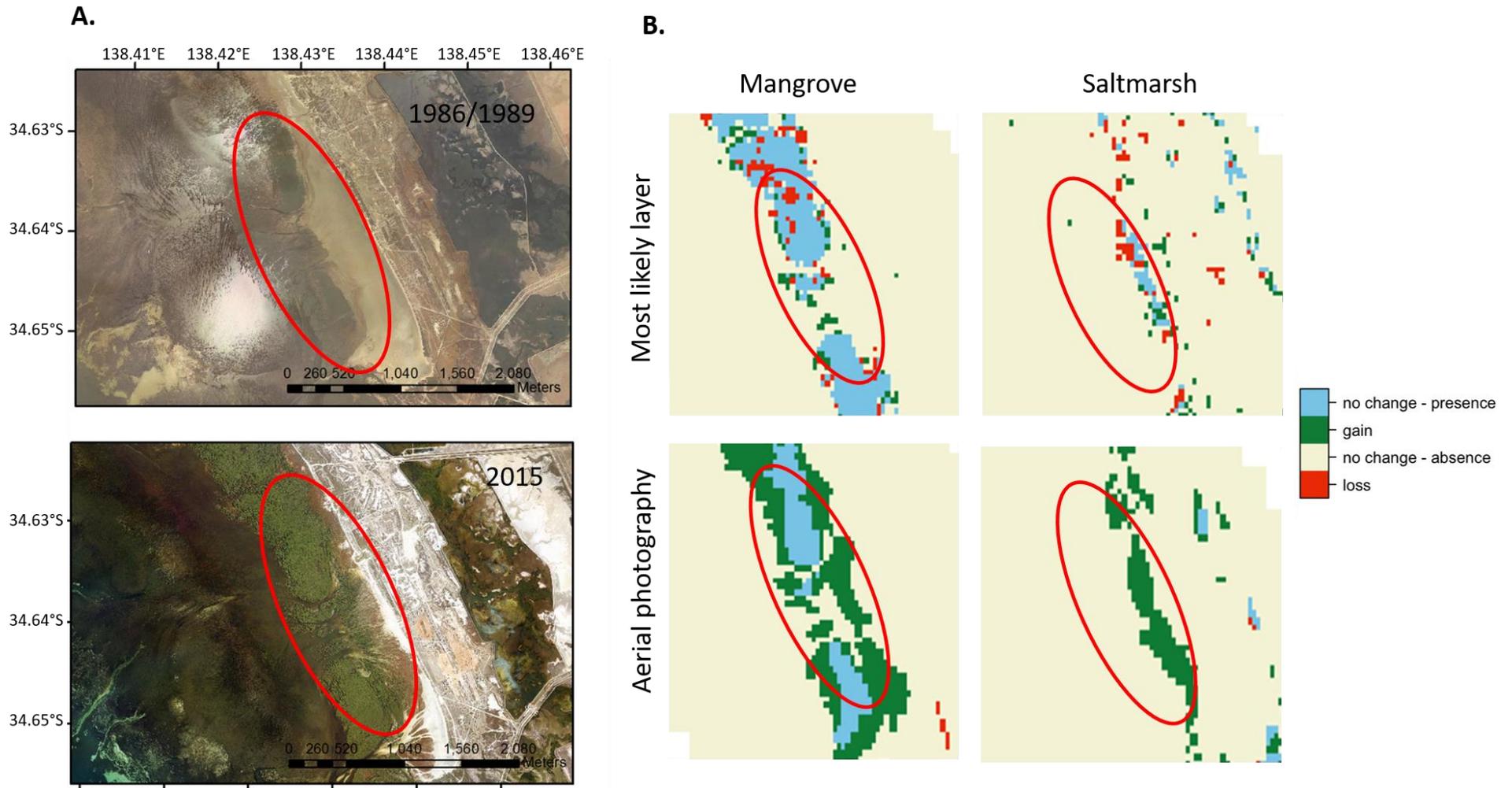


Figure 4. Comparison of estimated change in the cover of mangrove and saltmarsh vegetation over time at the Middle Beach area of interest using different data sets. A) Aerial photography showing clear increase in landward distribution of both mangrove and saltmarsh communities from 1986 and 2015. B) Landcover most likely layer and aerial photography change estimates over the same period for the same area as the photos on the left.

4 What this all means

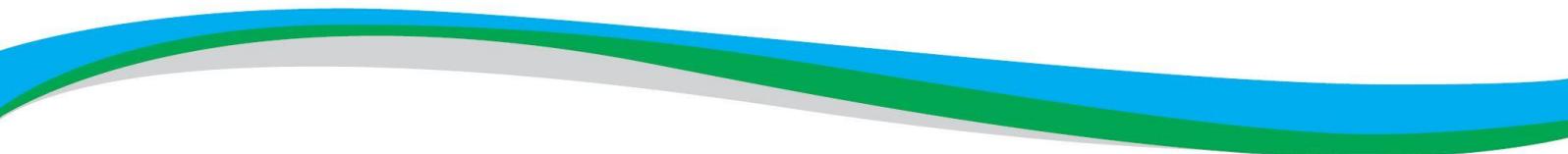
Our project, 'Coastal Carbon Opportunities' aimed to generate data to fill critical knowledge gaps around carbon in South Australian coastal ecosystems, including documenting the distribution of mangrove and saltmarsh, to support the development of state government climate strategies and policies.

This study documented small increases in the state-wide area of mangrove and saltmarsh vegetation in South Australia from 1987-2015 using the DEW Land Cover (most likely) Layers dataset. However, closer inspection of this data uncovered large error associated with these estimates. To address this, we carried out an external evaluation, which identified a critical limitation of this dataset, namely the inability to detect local-scale changes in mangrove and saltmarsh ecosystems due to errors in the identification of these vegetation types and misclassification of bare ground in the coastal zone.

These results will be important going forward when considering carbon sequestration by blue carbon habitat as we now have a better understanding of the limitations of the Land Cover Layers dataset for monitoring area coverage and change in mangrove and saltmarsh ecosystems. We also demonstrate the importance of carrying out external validation of vegetation distribution data, as there can be errors in the datasets. The impact of such errors depends somewhat on the question being asked and the scale of assessment. This is important from a management and policy perspective, as these need to be based on the best-available data and must also take account of uncertainty. For example, we acknowledge that the Land Cover Layers dataset is the best available state-wide mapping product for coastal vegetation currently available, however given the level of uncertainty in the classification of mangrove and particularly saltmarsh, we suggest that it is not used for local scale or site-based monitoring of change for either of these ecosystems. However, neither is it feasible to rely on aerial photographs as a stand-alone method for change detection, as they are limited both spatially and temporally and manually digitising these images is very time consuming and may be subjective. We therefore suggest a multi scale approach, which involves further external validation of the Land Cover Layers classification of saltmarsh and mangrove (e.g. for other sites across the state using alternative data sources and comparing patterns of change). We believe this is a practical way forward, especially when relating the area and changes in the distribution of these ecosystems to carbon stocks and accumulation, as this would improve accuracy at state scale while being robust at local validation sites. If the Land Cover Layers dataset is found to be consistently unreliable in the mapping of saltmarsh and mangrove (after further external validation), a dedicated mapping and modelling program for these difficult-to-classify coastal vegetation types should be undertaken. Accurate mangrove and saltmarsh mapping data is critical to assessing the states blue carbon stock inventory.

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