Assessing vulnerability of salt marshes to impacts of sea level rise in the Tamar Estuary, Tasmania: Report to Tamar NRM

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CONTENTS

Executive summary

This report provides an evaluation of the current conditions of saltmarshes in the Tamar Estuary and analysis of their vulnerability to sea level rise. Methods of analysis included a vulnerability ranking system approach. Vulnerability was measured using a total of 15 components including marsh elevation, historic loss, threat of invasive species and marsh management. These measurements were examined across six sites: George Town, Kelso, West Arm, Middle Arm, Middle Point and Native Point.

It was found that all saltmarshes have some degree of vulnerability that could be lessened by improved estuary management, wetland restoration and increased protection. Large saltmarsh areas showed impacts of previous mismanagement while disjunct saltmarsh patches show vulnerability resulting from external pressures. The six saltmarshes studied had a vulnerability rank between 1 and 3, where 1 is low vulnerability and 5 is high.

- Middle Point had the highest vulnerability of 2.87
- Middle Point is a good candidate for further protection
- George Town had the lowest vulnerability of 1.93
- The average vulnerability across all sites was 2.43

Recommendations discussed include:

- Suggestions for management actions including increased protection and increasing vegetated buffer zones (particularly at Middle Point)
- Community education such as a bioblitz, ongoing monitoring and self-guided walks

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What are saltmarsh wetlands?

The term saltmarsh wetland is used to describe areas that are subject to shallow tidal inundation and flooding in low energy coastal environments and are vegetated by halophytic plants that are adapted to saltwater inundation. Saltmarshes occur throughout eastern Australia, sometimes in competition with mangroves. In temperate climates such as Tasmania, saltmarshes dominate the vegetated intertidal zone because mangroves are excluded by low temperatures. Saltmarsh vegetation typically includes succulent elements (such as beaded glasswort or samphire) and grassy elements (such as juncus). Land and estuary animals take advantage of the environment created by the saltmarsh vegetation and the wetlands help to maintain a healthy estuarine system.

Saltmarsh wetlands at Middle Point with beaded glasswort (also called beaded samphire) and tussock grasses in the foreground, and mudflats and the Tamar Estuary the background.

Saltmarsh values: Biodiversity and buffering

The structure of saltmarsh ecosystems are multifaceted, providing vegetated platforms and tidal creeks creating continuity with surrounding habitats. Multiple environmental niches provide habitat for fish, invertebrates and avifauna. The inundated saltmarsh provides a nursery and feeding habitat for fish and crustaceans, zooplanktivorous and omnivorous species which transfer nutrients between intertidal and aquatic environments. Predatory fish take advantage of the draining tidal creeks providing a trophic connection from the saltmarsh to wider aquatic environment. The provision of habitat and flow of organic material to coastal waters is particularly important when considering flow on effects to commercial and recreational fisheries.

Saltmarshes influence nutrient and sediment loads of estuaries, buffering the effects of land-use impacts on the marine environment. Nutrients in aboveground runoff and belowground flow are intercepted by saltmarsh regulating algal blooms and the health of seagrass meadows. Similarly, sediment entrained in runoff can be

deposited in saltmarsh before reaching the estuary and sediment in the water column can settle and build up the marsh.

Saltmarshes are of high importance to avifaunal diversity by providing habitat for breeding, feeding and roosting. In South-eastern Australia common shorebirds gather in saltmarsh to nest, feed and breed while waterbirds find refuge from drought in coastal wetlands. Birds of prey utilize saltmarsh for hunting birds and mammals, contributing to the link between saltmarsh and terrestrial ecosystems. Migratory shorebirds such as the red-necked stint (*Calidris ruficollis*) roost and feed in saltmarshes of South-eastern Australia during the non-breeding season, and the critically endangered orange-bellied Parrot (*Neophema chrysogaster*) feeds on seeds of saltmarsh plants including species of *Sarcocornia*, *Tectocornia* and *Suaeda*.

Human impacts

Despite associated values saltmarshes have a history of human-mediated loss and degradation driven by the perception of saltmarsh as wasteland. This global history is reflected in Australia and the island state of Tasmania where saltmarsh area has been reduced and remaining marshes are subject to unsustainable practises and degrading processes. Contemporary recognition of saltmarsh values has seen increased interest in the reservation of saltmarsh wetlands, subsequent legislation for protection and large scale restoration. In Australia, temperate saltmarshes were listed as vulnerable under the national Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act) in 2013. The EPBC Act also administrates protection for wetlands of international importance as declared by the Ramsar convention with outcomes of varying degrees of success. In Tasmania some saltmarsh communities are protected under the Tasmanian Nature Conservation Act 2002 which includes saline aquatic herbland and undifferentiated wetlands. Although interest in saltmarsh conservation has increased, ecological and management research of saltmarshes is lacking. In New South Wales, surface elevation tables (SETs) have been used to measure changes in marsh surface elevation leading to dynamic elevation modelling incorporating estimates of marsh accretion into migration area modelling, however Tasmania lacks such projects as well as detailed studies on individual saltmarshes.

Human systems such as agriculture are at an increased risk to impacts of climate change by the loss of ecosystem services supported by biodiversity. In light of the ecological contributions made by saltmarshes and threats faced by climate change and ongoing pressure, the need for vulnerability assessments, identification of migration areas, baseline data and ongoing monitoring to inform adaptive management becomes clear.

Threats to saltmarshes by climate change and sea level rise

As the interface between terrestrial and marine environments, saltmarshes are particularly susceptible to impacts associated with climate change and sea level rise. Erosion of the seaward edge of the marsh has been documented in northern Tasmania which leads to a loss of vegetated area and loss of buffer for inland areas. Erosion may increase the sediment load of an estuary. Increased inundation and water depth coupled with changes in temperature and rainfall may lead to loss of saltmarsh or a shift in species composition. This has been documented in Tasmania as an increase in salt scalds and species adapted to increased aridity.

In response to increased inundation and water depth saltmarsh communities may progressively migrate inland where higher land is available. Where there is no higher land due to natural elevation or manmade barriers (such as buildings or roads) a loss in saltmarsh will occur. Further, saltmarshes currently in protected areas may have sufficient space for inland migration but may migrate from within a protected area towards private or unprotected land. In areas where a saltmarsh is bordered by rice grass sea level rise may facilitate advancement of rice grass into native salt marsh by increasing inundation to levels where rice grass outcompetes native species.

At a broader scale, increased temperatures will induce a southward shift in species ranges and encourage mangroves to migrate southward into areas where mangroves were previously excluded, including northern Tasmania.

At a local scale, it is believed that saltmarshes affected by human impacts will have less resilience than saltmarshes that are in good condition. Saltmarshes in poor condition are more sensitive to climate change impacts than saltmarshes in good condition.

Vulnerability assessment methodology

A literature review identified the threats posed to salt marshes (above) as well as a method to measure the vulnerability of different areas. The method was taken from Ellison (2015) which was applied to mangroves but is readily adaptable to other coastal communities. The basis of this method is promoted by International Union for Conservation of Nature (IUCN) for climate change and sea level rise adaptation.

A review of existing data found 3 studies that were integrated into the assessment: NRM North's 2015 TEER, foreshore risk assessment by Migus (2011) and shoreline vulnerability to erosion by Sharples (2006) which are accessible through TheLIST. These assessments have their own assumptions and limitations which are not entirely compatible with this studies objectives. For example NRM North (2015) includes high sediment levels as a negative indicator of aquatic health. This is problematic because increased sediment inputs may increase a saltmarshes capability for vertical accretion therefore increasing adaptive capacity. This particular issue was considered minor as the aquatic health measure includes several other pertinent indicators such as nutrients, pH, chlorophyll a, metals and bacteria. Further, increased sediment may be an appropriate negative indicator because *Spartina* invasion is excluded from the lower estuary due to low sediment levels.

Six study sites were identified to be measured for vulnerability. The study sites were Native Point, Middle Point, Middle Arm, George Town, Kelso and West Arm (Fig. 1). Sites were selected on the basis of spatial area and collectively these sites embody a large proportion of saltmarsh meadows or saltmarsh complexes in the estuary. All sites were visited and surveyed excluding Kelso and Middle Arm due to access constraints.

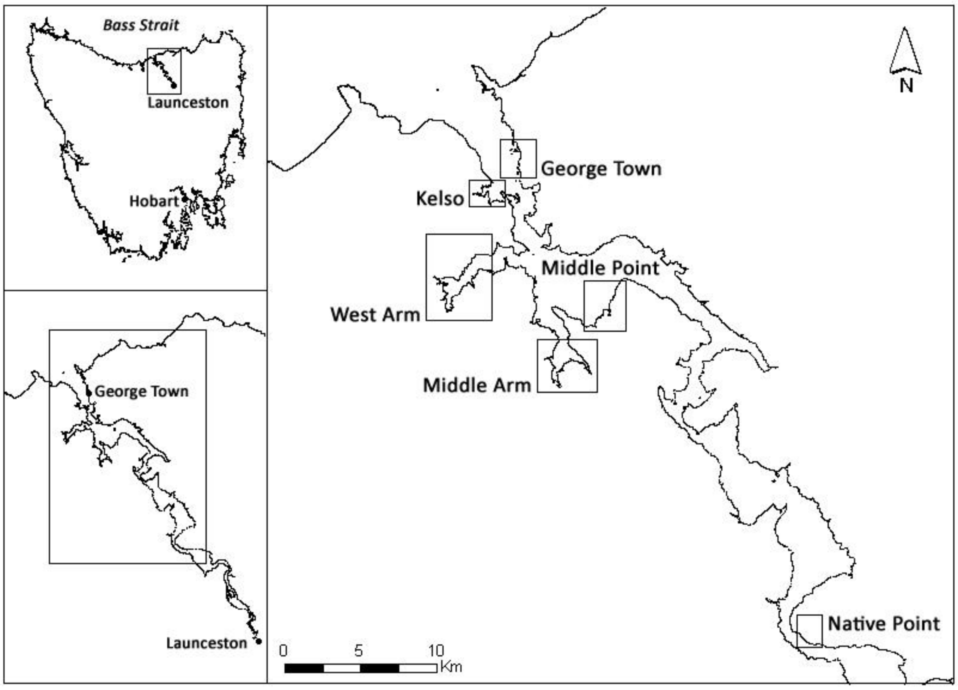

Fig. 1 Location of saltmarshes assessed for vulnerability in the Tamar Estuary, Tasmania

The protection status of each area was found using land tenure information from TheLIST. The level of protected given by different types of conservation areas was measured by their respective IUCN category which is available in the PWS reserve summary report. While it is acknowledged that private land can be invaluable for conservation, this study assumes migration spaces in reservation offer higher adaptive capacity than migration spaces on private land. In the study sites examined, nature reserves confer a greater adaptive

capacity than conservation areas because nature reserves have a lower IUCN category of 4 with the primary objective of conserving species or habitats while conservation areas have a higher IUCN category of 5 which includes human use as a primary objective. Historic sites may offer better protection than conservation areas because permission is required from both Tasmanian Houses of Parliament for revocation of historic sites but for not conservation areas. However in the study sites examined, conservation areas and historic sites are classified as IUCN category 5 and considered less protective than nature reserves.

Sea level rise models were used to gauge the availability of migration space. Models were developed by DPIPWE but have major limitations. The limitations are that inundation modelling lacks inclusion of possible responses and feedbacks to sea level rise including erosion, deposition, accretion and below ground and biological processes. Further, the projections of sea level are highly uncertain and observed rates and levels of sea level rise across the state vary markedly. The projection that the models are based on is an 80cm rise by 2100 and flooding modelling is based on 1 in 20 year floods. Areas inundated by 1 in 20 year flooding are thought to be suitable saltmarsh retreat areas. The allowance of an 80cm rise coincides with the most recent IPCC fifth assessment report projection under the RCP 8.5 emissions scenario of 0.52-0.98cm by 2100 at a rate of 8-16 mm per year. RCP 8.5 is the “business as usual” scenario of high emissions thus could be reduced by efforts to lessen emissions. With this considered, some discretion is required when interpreting modelling and projections.

Occupying low lying coastal areas, the distribution of salt marsh ecosystems are influenced by sea level and tidal ranges. Transects were used at Middle Point, Native Point, George Town and York Town to survey elevation and vegetation. The difference between the highest and lowest point of the saltmarsh can indicate the susceptibility of the marsh to complete inundation. A marsh that covers a large elevation range is less sensitive than a marsh that occupies a small elevation range. However the elevation range may vary within a marsh, particularly where there are many discrete patches of marsh such as at George Town and York Town.

High tidal ranges support a greater lateral extent of inundation compared to lower tidal ranges with a constant coastal surface gradient. Wetlands in microtidal areas have a greater distance to relocate compared to those in macrotidal areas. The tidal range in the Tamar increases upstream due to tidal amplification consequential of bedrock confinement from 2.34 m at George Town to 3.25 m at Launceston. To estimate the tidal range at each site, the increase in tidal range by upstream distance was extrapolated from tide gauges (Fig. 2). The shortest distance from each site to the estuary mouth was measured in ArcGIS and plotted against the extrapolated tidal range.

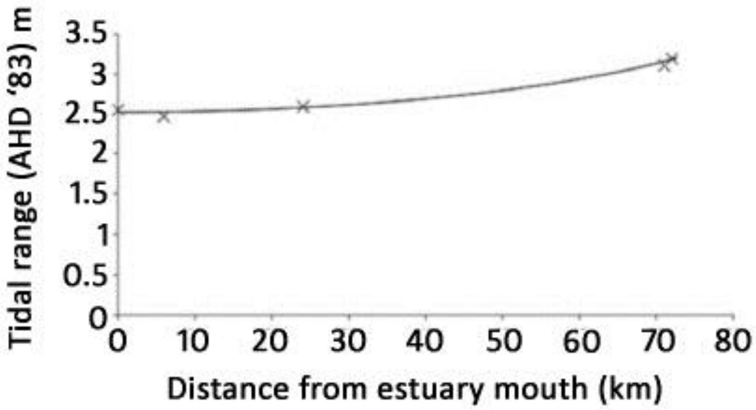

Fig. 2 The tidal range increases with distance from the mouth of the Tamar Estuary (from Ellison and Sheehan 2014)

Elevation was surveyed using a Topcon total station provided by the University of Tasmania. Survey control was obtained from LiDAR data which was the same elevation data used for the sea level rise and flood level modelling. The LiDAR data is accurate to ± 25 cm. Human impacts within salt marshes including hydrologic

modification and invasive species were measured with field visits and corroborated with mapping and data collected by Vishnu Prahalad in 2014.

Saltmarsh loss was investigated using historic photographs where loss was suspected. Suspected areas of loss were determined by current storm tide extent using inundation modelling and the presence of degraded saltmarsh. Current storm tide inundation was modelled for 1% annual exceedance probability (AEP) at 2010. Loss was identified at Middle Point and further analysis used an aerial photograph from 1969 captured at 1:31800 obtained from the Tasmanian Lands Department. This image was compared to the state orthophoto basemap obtained from the Tasmanian Lands Department which is continuously updated with the latest images. The image was georeferenced using ArcGIS 10 with a root mean square error of 2.0849. The current orthophoto basemap was also used to identify possible areas of hydrologic modification, land disturbance and adjacent land disturbance. Photo-interpretation of saltmarsh distribution, invasive species and human impacts was validated during fieldwork.

Floristic and elevation surveys were conducted around low tide on the following dates: 20 August (Native Point); 22 August (Middle Point); 5 September (West Arm); 10 September (George Town). Native saltmarsh communities were simplified into two categories: succulent and graminoid saltmarsh. Succulent saltmarsh was defined as dominated by succulent plants including *Sarcocornia quinqueflora*, *Selliera radicans*, *Suaeda australis*, *Tecticornia arbuscula* and *Limonium australe*. Graminoid saltmarsh was defined as dominated by monocotyledonous plants such as *Gahnia filum*, *Juncus kraussii*, *Austrostipa stipoides* and *Poa labillardieri*. Floristic presence/absence and graminoid and succulent community boundaries were recorded along transects. Plant species were identified using descriptive information, photographs and illustrations from Prahalad (2014) and Howells and Gulline (2011). Notes were taken on observed erosion, disturbance within saltmarsh and adjacent land and perceived changes in species composition. The density of invasive species such as *Spartina anglica* not included in transects that were within and along edges of saltmarshes was recorded and incorporated into scoring.

The components and sources for each site are summarized in Table 1.

Table 1 Components and sources of vulnerability used in the vulnerability assessment

Dimension	Component	Measurement	Sources
Exposure factors	Tidal range	Distance from estuary mouth and tidal gauge	Ellison and Sheehan 2014; GIS analysis
	Relative sea-level rise	Tectonic stability	Hunter et al. 2003
	Climate modelling	Rainfall projections	Grose et al. 2010
Sensitivity factors	Elevation within marsh	Difference between highest and lowest point of native saltmarsh	Elevation and vegetation survey
	Invasive species	Vegetation survey	Elevation and vegetation survey
	Shoreline vulnerability to erosion	Shoreline type	Sharples 2006
	Hydrologic modification	GIS analysis and ground truthing	Prahalad 2014b; Survey
	Land disturbance	GIS analysis and ground truthing	Prahalad 2014b; Survey
	Historic loss	GIS analysis and ground truthing	GIS Analysis
	Current marsh management	Land tenure	DPIPWE 2014; PWS 2015
	Foreshore risk assessment	Multiple measurements	Migus 2011
	Adjacent environment health	Ecosystem health monitoring	NRM North 2015
	Adjacent land disturbance	GIS analysis and ground truthing	Prahalad 2014b; Survey
Adaptive capacity factors	Available migration space	GIS analysis and ground truthing	Lacey et al. 2012; Prahalad 2014b; Survey
	Management of migration space	Land tenure	DPIPWE 2014; PWS 2015

The measurement of each aspect was assigned a rank between 1 and 5, where 1 was low vulnerability and 5 is high. If a saltmarsh complex had multiple ranks for a single aspect the rank best representative of the majority of the saltmarsh was chosen or a score was given to one decimal place. The overall vulnerability of each site was similarly ranked on a scale between 1 and 5 with 1 being low vulnerability and 5 being high vulnerability. The overall vulnerability rank was calculated by found by averaging the sum of the vulnerability components of each site using the formula:

$$\textbf{Vulnerability rank} = \frac{\textbf{Sum of component scores}}{\textbf{Number of components measured}}$$

Results

Saltmarsh elevation and vegetation profiles

The highest elevation of saltmarsh vegetation occurred at Middle Point at 2.03 m (Fig. 3). The lowest native saltmarsh vegetation occurred at George Town where succulent species sparsely occupied a gravel substrate at 1.00 m. The lowest extent of graminoid saltmarsh occurred at 1.25 m and 1.28 m at West Arm and Native Point respectively. The highest succulent saltmarsh occurred at 1.91 m at Middle Point, 1.76 m at Native Point and 1.73 m at George Town.

Patches of rice grass extended up to 1.77 m at Native Point where drainage channels facilitated landward invasion. This facilitation was also observed at Middle Point but was not captured by the transect.

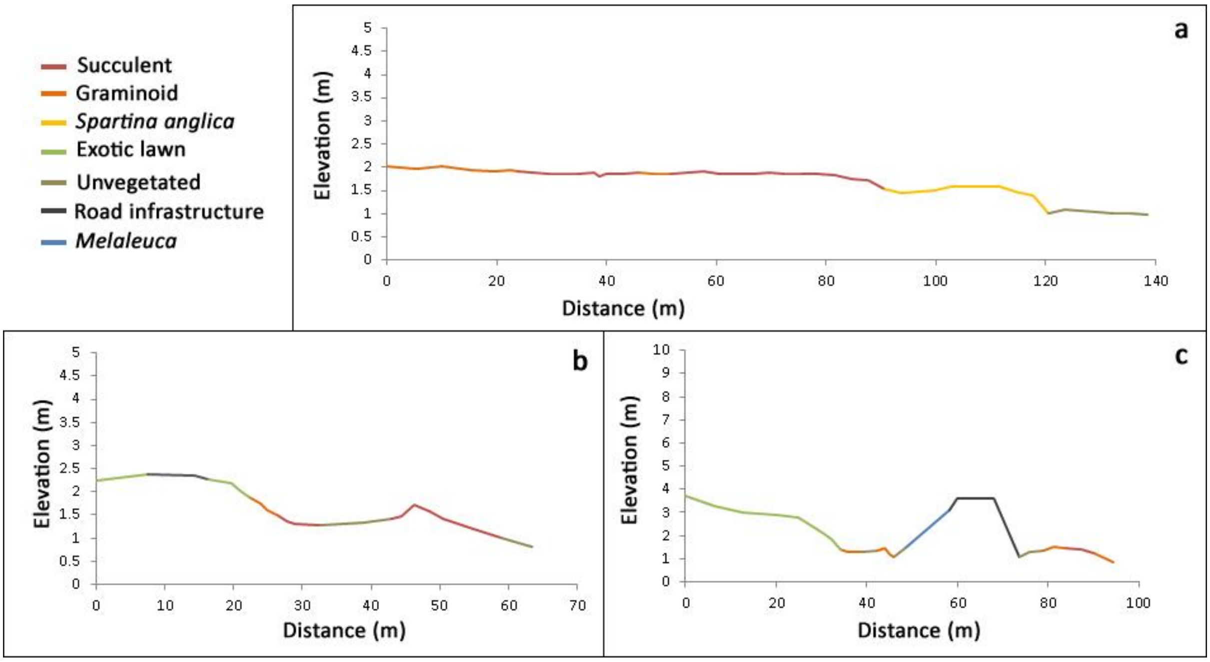

Fig. 3 Results of elevation and vegetation transect at Middle Point (**a**); George Town (**b**) and West Arm (**c**)

Native Point

The Native Point saltmarsh is located within the Native Point Nature Reserve. The marsh is bound by a sward of rice grass on the seaward side and natural elevation on the landward side. There are some ditches in the upper marsh which is allowing rice grass to invade higher than it normally could and rice grass occurs among native species in the lower marsh. Space for migration is limited and prospects for managed retreat appear low (Fig. 4).

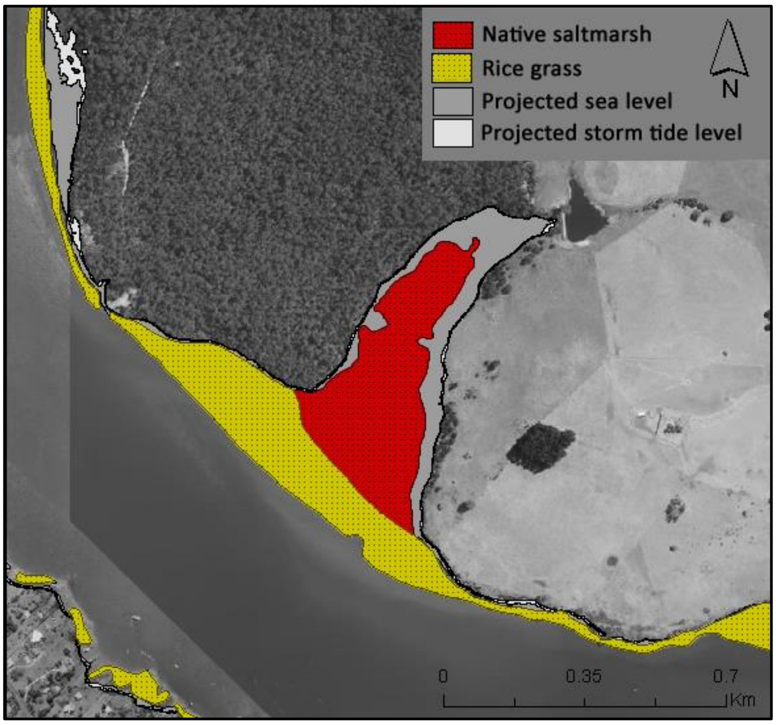

Fig. 4 Saltmarsh distribution and projected sea and storm tide level at Native Point

Plate 1 Upper Native Point marsh with Lanena, West Tamar on the opposite side of the estuary in the background.

Middle Point

Middle Point saltmarsh occurs within the Middle Island Conservation Area, a public reserve and private land (Fig. 5). There is some rice grass but most of the impacts are caused by previous mismanagement (Fig. 6; Fig. 7). There are extensive ditches, levees and tilled areas of native marsh which has potential for rehabilitation. Land adjacent to the marsh is irrigated and there are areas with no vegetated buffer between the saltmarsh and irrigated pasture. There is a large amount of low lying area that may provide migration space (Fig. 9). This space is entirely on private property. Some loss has occurred at Middle Point due to erosion, rice grass and land conversion (Fig. 8).

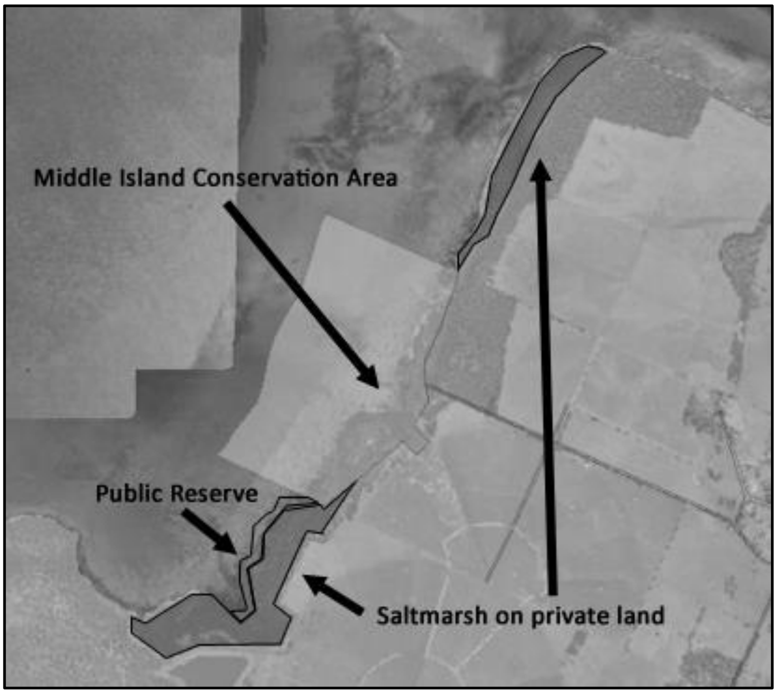

Fig. 5 Land tenure of saltmarsh at Middle Point

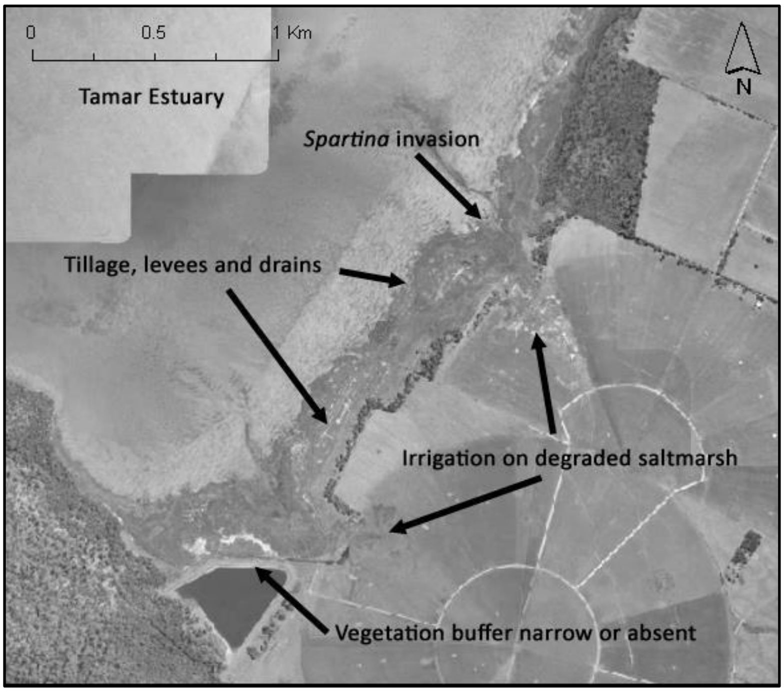

Fig. 6 Human impacts resulting from inappropriate land use and invasive species at Middle Point.

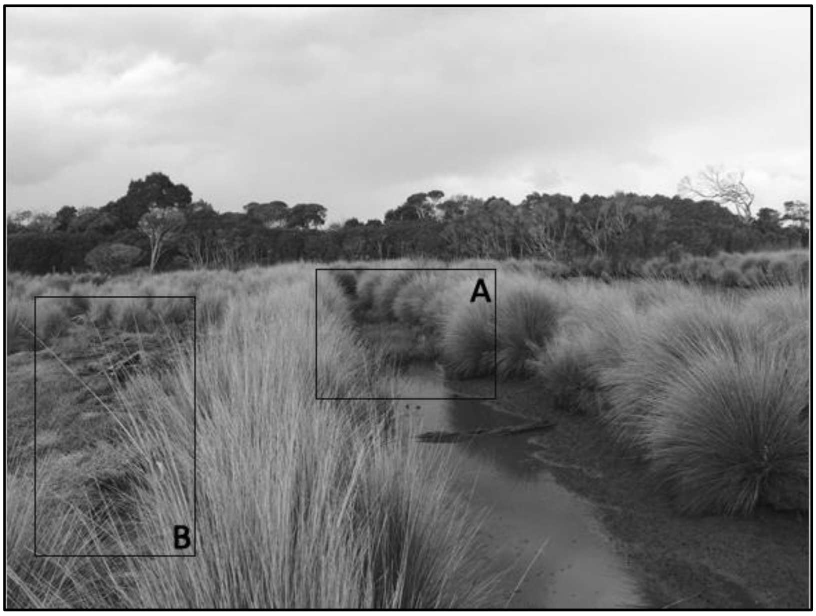

Fig. 7 Drainage ditch at Middle Point occupied by *Spartina* (**A**) adjacent to native saltmarsh (**B**)

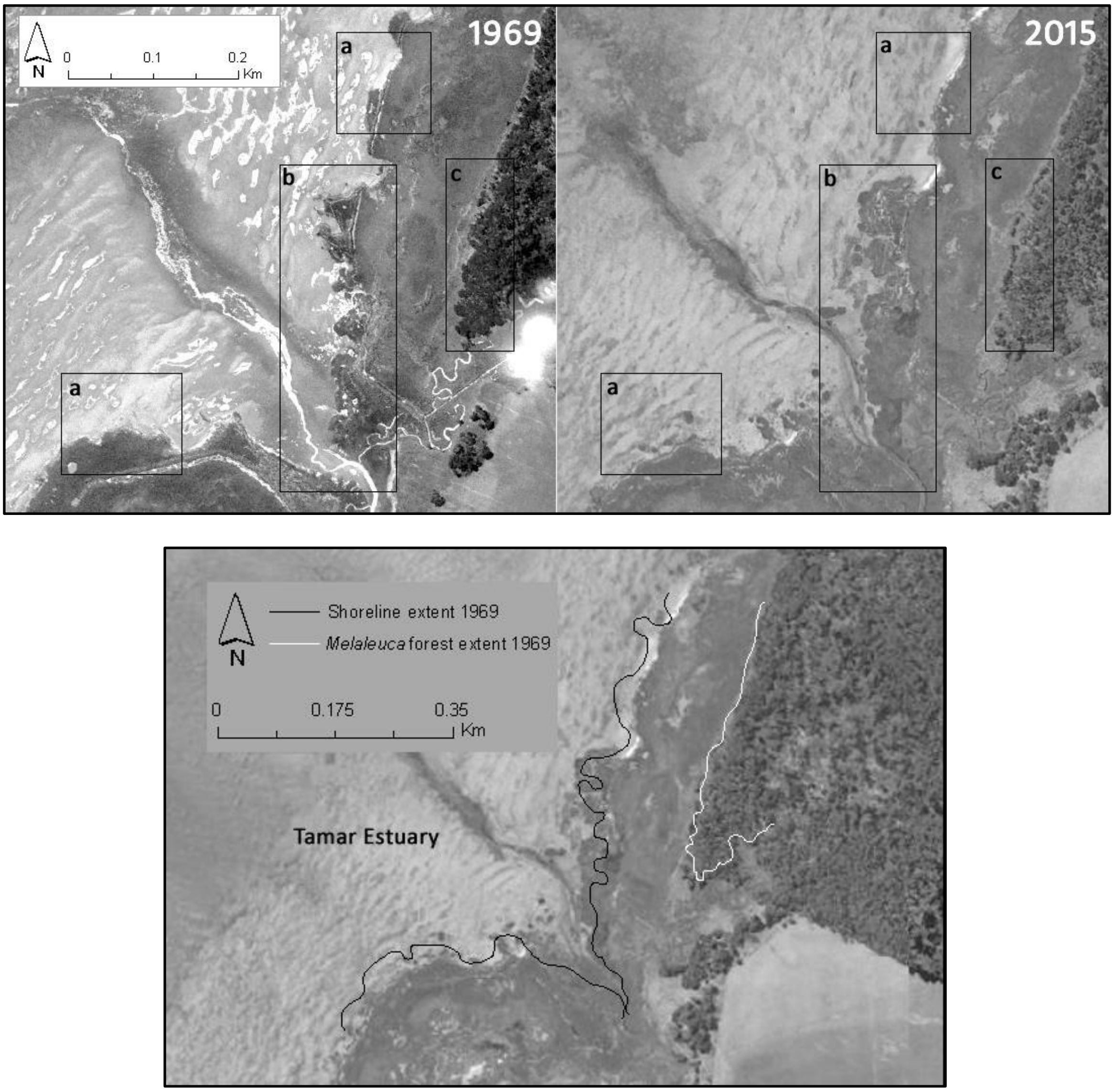

Fig. 8 Changes in vegetated shoreline extent and *Melaleuca* forest extent between 1969 (top left) and 2015 (top right) at Middle Point showing erosion (**a**), expansion due to *Spartina* (**b**) and minor expansion of *Melaleuca* forest (**c**).

Plate 2 Middle Point marsh taken from the Middle Island Conservation Area with rice grass in the foreground, saltmarsh in the middleground and Bell Bay, East Tamar in the background.

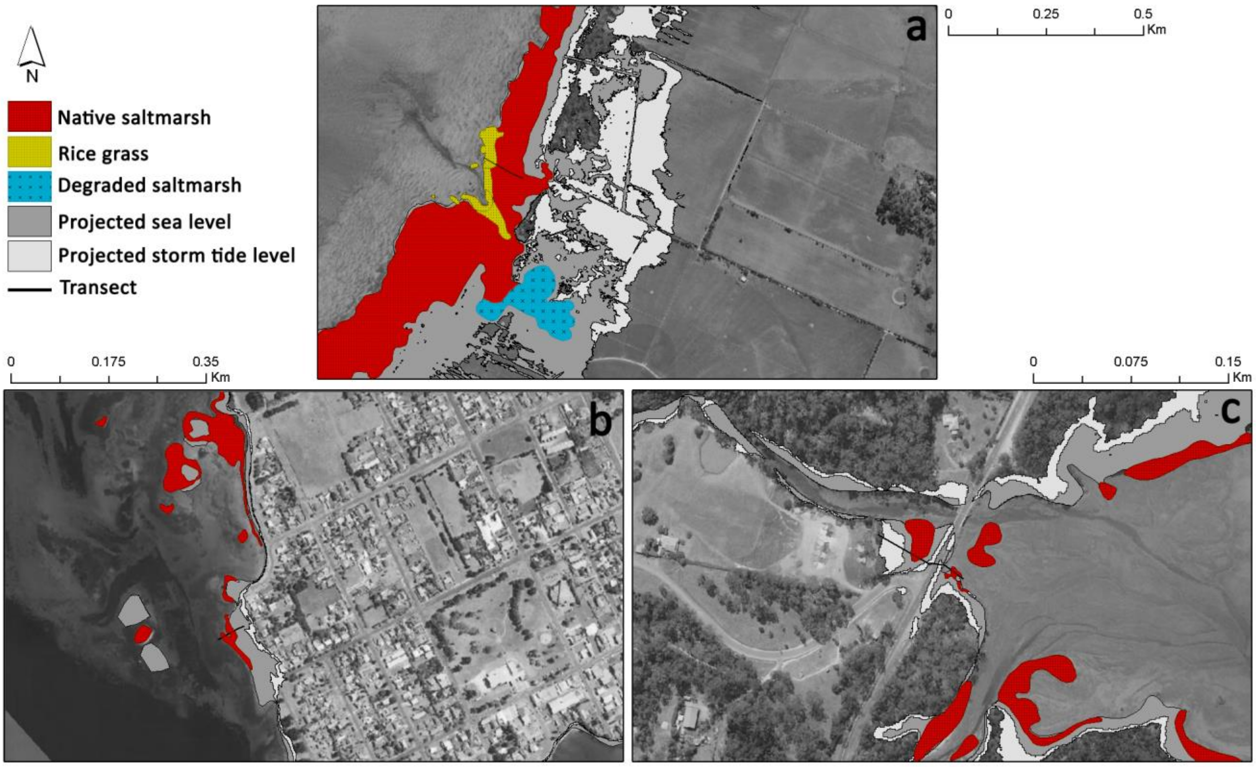

Fig. 9 Saltmarsh distribution and projected sea and storm tide levels at **a**: Middle Point (top), **b**: George Town (bottom left) and **c**: West Arm (bottom right).

West Arm

Saltmarshes studied in West Arm are located around York Town. Saltmarshes also occur downstream from York Town. Marshes currently occupy the York Town Historic Reserve and West Arm Conservation Area and have some space for migration. Some marsh may migrate onto private land and within the York Town Historic Reserve. The marshes appear to be in good condition and contain *Limonium australe* which is listed as rare in Tasmania.

George Town

George Town has areas of saltmarsh within the public reserve. Modelling shows that marshes will mostly remain within the public reserve with migration. The marshes appear to be in fair condition with some small patches of rice grass around drain outlets which could be eradicated however reestablishment is likely to occur in confined areas due to ongoing propagule pressure. *Limonium australe* was identified in George Town.

Plate 3 A small patch of saltmarsh with rice grass and eutrophication in a drainage outlet. The saltmarsh patch otherwise appears in good condition and contains *Limonium australe*.

Kelso

The marshes of the Kelso complex occur predominantly on private land. They are mostly backed by exotic grass lawn with a discontinuous buffer zone of native vegetation in some areas which could be extended to cover the saltmarsh boundaries. There is sufficient room for migration but occurs entirely on private land.

Middle Arm

Middle Arm marshes appear to occur mostly in the Middle Arm Conservation Area with some small areas on private land and Tas Water property. Some minor saltmarsh loss and land conversion may have occurred in the area. Saltmarshes in the Middle Arm area are difficult to access and probably understudied, so a "bioblitz" may be useful so identified sites of conservation value. The area between Middle Arm Creek and Battery Road appears to have a history of various land uses. Further investigation into the current and original vegetation of this area is required.

Site scores

Results of overall vulnerability ranking indicate that all sites fall below a rank of 3 (Table 2). Middle Point showed the highest vulnerability of 2.87 while George Town showed the lowest at 1.93. The average vulnerability of all sites was 2.43.

Ranks 1-2 indicate current resilience which may be enhanced by reducing any components higher than 1. Ranks 2-4 indicate a core vulnerability that may be improved with targeted management. Ranks >4 indicate very high vulnerability requiring immediate management actions. All sites are on the lower end of the vulnerability scale but resilience could be enhanced with targeted management.

The similarity of ranks is attributed to the narrow geographic range of the study. All sites within the study occur within the same tidal range, are tectonically stable and are expected to experience a slight increase in rainfall which explains the consistent results for components of exposure. Disparity is evident in measurements of sensitivity and adaptive capacity because variation of these components can occur at a finer scale and impose localized effects. Similar to components of exposure, some measurements are unmanageable such as elevation within marsh, potential for erosion and availability of migration space. However management action may ameliorate foreshore risk, adjacent environment health and adjacent land disturbance by promoting whole estuary and catchment health and the continuation of existing management programs. Further, vulnerability due to hydrologic modification and historic loss could be reduced by saltmarsh restoration.

Table 2 Results of component scores and overall site vulnerability scores for saltmarshes in the Tamar Estuary

Dimension	Component	Native Pt	Middle Pt	West Arm	George Town	Middle Arm	Kelso
Exposure factors	Tidal range	2	2	2	2	2	2
	Relative sea-level rise	3	3	3	3	3	3
	Climate modelling	1.5	1.5	1.5	1.5	1.5	1.5
Sensitivity factors	Elevation within marsh	3	3	4	1		
	Invasive species	5	3.5	3	2.5	1	1
	Potential for erosion	2.5	4	2.5		3.5	2.5
	Hydrologic modification	2	3	2	1	1	1
	Land disturbance	2	3.5	1	1	3	1
	Historic loss	1	3	1	1	1.5	1.5
	Current marsh management	1	2	2	3	3	5
	Foreshore risk assessment	3	3.5	3.5	2	3	3.5
	Adjacent environment health	2.5	2	2	2	2	2
	Adjacent land disturbance	2.5	4	1	2	3	2.5
Adaptive capacity factors	Available migration space	4	1	2	2	3	1
	Management of migration space	5	4	3	3	5	5
Total		40	43	33.5	27	35.5	32.5
Components scored		15	15	15	14	14	14
Vulnerability index		**2.67**	**2.87**	**2.23**	**1.93**	**2.54**	**2.32**

The components with the highest scores were foreshore risk with an average score of 3.08 and management of migration space which had an average score of 4.17. Components with the lowest scores were climate modelling at 1.5 across all sites and historic loss and hydrologic modification with average scores of 1.5 and 1.67 respectively.

Suggested management actions for saltmarsh conservation

The vulnerability of the Tamar Estuary saltmarshes is largely malleable and can be improved. Adaptation measures are required when there is a gap between what may happen as the climate changes and what is desired to happen. Targeted management would be particularly valuable at Middle Point which is the third largest saltmarsh in the northeast region and has the largest area available for migration but is the most vulnerable site with a rank of 2.87. This rank could be improved by multiple adaptation actions. Restoration of tilled areas and removal of levees and drainage ditches could ameliorate hydrologic modification and historic loss. Adjacent land disturbance could be improved by creating or extending a vegetated buffer zone around areas of saltmarsh. Cessation of irrigation and nutrient inputs on degraded saltmarsh and on adjacent land could improve the local hydrological regime and reduce favourable conditions for accelerated *Spartina* invasion. Sheehan and Ellison (2004) recommend containment of *Spartina* in the upper estuary and eradication in the lower estuary.

The Middle Island Conservation Area does not have a management plan. The Tasmanian Parks and Wildlife Service should be encouraged to create a management plan which includes the saltmarsh and considers

adjacent private properties. Management of migration space for Middle Point could be improved by extending the boundaries of the Middle Island Conservation Area to encompass the current saltmarsh area and modelled migration area. Costs of restoration and land acquisition may be offset by gains made in carbon sequestration (Rogers et al. 2014). Alternatively, agreements could be made with private landholders to manage projected migration spaces for conservation. The private sector including landholders and associates of local government such as NGOs are critical stakeholders in successful adaptation actions. For conservation of native grassland communities in agricultural areas under climate change Raymond et al. (2015) recommends two approaches to engage with private landholders. For landholders with high capacity for native grassland management, dissemination of information through respected conservation NGOs and farm system groups is encouraged. High capacity landholders were found to be typically commercially orientated, earning most income on-farm. For low capacity land managers, typically lifestyle land managers earning most income off-farm, formalized mentoring programs are recommended (Raymond et al. 2015). A similar approach could be used to engage with the several landholders adjacent to Middle Point using local environmental NGOs as facilitators of education and management actions.

Suggestions for increasing public awareness of saltmarsh values and conservation

Increasing public education and awareness of saltmarsh values is a key step towards saltmarsh conservation. Land owners with saltmarsh on or adjacent to their property should be engaged directly as they have direct influence over the condition of nearby saltmarsh. This could occur as direct consultation with the landowner through management advice or by tailoring a land management plan that encourages appropriate saltmarsh management. This could occur on a one-on-one basis or through a community meeting. A community meeting would ideally be led by a local with experience in the field (for example Emma Williams from NRM North, or Vishnu Prahalad from UTAS). The general public should also be engaged as they have influence on the condition of the estuary system as a whole. The Tamar Island Wetlands Centre provides an excellent example of education targeted towards the general public. The walking path along the George Town esplanade runs alongside areas of saltmarsh and coastal vegetation and could be utilised. This could be done with interpretation signage explaining saltmarsh and coastal vegetation and bird life, or by a self-guided tour with an information brochure that explains the natural values and historic highlights of the area, similarly to the Tamar Island Wetlands self-guided brochure.

Another approach to increasing education is active involvement in saltmarsh monitoring and research using community volunteers. A “bioblitz” is a short period of intense biological surveying which attempts to document all living species in an area. This would benefit saltmarsh research particularly in areas which are difficult to access and understudied such as Middle Point, Native Point, York Town and Middle Arm. This would probably require transport and access to be arranged. Saltmarshes closer to population centres such as the George Town saltmarsh could attract local residents and would benefit research from surveying. Ideally the bioblitz is led by a person with experience in saltmarsh ecology and plant and animal identification so that data can be gathered accurately in a way that is useable for conservation. The Bob Brown Foundation recently led a large scale bioblitz event in the North-west which gives a good example of bioblitz organisation (see http://www.abc.net.au/news/2015-11-25/tarkine-reveals-its-secrets-in-first-tasmanian-bioblitz/6957172 and http://www.bobbrown.org.au/bioblitz)

Monitoring of saltmarshes is another opportunity for active education within the community that can benefit research and conservation. Monitoring is ideally carried out at regular intervals in time such as every 6 months, 12 months or 24 months. Monitoring should also take place after management actions or perceived changes in marsh condition to give feedback to management. Monitoring requires more technical involvement compared to a bioblitz but provides valuable data if efforts are sustained over long periods. Monitoring methods range in simplicity with the simplest option being repeat photography/photopoint monitoring, where a photograph is taken in the same location over periods of time. Local residents may have a collection of personal images suitable for photopoint monitoring without knowing it! More technical methods involve transect or plot surveys and efforts should be led by a person experienced in ecological surveying or

monitoring. A community-based monitoring guide for saltmarshes is in progress by NRM North (see http://www.nrmnorth.org.au/saltmarsh-conservation) and will provide simple guidelines for monitoring. Guidelines for saltmarsh monitoring have been developed for other parts of Australia. A useful introduction video to saltmarsh monitoring can be found here: https://www.youtube.com/watch?v=VJBFpTIJpSg and more information can be found here: http://saltmarsh.enviroed.com.au/Vegetation.aspx , http://saltmarsh.enviroed.com.au/Vegetation/VegetationTransects.aspx , http://saltmarsh.enviroed.com.au/Vegetation/VegetationPlots.aspx

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