Clifton Saltmarshes, Pipe Clay Lagoon: Baseline Condition Assessment and Management Recommendations

CONSULTATION REPORT

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Report summary

- Pipe Clay Lagoon is a large enclosed, tidally influenced waterbody located on the eastern side of the South Arm Peninsula on the outskirts of Hobart, Tasmania. The margins of the Lagoon comprise of 45 ha of saltmarsh wetlands mapped in 2012 and identified to be part of the 'Pipe Clay Lagoon Saltmarsh Cluster.' The focus of this report is on the south bay area and the saltmarshes that form as a sub-cluster of **Clifton Saltmarshes**.

- **Clifton Saltmarshes** cover an area of 23.5 ha and make up close to a half of the saltmarsh extent mapped in the Pipe Clay Lagoon Saltmarsh Cluster. The extent of the marshes have been restricted and fragmented due to housing and road developments in the Clifton Beach area. The existing marsh areas are under varying land tenures, including: Pipe Clay Lagoon Coastal Reserve, Cape Deslacs Nature Reserve, Private Land (including Land for Wildlife properties) and Casement (Public Roads). The marsh areas on privately owned land are mostly left undeveloped but lack regular tidal connectivity characteristic of healthy saltmarshes.

- Clifton Saltmarshes is served by an active local **Wildcare Deslacs Group** involved in community engagement activities, management planning and on-ground works. Wildcare Deslacs commissioned this report to provide an outline of the current extent and function of Clifton Saltmarshes, document condition and threats.

- The largest impact leading to the loss in extent and function of Clifton Saltmarshes is **land-use conversion to buildings and roads**. Further to loss in extent, the function of the remaining saltmarsh area has been subject to **changes in tidal flows**. Other habitat disturbance features that affect saltmarsh extent and function involve **road widening**, **unmanaged tracks from off-road vehicle access**, **informal roads** (not including access roads) and **walking tracks**, **ditches** and **dumping of rubbish**.

- It is essential that future threats to Clifton Saltmarshes due to **infill development be excluded or limited to areas outside of the projected storm tide extent.** Where possible, **saltmarsh restoration could be achieved through reducing or moving existing infrastructure such as the access roads from the saltmarsh flooding zone**. The existing drains under Bicheno Street could be enlarged allowing for more tidal flushing and thereby improving the health and function of the saltmarsh.

- Key stakeholders in managing Clifton Saltmarshes include: Wildcare Deslacs, local residents, Clarence City Council, Natural Resource Management South, Parks and Wildlife Service, Birdlife Tasmania and University of Tasmania.

Recommendations

1. In order to address the issue of **tidal flow changes**, it is recommended that the existing **drains under Bicheno Street are enlarged**, allowing for more tidal flushing into the Cape Deslacs Nature Reserve, thereby improving the health and function of the saltmarsh and reducing the impact of sea level rise on the environment and inhabitants.
2. It order to address the issue of **habitat degradation due to unmanaged access**, it is recommended that:
    2.1. The 14 current access points be consolidated to no more than four through the construction of sustainable tracks and access points into the Reserve.
    2.2. Fencing and other physical barriers should be placed along Bicheno Street to restrict vehicle access and manage pedestrian traffic into the Reserve.
    2.3. Crown Land Services to identify vehicle access points for oyster farmers and restrict access to other parts of the shoreline in the Reserve.
3. In order to address the issue of **habitat degradation due to domestic weed encroachment**, it is recommended that:
    3.1. Weed control activities be undertaken.
    3.2. Suitable native plant species be planted, in order to increase the current extent of native fringing vegetation in the site from 5-30% to 30-70% coverage.
4. In order to address the issue of **habitat degradation due to continual road widening and traffic**, it is recommended that Clarence City Council institute best practice roadworks when undertaking road maintenance.
5. In order to address the **issue of community engagement and science communication**, it is recommended that:
    5.1. New interpretation signage is installed at key locations that highlight saltmarsh and broader inter-tidal landscape values (including of seagrass), and ways to reduce further threats to promote the functions of these coastal systems.
    5.2. Regular community information sessions (saltmarsh walk and talks) should be scheduled to engage residents about the natural values of the area.
6. It is also recommended that **monitoring be undertaken on an ongoing basis on various aspects relating to the health and function of the saltmarsh**. Monitoring activities can be linked with community engagement and science communication through the involvement of citizens and scientists.

Acknowledgements

I acknowledge Wildcare Deslacs for their support and inputs in producing this report. I also particularly acknowledge the contribution by Dr. Elizabeth Shannon in coordinating this work and providing crucial support and inputs towards this report.

Ian Mace from Wildcare Deslacs and Debby Ng from University of Tasmania are greatly acknowledged for their support with field work.

Lorne Kriwoken from University of Tasmania is acknowledged for his review of this report.

All photos and maps used in this report are by the author unless otherwise noted. Michael Helman is acknowledged for adding design graphics to the map in Appendix II.

Cover image of the Clifton Saltmarshes with storm tide data (as blue coloured areas) is a screenshot taken from LISTmap interface: http://maps.thelist.tas.gov.au/listmap/app/list/map.

Contents

1. Introduction

Pipe Clay Lagoon is a large enclosed, tidally influenced waterbody located on the eastern side of the South Arm Peninsula on the outskirts of Hobart, Tasmania. The margins of the Lagoon comprise of 45 ha of saltmarsh wetlands mapped in 2012 and identified to be part of the 'Pipe Clay Lagoon Saltmarsh Cluster' (Prahalad and Jones, 2013, page 28). The Lagoon is defined by four main features given its highly indented shoreline, namely the north, west and south bays and the narrow channel area opening in to Frederick Henry Bay on the east of South Arm (cf. Guiler 1950; Figure 1). The focus of this report is on the south bay area and the saltmarshes that form here as a sub-cluster, henceforth referred to as the Clifton Saltmarshes (or the 'study site').

Clifton Saltmarshes cover an area of 23.5 ha and make up close to a half of the saltmarsh extent mapped in the Pipe Clay Lagoon Saltmarsh Cluster. The extent of the marshes have been restricted and fragmented due to housing and road developments in the Clifton Beach area. The existing marsh areas are under varying land tenures, including: Pipe Clay Lagoon Coastal Reserve[1], Cape Deslacs Nature Reserve[2], Private Land (including Land for Wildlife properties[3]) and Casement (Public Roads[4]). The marsh areas on privately owned land are mostly left undeveloped but lack the regular tidal connectivity characteristic of healthy saltmarshes. The site is served by an active local Wildcare Deslacs Group involved in community engagement activities, management planning and on-ground works.

This report was commissioned by Wildcare Deslacs with support from the Clarence City Council Landcare Coastcare Grants Program. The overarching objective is to improve saltmarsh condition and ecological function. The aim of the report is to provide an outline of the current extent and function of Clifton Saltmarshes, document condition and threats using key attributes from the Saltmarsh Human Impacts Checklist (and the Saltmarsh Matters App, both available from http://www.nrmsouth.org.au/saltmarsh-monitoring/), and provide management recommendations for addressing some of the threats. The background work for the report involved two site visits, one involving a public 'walk and talk' event organised by Wildcare Deslacs on Sunday 28 February 2016, and another involving installation and baseline survey of line transects at the study site on Sunday 12 June 2016.

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[1] **Coastal Reserve** areas are Public Reserves designated under the Tasmanian *Crown Lands Act 1976* and managed under the *Crown Lands Regulations 2011*, by Crown Land Services.

[2] **Nature Reserve** areas are designated under the Tasmanian *Nature Conservation Act 2002* and managed under the *National Parks and Reserves Management Act 2002*, by Parks and Wildlife Service Tasmania.

[3] **Land for Wildlife** is a voluntary, non-binding conservation scheme which is part of the Tasmanian Government Private Land Conservation Program established in 2006.

[4] **Public Roads** and associated footways are managed by Local Councils. Crown Land Services has some control over the management of the extension of Bicheno St past Cape Deslacs Track.

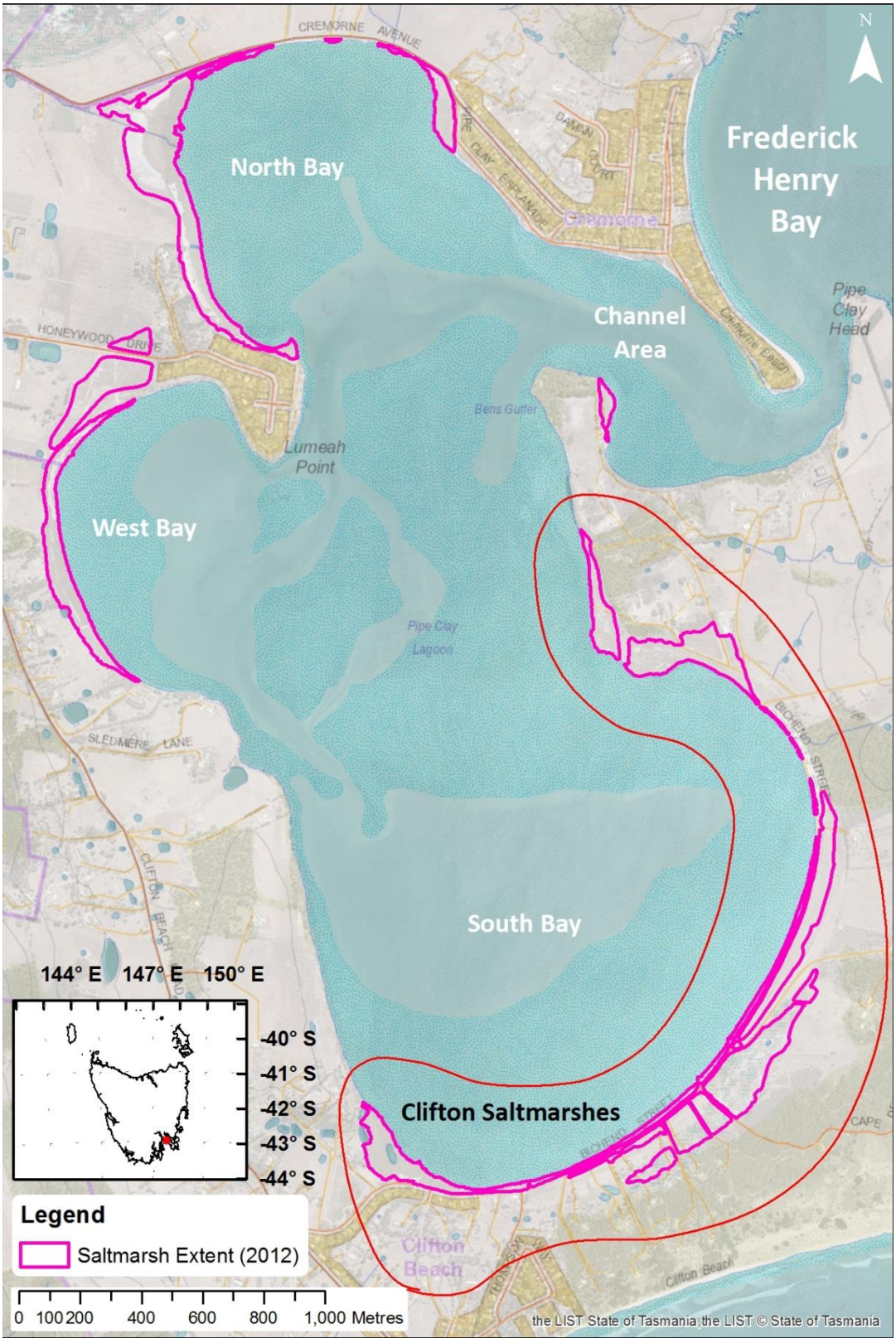


Figure 1. Pipe Clay Lagoon area with the 45 ha of saltmarsh wetlands mapped in 2010. Also indicated are the four main features given the Lagoon's highly indented shoreline, namely the north, west and south bays and the narrow channel area opening in to Frederick Henry Bay on the east of South Arm. The focus of this report is the Clifton Saltmarshes of the south bay area, within the area encircled in red. Base image by TASMAP, © State of Tasmania.

2. Saltmarsh ecosystem functions and services

Saltmarshes are dynamic and productive ecosystems that support a range of lifeforms and key ecological processes (see 'Riches behind our beaches' conceptual diagram on page 9 below). The ecosystem functions and services provided by Clifton Saltmarshes can be summarised as:

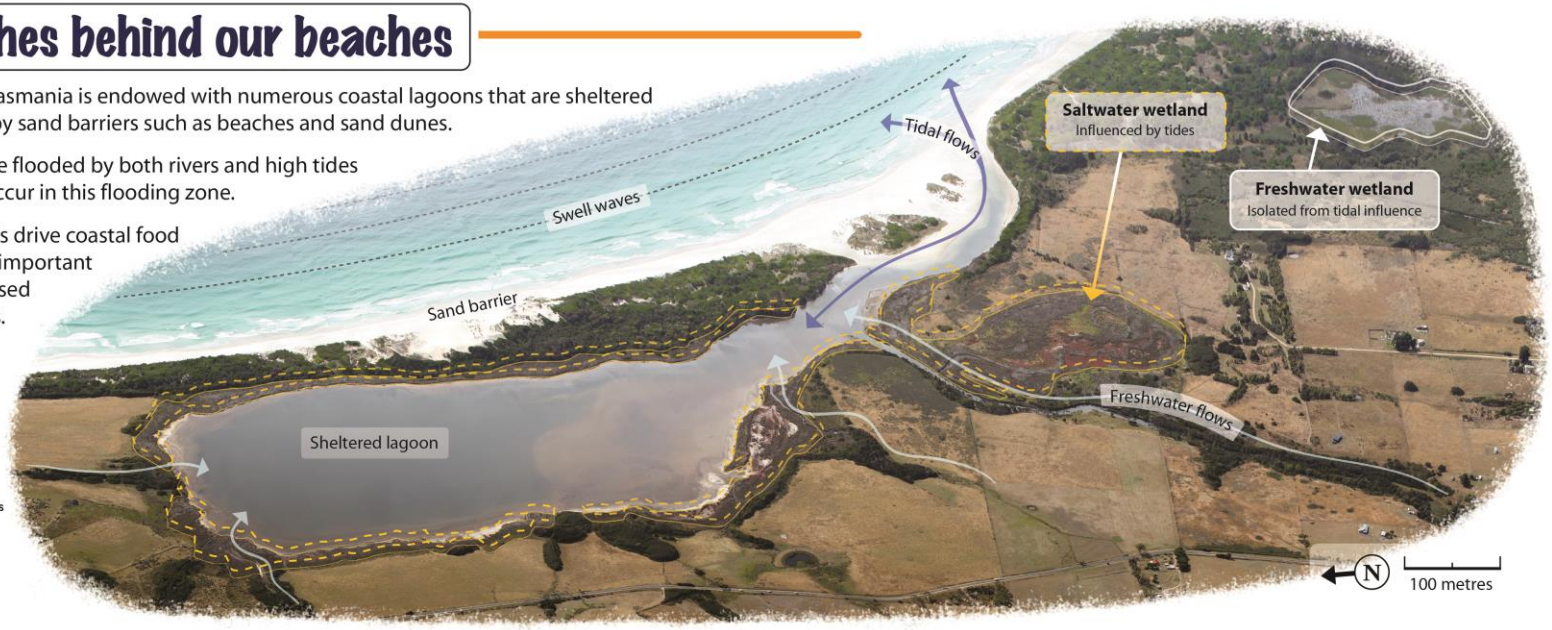
- **Supporting biodiversity**, with, for example:
  - highly specialised flora species (halophytes) such as succulent shrubs, herbs, grasses, rushes and sedges;
  - numerous marine and terrestrial invertebrates such as molluscs, crabs, spiders and insects, which form an important part of the saltmarsh food web;
  - providing crucial feeding, roosting and breeding habitats for resident and migratory shorebirds (notably, Pipe Clay Lagoon is recognised as part of the South Arm Important Bird Area, which also includes parts of Ralphs Bay and Pitt Water-Orielton Lagoon areas, see: http://www.birdata.com.au/iba.vm); and
  - supporting waterbirds, birds of prey and other terrestrial birds, especially white-fronted chats (*Epthianura albifrons*).
- **Increasing coastal food production**, with saltmarshes acting as fish nursery by both:
  - providing a source of organic material (e.g. crab larvae) that acts as food for fish; and
  - supporting juvenile fish to evade predation risk in the open sea during high tides.
- **Improving coastal water quality**, by intercepting and sequestering nutrients and sediments from nearby land and reducing negative effects such as algal blooms affecting water quality and aesthetics in the Pipe Clay Lagoon.
- **Acting as buffers against storm surges and sea level rise**, by building up soil and providing a buffer (and a 'flood soak') between the land and sea.
- **Attenuate global warming by sequestering carbon**, where the value of coastal saltmarshes as efficient carbon sinks is increasingly recognised (e.g., see http://bluecarbonlab.org/).
- **Providing recreational, amenity and educational values**, where:
  - the services that flow on from saltmarshes are important for maintaining many recreational pursuits around the Pipe Clay Lagoon area, especially fishing, bird watching, and other activities that require good water quality;
  - by engendering a sense of place with people who relate to these habitats at a personal level (as seen in the 'Save Ralphs Bay' campaign to protect the saltmarshes and intertidal flats at Lauderdale); and
  - providing excellent opportunities for communication and public awareness of coastal ecological values and ecosystem services, such as nutrient flows and processes in the landscape, climate change and sea level rise processes.
- **Living laboratories for research and development in science and technology**, where unexplored future benefits may arise out of further research into saltmarshes that may help advance science and technology. For instance, Clifton Saltmarshes have been used by University of Tasmania students for several science projects.

Riches behind our beaches

The east coast of Tasmania is endowed with numerous coastal lagoons that are sheltered from swell waves by sand barriers such as beaches and sand dunes.

Coastal lagoons are flooded by both rivers and high tides and saltmarshes occur in this flooding zone.

Saltmarsh wetlands drive coastal food webs and provide important habitat for specialised plants and animals.



SALTMARSH LIFEFORMS

Grasses, sedges and rushes
- Grasses (*Phragmites*)
- Sedges (*Gahnia*)
- Rushes (*Juncus*)

Upland trees
- Paperbark (*Melaleuca*)

Microscopic organisms

Succulent herbs and shrubs
- Succulent herbs (*Sarcocornia*)
- Succulent herbs (*Samolus*)
- Succulent shrubs (*Tecticornia, Suaeda*)

Marine animals
- Worms
- Snails
- Crabs
- Fish

Insects and spiders
- Insects
- Spiders

Birds
- Blue Wren
- Chat
- Migratory birds
- Pied Oyster Catcher
- Waterbird
- Black Swan

Aquatic herbs and grass
- Seagrass (*Zostera, Ruppia*)
- Water milfoil (*Myriophyllum*)

Native marsupials

Humans

Decaying organic matter (wrack)

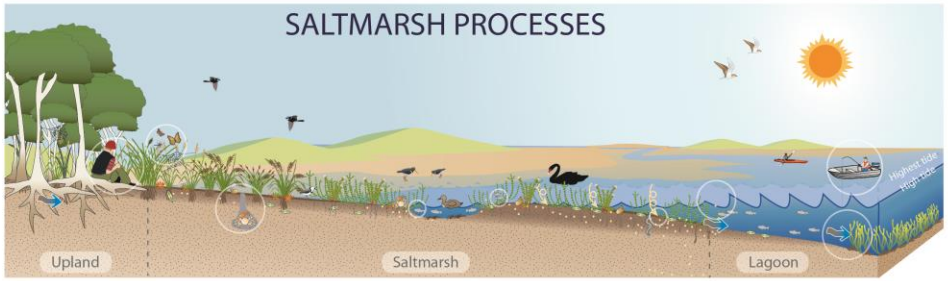
Education and research

Wetlands are live classrooms for connecting with and learning about nature and provides a rich living laboratory for scientific research and development.

Upland vegetation

Native upland vegetation cover of 100-200 m improves water quality and coastal productivity in the immediate low lying area. Trees also provide habitat for a greater diversity of plants and animals.

SALTMARSH PROCESSES



Birdlife

Many species of birds (especially waterbirds and shorebirds) flock in and around saltmarshes. Their diversity and abundance are a sign of healthy wetlands.

Insects and spiders

A wide variety of insects and spiders can be found in saltmarshes. They form an important part of the saltmarsh food web and their abundance can vary over seasons.

Crabs and snails

Crabs and snails are the most abundant of saltmarsh invertebrates. They are a significant food source for birds and fish, and play an important role in the soil building process by breaking down plant matter.

Tidal creeks

Tidal creeks are an integral part of saltmarsh and from branched networks within larger marshes. Besides providing habitat for fish and invertebrates, they also channel and dissipate the wave energy.

Fish nursery

Fish shelter and feed in saltmarsh during high tides on food derived from crabs, snails, insects and microalgae. Up to 35 species of fish have been recorded with densities of up to 56 fish found within an area of 100 square metres.

Carbon capture

Saltmarsh soil forms as the plants trap fine sediment (sand and mud) and organic particles generated by both plants and animals. This soil building process contributes to reducing global carbon pollution.

Coastal buffer

Saltmarshes provide a coastal buffer to soak up flooding water and dissipate the wave energy providing protection against extreme weather events and sea level rise.

Supports human use

Saltmarsh processes support human use of coastal areas for a range of recreational and commercial reasons including fishing and tourism.

Benefits nearby habitats

Water running off from the land is slowed down and filtered by saltmarsh and native upland vegetation. This improves coastal water quality and benefits the nearby submerged aquatic vegetation.

Project: Steps to Saltmarsh Conservation in Northern Tasmania; 2014
Project contact: Emma Williams, NRM North
Concept and text: Vishnu Prahalad, University of Tasmania
Aerial photo: Templestowe Lagoon by Matt Dell
Illustration: Michael Holman, adapted from Jan Tilden (2010)

3. Inventory of human impacts

3.1 Loss in saltmarsh extent and function due to land-use conversion

The largest impact leading to the loss in extent and function of Clifton Saltmarshes is land-use conversion to buildings and roads. The footprint of the built environment and the matrix of roads have reduced the likely area the saltmarsh would have previously occupied. Based on aerial photo observation and field visits, it is estimated that the loss in saltmarsh extent due to these major developments is between 5-30% (see page 6 of Saltmarsh Human Impacts Checklist available from http://www.nrmsouth.org.au/wp-content/uploads/2016/05/Human-Checklist-web.pdf).

Further to loss in extent, the function of the remaining saltmarsh area has been subject to changes in tidal flows. The matrix of roads, mainly Bicheno Street, acts as a tidal barrier for the saltmarsh area on the southern part of the site (Figure 2). There are currently two areas in Bicheno Street where drains serve to allow some tidal exchange to the marsh area on the Cape Deslacs Nature Reserve. Their capacity, however, is limited by the small size relative the marsh area in the Nature Reserve. Further, the Cape Deslacs Track that runs perpendicular from Bicheno Street further restricts tidal flow into marsh areas towards Clifton Beach.

Figure 2. Left: Bicheno Street built over saltmarsh acts as an impediment for tidal flow separating the southern end of the Clifton Saltmarshes from Pipe Clay Lagoon. Right: The small drains under Bicheno Street have limited capacity in facilitating tidal exchange.

3.2 Saltmarsh loss due to other habitat disturbance features

Other habitat disturbance features that affect saltmarsh extent and function involve road widening, unmanaged tracks from off-road vehicle access, informal roads (not including access roads) and walking tracks, ditches and dumping of rubbish. Of these, the most important disturbance is due to road widening and unmanaged vehicle access of saltmarsh fringes causing soil compression and loss of vegetation (Figure 3). As another related impact, there are several informal roads spread across the study site and about 12 walking tracks cut through the narrow section of the marsh between Bicheno Street and the Lagoon. Both of these impacts affect between 5-30% of the saltmarsh area (see page 7 of Saltmarsh Human Impacts Checklist).

Another notable impact is the ditches in the saltmarsh, including one that runs parallel to the Bicheno Street and others on the southern side at several locations (Figure 4). The estimated extent of saltmarsh area affected by these ditches is between 5-30%.

Figure 3. Edge effects on saltmarsh caused by road widening and unmanaged vehicle access resulting in soil compression and loss of vegetation. Photos by Elizabeth Shannon.

Figure 4. Left: Ditch running parallel to Bicheno Street. Right: Ditch on the southern side of Bicheno Street, by the Cape Deslacs Track, which also serves as an artificial tidal channel linked to one of the two road drainage areas.

3.3 Livestock and feral animal disturbance

The only evidence of livestock or feral animal disturbance was rabbit scats found widely on the southern side of Bicheno Street, in Cape Deslacs Nature Reserve. Rabbit grazing can negatively affect native saltmarsh vegetation structure by stifling the regeneration of structurally important plants such as succulent shrubs and sedges (cf. in Orielton Lagoon, see Parks and Wildlife Service, 2013). The estimated extent of saltmarsh area likely to be subject to active rabbit disturbance is between 5-30% (see page 7 of Saltmarsh Human Impacts Checklist).

3.4 Extent and condition of fringing native vegetation

The estimated extent of fringing native vegetation adjacent to the saltmarsh site is 5-30% (both lateral extent and width of 100m from the edge of the marsh, see page 4 of Saltmarsh Human Impacts Checklist, and depicted in Figure 5). The fringing native vegetation relative to introduced species is estimated to be >70%. Among the weeds, the major concern in the site is spanish heath (*Erica lusitanica*), which has a separate management plan (North Barker Ecosystem Services, 2013; also see North Barker Ecosystem Services, 2016).

Figure 5. Tasmanian vegetation community mapping (TASVEG 3.0) indicating saltmarsh (blue areas) surrounded largely by agricultural, urban and exotic vegetation (faded yellow areas are mapped as agricultural land and the faded white areas are urban). The extent of remnant native woodland vegetation surrounding saltmarsh is minimal (shades of green area of dry eucalypt forest and woodland, and faded red area being scrub, heathland and coastal complexes).

4. Saltmarsh resilience to climate and sea level change

Adaptive capacity of saltmarshes to cope with the effects of climate change and sea level rise depends on a range of interrelated factors, of which, the three most significant factors in the Tasmanian context include (adapted from Prahalad, 2016):

1. **Retreat pathway**: availability of sufficient low lying areas landwards of current saltmarsh patches.
    - The expectation is that, with all other factors being equal, a rise is sea level will result in the landward movement of the inter-tidal niche that saltmarshes occupy (starting below the mean high tide mark extending landward to the extent of storm tide flooding).
2. **Vertical accretion**: availability of sufficient sediments, both from endogenous biotic sources and exogenous abiotic and biotic sources.
    - The expectation is that, with sufficient sedimentation rates, saltmarshes can continue to accrete vertically and maintain their positon in the tidal frame irrespective of changes in relative sea level.
3. **Wave exposure**: protection from being exposed to high energy waves generated through increasing wind speeds and/or relative sea levels.
    - The expectation is that, in areas where sedimentation rates are an insignificant factor in relation to relative sea level rise, only those saltmarshes that are within shorelines with lower wave exposure will continue to maintain its inter-tidal position with increasing wind speeds and/or relative sea level rise (Prahalad et al., 2015).

A strategic assessment of the adaptive capacity of Clifton Saltmarshes cannot be completed without generating information across all the above three environmental factors. In the interim, it is important to manage low lying areas on the coast subject to storm tide inundation for its potential to host saltmarsh with the landward movement of the tidal frame. This includes having planning and building regulations over infill development in these areas hosting potential retreat pathways. To assist this process, the areas subject to storm tide inundation have been depicted in Figure 6 below and also in Prahalad and Jones (2013, page 28). The projected storm tide information has been sourced from the Tasmanian Department of Premier and Cabinet (DPAC) Projected Storm Tide Layer. This layer has the modelled extent of storm tide under current and future sea level rise scenarios (Lacey et al., 2012). The mapping is available through the online interactive LISTmap interface, at: http://maps.thelist.tas.gov.au/listmap/app/list/map.

The Projected Storm Tide Layer is an indicative guide only, and the actual area suitable for saltmarsh retreat pathway can be 'ground-truthed' through recording the landward extremities of flooding during a storm tide event (e.g. using the Witness King Tides Project: http://www.witnesskingtides.org/). Flood water will access areas of lower elevations that have not been subject to infill development in the form of roads and building infrastructure. These areas of lower elevations are best utilised for saltmarsh accommodation, that can then act as 'flood soaks' and reduce flooding externalities on other human assets (a process termed as 'managed realignment' and widely followed in the Northern Hemisphere, see for example the Online Marine Registry: http://www.omreg.net/, or the ClimateTechWiki online platform: http://www.climatetechwiki.org/content/managed-realignment).

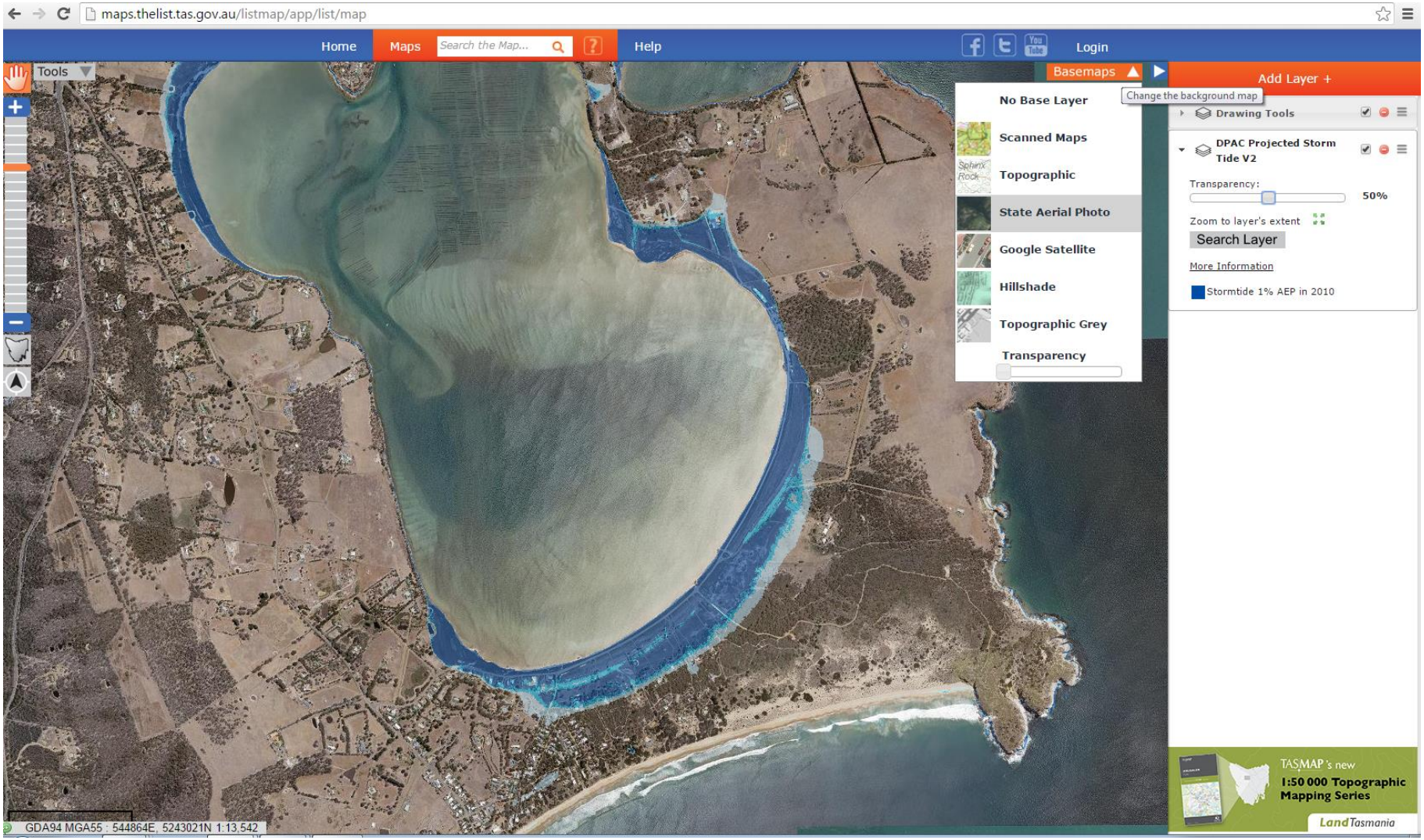


Figure 6. Screenshot of the 'Projected Storm Tide layer' available online through LISTmap interface, at: http://maps.thelist.tas.gov.au/listmap/app/list/map.

5. Management framework and recommendations

5.1 Management framework and key stakeholders

A saltmarsh management and stakeholder engagement framework is presented in Figure 7 below (taken from Prahalad and Pearson, 2013). The framework recognises that there are several 'actors' involved in the management of saltmarshes and that can be engaged at multiple scales. Local land owners in the Clifton Beach area are key stakeholders in managing individual saltmarsh patches on private property. Care groups such as the Wildcare Deslacs, Friends of Lumeah Point and Pipe Clay Lagoon Coastcare Inc. play a crucial role in advocating, facilitating and building understanding of the saltmarsh values, threats and explore opportunities for maximising these values. Their activities are supported by non-government organisations (NGOs) such as Birdlife Tasmania. In addition, University of Tasmania, Natural Resource Management (NRM) South and State agencies such as Parks and Wildlife Service play essential roles in providing funding, technical and procedural assistance towards managing saltmarshes. Clarence City Council is another important stakeholder with their role in asset management in the area. This includes exploring possibilities for tidal restoration through 'saltmarsh friendly' road infrastructure as part of council risk management in the area with respect to flooding related issues (repair of roads post flooding now involves consideration of 'water sensitive design' in 'building back better', e.g. ABC, 2016; and also see Cooperative Research Centre for Water Sensitive Cities: https://watersensitivecities.org.au/).

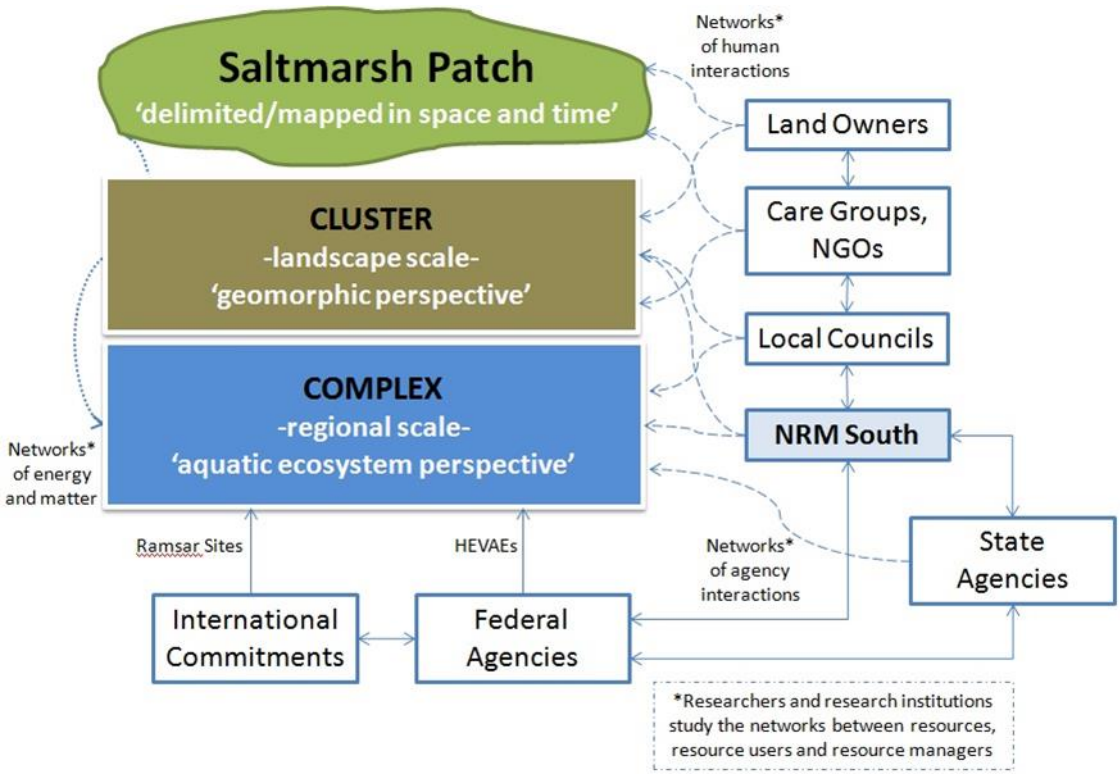


Figure 7. A management framework with key stakeholders (in the boxes) who influence saltmarsh management at multiple scales. Clifton Saltmarshes are a 'sub-cluster' and are not part of a Ramsar Site or High Ecological Value Aquatic Ecosystems (HEVAEs), which focus on multiple objectives at the level of organisation of coastal complexes. They do have other internationally recognised values as part of the South Arm Important Bird Area designation.

5.2 Management recommendations

5.2.1 Roads and other built environments

Clifton Saltmarshes have been subject to saltmarsh loss and fragmentation, due to historic development of roads and other built environmental modifications. It is essential that future threats due to infill development be excluded or limited to areas outside of the projected storm tide extent (see Figure 6). Where possible, saltmarsh restoration could be achieved through reducing or moving existing infrastructure such as the access roads from the saltmarsh flooding zone. As a case in point, there are about 14 access roads cutting through the saltmarsh on the southern side of Bicheno Street and between Cape Deslacs Track and Thompson Way. If these numerous tracks were consolidated to about four, this could help return these areas back to functioning saltmarsh and also reduce overall road maintenance costs.

Another important aspect of managing roads requires consideration towards improving tidal flushing of the saltmarsh on the southern side of the Bicheno Street, including some of the area between Cape Deslacs Track and Thompson Way. The existing drains under Bicheno Street could be enlarged allowing for increased tidal flushing and thereby improving the health and function of the saltmarsh. Saltmarshes with healthy tidal flushing have lower issues with smell, algal growth and breeding of mosquitoes (Lyth et al., 2013). Another benefit would be the reduced need for weed management as many of the weeds, including spanish heath, are unlikely to survive well with the regular influx of sea water. Also noteworthy is the indirect benefit of spreading the volume of water over and away from the Pipe Clay Lagoon area and thereby reducing stress on shoreline erosion (Prahalad et al., 2015). For these reasons, and many others such as carbon sequestration, flooding and water quality management, previously impounded saltmarshes are re-connected back to the sea around the world through tidal restoration (e.g. Roman and Burdick, 2014). Clarence City Council play an important role in this as noted previously with their responsibility for local land use planning, road assets and risk management.

3.2.2 Access for vehicles and walking tracks

Vehicle access off-road from the designated access roads must be avoided to reduce saltmarsh degradation and also the potential for the spread of weeds. This can be addressed through local community engagement, signage and fencing. There are currently about 12 entry points for walkers to access Pipe Clay Lagoon foreshore via tracks through the saltmarsh. It is recommended that the walking access points be reduced to four tracks, aligned to road outlets, walker flow and housing density. Access can be restricted through local community engagement, signage and fencing where necessary. Access points can also provide focal areas for science communication through interpretation signage.

3.2.3 Interpretation signage

Currently there are several interpretive signs at the site, mainly focusing on birds and access restrictions for dogs and horses (Figure 8). It is recommended that new signage is installed at key locations that highlight saltmarsh and broader inter-tidal landscape values (including of seagrass), and ways to reduce further threats to promote the functions of these coastal systems. The new signs could also highlight keystone and iconic saltmarsh specialist species such as the shrubby glasswort and white-fronted chat, both found in the area.

Figure 8. Top: Existing signage in the area focusing on birds and access restrictions for dogs and horses; Bottom: Example of signage with saltmarsh values and highlighting keystone and iconic saltmarsh specialist species installed in Musselroe Bay by NRM North.

3.2.4 Fringing vegetation and weed management

Fringing native vegetation can improve the health and function of saltmarshes (see evidence summarised in Prahalad, 2014a). It is recommended that the current extent of native fringing vegetation in the site be increased from 5-30% to 30-70% coverage (see page 6 of Saltmarsh Human Impacts Checklist). This can be undertaken through planting of suitable native plants in areas fringing the saltmarsh. A list of native plants suitable to Clarence City Council area is maintained by Understory Network, accessible from:
http://www.understorey-network.org.au/municipalities/understorey_clarence.pdf

3.2.5 Rabbits and other non-native animals

Options for rabbit control in the area, especially within Cape Deslacs Nature Reserve could be explored in conjunction with Parks and Wildlife Service. A pre-control study could be conducted by excluding a selected area of saltmarsh within Cape Deslacs Nature Reserve with rabbit-proof fencing and monitoring any changes in vegetation compared to nearby unfenced areas. This will help estimate the likely effect that rabbit control may have on saltmarsh structure and function before investing in a dedicated control effort. Information on rabbit control measures are available through the Australian Government's *Threat abatement plan for competition and land degradation by rabbits*, accessible from:
http://www.environment.gov.au/biodiversity/threatened/publications/tap/competition-and-land-degradation-rabbits

3.2.6 Ongoing monitoring and community engagement

It is recommended that monitoring be undertaken on an ongoing basis on various aspects relating to the health and function of the saltmarsh (monitoring variables depicted in Figure 9 and summarised in Table 1). Monitoring data collection would depend on the interest and capacity of people acting as 'citizen scientists' and the medium made available for interpreting, collecting, and storing data. Potential citizen scientists include individuals, community group representatives (e.g. from Wildcare Deslacs, Figure 10), naturalist groups (e.g. Field Naturalists), students from University of Tasmania and various School groups. Existing medium for saltmarsh data collection and accompanying resources are available from NRM South webpage (Figure 10): http://www.nrmsouth.org.au/saltmarsh-monitoring/

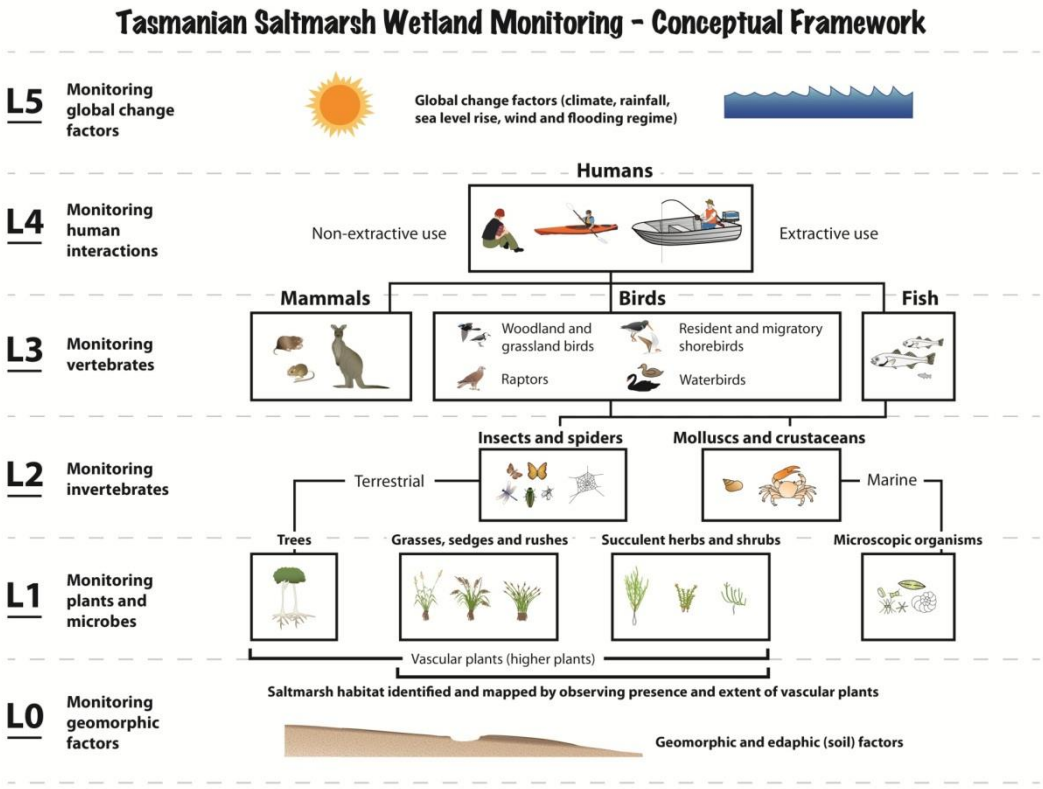


Figure 9. Tasmanian saltmarsh monitoring framework with various levels (0-5) and aspects relating to their health and function (image from Prahalad 2014).

Figure 10. Left: citizen scientists for saltmarsh monitoring; Middle and Right: Saltmarsh Matters App for tablet/phone and the App as a weblink (http://www.nrmsouth.org.au/saltmarsh-monitoring/).

Table 1. Compilation of various indicators and methods that can be used in saltmarsh monitoring. PPM – photo point monitoring (see Photopoint Monitoring Fact Sheet from NRM South, n.d.); API – aerial photo interpretation (see for example Prahalad, 2014a); TASMARC – Tasmanian Shoreline Monitoring and Archiving Project (see http://www.tasmarc.info/) . Adapted from: Prahalad, 2014b.

Indicators for saltmarsh conservation	Monitoring methods	Checklist
Level 1: Plants and microorganisms		
Listed flora species	Transect/visual survey, PPM	Plants
Diversity of flora (no of species)	Transect/visual survey, PPM	Plants
Density of flora cover (% cover)	Transect survey, PPM	Plants
Introduced species of flora	Transect/visual survey, PPM	Plants
Algae		
Filamentous algae (% cover)	Transect/visual survey, PPM	Human Impacts
Level 0: Geomorphology and edaphic factors		
Shoreline facies	Transect/visual survey, PPM	-
Shoreline movement	TASMARC survey, API	-
Edaphic factors		
Drainage, texture	To be developed	-
pH, salinity	To be developed	-
Level 2: Invertebrates		
Listed invertebrate species	Visual survey, pitfall trapping	-
Diversity of invertebrates (no of species)	Pitfall trapping, beat sheets	-
Density of invertebrates (% abundance)	Pitfall trapping, beat sheets	-
Introduced species of invertebrates	Visual survey, pitfall trapping	-
Level 3: Vertebrates		
Marsupials		
Presence of native marsupials (mainly diversity, also density for listed species)	Visual survey, tracks, scats, bat detector	-
Introduced species of fauna (e.g. rabbits)	Visual survey, scats, digging	Human Impacts
Birds		
Diversity of birds (no of species)	Visual survey	Birds
Density of birds (relative abundance)	Visual survey	Birds
Fish		
Diversity of fish species (no of species)	To be developed	-
Density of fish species (relative abundance)	To be developed	-
Level 4: Human interactions		
Inappropriate development	Visual survey, PPM, API	Human Impacts
Grazing and trampling	Visual survey, PPM	Human Impacts
Off-road vehicles	Visual survey, PPM	Human Impacts
Dumping rubbish	Visual survey, PPM	Human Impacts
Removal of fringing vegetation	Visual survey, PPM, API	Human Impacts
Level 5: Global change factors		
Flooding extent	Inundation modelling	See Figure 6
Landward boundary of flooding	Witness King Ties	-
Temperature, rainfall, wind conditions	To be developed	-

6. Baseline vegetation survey

As a part of the project, a baseline assessment of saltmarsh vegetation condition (implied from vegetation composition) was undertaken to monitor future changes in saltmarsh health. The condition assessment was undertaken employing line transects along two sections of the marsh. The first section was on the Cape Deslacs Nature Reserve, on the southern side of Bicheno Street and to the left (or north-eastern side) of Cape Deslacs Track. This section was made of two line transects. The first transect began from the fence on the southern side of Bicheno Street and ran to the elevated bund in the marsh dominated by woody native vegetation. The second transect was perpendicular to the first, starting from the fence and running eastwards to the elevated bund in the marsh. The second section was on the Public Reserve north of Bicheno Street, with a single line transect running from the edge of the marsh and towards Bicheno Street (close to the intersection of Buckland Street). The starting and end points of all three transects have been marked with a permanent stake (steel picket with a plastic cap) driven securely on the marsh platform. The latitude and longitude data for these point locations were also recorded.

A vegetation survey was undertaken along each line transect at 20-30 m intervals, starting at the seaward edge of the marsh and progressing inland towards the landward edge. A 1x1 m quadrant was employed to estimate the percentage cover of each species. The first quadrant was placed in front of the stake facing away from the intertidal flat and on the right side of the tape measure running along the transect line (e.g. Figure 11). Field personnel walked on the left of the tape measure to avoid trampling of vegetation likely to be surveyed. Species percentage cover was calculated by listing all the species falling under the quadrant, and then estimating percentage cover starting with the least significant species in terms of cover. Species with less than 1% cover were only recorded as present but not assigned a cover estimate. The total cover was totaled to be 100% to avoid any observation or data entry errors. At each quadrant, an oblique photograph was taken of the marsh covered by the quadrant. These were later used during data entry as additional evidence to cross check field notes for species listings and cover estimates.

The data for all the three line transects have been documented in Appendix I: Data recorded from the line transects. The oblique photographs of quadrants on the extremities of each of the three line transects are presented in Figure 11.

Figure 11. First, second and third row of images indicate the first and last quadrant of the three line transects 1-2-3 respectively (see text above and Appendix for more details). The fourth row of images shows the areas behind the last quadrant of three transects 1-2-3 respectively.

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Appendix I: Data recorded from the line transects

LINE TRANSECT 1: Southern side of Bicheno Street, starting from the fence and running to the elevated bund in the marsh vegetated by *Acacia* sp., *Dodonea viscosa* and *Lecopogon parviflorus* and *Lepidosperma concavum*.

Line Transect 1: Quadrant 1-4	Genus	Species	Cover (%)	Height (cm)	Coordinates (lat, long)
T1Q1 (0 m)	*Austrostipa*	*stipoides*	60	-	-42.982336, 147.535272
T1Q1 (0 m)	*Polytrichum*	*juniperinum*	20	-	
T1Q1 (0 m)	*Acaena*	sp.	10	-	
T1Q1 (0 m)	*Poa*	sp.	5	-	
T1Q1 (0 m)	*Selliera*	*radicans*	4	-	
T1Q1 (0 m)	*Ficinia*	*nodosa*	1	-	
T1Q1 (0 m)	*Geranium*	sp.	<1	-	
T1Q2 (30 m)	*Sarcocornia*	*blackiana*	60	-	
T1Q2 (30 m)	*Wilsonia*	*backhousei*	20	-	
T1Q2 (30 m)	*Disphyma*	*crassifolium*	15	-	
T1Q2 (30 m)	Bare ground	wet	5	-	
T1Q3 (60 m)	*Disphyma*	*crassifolium*	60	-	
T1Q3 (60 m)	*Sarcocornia*	*quinqueflora*	15	-	
T1Q3 (60 m)	*Sarcocornia*	*blackiana*	15	-	
T1Q3 (60 m)	*Wilsonia*	*backhousei*	5	-	
T1Q3 (60 m)	*Bare ground*	*waterlogged*	3	-	
T1Q3 (60 m)	*Triglochin*	*striata*	2	-	
T1Q4 (90 m)	*Lepidosperma*	*concavum*	40	-	-42.973213, 147.513593
T1Q4 (90 m)	*Poa*	sp.	30	-	
T1Q4 (90 m)	Bare ground	dry/damp	25	-	
T1Q8 (90 m)	*Ficinia*	*nodosa*	5	-	
T1Q8 (90 m)	*Leucopogon*	*parviflorus*	<1	-	
90 m			**400**		

LINE TRANSECT 2: Eastern side of Cape Deslacs Track, starting from the fence (10th steel post north of steel post with star picket by the trees and shurbs), and running eastwards to the elevated bund in the marsh.

Line Transect 2: Quadrant 1-3	Genus	Species	Cover (%)	Height (cm)	GPS coordinates (lat, long)
T2Q1 (0 m)	*Sarcocornia*	*quinqueflora*	45	-	-42.972330, 147.511337
T2Q1 (0 m)	Bare ground	wet	40	-	
T2Q1 (0 m)	*Sarcocornia*	*blackiana*	15	-	
L2Q2 (20 m)	*Sarcocornia*	*quinqueflora*	75	-	
L2Q2 (20 m)	*Disphyma*	*crassifolium*	12	-	
L2Q2 (20 m)	Bare ground	wet	6	-	
L2Q2 (20 m)	*Triglochin*	*striata*	5	-	
L2Q2 (20 m)	*Plantago*	*coronopus*	2	-	
T2Q3 (40 m)	Bare ground	waterlogged	60	-	
T2Q3 (40 m)	*Sarcocornia*	*quinqueflora*	30	-	
T2Q3 (40 m)	*Disphyma*	*crassifolium*	5	-	
T2Q3 (40 m)	*Wilsonia*	*backhousei*	3	-	
T2Q3 (40 m)	*Triglochin*	*striata*	2	-	
T2Q3 (40 m)	*Angianthus*	*preissianus*	<1	-	
T2Q4 (70 m)	*Sarcocornia*	*quinqueflora*	30		-42.973249, 147.507216
T2Q4 (70 m)	Bare ground	waterlogged	25		
T2Q4 (70 m)	*Triglochin*	*striata*	20		
T2Q4 (70 m)	*Austrostipa*	*stipoides*	15		
T2Q4 (70 m)	*Junucs*	*kraussii*	3		
T2Q4 (70 m)	*Disphyma*	*crassifolium*	3		
T2Q4 (70 m)	*Carpobrotus*	*rossii*	3		
T2Q4 (70 m)	*Plantago*	*coronopus*	1		
70 m			**400**		

LINE TRANSECT 3: Northern side of Bicheno Street, starting from the waters' edge and running to the road (opposite to Buckland Street).

Line Transect 3: Quadrant 1-5	Genus	Species	Cover (%)	Height (cm)	GPS coordinates (lat, long)
T3Q1 (0 m)	*Suaeda*	*australis*	60	-	-42.90413, 147.45744
T3Q1 (0 m)	*Samolus*	*repens*	20	-	
T3Q1 (0 m)	Bare ground		10	-	
T3Q1 (0 m)	*Austrostipa*	*stipoides*	5	-	
T3Q1 (0 m)	*Sarcocornia*	*quinqueflora*	5	-	
T3Q2 (20 m)	*Sarcocornia*	*quinqueflora*	90	-	
T3Q2 (20 m)	Bare ground		6	-	
T3Q2 (20 m)	*Samolus*	*repens*	4	-	
T3Q2 (20 m)	*Tecticornia*	*arbuscula*	<1	-	
T3Q2 (20 m)	*Suaeda*	*australis*	<1	-	
T3Q3 (43 m)	*Samolus*	*repens*	65	-	-42.985919, 147.525022
T3Q3 (43 m)	*Suaeda*	*australis*	30	-	
T3Q3 (43 m)	Weedy grass		5	-	
T3Q3 (43 m)	*Triglochin*	*striata*	<1	-	
43 m			**300**		

Appendix II: Locations identified in recommendations

Indicative locations identified as part of recommendations made in text above. Michael Helman added graphic design to this map. Base image by TASMAP, © State of Tasmania.