Australia's saltmarshes: *a synopsis to underpin the repair and conservation of Australia's environmentally, socially and economically important bays and estuaries*

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Plate 1. Saltpan habitat in north Queensland. *T. Baumgaertner*


Plate 2. Saltmarsh habitat in Little Swanport, Tasmania. *V. Prahalad*

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A Report for the National Environmental Science Programme:
Marine Biodiversity Hub

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EXECUTIVE SUMMARY

Saltmarshes in this report refers to the mosaic of coastal wetland ecosystems that occupy areas of low energy, intermittent tidal inundation, typically in bays, inlets and estuaries, on sheltered soft substrate foreshores, often at the foreshore in southern Australia and occurring behind mangroves in tropical Australia.

Functional role of saltmarshes

Saltmarshes serve multiple functions including sediment trapping, nutrient cycling, dissipation of wave energy, fish and prawn nursery, net primary production, carbon sequestration and resting and feeding areas for birds. Saltmarshes are a key component of our estuaries and coastal landscapes and provide connectivity between freshwater to brackish to tidal and sub-tidal ecosystems.

This synopsis

This report summarises key attributes about our saltmarshes for Queensland (Qld), New South Wales (NSW), Victoria (Vic), Tasmania (Tas) and South Australia (SA) including:

- Current extent;
- Losses and changes to the saltmarsh landscapes;
- Vegetation types and nature of this mosaic landscape;
- Role in net primary productivity and in Australia's seascapes;
- Legislation, regulations and protection mechanisms in each state;
- Simple indices to represent their benefits and as a basis for developing return on
- Investment analysis; and
- Priorities for repair.

Resources for preparation of this report were limited. Thus, the study focus could not extend to include temperate saltmarshes in Western Australia and tropical saltmarshes in Western Australia and the Northern Territory.

Key findings

This report has found that the challenges Australia faces to repair saltmarshes for the benefit of Australian coastal communities are substantial. Key aspects include:

- Different saltmarsh community types with accompanying different roles and functions occur within and across different states;
- Knowledge (i.e. extent, mapping and definition) and protection (i.e. legislation, planning and regulations) of saltmarsh community types also vary amongst states, so that a "one size fits all" approach to conservation and to restoration is not appropriate;
- Community knowledge and appreciation of the value of saltmarshes is low, inhibiting protection, conservation and restoration; and
- Australia does have some good examples and demonstrations of successful saltmarsh restoration that can serve to underpin the scale-up of restoration activities.

Ecosystem services

This synopsis is a first step towards understanding the value of ecosystem services provided by saltmarshes. Different saltmarsh community types produce different benefits and so each state approach will be different (e.g. fisheries production such as prawns as an easily understood indicator of net primary productivity (Qld/NSW/SA) and coastal protection, food chains, biodiversity and blue carbon (Vic/Tas). There are substantial gaps in our knowledge of saltmarsh ecosystem services. Future research will help to quantify some of these key values. Once quantified, the values of these ecosystem services can be incorporated into cost-benefit analysis and used to build business cases to show the value of scale-up of saltmarsh restoration.

Saltmarsh repair and protection – next steps

Two broad groups of activities are required if we are to retain and protect Australia's remaining saltmarshes and re-establish significant areas of saltmarshes in Australia's developed coasts. Firstly, we must understand what is required to re-establish saltmarshes. This is detailed in the key proposed management interventions in Chapter 2. For protection of existing and repaired saltmarshes to be successful, all states and the Australian Government will need to have appropriate policy and preferably legislation and accompanying regulations in place. A review of state and Australian legislation and regulations pertaining to saltmarshes with suggestions for enhancements is provided in Chapter 3 of this report.

To underpin repair and protection of saltmarshes and provide a business case type argument for negotiating investment and actions, key interest groups such as recreational and commercial fishers and conservation groups need clear and precise statements of saltmarsh values. This project takes the view that being able to precisely articulate the role of saltmarshes in supporting easy to understand benefits such as prawn productivity provides a simple index of saltmarsh benefits. Two states, SA and Queensland provide preliminary assessments of the importance of saltmarshes to prawn productivity in Chapters 4 and 6 of this report. Research into determining simple benefit indices for NSW, Victoria and Tasmania has begun recently and is an important area of continued research.

At the end of each state chapter, summary detail is provided as to the next phase of activities to build our knowledge. These sections conclude with summary details of the proposed focus of research under phase II of this project, as part of the Marine Biodiversity Hub, National Environmental Science Program. This information is also collated in Appendix 1. These focused investments have been chosen specifically to quantify some of the key benefits of saltmarshes as major knowledge contributions to the cost-benefit analysis and business cases that will be required to justify scale-up of saltmarsh restoration.

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1. SALTMARSHES – THEIR ROLE IN ENSURING A HEALTHY & PRODUCTIVE COASTAL AUSTRALIA

Saltmarshes – a functional definition

Saltmarshes in this report refers to the mosaic of coastal wetland ecosystems that occupy areas of low energy, intermittent, tidal inundation, typically in bays, inlets and estuaries, on sheltered soft substrate foreshores, often occurring behind mangroves (Figure 1). These saltmarshes serve multiple functions including sediment trapping, nutrient cycling, dissipation of wave energy, fish and prawn nursery, carbon sequestration and resting / feeding areas for birds.

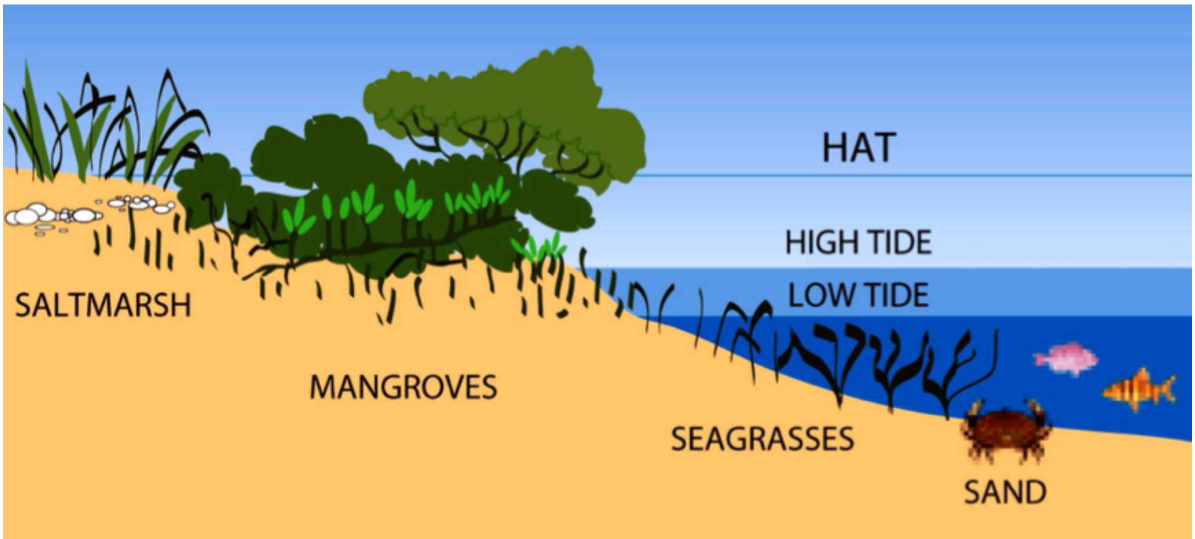

Figure 1. Common aquatic zones in estuaries. HAT = Highest Astronomical Tide. *Adapted from Kailola et al. (1993)*

Saltmarshes – part of the coastal wetland continuum linking mangroves to freshwater wetlands

Saltmarshes are functionally part of the continuum that drives coastal ecological productivity and delivers multiple ecosystem services. These services include supporting the productivity of fish and prawns, supporting biodiversity, providing habitat for birds, improving water quality and quantity regulation, and carbon sequestration, flood mitigation and shoreline protection (Laegdsgaard 2006; Victorian Saltmarsh Study 2011; Saintilan and Rogers 2013; Creighton et al. 2015).

The sustainability of saltmarshes relies on tidal inundation and fresh water inputs from rain, groundwater flows and rivers. Inputs of fresh water can influence soil and water salinities and the nutrient dynamics and movement of sediments (e.g. Victorian Saltmarsh Study 2011). A severe reduction in freshwater flows can have devastating effects on coastal salt marsh and other coastal wetlands, as demonstrated with the Coorong, South Australia (Adam 2002). The ecosystem services provided by saltmarshes rely on the connectivity between land and sea being maintained so both fresh water and tidal water have adequate opportunities to meet. Barriers to connectivity occur along almost every river and estuary in the more populated parts of Australia (Creighton et al. 2015). Re-instating connectivity for biological, chemical and hydrological fluxes is key to re-establishing productivity.

Saltmarshes – extensive losses

Unfortunately, saltmarshes being almost flat, with amenity value by virtue of their coastal location and close proximity to urban areas have often been filled and drained, especially for playing fields, houses, canal or industrial estates. Within coastal floodplain environments, as part of land development for agriculture (e.g. cane lands) or grazing (e.g. ponded pastures), saltmarshes have been drained, sometimes filled and levees constructed to exclude tidal inundation.

Loss of saltmarshes is one of the key-contributing agents to the loss of amenity and condition of our coastal resources. An Australia-wide assessment of 1000 estuaries and embayments undertaken by the National Land and Water Resources Audit of 1997-2002 (National Land and Water Resources Audit 2002) indicated that 30% were modified to some degree. The most highly degraded were in New South Wales, where 40% were classified as 'extensively modified' and 10% were 'near pristine'. Saltmarsh losses are part of this degradation. Since that review, urban populations have continued to grow rapidly, and increasing pressures for industrial and agricultural development in the coastal zone have resulted in ongoing degradation of Australia's estuaries and embayments. This degradation has had serious effects on biodiversity, carbon sequestration (e.g. Lawrence et al 2012) and commercial and recreational fishing (Creighton et al 2015).

Specific quantitative information on the loss of critical habitat is available from a number of habitat- or region-specific studies to expand upon the National Land and Water Resources Audit's (2002) Australia-wide assessment. Saintilan and Williams (2000), for example, reviewed loss of coastal saltmarsh in eastern Australia since World War 2, and reported losses as 100% for parts of Botany Bay, New South Wales over the period 1950-1994 and 67% for the Hunter River (excluding Hexham) from 1954-1994. Harty and Cheng (2003) reported a loss of 78% of saltmarshes in Brisbane Water, near Gosford, New South Wales, between 1954 and 1995. Sinclair and Boon (2012) showed that the state-wide loss of coastal wetlands (mainly mangroves and saltmarsh) in Victoria since European colonisation has been variously 5-20% by area across the state, with the greatest losses occurring in heavily urbanised areas such as around Port Phillip Bay (~50% loss) and in agriculturally developed regions such as Gippsland (e.g. 60% loss from Anderson Inlet in South Gippsland).

Saltmarshes – their vegetation

Saltmarsh communities can be dominated by a single plant species or occur as a mosaic, with the diversity of plant species increasing in higher elevated areas that are less frequently inundated. The combination of salinity, elevation and inundation that is responsible for many of the patterns seen in the distribution of saltmarsh plant species has been explained by many (Adam 1981a; b; 1990; King 1981; Zedler et al. 1995; Streever and Genders 1997).

The zonation patterns of saltmarshes have been described extensively (Zedler et al. 1995; Streever and Genders 1997). Vegetation is usually zoned parallel to the shoreline, and there is a general broad scale zonation from the estuary landward. The zones can be described as lower, mid and upper levels, usually each with a distinct mosaic of species that is often complicated by small-scale patchiness. Succulents dominate the lower marsh (e.g. *Sarcocornia* spp.), while the mid-marsh usually contains species such as *Sporobolus* spp. and *Samolus* spp. The upper marsh is a mosaic of species including *Juncus kraussii* and *Baumea juncea*. The area behind the upper marsh under natural conditions can be brackish to fresh back swamps dominated by sedges and casuarinas (e.g. *Casuarina glauca*) in the saltier, sometimes tidally inundated areas transitioning to melaleucas (e.g. *Melaleuca quinquenerva*) and various reeds and sedges (e.g. *Phragmites australis*) in the fresh swamps and then eucalypts and angophoras (e.g. *Angorphora costata*).

Saltmarsh sediments generally consist of poorly sorted anoxic sandy silts and clays. Carbonate concentrations are low, concentrations of organic material are high and the sediments may have salinity levels that are much higher than that of seawater. Acid sulfate soils have the potential to become oxidised, releasing significant amounts of sulphuric acid into coastal waterways leading to chronic poor water quality and fish kills (Creighton 2013).

Saltmarshes – their role in coastal water quality and net primary productivity

Saltmarshes, as are all coastal wetlands, are sometimes described as 'nature's kidneys', helping to maintain water quality by collecting, assimilating and recycling nutrients and contaminants from runoff. As water flow slows over the marsh, sediments and chemicals drop out of the water column, dissolved oxygen levels increase and nutrient levels reduce. High rates of productivity lead to high rates of mineral uptake, and decomposition processes take place in wetland sediments. Saltmarshes remove nitrates and phosphates, processing and transferring these inputs into biological outputs such as diatoms and phytoplankton − essential components of the coastal and marine food chain.

Saltmarshes also perform necessary water quantity functions, moderating the rate of catchment runoff. By reducing strength of flow and ensuring a more dampened water flow hydrograph, these brackish ecosystems are key to fostering high levels of coastal net primary productivity. Indeed, a brackish estuarine system linked to both fresh and tidal water is one of the world's most productive ecosystems.

In parallel with their role in moderating and slowing catchment runoff, saltmarshes with their often-sandy sediments play a role in coastal groundwater recharge. This again results in longer return periods and expanses of brackish water between fresh and seawater, leading to highly productive ecosystems and thus net primary productivity. From a water quality perspective, these ecosystems are assimilating nutrients and translating them into the basic building blocks for net primary productivity, such as diatoms and phytoplankton.

Saltmarshes – net primary productivity, food chains and biodiversity

Saltmarshes by virtue of being highly productive communities, provide substrate, shelter and food for a diverse range of species including fish, invertebrates, mammals, birds and plants. Soils of saltmarshes contain a lot of decomposing plant material that feed a wide range of organisms in food webs, from bacteria and fungi through to mammals (Victorian Saltmarsh Study 2011). The production of biomass in these ecosystems can be over three times higher than in a terrestrial ecosystem. The above ground net primary productivity of Australian coastal saltmarsh plants has been estimated to range between 3-13 tonnes ha^{-1} $year^{-1}$ (Congdon and McComb 1980; Clarke and Jacoby 1994; Victorian Saltmarsh Study 2011).

Saltmarshes – nursery areas for fish and prawns

Saltmarshes provide habitat and shelter and act as nursery grounds for many commercially important fish and for fish and crustacean species that are part of the coastal and marine food chain. Commercial and recreationally important species that exploit saltmarshes in their nursery phases include yellowfin bream (*Acanthopagrus australis*), dusky flathead (*Platycephalus fuscus*), sand whiting (*Sillago ciliate*), several mullets species (e.g. sea mullet, *Mugil cephalus*), garfish (*Arrhamphus sclerolepis*), mulloway (*Argyrosomus japonicus*]) eels and many crustaceans such as mud crabs (*Scylla serrate*) and prawns (e.g. School prawn, *Metapenaeus macleayi*; Banana prawn, *Fenneropenaeus merguiensis*; and western school prawns, *Metapenaeus dalli*) (Daly 2013, Creighton 2013).

Specialised plants are the foundation of the highly productive saltmarsh ecosystem. As saltmarsh plants die and decompose, bacteria and fungi break down the plant detritus, converting it into carbohydrates and proteins that are more easily digestible by crabs, finfish and filter feeders such as oysters or mussels. Algae play a significant role in fuelling an ecosystem rich in biodiversity. This biodiversity ranges from bacteria and invertebrates (e.g. crabs, prawns, molluscs, spiders) to the birds and finfish that prey on them. For example, Yellow-finned Bream (*A. australis*) feeds on crabs and prawns while small fish such as gobies feed on mosquito larvae. Worms, snails, insects and plant detritus are also important opportunistic food sources for fish and birds inhabiting the saltmarsh.

Saltmarshes – their role in carbon sequestration

Saltmarsh sequesters significant quantities of carbon both in plants and in the sediment below them. Colloquially part of 'blue carbon', saltmarshes are among the highest carbon sequesters of all vegetation communities (e.g. Lawrence et al 2012). Protection of existing saltmarsh ensures that this accumulated carbon is not released as carbon dioxide into the atmosphere. Repairing of saltmarshes will add to the volume of carbon sequestered in the Australian landscape. As for all "blue carbon", saltmarshes are not yet part of Australia's National Carbon Accounts.

Saltmarshes – their role in biodiversity

Saltmarshes also function as important habitat, nursery grounds for larvae and small organisms and provide unique feeding and habitat opportunities for several species of threatened micro-bats and birds, and migratory shorebirds (Saintilan and Rogers, 2013). Many diverse species of birds use coastal saltmarsh, including foraging rails, crakes, plovers, stilts, avocets, ibis, egrets and ducks, and roosting swans, cormorants and pelicans (e.g. Land Conservation Council 1993 as cited by Victorian Saltmarsh Study 2011). Species of migratory birds protected under federal legislation and international treaties (e.g. China Australia Migratory Bird Agreement or CAMBA and Japan Australia Migratory Bird Agreement or JAMBA), such as the sharp-tailed sandpiper often roost and feed in saltmarsh during their stay in Australia.

Saltmarshes – providing shoreline protection by reducing the impact of extreme events

Saltmarshes protect shorelines from erosion by buffering wave action and trapping sediments. They reduce flooding by slowing and absorbing rainwater and protect water quality by filtering runoff, and by metabolising excess nutrients (e.g. http://oceanservice.noaa.gov/facts/saltmarsh.html).
Saltmarshes protect estuary foreshores by dissipating the energy of wind and wave action and providing a natural buffer that helps minimise erosion (e.g. Moller et al., 1996). With predicted increases in storm surge intensity and rising sea levels associated with a changing climate, saltmarshes will become increasingly important in protecting estuary foreshores (Creighton 2014).

Saltmarshes – a checklist of their ecosystem services

Key components of any ecosystem services inventory for saltmarshes include (see Table 1):

Commercial and recreational food value
A diverse community of finfish, crustaceans and shellfish use saltmarshes for food, shelter, spawning, nursery areas and refuge from predators. These ecological functions have substantial economic value. Over 75% of Australia's commercial or recreationally caught fish and shellfish species depend on estuaries and coastal wetland habitat at some point in their life cycles.

Erosion control and storm surge protection
Saltmarsh vegetation helps shield the upland from erosion by waves and currents. In addition, saltmarshes can absorb and moderate much of the impact of coastal storm surge and floods.

Water quality and quantity maintenance
As saltmarshes slow and retain water, these ecosystems also filter pollutants, sediments and nutrients. Both nitrogen and phosphorous can be absorbed by plants and form part of the coastal food web. Nutrients such as phosphorous can also be bound in sediments, and then deposited. Nitrogen can be lost as gas, leached as nitrate or exported in the form of animal or bird tissue.

Recreational value
Saltmarshes provide exceptional sites for access to recreational fishing sites, crabbing in their tidal channels, and enriches the visual landscape for painting, photography and bird watching.

Carbon sequestration
Saltmarshes along with mangroves and seagrasses are collectively known as "blue carbon" and sequester more carbon per hectare than any terrestrial ecosystems.

Coastal biodiversity
Saltmarshes as part of the coastal wetland continuum provide the habitat for our coastal biodiversity.

Table 1. Some of the goods and services that saltmarshes provide were considered to be of 'high' importance by an expert panel. Saltmarshes were estimated to provide more economic value per unit area than most other ecosystems if tourism, carbon storage and coastal defence were combined. Sourced from Bakker (2012)

Ecosystem service P:provisioning R:regulating C:cultural	**Goods and benefits**	**Salt marsh (semi) natural**	**Salt marsh restored**
(P) Crops, plants, livestock, fish, etc. (wild and domesticated)	Meat: sheep/cattle/ fish	High	High
	Wild food: Salicornia/other plants/ fish/wildfowl	Some	Some
	Wool (sheep)	Some	Some
	Genetic resources of rare breeds, crops	Some	Some
(P) Trees, standing vegetation and peat/other resources	Turf/peat cutting	Some	None
	Military use	Some	None
	Industrial use: pipeline landfall	Some	None
(R) Climate regulation	Carbon sequestration	High	Some
(R) Hazard regulation –vegetation and other habitats	Sea defence	High	High
	Preventing soil erosion	High	Some
(R) Waste breakdown and detoxification	Immobilization of pollutants	High	Some
(P,R) Wild species diversity including microbes	(P) High diversity, or rare/unique plants, animals and birds, insects	High	Some
	(P) Ecosystem-specific protected areas	High	High
	(R) Nursery grounds for fish	High	High
	(R) Breeding, over-wintering, feeding grounds for birds	High	High
(R) Purification	Water filtration: groundwater, surface flow, seawater	?	?
(C) Spiritual/religious + cultural heritage and media	Sites of religious/cultural significance; World Heritage Sites; folklore; TV and radio programmes and films	Some	—
(C) Aesthetic/inspirational	Paintings, sculpture, books	High	Some
(C) Recreation/tourism	Many opportunities for recreation: incl. sunbathing, walking, camping, boating, fishing, birdwatching etc.	High	Some
(C) Physical/mental health + security and freedom	Opportunities for exercise, local meaningful space, wilderness, personal space	Some	Some
(C) Education/ ecological knowledge	Resource for teaching, public information, scientific study	High	High

Australia's coastal lifestyle

Our coastal and intertidal habitats are essential for healthy fisheries, coastlines, and communities, and they are an integral part of our economy and culture (Figure 2).

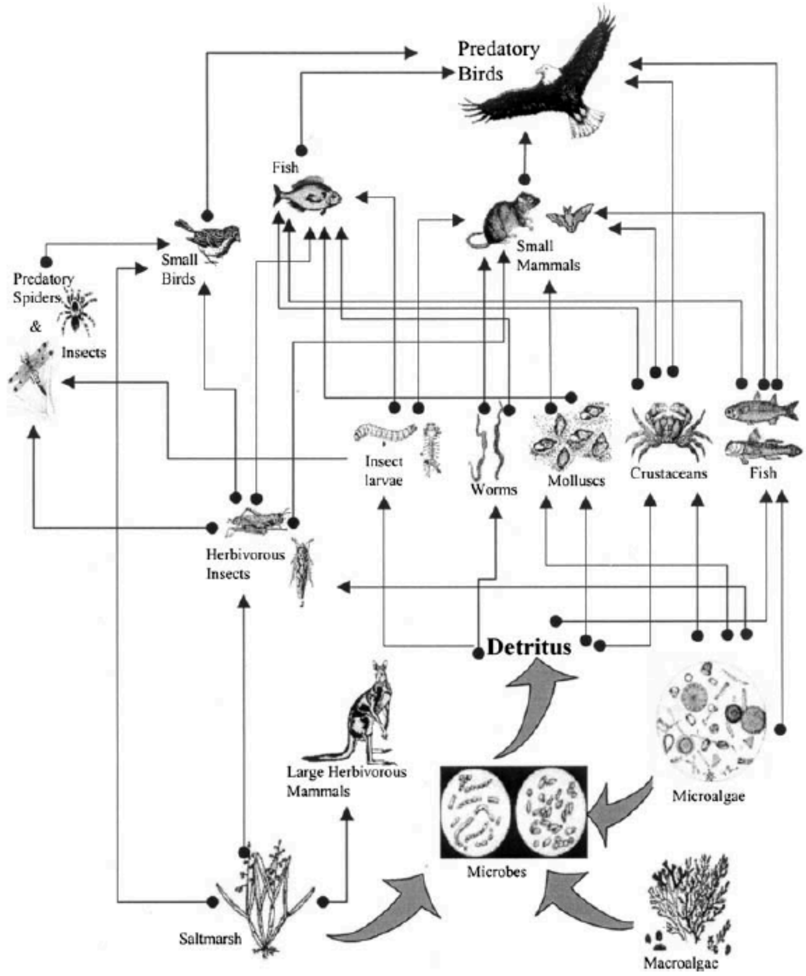

Figure 2. Representation of the food web of a typical coastal saltmarsh in Australia. Arrows represent the direction of the links in the food web with respect to consumers (copied from *Laegdsgaard, 2006*)

2. REPAIRING AUSTRALIA'S SALTMARSHES

Objective

Repair of saltmarshes is often undertaken with the intention of mitigating or offsetting the damage caused by development or as part of a more general program to repair past damage, now realised in hindsight as a less than optimal use of the coastal landscape. The objective may be simply stated as:

"the re-establishment wherever practical of functional (or healthy) saltmarsh ecosystems".

There are well-documented examples of repair overseas (Zedler 1995, 1996). Examples within Australia include Homebush Bay as part of the Sydney Olympic site where as Burchett et al 1998 noted, re-vegetation via planting was unnecessary – "re-establishing the micro-topography and tidal flows were all that was required and then natural processes will ensure a return to functionality".

Repair in tropical Australia

One of the main causes of saltmarsh losses in tropical Australia has been the development of ponded pastures (Figure 3). Ponded pastures were constructed initially as an attempt to improve cattle grazing carrying capacity. Pasture grasses such as Hymenachne (*Hymenachne amplexicaulis*) and Para grass (*Urochloa mutica*), now both considered to be major weeds, were introduced based on the work of the then CSIRO Division of Tropical Crops and Pastures and its somewhat mistaken vision of introducing novel pasture species to tropical Australia.

Ponded pastures predominate in the drier more extensive tropical catchments of Australia, particularly the dry tropical coast of the Great Barrier Reef and to a lesser extent in the Gulf of Carpentaria, Northern Territory and tropical Western Australia. Many of the works along the Great Barrier Reef coast are unauthorised or were done prior to legislative control, some are on private lands and many are on public lands and cut off watercourses. From a food security perspective these areas are likely to be more productive per unit area for fisheries production (e.g. banana prawns) than they are for beef meat production and this is an important subject for future research.

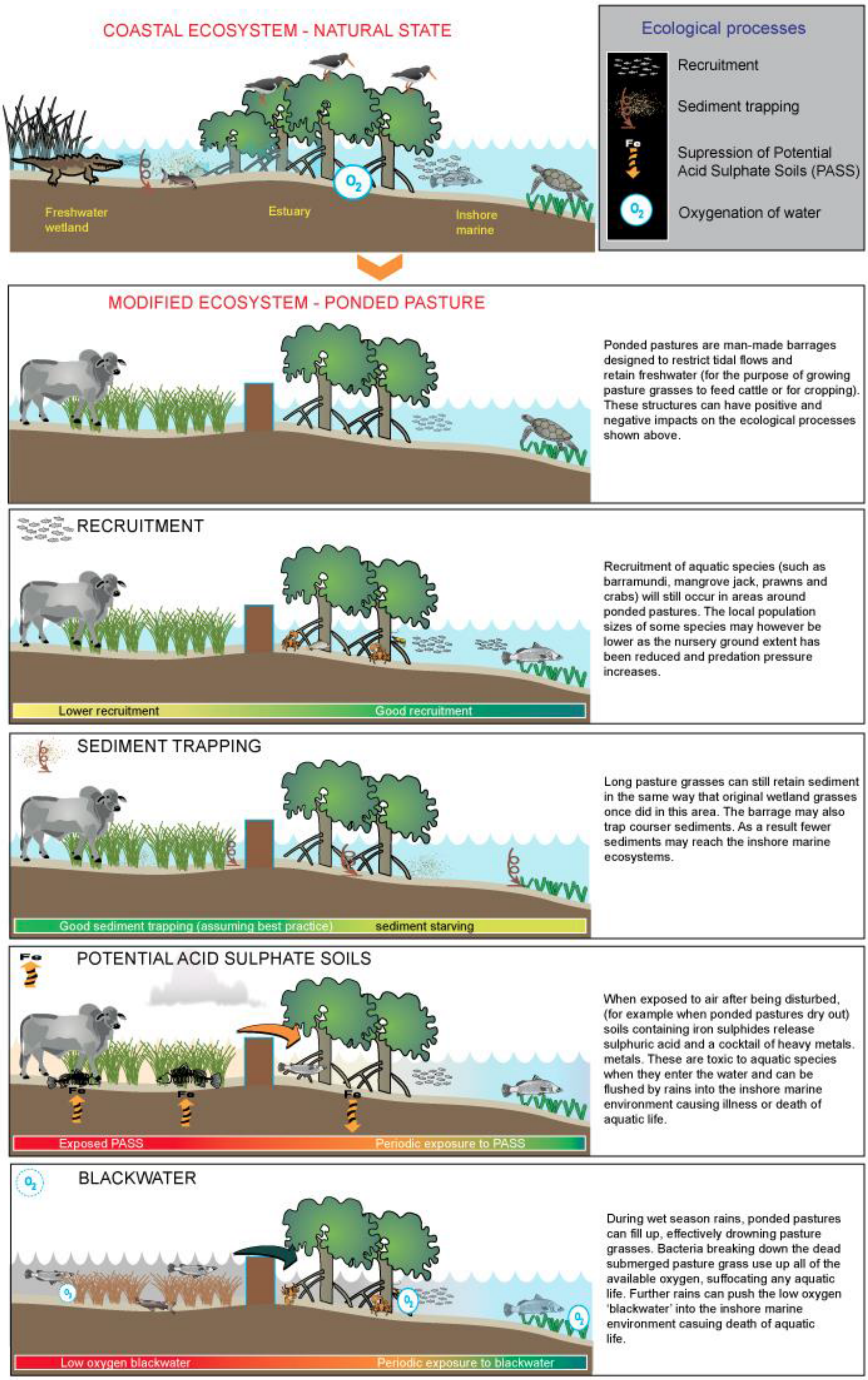

Figure 3. The Ponded Pasture landscape and its impact on saltmarsh function. Source: GBRMPA

The top five basins within the Great Barrier Reef catchment with extensive areas of salt marsh/mangrove complex are:

- Shoalwater – 527 km^2 or 12% of Great Barrier Reef estuarine wetlands – with many areas outside the Shoalwater Defence Lands altered by ponded pastures;
- Styx – 356 km^2 or 8% of Great Barrier Reef estuarine wetlands – with very extensive areas of ponded pastures;
- Fitzroy – 332 km^2 or 8% of Great Barrier Reef estuarine wetlands – with very extensive areas of ponded pastures
- Haughton – 318 km^2 or 8% of Great Barrier Reef estuarine wetlands – with very extensive areas of ponded pastures and bunded off estuarine creeks;
- Normanby – 335 km^2 or 8% of Great Barrier Reef estuarine wetlands – with the vast majority in excellent condition by virtue of very limited agriculture and grazing development.

All works to repair saltmarsh and mangrove complexes will need to be carefully designed and agreed to by adjacent landholders. Incentives for fencing and the installation of watering points would be required in some cases. In other cases, acquisition will be required and could be funded through the Australian Government's *Reef Trust* initiative or the Queensland Government's *Reef Catchment Repair* initiative.

Repair in temperate Australia

Similar issues of saltmarsh degradation due to grazing are found across all of temperate Australia. Generally, the degradation is due to unrestricted access of cattle into saltmarsh and mangrove ecosystems, and in some cases to the construction of levees to exclude tidal flows and other infrastructure such as roads and rail. Incentives for fencing to better manage stock movements, removal of levees, rationalisation of drainage systems and re-establishment of tidal flows would provide benefits for both graziers and fisheries productivity.

South Australia

Within South Australia, areas of saltmarsh have been affected by coastal development, aquaculture and tourism, changed flow regimes due to coastal engineering works such as roads and levees, disturbance by vehicles, and in some cases invasive species and rubbish dumping.

Tasmania

With Tasmania's low tidal prisms, saltmarshes and sedgelands dominate Tasmania's estuarine wetlands. Many of these areas are underlain by peaty soils which when disturbed (e.g. drains), lead to an acidic leachate, changing the pH of receiving waters. Some of these wetlands, as well as being drained in the past were leveed, excluding tidal interchange. Most of these drainage and levee works are now recognised in hindsight as mistakes. The works did not create additional good quality agricultural lands and these areas are now 'wastelands' – neither of agricultural nor of estuarine value, and at most is poor quality grazing land.

Important Tasmanian coastal saltmarshes and sedgelands that have been significantly modified include:

- Robin's Passage in the northwest;
- The northeast including Ringarooma estuary and Musselroe Bay;
- Moulting Lagoon on the east coast; and
- Pitt Water – Orielton Lagoon and the Derwent estuary in the southeast.

New South Wales

In NSW, agriculture and infrastructure, as well as increasing urbanisation adjacent to estuarine fringes, and elevated sediment loads have had a detrimental impact on saltmarsh communities.

Saltmarsh losses within the Hunter and Parramatta Rivers are estimated to be 67% and 80% respectively over the last 50 years (Daly 2013). The losses across coastal NSW have been so widespread that saltmarshes within the North Coast, Sydney Basin and South East corner Bioregions of NSW are now listed as a "Endangered Ecological Community" under the *NSW Threatened Species Conservation Act 1995*.

The Clarence River, the largest river catchment with the largest river flows in NSW supports NSW's largest estuary-based fishery. Of particular interest for repair are the saltmarshes of Lake Wooloweyah. Most of the Clarence saltmarshes' prior and current extent is within the Wooloweyah deltaic islands and lower estuary section. Wooloweyah Lagoon is a shallow tidal barrier lake approximately 23 km^2, and 15 km from the Clarence River mouth. It is connected to the main estuary through Oyster, Shallow, Romiaka and Palmers Channels with its own reverse delta of islands and wetland areas. These islands are comprised of private land and unallocated Crown land and Crown reserves with extensive draining and clearing of the floodplain alluviums and wetlands for sugarcane farming and grazing. This area offers potential for the restoration of saltmarsh and mangrove communities on a significant scale through drain and levee rationalisation and re-instatement of tidal flows such as further culverts for Shallow Channel.

The southwestern shoreline of Lake Wooloweyah was an extensive mosaic of saltmarshes and mangroves. It extended for at least 10 km around the lake foreshore and landward in parts up to 6 km. As part of a flood mitigation and drainage scheme, a levee and ring channel were constructed immediately adjacent to the lake foreshore, lateral drains were dug through the wetland complex and floodgates installed. The soils are either gleyed clays or acid sulfate and while the intention was to create farmland, these soils are totally unsuited to any form of agriculture. Rough grazing is at best marginal on these lands.

Prior planning studies (*Integrated Development Application, Taloumbi Drainage Scheme Redesign*, WetlandCare Australia 2002) demonstrated the higher productivity returns from fisheries if the drains were rehabilitated and the wetland was returned to a mosaic of saltmarsh and mangroves. Even a landward extension of the ring drain of 1 km would re-create over 800 ha of saltmarsh. Hydrodynamic surveys at the time established that removal of the levee would lead to tidal inundation on at least 264 days per year.

Planning for possible remediation has occurred previously, however due to delays the plan will require review and presumably upgrading. The benefits to the fishery are possibly now even higher, as the dredging of the Palmers Channel entrance and the two culverts in Shallow Channel have improved tidal flushing.

Next Steps

Resources for repair programs will always be limited. Repair schemes in the various jurisdictions would need to be well promoted and most importantly demonstrate a high return on investment. This is particularly important as most of the areas that could be repaired are under some form of freehold or leasehold arrangements and many will require changed land management arrangements and in some cases acquisition. This report, by quantifying key benefits of repair, will provide a substantial contribution to business cases for repair.

3. PROTECTING & MANAGING AUSTRALIA'S SALT MARSHES

Australia's saltmarshes are protected through various legislation, and planning policies and management activities. These are applied at international, Australian Government and State jurisdictions and seek to mitigate further saltmarsh loss and aid in recovery efforts.

The level of protection and management options for the conservation and recovery of Australian saltmarsh communities are summarised below.

International agreements

Ramsar
Australia is a signatory to the Ramsar Convention of Wetlands (Ramsar, Iran 1971) an international, inter-governmental agreement for the protection and wise use of wetlands. Under the Convention, Australia is obliged to maintain the ecological character of declared Ramsar sites and manage each site consistently with the principles of ecologically sustainable development. Saltmarshes are recognised as one of 12 coastal and marine wetland habitat types. The Commonwealth Government establishes management plans for each Ramsar site under the EPBC Act (2009), which can include options for protecting and restoring saltmarshes.

Migratory bird agreements
Australia is a signatory to a number of bilateral migratory bird agreements with Japan (JAMBA), China (CAMBA) and the Republic of Korea (ROKAMBA) and the East Asian–Australasian Flyway Partnership (EAAFP). These agreements require management actions to be taken to conserve migratory bird populations (particularly shorebirds and seabirds) and their foraging habitats, including coastal saltmarshes.

Australian legislation

Subtropical and temperate coastal saltmarshes are listed as a "Threatened Ecological Community" under the *Commonwealth EPBC Act (2009)* that provides legislative protection for these saltmarsh communities.

Under the *EPBC Act,* the Subtropical and Temperate Coastal Saltmarsh Threatened Community Recovery Plan lists a series of priority conservation actions:

- Avoid native vegetation clearance and destruction of the ecological community and its buffer zones; including protecting potential areas of natural retreat;
- Collate effective policies and management actions already in progress (including development controls) to support and widely disseminate best practice and lessons learnt;
- Undertake surveys to identify areas where natural retreat of coastal saltmarsh may be possible, and actively manage them to enable natural retreat in the future;
- Undertake effective community engagement and education to promote the value of the ecological community (e.g. it is not 'wasteland' as some perceive); also to highlight the importance of minimising disturbance (e.g. during recreational activities), and of minimising pollution and littering (e.g. via signage); and
- Liaise with planning authorities to promote the inclusion of coastal saltmarsh protection and projected tidal inundation zones in their plans/responses to climate change and sea level rise and in coastal zone management generally.

Two South Australian Samphire saltmarsh species (*Tecticornia flabelliformis* and *T. bulbosa*) are also listed individually as "Vulnerable" under the Act, as well as one Tasmanian leadwort species (*Limonium baudinii*).

Protection of saltmarshes can also occur under the Act when considered as critical habitat for other threatened species, such as the False water rat (*Xeromys myoides*), green and golden bell (*Litoria aurea*), Slender-billed thornbill (*Xeromys myoides*), Australasian bittern (*Botaurus poiciloptilus*) Orange-bellied parrot (*Neophema chrysogaster*), Australian painted snipe (*Rostratula australis*) Australian fairy tern (*Sternula nereis nereis*), Southern emu-wren (*Stipiturus malachurus intermedius*) and (Dawson) yellow chat (*Ephthianura crocea macgregori*).

State legislation

Some states such as New South Wales (NSW) and Queensland provide protection for saltmarsh communities through legislation and policies related to biodiversity protection, fisheries management, coastal planning and vegetation clearing. Further detail for each state is covered in each of the state chapters.

For example, saltmarshes are declared an "Endangered Ecological Community" (EEC) under the *NSW Threatened Species Conservation Act (1995)* and are protected in Queensland under the *Fisheries Act (1994)*. Also, the Yellow chat (Dawson, *Epthianura crocea macgregori*) is currently listed as "Critically Endangered" by the Nature Conservation Act 1992 (Queensland). Saltmarshes in the Fitzroy River Delta and Torilla Plains are critical for the successful breeding, feeding and shelter of this species.

Relevant legislation governing the clearing and protection of saltmarshes falls under various and differing planning, native vegetation, parks and wildlife and coastal management Acts (See Table 9.1 in Laegdsgaard *et al*. 2009 for a list of relevant state-based legislation and policies).

Local government

Local governments can undertake a range of actions related to the planning and management of public foreshore lands and the type and location of development on private land. Local government can also implement measures to use natural rather than hardened coastal defences that include or protect saltmarshes. Management options available to local governments include:

- Building and zoning regulations – which control the physical development of structures on coastal land;
- Setbacks or buffers – which control the distance development can occur from the coastal edge;
- Conditional development and extractions (also known as hazard trigger basis development) – which allow development in the present time but with the landowner agreeing in advance to relocate or remove the structure once the pre-designated threshold is reached;
- Rolling and conservation easements – a type of development restriction preventing structures from being built on the coastal edge and thereby allowing for the migration of shorelines landward;
- Planned managed retreat – includes the planned surrender and active management of terrestrial lands to coastal wetlands; and
- Horizontal levees and living shorelines – which promote the use of green and grey, and soft and hard shoreline protection infrastructure to reduce erosion or protect coastlines and coastal habitats from storm damage.

Private lands

Private landholders can protect saltmarshes by undertaking sustainable land management practices, including: minimising erosion, reducing fertiliser and weed application, preventing mowing, preventing rubbish dumping and excluding grazing. Long-term protection of saltmarshes can occur on private lands through private land covenants.

Opportunities for further protection and repair

A number of local and international examples have demonstrated that saltmarshes can be protected and restored through financial (e.g. tax and market based tools) and Indigenous land rights. These include:

- Acquisition and buyout schemes;
- Discounted flood insurance schemes;
- Incentive payments/tender schemes to carry out conservation works;
- Establishing voluntary or regulated market-based payment for ecosystem service schemes (e.g. for blue carbon or fish habitat); and
- Extending Indigenous land rights to include tenure over coasts and seascapes.

Emerging Issues

Saltmarshes, by virtue of their tidal position are susceptible to sea level rise. Sea level rise will bring into play the following issues:

- Potential for increased erosion of saltmarsh foreshores, especially in southern Australia where there is limited or nil fringing mangrove vegetation;
- Landward migration of mangrove species, thereby possibly contracting the areas of actual saltmarsh, especially in NSW and Queensland; and
- Landward extent of saltmarsh, possibly overtaking other communities such as the fresh to brackish landscapes that are currently only tidally impacted by storm surge or supratidal conditions.

4. SOUTH AUSTRALIA

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Saltmarshes within the South Australian 'seascape nursery'

Nagelkerken et al. (2015) recently introduced the term 'seascape nursery', the concept providing a model of nursery habitat that represents the importance of the mosaic of functionally connected habitat patches that underpin many coastal ecosystems, and their ecological productivity. What is known vegetatively as 'saltmarshes' in South Australia are a key part of the South Australian seascape nursery and are 'the expression of a number of inter-related factors', including tidal inundation, climate and freshwater input, physical aspects such as slope and exposure to wave action, and the biota, including the organisms that occupy the habitat (Fotheringham and Coleman, 2008).

The other key parts of the South Australian seascape are the sub-tidal through to intertidal habitats, especially seagrasses, sand flats, mud flats and mangroves together with areas well above high mean water, known as 'hind-marsh' habitat and patches of vegetation that have become stranded from inundation by seawater.

Collectively these seascapes provide prawn nursery areas that support the productivity of South Australia's prawn fisheries, for the single target species Western King Prawn, *Penaeus* (*Melicertus*) *latisulcatus* (Roberts *et al.*, 2010). *P. latisulcatus*, like other penaeids, maintain an offshore adult life phase and an inshore juvenile phase. Juvenile prawns occur predominantly over intertidal sand- and mud-flats, between the shallow subtidal through to the mosaic mudflat-mangrove-saltmarsh vegetation types higher on the shoreline (Roberts et al., 2010). The extent of seascape habitat has been linked to the production of the state's prawn fisheries (Roberts et al., 2009) operating in Spencer Gulf and Gulf St Vincent.

Dixon et al. (2012) estimated that 76% of the Spencer Gulf coastline comprises appropriate habitat for prawn nursery areas, i.e. 51% tidal flat only and 25% mangrove forests only, with the remainder a mosaic of mudflat, mangrove and saltmarsh. For Gulf St Vincent, the seascape comprises tidal flats (41%) and mangroves (14%) in conjunction with large expanses of vegetated and intertidal saltmarsh, often in a mosaic (Fotheringham and Coleman 2008; Dixon et al. 2012).

Extent of saltmarshes, present and past

From a vegetation perspective, saltmarshes in South Australia are a diverse, complex association of plants typically characterised by the presence of the salt-tolerant species *Sarcocornia quinqueflora*, *Halosarcia spp*., *Sclerostegia arbuscula*, *Suaeda australia*, *Maireana oppositifolia*, and in some cases *Melaleuca spp*. (Bryars 2003; Fotheringham and Coleman, 2008).

Saltmarshes occur within many of the state's bays and estuaries. the South Australian 'Inventory of Important Coastal Fisheries Habitats in South Australia' identified a total of 684 habitat units, across 54 'Fish Habitat Areas', including 54 discrete saltmarsh units (Bryars, 2003). This complexity of saltmarsh vegetation types is better recognised functionally, through their role in marine productivity and hence the 'seascape' concept.

The total state-wide area of these communities (reported vegetatively as either mangrove or saltmarsh) has been estimated at around 82,000 hectares. The largest communities occur in Spencer Gulf (46,000 ha) and Gulf St Vincent (20,000 ha), with further communities recorded on the west coast of Eyre Peninsula (9,000 ha), lower Spencer Gulf (6,000 ha) and on Kangaroo Island (7,000 ha) (Edyvane 1999b). The present extent has been collated through Enviro Data SA and is publicly viewable through the NatureMaps initiative of the South Australian Government (https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx).

An accurate record or estimation of pre-European distribution is lacking. The period of European colonisation represents the start of human-mediated ecological change for many coastal habitats, including many significant declines. Records of early explorers highlighted the past extent of saltmarsh habitat along the state's coastlines e.g.
"It seemed remarkable, and very mortifying, to find the water at the head of the gulph as salty nearly as at the ship…. Never the less it was evident that much freshwater was thrown into it in wet seasons, especially from the eastern mountains… All else to north and west was mangroves and swamps." (Flinders, 1814).

Fotheringham and Coleman (2008) documented that at the time of European settlement, tidal and supra-tidal saltmarshes extended up to 5 km inland behind the mangroves that fringed the Port River and Barker Inlet (Gulf St Vincent) and that loss of habitat has been particularly significant on the Adelaide plain. Edyvane (1999a) reported that approximately 80% of tidal saltmarshes (dominated by *Halosarcia* spp. and *Sarcocornia* spp.) and 100% of saltwater tea tree (*Melaleuca* spp.), reed beds (*Phragmites australis*) and native grasses have been lost in the metropolitan region of Gulf St Vincent since 1954.

Threats and impacts on South Australian seascapes have been systematically documented by Bryars (2003). This inventory documents, off-road vehicle use, stock grazing, pollution due to industrial effluent, the dumping of rubbish, and the stranding of seascapes due to the construction of roads. These activities highlight the broad nature and large number of ongoing pressures, which will be exacerbated by the effects of land subsidence and sea level rise (Edyvane, 1999a; Fotheringham and Coleman, 2008).

The role of habitat in maintaining seascape productivity and integrity

Ecological disturbances can have additive and synergistic effects when they overlap in space and time, such that they generate an ecological response in an ecosystem, species or habitat, that is different or greater than their independent effects (Doherty et al., 2015). Penaeids can be impacted by the occurrence of diseases, pathogens or viral infections, and parasite loads, that can affect their productivity through changes to growth, reproductive output and ultimately survival (e.g. Courtney et al., 1995). The occurrence of environmental pollution can increase the susceptibility of prawns to disease and reduce reproductive output (Nash *et al.*, 1988). Recent surveys targeting analysis of the presence of a range of diseases and pathogens within the Spencer Gulf and Gulf St Vincent prawn populations did not detect four key notifiable viruses (notifiable by regulation), but did record a number of pathogens and parasites at low prevalence (Roberts et al., 2010). Saltmarshes and seascapes generally provide an important function through their capacity to filter surface water prior to its release to sea (Connolly et al., 1997), a function that reduces the effects of pollution and likely supports the ongoing healthy and sustainability of the state's prawn fisheries.

Prawn productivity as a surrogate for broader ecosystems services

South Australia maintains two prawn fisheries, which represent a culturally important industry that makes a significant contribution to the state's economy. The Spencer Gulf Prawn Fishery and the

Gulf St Vincent prawn fishery produce an annual harvest of approximately 2,200 t with a landed value of approximately $33 million (Noell et al., 2015). The most recent fisheries stock assessment for the Gulf St Vincent prawn fishery indicated that while adult biomass increased following the closure from 2012 through 2014, low catch rates of recruits in 2015 suggest that future recruitment may be limited. This stock status resolved the classification of the fishery as 'transitional depleting', which contrasts the Spencer Gulf prawn fishery classification as a 'sustainable' stock.

The Gulf St Vincent Prawn Fishery

The Gulf St Vincent Prawn Fishery was closed in December 2012, at the request of all 10 licence-holders due to poor economic performance. The economic performance of the fishery had declined, in part due to decreasing catches. This recent closure follows the suspension of fishing for two seasons between June 1991 and February 1994 following a parliamentary review (Dixon et al., 2012). At its peak, the fishery maintained 22 vessels, but after a buy-back scheme in 1987 and further surrender of licences in 1990, the fishery has since that time maintained 10 licenses across the Gulf St Vincent (Dixon et al., 2012).

Broader, long-term ecosystem degradation has occurred in Gulf St Vincent that may potentially have affected the abundance and recruitment of prawns over time, historically and in recent years. Habitats that are critical to maintaining a healthy seascape have deteriorated, such as wetland and vegetated habitat, and there has been a loss of natural water filtration capacity through overexploitation of shellfish and shellfish reefs and associated declines in water quality. It is likely that these impacts have compounded the effects of each, as opposed to their occurrence in isolation, the result being an overall deterioration of the integrity and productivity of this region (Doherty *et al.*, 2015). An understanding of broader ecosystem function of Gulf St Vincent is being built, alongside a more detailed analysis of the long-term natural versus human mediated changes that have occurred and the impacts of this change on the productivity of fisheries.

Effects of decreased prawn productivity

The link between prawn nursery habitat or seascapes and productivity is strong (Dixon et al., 2013; Noell and Hooper, 2015) and, as a result, some basic assumptions about the potential impact of declines in nursery habitat on prawn productivity can be made. Dixon et al. (2012) estimated approximately 304 km of coastline within Gulf St Vincent to be prawn nursery habitat. In 2011/12, total production from this fishery was 178 t with a total gross value of approximately $2.5 M (based on 2009/10 data). Though a coarse estimation, this catch reflects a production of 0.58 t of prawns per km of nursery habitat.

Based on the knowledge that at the time of European settlement tidal and supra-tidal saltmarshes extended up to 5 km inland behind the mangroves (Fotheringham and Coleman, 2008) and that approximately 80% of tidal saltmarshes have been lost in the metropolitan region of Gulf St Vincent since 1954 (Edyvane 1999a), it is likely that a further 50 km of saltmarsh habitat could have been lost from Gulf St Vincent, as a result of coastal development or the ongoing effects of pollution and habitat disturbance. Using the assumption of a production of 0.58 t of prawns per shoreline km (area) of nursery habitat, a decrease in the current area of prawn nursery habitat in Gulf St Vincent of 50km, from 304 km (Dixon et al., 2012) to 250 km, would result in a decrease of overall fisheries production from 178 t to 146 t, a drop of nearly 18% (this assumption does not account for fisheries management actions that regulate catch and effort and may enable total production quantities to be maintained from year to year). In 2009/10 the gross value of production from the Gulf St Vincent Prawn Fishery was $2.57 M (Dixon et al., 2012). A decrease in production of 18%, if directly proportional to this decline, would result in a decrease of nearly $0.5 M in annual value. Conversely, were 50 km of prawn nursery habitat to be protected, repaired or restored, it may be possible to realise an increase of $0.5 M. The Gulf St Vincent Prawn Fishery has a recent history of a lack of security in long-term sustainability, as well as intermittent closure of the fishery. The benefits of any increase in economic value would be high.

Protecting and managing saltmarshes and prawns

Legislative and management frameworks exist in South Australia that provide the regulatory means to implement and enforce protection of seascapes habitat. Key state-based legislation includes:

- The *Fisheries Management Act 2007*, which prevents the harvesting of prawns from waters shallower than 10 m and also establishes a management framework for pre-determined harvestable limits. From a habitat perspective the harvesting in waters shallower than 10 m has the objective of protecting prawns and prawn nursery habitat in easily accessible areas, e.g. tidal creeks, which can be impacted by physical disturbance and through vehicle access and trampling;
- The *Marine Parks Act 2007*, which provides for a system of marine parks across South Australia for the protection and conservation of marine biodiversity and habitats; and
- The *Native Vegetation Act 1991*, which provides incentives and assistance to landowners in relation to the preservation and enhancement of native vegetation and protection against clearance for important species, including those that contribute to the seascape habitat.

Key actions and sites for investment and repair

As well as legislated protection, it is increasingly recognised that conservation strategies must incorporate restoration, not only protection, and that, in fact, restoration may be a preferred approach because it can achieve greater outcomes from investment (Possingham et al., 2015). Management actions that actively seek the return of habitat through on-ground works continue to be few, which is especially true for fisheries habitats despite the significant economic outcomes that can be realised (Creighton et al., 2015).

There is value in pursuing a robust model of ecosystem services to quantify the direct link between seascapes for prawn habitat, and prawn productivity. This model could build on existing fisheries monitoring, which provides regular assessment of relative prawn abundance (prawns per m2) at key nursery sites within Gulf St Vincent. Through this model it could be possible to estimate the benefits of investment in on-ground restoration and the area of habitat repair that would be required to increase relative abundance of juvenile prawns and elicit positive economic outcomes for the Gulf St Vincent Prawn Fishery.

Immediate gaps in understanding

The next steps for South Australian seascapes and understanding prawn productivity could focus on:

1. Quantifying the direct effects of positive and negative change in prawn nursery area on total prawn biomass and fishery production, through a spatially-linked ecological model;
2. Estimating the impact of on-ground repair and restoration and the area of habitat repair that would be required to increase relative abundance of juvenile prawns (e.g. prawns per m^2) and support ongoing recruitment, at three locations in Gulf St Vincent, specifically:
   - Pt Arthur;
   - Pt Wakefield;
   - Webb Beach.
3. Implementing a small-scale trial restoration site along the northeastern Gulf St Vincent, to test the estimated effect of on-ground restoration on increasing prawn recruitment and the relative abundance of juvenile prawns in association with seascape at these sites.

For the limited resources available in the Phase II of this project in the Marine Biodiversity Hub it is proposed to focus on quantifying the direct link between repair and relative prawn abundance, through ecological modelling as a precursor to field validation of outputs through a trial restoration project.

5. VICTORIA

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Definition & diversity

What is coastal saltmarsh?

In Victoria, coastal saltmarsh is defined as a low shrubby (to herbaceous, sedgy or grassy) type of vegetation that occurs in sheltered embayments and estuaries, on salinised coastal soils that are tidally influenced (Department of Sustainability and Environment 2013). It is termed 'coastal saltmarsh' in order to differentiate it from the large areas of saltmarsh that occur in inland parts of the state, especially in the Northwest. The floristic composition of coastal saltmarsh in Victoria variously includes shrubby dicots such as *Tecticornia* (previously *Sclerostegia*) *arbuscula*, *Tecticornia pergranulata* and *Tecticornia halocnemoides*, grasses such as *Austrostipa stipoides* and *Distichlis distichophylla*, and dicot herbs such as *Sarcocornia quinqueflora*. The definition adopted by Boon *et al*. (2015) for a state-wide assessment of coastal wetlands in Victoria was that coastal saltmarsh was '*land that experiences recurrent low-energy inundation by seawater and not usually by substantial fresh water flows, which is vegetated by low-growing vascular plants (generally <1.5 m height), such as succulent chenopods and salt-tolerant monocots, but excluding vegetation dominated by the mangrove Avicennia marina*'.

Coastal saltmarsh near Werribee. *P. Boon*

Structural and floristic diversity of Victorian coastal saltmarsh

Victorian coastal saltmarsh is structurally and floristically diverse. The structural complexity is due to the range of life forms present in the Southeast Australian flora, and the fact that species with different architectures are often assembled into spatially and temporally complex patterns. Succulent shrubs such as *Tecticornia* spp. form one distinctive structural type; large tussock-forming monocots (e.g. *Austrostipa stipoides* and *Gahnia filum*) make up one graminoid form, and low rhizomatous/stoloniferous grasses another (e.g. *Distichlis distichophylla* and *Sporobolus virginicus*). Succulent herbs (e.g. *Sarcocornia* spp., *Hemichroa pentandra, Disphyma clavellatum*) and prostrate shrubs (e.g. *Frankenia pauciflora*) constitute another form. Moreover, local patches dominated by annuals are not uncommon; submerged macrophytes (e.g. *Ruppia* spp.) in the shallow pools of low-lying depressions are yet another structural form.

Seven types of Victorian coastal saltmarsh were identified by Boon *et al*. (2011, 2015) and they have received provisional acceptance by the State Government as *bona fide* native-vegetation units (Department of Sustainability and Environment 2012):

- Wet Saltmarsh Herbland - low herbland dominated by succulent to semi-succulent halophytic herbs or semi-shrubs, occupying low-lying areas of coastal saltmarsh subject to regular tidal inundation. Often very species-poor, most frequently dominated by *Sarcocornia quinqueflora*, less commonly by *Hemichroa pentandra*, *Selliera radicans*, *Samolus repens* or *Sueda australis*, and on rare occasions *Triglochin striata*;
- Wet Saltmarsh Shrubland - shrubland dominated by halophytic species and subject to regular tidal inundation. Often very species-poor, most frequently dominated by *Tecticornia arbuscula*, much less commonly by *Atriplex paludosa*, and rarely by *Atriplex cinerea*. *Sarcocornia quinqueflora* is also frequent in wetter communities;
- Coastal Saline Grassland - grassland dominated by rhizomatous grasses, occurring towards upper zones of coastal saltmarsh. Frequently very species poor and typically dominated by either *Distichlis distichophylla* or *Sporobolus virginicus*;
- Coastal Dry Saltmarsh - herbland to low shrubland of upper saltmarsh, subject to relatively infrequent or rare tidal inundation. Variously dominated by *Sarcocornia blackiana*, *Frankenia pauciflora*, *Disphyma crassifolium*, *Angianthus preissianus* or very rarely *Sebaea albidiflora*;
- Coastal Hypersaline Saltmarsh - low shrubland dominated by succulent chenopods (or rarely Salt Lawrencia *Lawrencia squamata*), occurring in highly hypersaline saltmarsh habitat above the zone of regular tides. Dominated by *Tecticornia pergranulata*, *T. halocnemoides*, or very locally *Lawrencia squamata*;
- Coastal Tussock Saltmarsh - upper saltmarsh zones dominated by robust tussock-forming grasses or graminoids, such as *Gahnia filum* or *Austrostipa stipoides* with a range of halophytic species at lower covers;
- Saltmarsh-grass Swamp - inundation-prone saltmarsh vegetation dominated by Australian Saltmarsh-grass *Puccinellia stricta* and sometimes with *P. perlaxa*.

The inventory of the Victorian vascular flora of coastal saltmarsh and mangrove lists a total of 140 indigenous taxa (species, infraspecific taxa and informal names) that have been recorded in upper and lower saltmarsh in the state. Of the total, 68 species are halophytes, being confined to saline environments or able to tolerate moderate salinity if not confined to saline areas. Boon *et al*. (2011) identified 131 indigenous plant taxa in Victorian saltmarsh, mangroves and saline aquatic meadows; in addition, there were 118 exotic taxa. Carr (2012) provided an updated and expanded inventory of the plant taxa found in Victorian marine coastal wetlands. Given this floristic diversity, it is likely coastal saltmarsh in Victoria is among the most species-rich of any saltmarsh occurring on the Earth.

Critical sites for coastal saltmarsh in Victoria

Saltmarsh is found along many parts of the Victorian coast, although it is most extensive along the western coast of Port Phillip Bay, northern parts of Western Port, throughout the Corner Inlet-Nooramunga complex, and behind the sand dunes that line the Ninety Mile Beach in Gippsland, especially in Lake Reeve. In their analysis of vegetation of the Victorian coast, Barson & Calder (1981) concluded coastal saltmarsh was best developed in the region between Barwon Heads and Corner Inlet. To the west of Barwon Heads, notable patches occur at Breamlea, the mouth of the Anglesea River, Painkalac Creek, Aireys Inlet, at Port Fairy, and in the estuary of the Glenelg River. To the east of Corner Inlet, saltmarsh fringes the shoreline of parts of the Gippsland Lakes (especially in Lake Reeve), and extends as far east as the mouth of the Snowy River, to Wingan Inlet, and to Mallacoota.

Particularly noteworthy are the coastal saltmarshes of eastern Victoria, especially in the Corner Inlet-Nooramunga complex and behind the sand dunes that line the Ninety Mile Beach in Gippsland, especially surrounding Lake Reeve, and in the far east of the state; these are among the least modified of all coastal wetlands in Victoria.

Historic and current area

Because of their position along the coast, where land has been appropriated for human settlement, coastal wetlands and floodplains have experienced a long history of reclamation (Sinclair and Boon 2012). Almost all estuarine wetlands in Southeastern Australia have experienced some degree of 'reclamation' or other form of habitat destruction.

The extent of loss of coastal saltmarsh, mangroves and *Juncus kraussii*-dominated wetlands in Victoria has been quantified by Sinclair and Boon (2012) and Boon *et al*. (2015). This is on the basis of archival maps and field observations to reconstruct the pre-European (i.e. ‘pre-1750’) distribution of intertidal wetland vegetation. It was not possible to differentiate losses from each of the various types of coastal wetland. Losses of coastal marshes were very uneven across the Victorian coast, with some regions having suffered massive loss (notably Corner Inlet and parts of the Nooramunga coast, Anderson Inlet, Shallow Inlet and Port Phillip Bay), but others having retained most of their pre-colonial area of intertidal wetland. In some regions (e.g. eastern shore of Western Port, possibly parts of the Gippsland Lakes) there was evidence of expansion, generally associated with changed hydrology such as the drainage of the major swamps behind Westernport or the development of a permanent entrance for Gippsland Lakes. Some of the greatest losses occurred along the South Gippsland coast; ~60% of coastal saltmarsh had been lost from Shallow Inlet and in the Powlett-Kilcunda region. State-wide, the loss of coastal marsh vegetation (mangrove shrublands, coastal saltmarsh and Ecological Vegetation Class (EVC) 10 Estuarine Wetland combined) was estimated at ~5–20%, depending largely on assumptions about changes in the Gippsland Lakes region (Sinclair and Boon 2012).

The state-wide inventory prepared by Boon *et al*. (2015) indicated that Victoria currently (i.e. based on mapping undertaken *c.* 2008) supports 192 km^2 of coastal saltmarsh of all types, 52 km^2 of mangroves, and 32 km^2 of the *Juncus kraussii*-dominated EVC 10 Estuarine Wetland. These figures exclude some EVCs that may occasionally be considered saltmarsh on less spatially resolved maps, such as Seasonally Inundated Subsaline Herbland (EVC 196, approximately 648 ha) and Saline Aquatic Meadow (EVC 842, no area calculated since it is an ephemeral EVC).

Ecological functions

It is widely acknowledged that coastal wetlands provide valuable ecosystem services (Woodward and Yui 2001; Bateman *et al*. 2011). Two recent meta-analyses have demonstrated fringing vegetation – and in particular mangroves and coastal saltmarsh – makes shorelines less susceptible to erosion and to damage by storm surges, and potentially, even to small tsunamis (Gedan *et al*. 2011; Shepard *et al*. 2011). These overviews are consistent with a number of more broad-ranging assessments, for example by French (1997) and Doody (2008), that argued coastal wetlands were highly effective in protecting shorelines against erosion in the Northern Hemisphere.

Coastal saltmarsh of southeastern Australia provides important feeding, breeding and roosting areas for water birds, including many migratory species listed under treaties such as the *Japan-Australia Migratory Bird Agreement* (JAMBA), the *China-Australia Migratory Bird Agreement* (CAMBA), and the *Convention on the Conservation of Migratory Species of Wild Animals* (Bonn Convention). These treaties require that the habitats of listed taxa be protected, conserved, secured and restored. Even so, the degree to which adequate protection is afforded to coastal wetlands varies greatly across states and wetland types in southeastern Australia (Boon *et al*. 2015). The value of coastal wetlands in general is reflected in the fact that roughly one-third of Australia's Ramsar-listed wetlands are in the coastal southeast of the country, and in total they cover an area of over 420,000 ha (Boon *et al*. in press).

Conservation significance

Ecological Vegetation Classes (the units by which native vegetation is delimited and mapped in Victoria) are provided with a Bioregional Conservation Status (BCS), a state-wide classification of the degree of depletion in the extent and/or quality of an EVC within a bioregion in comparison with its estimated pre-1750 extent and condition. Current BCS ratings for coastal saltmarsh and mangroves vary across the state's bioregions, but for those containing the majority of coastal saltmarsh and mangrove vegetation the status is of the lowest category (i.e., of 'least concern') which reflects the assumption there was greater than 50% pre-European extent remaining and existing areas were subject to little to no degradation over a majority of this area (Department of Natural Resources and Environment 2002). This ranking was challenged by Boon *et al*. (2011, 2015) on both grounds, who proposed a more refined ranking based on coastal sector and specific type of saltmarsh. In many cases, the BCS was increased to higher categories (i.e., of greater conservation significance).

Threats to coastal saltmarsh have been qualitatively described in a number of reviews (e.g., Laegdsgaard 2006; Laegdsgaard *et al*. 2009; Saintilan and Rogers 2013). Boon *et al*. (2015) built on these generic appraisals by undertaking for the Victorian case semi-quantitative assessments of coastal wetlands on a geographic sector-by-sector approach along the entire coastline. The major threats facing coastal wetlands were found to be:

- Land-claim, infilling, habitat destruction and fragmentation;
- Fire;
- Mangrove encroachment;
- Excessive freshwater inputs (e.g., from stormwater);
- Nutrient enrichment and eutrophication;
- Toxicants
  - Oil pollution
  - Polycyclic aromatic hydrocarbons
  - Halogenated hydrocarbons
  - Heavy metals;
- Disturbance of acid sulfate soils;
- Introduced plants (e.g., agricultural weeds in upper saltmarsh; **Spartina* in lower levels and in mangroves);
- Grazing
  - Domestic stock (e.g., sheep, cattle)
  - Feral animals

  - Exotic invertebrates;
- Inappropriate mosquito control;
- Recreation
  - Disturbance (bait digging, trampling, noise)
  - Inappropriate infrastructure (e.g., bridges)
  - Vehicle access;
- Inappropriate rehabilitation
  - Non site-native taxa
  - Non-saltmarsh (especially woody) taxa
  - Modification towards freshwater systems.

Gaps in understanding

The next steps for a holistic and management-orientated research program for coastal saltmarsh in southeastern Australia could focus on:

1. Strategies and techniques to repair damaged coastal wetlands, especially re-instatement of appropriate tidal regimes and acquisition and repair of coastal wetland integrity;
2. Strategies and techniques to minimise threats such as
   - Mechanisms for weed control
   - Assessment of impacts of domestic, feral and exotic fauna;
3. Strategies for climate-change adaptation
   - Identification of retreat pathways and opportunities for land reservation
   - Assessment of rates of relative sediment elevation with regard to sea-level rise
   - Migration of different wetland types in response to sea-level rise (e.g., invasion of coastal saltmarsh by mangroves);
4. Improved understanding of the role played by coastal wetlands in biodiversity conservation and valuing the provision of ecosystem services such as
   - Assessment of the way coastal saltmarsh provides animal habitat
   - Assessment of the role of coastal wetlands in shoreline protection
   - Assessment of the role of coastal wetlands in supporting food webs in adjacent waters, including of commercially important species.

For the limited resources available in the Phase II of this project in the Marine Biodiversity Hub it is proposed to focus on the Corner Inlet-Nooramunga region of Gippsland and determine:

- Estimates of the $ value of this resource for commercially important species as a subset of their total value in ecosystems services; and
- The opportunities for repair, enhancement and protection of these coastal wetland systems, including re-establishing tidal hydrology and changes to land use.

6. TASMANIA

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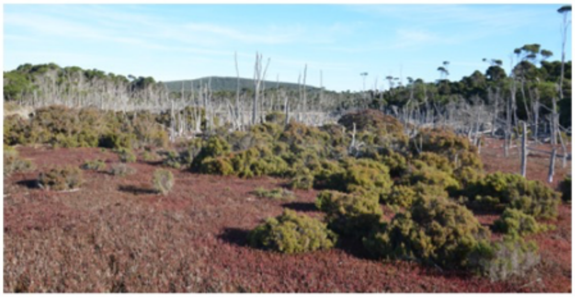
Tasmanian saltmarshes

Saltmarshes in Tasmania are formally defined and mapped by their vegetation communities as outlined by the Tasmanian Vegetation Monitoring and Mapping Program (TASVEG, Kitchener and Harris, 2013). Tasmanian coastal saltmarshes include two TASVEG community types (listed below) and can often occur with tidal freshwater marshes and/or *Melaleuca ericifolia* swamp forests (Figure 4). Mangroves are absent in Tasmania.

Succulent Saline Herbland (ASS)
Vegetation dominated by herbaceous species growing on the margins of highly saline, protected, flat estuarine shorelines inundated with sea water during high tides, dominated by halophytic plants, predominantly *Sarcocornia quinqueflora* and/or *Tecticornia arbuscula*.

Saline Sedgeland/Rushland (ARS)
Vegetation dominated by sedges, rushes and occasionally tussock grasses growing in highly saline environments, often inundated by tidal water, dominated by halophytic plants, predominantly *Juncus kraussii* and *Gahnia filum*, sometimes *Austrostipa stipoides*. Some succulent species may be intermixed.



Succulent saltmarsh in North East River, Flinders Island, domniated by Shrubby Glasswort *(Tecticornia arbuscula)* and Beaded Glasswort *(Sarcocornia quinqueflora)*

Grassy saltmarch in Scamander River on the east coast of Tasmania, dominated by Sea Rush *(Juncus kraussii)* and Chaffy Sawsedge *(Gahnia filum)* with Beaded Glasswort understorey.

Figure 4. Saltmarshes in a typical coastal landscape (above). Tasmanian coastal saltmarshes are defined and mapped by two vegetation community types: succulent saltmarsh (ASS) dominated by herbs and shrubs; and grassy saltmarsh (ARS) dominated by rushes and sedges

Presumed extent

The natural extent of Tasmanian coastal saltmarshes is presumed to be about 5,000 ha (Figure 5). This estimate excludes tidal freshwater marshes adjacent to saltmarshes, and several inland saltmarshes occurring in saline depressions, which are *not* inundated by tidal water. The most extensive saltmarshes occur in the southeast, east, north and northwest parts of the state, as well as Flinders Island, where favourable landform settings are present (i.e. protection from high energy swell waves). These areas also have a favourable climate characterised by relatively low rainfall (average range between 500 mm/yr. in the southeast to 1000 mm/yr. in the northwest) and high evaporation rates suitable for saltmarshes. For these reasons, saltmarshes are relatively uncommon along the expansive high-energy open shorelines along the west and southwest coast, which also receive heavy rainfall.

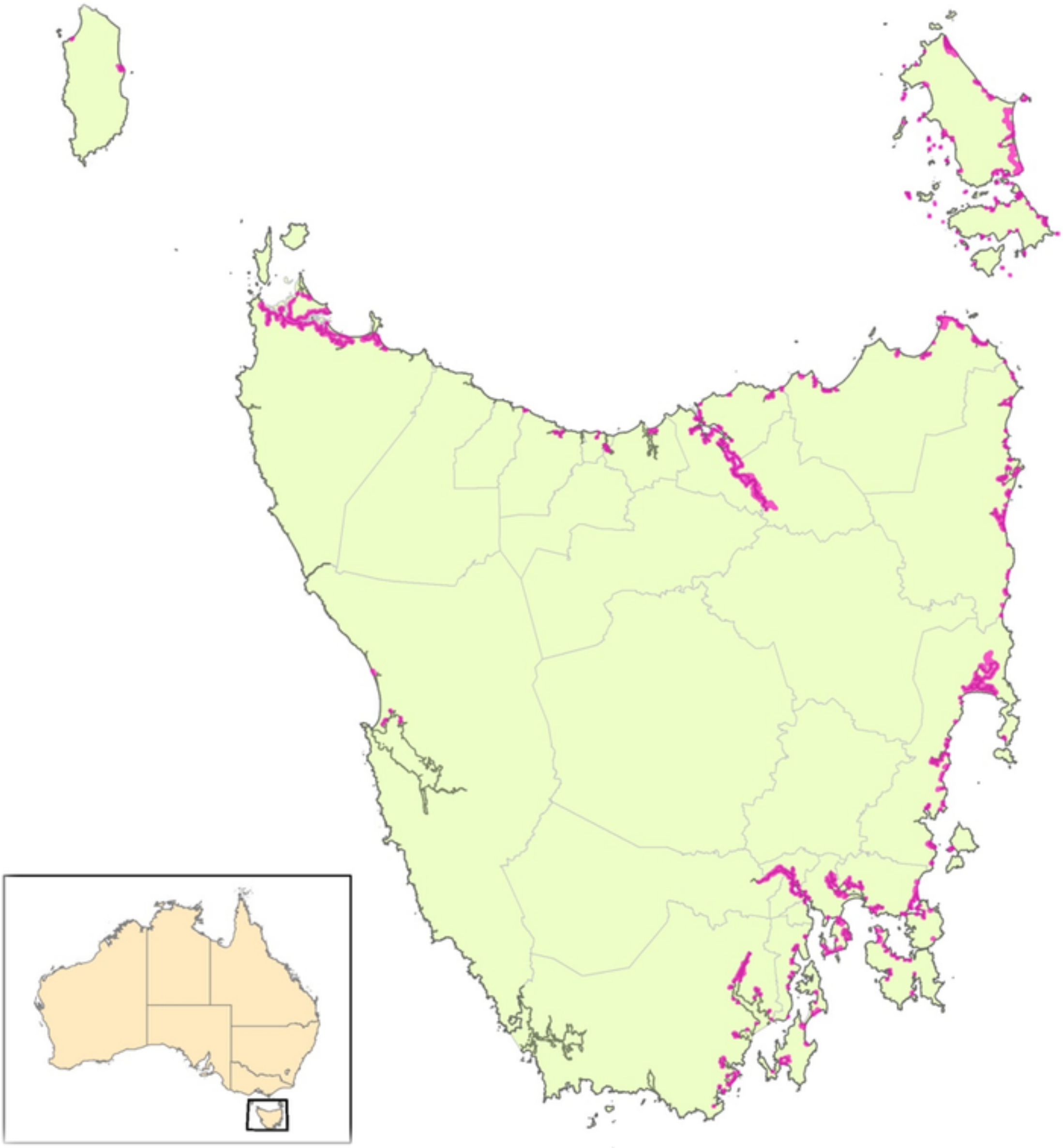


Figure 5. Distribution and extent of Tasmanian coastal saltmarshes (data sourced from Prahalad 2014b, Prahalad and Pearson 2013, Mount et al. 2010 and TASVEG ver 3.0 theLIST, ©State of Tasmania). The areas shown here also include tidal freshwater marshes of the Derwent, Huon and Tamar estuaries and the Apsley Marshes

Ecological decline

Tasmanian coastal saltmarshes have been subject to widespread decline both in natural extent and ecological function. Losses in natural extent are where saltmarsh wetlands have been converted to other land uses. These losses have been categorised as being either reversible (e.g. agricultural land, public open spaces) or irreversible (e.g. roads, buildings, rubbish tips). Estimates of this loss vary across regions depending on the extent of historical land development and available data (for a summary, see Table 2).

Table 2. Types and magnitude of saltmarsh loss and degradation between 1952 and 2006. Percentages presented distinguish between the area of saltmarsh lost and degraded from a historic baseline (1952-2006) and current baseline (2006). Table 2 reproduced from Prahalad (2014a)

Type of saltmarsh loss (1952-2006)	Area (ha)	% of historic loss (1952-2006)
Loss on landward side due to levees	152	70%
Loss on seaward side due to levees	38	17%
Land clearing not associated with levees	18	8%
Expansion of Melaleuca ericifolia	11	5%
Total area of saltmarsh lost from a historic baseline (1952-2006)	219	16%
Type of saltmarsh degradation (2006)	Area (ha)	% of current extent (2006)
Saltmarshes associated with levees	218	19%
Saltmarshes associated with ditches or/and levees	629	55%
Saltmarshes without a contiguous vegetative buffer zone	505	44%
Saltmarshes affected by grazing in the absence of other major impacts	104	9%
Saltmarshes affected by rice grass (*Spartina anglica*)	93	8%
Estimated area of current saltmarsh extent associated with recorded human impacts (levees/ditches/buffer zone removal/grazing/rice grass)	752	65%
Estimated area of saltmarsh either lost or degraded from a historic baseline (1952-2006)	971	71%

Even where saltmarshes currently occupy their natural extent, they have experienced degradation and decline in ecological function though both direct human impacts and global changes. Degradation through direct human impacts includes (Prahalad, 2014a):

- Inappropriate development through landfill, tidal restriction (building levees and other tidal barriers);
- Nutrient enrichment from human activities such as farming or industrial effluents causing nuisance algal blooms and rotten spots;
- Livestock (cattle, sheep and horses) grazing and trampling on the saltmarsh removing plant biomass, disturbing the soil and clogging up the tidal channels;
- Use of off-road vehicles that cause plant die-back and soil compression;
- Introduction and spread of invasive species such as rabbits, pigs and a suite of weeds that displace native species;
- Dumping of rubbish (other than as landfill), both in-situ and ex-situ, including unmanaged waste drift from adjacent oyster farms;
- Land clearing of upland fringing vegetation along the saltmarsh boundary (this can range from 50 – 200m depending on the size of the saltmarsh and the upland land use activities); and
- Lack of sympathetic management in low lying landward areas to accommodate the natural saltmarsh response to sea level rise as they move upland and inland.

Saltmarshes have also experienced degradation due to the effects of climate change and relative sea level rise, causing edge retreat, creek widening, and loss of vegetation evidenced through increased bare spots (Prahalad et al., 2011, 2015a).

Surrogates for saltmarsh community value

Tasmanian coastal saltmarshes provide a range of ecosystem services (Figure 6), many of which are still poorly recognised and none quantified in monetary terms. A notable example is birdlife and associated bird watching and duck hunting activities:

- Bird watching is an important recreational and commercial activity in Tasmania. A recent inventory of bird use of Tasmanian saltmarshes identified a total of 113 avian species using saltmarshes, representing 12 orders and about 30 families (Prahalad et al., 2015b). Notably, they provide critical habitat for White-fronted Chats (*Epthianura albifrons*), which have experienced decline in mainland Australia;
- Recreational duck hunting in Tasmania targets five species of waterfowl, of which the Mountain Duck (Australian Shelduck), Chestnut Teal and Grey Teal are highly dependent on saltmarsh habitats (Prahalad et al., 2015b). Almost all major saltmarshes in the state have duck-hides (Prahalad, pers. obs.).

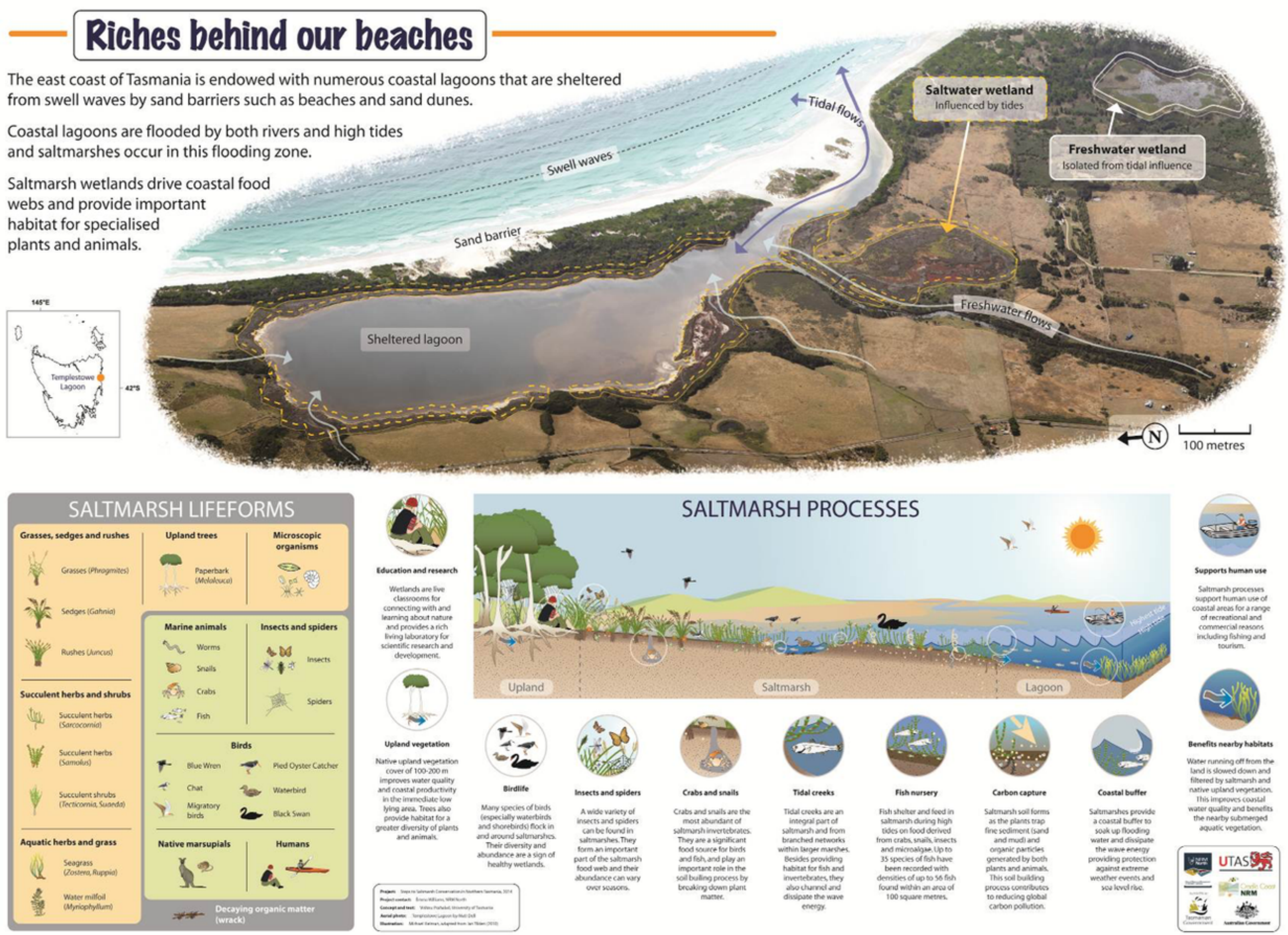


Figure 6. Conceptual diagrams of saltmarsh components and processes typical of Tasmanian coastal saltmarshes

Case for fish use of saltmarshes as a surrogate

In Tasmania the use of saltmarshes by fish species is not well documented with no published account known of except for a few surveys targeting particular species (P. Davies, pers. comm.). Anecdotal evidence from observing low marshes (inundated by the high tide on a daily basis) and tidal creeks (during high tides and also at low tides in water filled depressions) suggests extensive use by smaller fish (Prahalad, pers. obs., Figure 7).

In comparison, evidence from mainland studies reporting on the use of comparable temperate saltmarshes by Australian fish species suggest that up to 35 species have been recorded with densities of up to 56 fish found within an area of 100 m^2 (reviewed by Connolly, 2009). This conforms with the general expectation that saltmarshes and the associated tidal creeks and pools provide secure habitat for smaller fish to evade predation risk in the open sea (e.g. Deegan et al., 2000), and has been highlighted as a research need for Australian saltmarshes by Connolly (2009).

Saltmarshes are documented to produce organic materials (plant and animal matter) that are exported to coastal waters through tides, thus improving coastal productivity (Valiela et al., 2000). There is evidence for this from Australian mainland studies indicating that saltmarshes drive fish productivity through exporting high concentrations of crab and gastropod larvae from the saltmarsh providing food for fish species (Mazumder et al., 2009). Gut content analysis of the extremely abundant Port Jackson glassfish (*Ambassis jacksoniensis*) indicated that crab larvae in the saltmarsh provided a predominant food source (Mazumder et al., 2006). When the glassfish retreat back to the deeper waters at low tide they in turn form an important food source of larger fish, thereby driving coastal fish productivity. Another study by Crinal and Hindell (2004) documented 10 species of juvenile and sub-adult fish in temperate Australian saltmarshes feeding primarily on amphipods and hemipteran insects.

There is an important need for generating baseline data on fish use of Tasmanian saltmarshes and alongside trialling fish sampling techniques that are suitable for specific local conditions (e.g., flooding regime, landscape structure, fish size; Connolly, 1999; Mazumder et al., 2005; Connolly, 2009).

Figure 7. Left: Typical fish habitat in a saltmarsh submerged during high tide. Right: School of glassfish found in a saltmarsh during high tide

Opportunities for repair

Repair efforts of saltmarshes should aim to promote both increases in extent (where past losses are reversible) and functional health (where degradation has occurred due to direct human impacts). Studies from the southern (Prahalad and Pearson, 2013), northern (Prahalad, 2014b) and northwestern regions (Prahalad 2014a, Table 2) identify that agricultural levees are the single most important factor involved in saltmarsh loss and degradation.

The foremost areas in the state for levee removal are the Circular Head coast of far-northwest Tasmania (with 27 kms of levees), and the Pitt Water area of southeast Tasmania (with 2.5 kms of levees). Notably in the Pitt Water area, a single 100 m long levee affects 40 ha of saltmarsh area and the landowner has expressed interest in supporting on-ground works to provide larger culverts for tidal flow (pers. comm.). Facilitation of this activity would require funding for flood modelling, coordination with the landowner, undertaking the on-ground works, and follow-up monitoring.

Other key areas in the state that could benefit from on-ground works to improve tidal flushing are: Lauderdale saltmarsh, Ralphs Bay; Sherbourne Bay area of Moulting Lagoon; George River saltmarshes near St Helens, Georges Bay; Middle Point, Tamar Estuary. Selection of priority areas for saltmarsh repair must consider opportunity costs for achieving landowner engagement in the restoration process, and coupled with an assessment of ecosystem services to be derived for the promotion of saltmarsh community values.

Protecting and managing saltmarshes

Saltmarshes in Tasmania fall under several land tenures and management regimes. In the Southern NRM Region, about 74% of the total mapped area fall either entirely or partly within private land (Prahalad and Pearson, 2013). In the Northern NRM Region, 44% of saltmarshes fall either entirely or partly within private land (Prahalad, 2014b). Engagement with the State and Local governments, especially ensuring their protection within the relevant planning scheme, is crucial for the protection of these saltmarshes.

Tasmania does not recognise the saltmarsh ecosystem as threatened, but affords protection for several flora and fauna associated with saltmarshes through the *Threatened Species Protection Act 1995*. In addition, the State and Local governments own a considerable proportion of saltmarshes and are responsible for their ongoing protection and management. In the Southern NRM Region for example, about 23% of the total mapped area is managed by the Tasmanian Parks and Wildlife Service under the *National Parks and Reserves Management Act 2002*.

Non-regulatory approaches also play an important role in saltmarsh protection and management in Tasmania. For example, the Tasmanian Land Conservancy owns and manages several saltmarshes including the single largest patch in Tasmania, Long Point in Moulting Lagoon. As another example, a local Landcare group has entered into a private land-management agreement with a landowner to protect and improve the functional health of a saltmarsh in Ralphs Bay, Derwent Estuary.

Action Plan

Immediate

- Complete state-wide mapping and inventory of the current extent of saltmarshes (ongoing project due for completion in April 2016);
- Complete state-wide assessment of saltmarsh loss and degradation due to direct human impacts for targeting restoration activities (ongoing project due for completion in April 2016);
- State-wide extension of modelling and development of 'coastal refugia' planning overlay currently available for much of the Southern NRM Region area;
- Actively engage with the ongoing Planning Reform in Tasmania and integrate current saltmarsh extent and coastal refugia planning overlay in the forthcoming Tasmania-wide planning scheme;
- Continue state-wide roll-out of community-based saltmarsh monitoring tools (including a web app under development) and associated media and community engagement activities.

Short term

- Undertake studies on fisheries productivity in key locations, especially in areas where scope for restoration work is recognised;
- Engage with targeted landowners who own and manage areas where saltmarsh conservation and restoration work is recognised;
- Develop a system of payment for ecosystem services for landowners who would be affected financially through saltmarsh restoration works;
- Ensure that current and modelled future extent of saltmarshes is recognised for protection under the new Tasmania-wide planning scheme.

Long term

- Extend saltmarsh restoration to cover all coastal regions of Tasmania, including regeneration of a protective buffer zone of native upland vegetation;
- Continue state-wide community-based monitoring of saltmarsh condition and values linked with media and community engagement activities.

Concluding comments

Saltmarshes form an integral component of the Tasmanian coastal landscape (as depicted in Figure 6), and are important for the delivery of a range of ecosystem services in the coastal and marine context. The area of saltmarsh that has experienced degradation is much greater than the still quite substantial area irrevocably lost since European settlement. This highlights both the need and potential for reversing functional degradation by undertaking saltmarsh repair. This includes the re-instatement of natural tidal regimes, provision of buffer zones, planning for landward retreat areas, exclusion of grazing, restriction of vehicle access, local waste disposal management, and catchment management for nutrients and sediment.

Of particular and immediate concern for repair and protection of Tasmanian saltmarshes are:

- Protection of existing saltmarshes and coastal refugia areas through the new Tasmania-wide planning scheme;
- Restitution of natural tidal regimes through targeted on-ground works, especially focussed on the Circular Head coast and Pitt Water area;
- Ongoing community engagement for bottom-up in-kind support for community-based saltmarsh monitoring, on-ground works (weeding, re-vegetation), and advocacy for regulatory and fiscal support for saltmarsh repair and protection.

For the Phase II component of the Marine Biodiversity Hub project and the limited resources available it is proposed to focus on:

1. Preparing based on assumptions and known life history features of key fish and crustacean species a set of summary food chains that demonstrate coastal productivity benefits and provide estimates of the likely value per hectare of repaired saltmarshes;
2. Apply these findings to both the Circular Head and Pitt Water sites to demonstrate the likely return on investment of repair activities; and
3. Support the completion of state-wide assessment of saltmarsh loss and degradation due to direct human impacts for targeting broader restoration activities.

7. NEW SOUTH WALES

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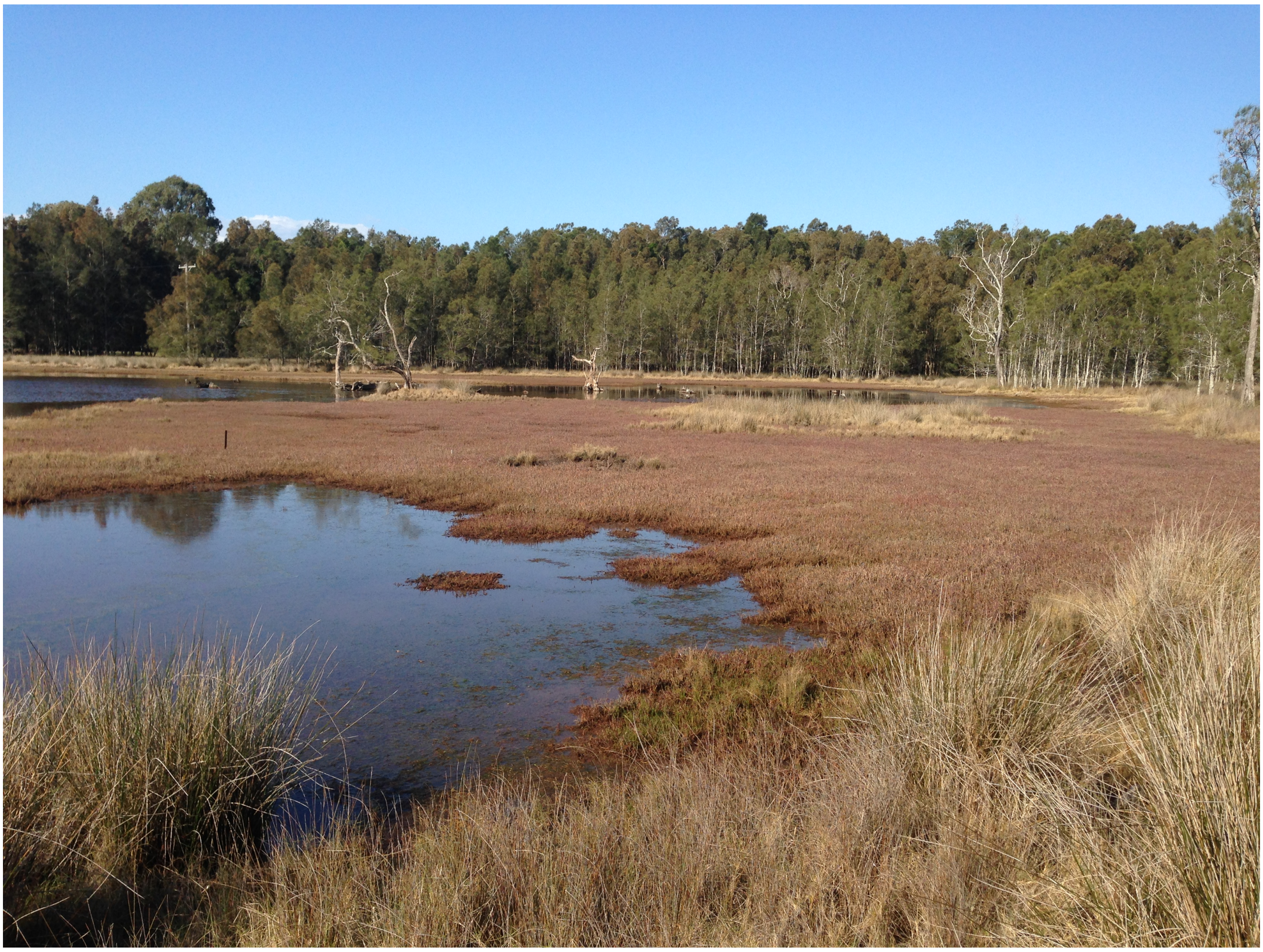
Extent and change

Coastal saltmarsh has historically been undervalued and as a result many areas of saltmarsh in New South Wales have been lost or become fragmented and degraded with a resulting reduction in their extent and the important ecosystem services that they provide.

Numerous studies have tracked the decline of saltmarsh extent in NSW, with Wilton (2002) recording catchment losses ranging from 12% in Swansea Channel, Lake Macquarie, to 97% in Careel Bay, Pittwater. Factors leading to this decrease include widespread reclamation for urban and rural development, physical and chemical damage and weed incursions. In coastal floodplains, extensive flood mitigation, drainage and levee activities have led to large-scale changes in hydrological and connectivity. Mangrove incursions into saltmarsh following changes to tidal prisms and catchment changes have also contributed to losses, for example, since 1941 50% of saltmarsh at the Hawkesbury River mouth have been replaced by mangroves (Williams and Watford 1997).



Healthy saltmarsh. *P. Dwyer*

Saltmarsh Functions

Ongoing research by NSW DPI due for completion in 2016 is using stable isotopes to uncover the economic value and benefits of coastal wetlands for dependent (and commercially valuable) species of crustaceans such as Eastern King Prawn (*Penaeus plebejus*) and School Prawn (*Metapenaeus macleayi*) (FRDC 2013/006). The impact of habitat loss and rehabilitation on recruitment to the NSW eastern king prawn fishery). Preliminary results indicate that a range of non-commercially targeted species dominate the upper saltmarsh areas.

Previous work has demonstrated that the restoration of tidal flows to Hexham Swamp (Hunter River, Boys 2015) has led to a significant expansion in the distribution and abundance of both school and eastern king prawns. The saltmarsh components of these wetlands are a critical primary and secondary source of food and nutrients that drive the productivity of the estuary, with evidence such as high crab larvae concentrations in water and fish stomach contents moving off saltmarshes (Mazumder 2004). Further investigation of the extended trophic links from the primary productivity of saltmarshes driving the productivity of commercial and recreationally important species is warranted.

Protecting NSW Saltmarshes

Saltmarsh is protected under the *Fisheries Management Act,* 1994 and is also recognised as an Endangered Ecological Community under the *Threatened Species Conservation Act* 1995. Permits are required to undertake any works that may impact on saltmarsh. The Acts also provide opportunities for mitigation measures and offsets to be included in any determinations.

There are also a range of statutory and non-statutory means in NSW to encourage improved management and protection of saltmarsh by private landholders such as the state Biobanking scheme and conservation covenant arrangements, or management agreements associated with a range of financial incentive options. The recently enacted *Marine Estate Management Act* 2014 offers opportunities to facilitate a whole of government response to identified key threats to marine systems. While the formal threat and risk assessment and strategy process is not yet completed (October 2015), feedback is already highlighting the need to provide a greater emphasis on protecting and rehabilitating estuarine habitat, including saltmarsh.

Repairing NSW saltmarshes

Given the significant historic loss of saltmarsh, the opportunities for repair are extensive and necessary, and largely involve restoring natural hydrology. Some key sites have already been identified and are currently becoming more realistic for action in NSW with the support of a range of stakeholders, including the recreational and commercial fishing sectors. These include major floodplain wetlands (e.g. Tuckean Swamp, Everlasting Swamp, the Collombatti-Clybucca) and deltaic islands in the lower section of most estuary floodplains areas (e.g. around Wooloweyah Lagoon, Clarence; Macleay, Hastings, Shoalhaven).

A proven technique, applied in recent years to Hexham, Tomago, Big Swamp and other areas in NSW for large-scale floodgate and estuarine floodplain management and wetland rehabilitation (Rayner and Glamore 2011; Glamore *et al*. 2012, 2014), uses a process of hydrological and hydrodynamic modelling to fully understand the likely changes in flooding and salinity from a range of management options. This is developed in partnership with local authorities and landholders before a particular option for on-ground works is selected and implemented. This technique is essential for large sites and is recommended as part of the planning towards wetland and estuary repair.

Using the established planning, regulation and incentive mechanisms alone will not be enough to ensure adequate recovery of saltmarsh in NSW. Targeted hydrological restoration projects are required to maximise the opportunities to repair NSW estuaries and their productivity. The multiple benefits of repair include overall estuary health, jobs in fisheries productivity, tourism and recreational services, enhanced biodiversity such as birdlife, water quality, flood control and water storage to minimise flood peaks and impacts on infrastructure, carbon sequestration and various other ecosystem service benefits flowing from saltmarsh repair. By accurately quantifying these benefits estuary-by-estuary business cases can be developed.

Effects of fencing. *K. Russel*

Action Plan for Marine Biodiversity Hub follow-on investment

Progressing the recovery and protection of NSW estuaries and their key habitats such as saltmarshes will require:

- Better articulation of the likely benefits of repair to coastal communities;
- Research to underpin and provide the evidence base for these various benefit statements;
- A suite of revenue generation mechanisms to provide the necessary resources for activities such as acquisition, change of land use and remedial works.

Phase II of this Marine Biodiversity Hub project, with its limited resources, can most usefully contribute to this long-term agenda by developing an assumption-based set of metrics for the likely benefits of repair to school prawn productivity and supporting broader food web.

Fresh to brackish wetlands, saltmarshes and mangroves all form a mosaic continuum of vegetation, water, diatoms, phytoplankton and shelter - all elements of the food chain towards school prawn productivity. This small research project will build on prior research, be based on the well documented life history of school prawns, be applied to a nominal representative mosaic of connected wetland ecosystems, and provide estimates of the likely range of school prawn potential productivity with repair with all errors specified.

This information can then be used as an input to the overall benefit assessments in any business case. The companion HSBC funded TNC project in Mapping Ocean Wealth will attempt to provide similar estimates for other potential benefits. Should supplementary funding become available, these resources would be used to support the completion of the state-wide identification and prioritisation of areas of public and private saltmarsh rehabilitation opportunities so that a state-wide blueprint for repair could then be developed.

8. QUEENSLAND - DEVELOPING SIMPLE INDICES FOR SALTMARSH COMMUNITY VALUE

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Presumed extent

It is estimated that prior to European settlement saltmarsh covered 738,691ha of Queensland's coast. In 2013, the total area of saltmarsh was 703,029ha or 95.2% of the pre-clear area (Neldner *et al.*, 2015). This equates to a loss of around 35,000ha of saltmarsh since European settlement.

The most extensive saltmarsh communities occur in the dry or seasonally dry areas along Queensland's coast (Figure 8):

- The Gulf of Carpentaria: 58% of Queensland's saltmarshes (Neldner *et al.*, 2015) and one of the largest areas of saltmarsh in Australia (Johns, 2006);
- The Brigalow Belt bioregion: 20% of Queensland's saltmarshes in the Fitzroy River Delta and Broad Sound and between Townsville and Bowen;
- Cape York Peninsula: 15% of Queensland's saltmarshes (Neldner *et al.*, 2015).

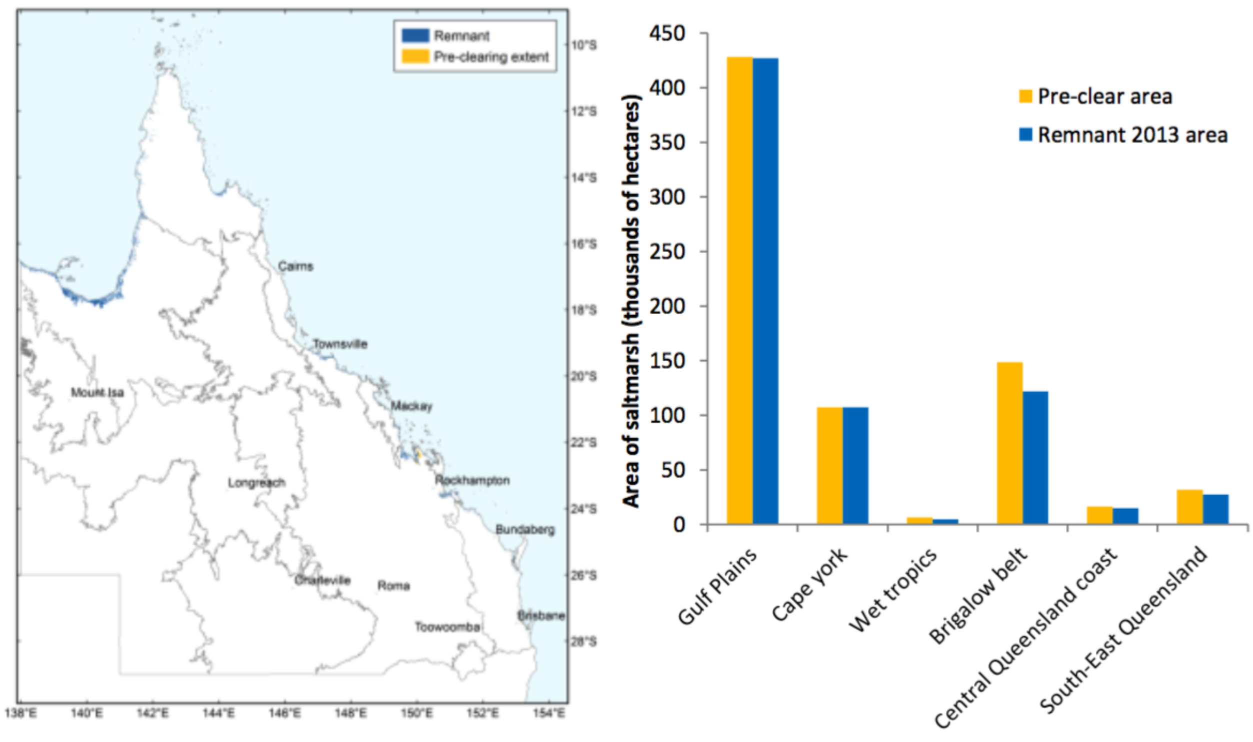

Figure 8. Map and chart showing remnant (2013) and pre-clear extent of saltmarsh in Queensland bioregions. Source: Nelder et al (2015) and Accad and Neldner (2015)

Ecological decline

Since European settlement, Queensland's saltmarshes have been lost or degraded through coastal agriculture, urban and industrial development, including:

- Ponded pastures: The construction of tidal bunds to create ponded pastures for cattle grazing. Extensive areas of intertidal habitat in the Fitzroy River Delta and Broad Sound were lost, with around 6,500ha lost in the Broad Sound (Bruinsma, 2000);
- Salt works: Around 2,890ha or 11% of saltmarsh at the mouth of the Fitzroy River was converted to salt evaporation ponds (Bruinsma, 2000);
- Industrial, infrastructure and urban development: 1,342 hectares or 34.8% of saltmarsh in the Port Curtis region was lost between 1941 and 1999 (Duke *et al.*, 2003). Approximately 3,000ha was lost in Moreton Bay between 1974 and 1998 due to reclamation for airport, industrial and canal estate development and mangrove encroachment (Duke *et al.*, 2003).

There has been minimal loss of saltmarsh in the Gulf of Carpentaria, with almost 100% of the pre-clear area remaining (Accad and Neldner, 2015).

Current and future threats to Queensland's saltmarshes include:

- Urban and industrial development
- Encroachment by agricultural and grazing land uses
- Eutrophication from urban, aquaculture and agriculture discharge or run-off
- Oil spills and other toxicants
- Fragmentation and disruption to connectivity due to barriers
- Shifts in communities and ecosystem function due to climate change
- Alterations to communities and ecosystem function due to invasive species
- Rubbish dumping and vehicular access (Jaensch 2005).

Prawn productivity as a surrogate for broader ecosystems services

Saltmarsh is important for fish and invertebrates, many of which are targeted by commercial, recreational and Indigenous fishers. Banana prawns (*Fenneropenaeus merguiensis*) have a particularly strong affinity for estuarine wetlands, with offshore catch per unit effort positively correlated with the area and perimeter of mangroves in different estuaries (Manson *et al.*, 2005). Within estuaries the extent of intertidal habitat and sediment type are stronger indicators for banana prawn catch (Sheaves *et al.*, 2012). Therefore, to determine banana prawn productivity, the mosaic of intertidal habitats, including mangrove, saltmarsh, mud banks and sand bars should be considered as a whole (Figure 9).

Figure 9. Aerial image of an estuary south of Townsville, showing the mosaic of intertidal habitats important for banana prawn production. Source: Department of Agriculture and Fisheries

Sheaves *et al.* (2012) surveyed and recorded biomass and density of *F. merguiensis* in 21 creeks between Cairns and Mackay. Sampling was conducted at low tide and involved cast netting (2.4m radius, 5mm mesh) along mangrove forest edges. The results provide an estimate of the density of banana prawns in the particular 'low tide habitat' sampled, i.e. the mangrove edges and banks used at low tide when prawns cannot access intertidal wetlands. Further research is needed on the use of different wetland habitats by banana prawns, including how prawns exploit various wetlands under a range of hydrological and tidal conditions. In the absence of this knowledge, only banana prawn density in the low tide habitat can be estimated, recognising that there is a link to the intertidal areas that drain to this habitat as the tide recedes. Therefore, the survey results can only be used to provide a rough, conservative estimate of the standing stock in an estuary.

Based on these limitations and the set of assumptions shown in Table 3, it is estimated that individual estuaries along Queensland's east coast produce an average minimum of 365 kg (±157) of banana prawns annually. This equates to an annual banana prawn productivity worth at least $7600 per estuary based on a market value of $21/kg.

Each estuary differs in terms of the area and composition of the intertidal wetlands leading to differences in prawn density and biomass, as shown in Manson *et al.* (2005). Of the estuaries used in the analysis, the estimated annual biomass exported ranged from 215 kg in Constant Creek, near Mackay (length of both banks =60 km, intertidal habitat area =2111 ha) to 570 kg in Barratta Creek, near Townsville (length of both banks =100 km, intertidal habitat area =4059 ha). As these estimates are based on low tide habitat alone, which is only a small proportion of each estuary, the actual biomass is likely to be significantly higher.

Table 3. Calculations and assumptions used to estimate annual banana prawn production

Calculations and assumptions
Five estuaries were selected from the Wet Tropics, Burdekin Dry Tropics and Mackay Whitsundays regions covering the range of banana prawn biomass and density results. The length (in metres) of both banks of each estuary was calculated using Google Earth and divided by 4.8 (cast net diameter).
This length was multiplied by the mean density of banana prawns sampled in each estuary to estimate the total density of banana prawns within each estuary. The numbers of juvenile prawns caught in 2007 was assumed to be representative of an average year, although it is known that banana prawn productivity varies considerably from year to year based on rainfall and river flow (Vance *et al.*, 2003).
The total density was multiplied by 0.6, assuming 60% of the juvenile banana prawns would survive and be exported to the fishery (based on a $0.02week^{-1}$ mortality (Wang and Haywood, 1999) over six months).
The number of prawns was multiplied by 25 to give the total biomass exported to the fishery assuming these prawns would reach 25 g (average market range is 20-30 g (Sydney Fish Market, 2015).
The mean and standard deviation of total biomass of banana prawns exported from these estuaries was calculated to give an estimate for other east coast estuaries. It was assumed that the biomass, count and size class of banana prawns in the estuaries sampled is comparable to other estuaries along the east Queensland coast.
Market price of $21/kg for green banana prawns (Ruello & Associates Pty Ltd, 2010).

Saltmarshes in Queensland provide a range of other ecosystem services including:

- Habitat for a range of species of value to commercial, recreational and Indigenous fishers, including barramundi, mangrove jack and mud crabs (Meynecke *et al.*, 2008);
- Supporting terrestrial and aquatic biodiversity including the critically endangered Capricorn (Dawson) subspecies of yellow chat (*Epthianura crocea macgregori*) and the bare-rumped sheathtail bat (*Saccolaimus saccolaimus nudicluniatus*) (Department of the Environment, 2015b);
- Improving water quality by trapping sediments and nutrients and organic carbon from catchment, riverine and oceanic sources (Mcleod *et al.*, 2011);
- Protection of coastal assets from natural hazards such as cyclones and storms;
- Cultural and social values;
- Carbon sequestration and storage (Jaensch, 2005).

Opportunities for repair

Large areas of estuarine wetlands have been lost along the Great Barrier Reef coast (Sheaves *et al.*, 2014), with potential impact on this iconic World Heritage-listed asset. The greatest losses have been in the Fitzroy Region, with 17% of estuarine wetlands lost, primarily as a result of conversion to ponded pastures. The strategic removal of bund walls in the Fitzroy region (e.g. Fitzroy River Delta, Corio Bay and Broad Sound) could facilitate saltmarsh restoration with associated fisheries and environmental benefits. The physical works to remove or modify bund walls can be relatively inexpensive (Figure 10). Nevertheless, landholder involvement is essential and incentives may be needed.

Figure 10. The removal of bunds such as this, can facilitate saltmarsh repair. Source: GBRMPA

Based on the banana prawn productivity estimate, restoring habitat condition and connectivity to just 20% of ten estuaries on the east Queensland coast could potentially increase the banana prawn stock by over 730 kg a year. This equates to an annual production worth over $15,000 in banana prawns alone, which would exceed the original investment in repair works in the short term. Analyses to determine the precise returns on investment would be required site by site. This should include an economic cost-benefit analysis of ponded pasture bund removal that included both fisheries benefits and any lost grazing production.

Priority should be given to restoring areas that:

- Have high potential fish habitat value (e.g. adjacent to declared Fish Habitat Areas);
- Could provide suitable habitat for the dawson chat (*E. crocea macgregori*), bare-rumped sheathtail bat (*S. saccolaimus nudicluniatus*) or migratory birds; and
- Would have minimal impact on landholders and neighbouring properties.

When assessing options for wetland repair, there also needs to be an evaluation of the current and potential ecosystem services provided by the target coastal wetland complex. This needs to be inclusive of freshwater and estuarine communities. For example, in some catchments ponded pastures may now be partially compensating for the historic loss of up to 60% of freshwater wetlands in catchments adjacent to the Great Barrier Reef (Great Barrier Reef Marine Park Authority, 2012). In these areas, ponded pastures may be providing replacement freshwater fish and bird habitat, if fish passage is adequate and weeds are controlled (Figure 11). Multi-objective and landscape scale approaches to deliver a range of ecosystem services should be considered such as fish passages, habitat maintenance, facilitating nutrient assimilation and sediment trapping and ventilation by tidal water.

Figure 11. Ponded pastures can potentially provide freshwater fish and bird habitat if weeds, water quality and fish passage are managed. Source: Department of Agriculture and Fisheries

Protecting and managing salt marshes

Queensland has a range of legislative measures aimed at protecting and minimising impacts on estuarine wetlands including saltmarsh:

- The *Fisheries Act 1994* protects all marine plants (i.e. those growing on or adjacent to tidal lands) in Queensland, regardless of land tenure. There are additional protections for declared Fish Habitat Areas - areas of particularly high value to Queensland's commercial, recreational and Indigenous fisheries (Figure 12);
- *Ponded Pastures Policy 2001* precludes the construction of ponded pastures on tidal areas, in wetlands or other fish habitats (Challen and Long, 2004);

- *Sustainable Planning Act 2009* regulates coastal development (Department of Environment and Heritage Protection, 2014);
- *Environment Protection and Biodiversity Conservation Act 1999* protects the Ramsar wetlands, listed migratory species, threatened species and World Heritage Areas in Queensland.

  Although existing saltmarsh communities are protected under legislation, stronger policies, planning and adaptation strategies are needed to ensure buffers are set aside for landward migration of coastal wetlands with sea-level rise (Beumer *et al.*, 2012).

Figure 12. All marine plants in Queensland, including saltmarsh and mangroves, are protected under the *Fisheries Act 1994*. *T. Baumgaertner*

Action Plan

Listed below are recommendations to maintain and where possible restore the ecosystem services and productivity of Queensland's saltmarshes.

Immediate actions

- Identify suitable sites for tidal bund removal in the Fitzroy region and work with the community to undertake repair works;
- Using these as case study sites, undertake a cost benefit analysis of the economic and ecosystem service benefits including the improvements to primary productivity;
- Undertake research to assess the use of different coastal wetland habitats by prawns and other fish species to estimate the relative productivity and connectivity of saltmarsh, mangrove, mud/sand flat and adjacent freshwater wetlands.

Short to medium term actions

- Identify possible saltmarsh restoration sites as part of a strategic planning process to identify sites suitable for restoration or buyback as part of Queensland's environmental offsets framework;
- Ensure plans for new development in the Gulf of Carpentaria, as part of the *Developing Northern Australia* initiative take into account the value of saltmarsh and wherever possible do not alter saltmarsh habitat or hydrology;

- Strengthen planning and legislation to provide buffers to allow for the landward migration of coastal wetlands with sea-level rise.

Long term actions

- Supplement the 1:100,000 scale mapping of regional ecosystems with 1:10,000 scale mapping to enable finer scale monitoring of estuarine wetlands;
- Monitor saltmarshes to assess the capacity of saltmarsh to migrate landward and achieve functional equivalency under sea-level rise.

Concluding comments

Since European settlement, 43,000 ha of estuarine wetlands (saltmarshes and mangroves) in Queensland have been lost (Accad and Neldner, 2015). Using banana prawns (*F. merguiensis*) as an indicator of productivity, it is estimated that individual estuaries on Queensland's east coast can produce a minimum of 365 kg (±157) of banana prawns each year, worth over $7600. Restoring habitat condition and connectivity in these estuaries could increase the banana prawn stock and provide annual returns that could rapidly offset the original cost of restoration activities.

There is a need to continue protecting remnant saltmarsh habitat from coastal development pressures, through existing legislative controls under the *Fisheries Act 1994*. The relatively intact saltmarshes in the Gulf of Carpentaria need to be protected from disturbance and hydrological impacts associated with new development as part of the *Developing Northern Australia* initiative. Stronger policy and planning mechanisms are required throughout Queensland to provide for landward migration of coastal wetlands with sea-level rise.

The greatest losses of saltmarsh, mud flats and accompanying mangrove lined tidal channels have been in the Fitzroy region through conversion to ponded pastures for cattle grazing. There are opportunities for saltmarsh repair, through the strategic removal of some of these ponded pasture bunds. This would increase fisheries productivity and provide a range of other ecosystem services.

For the limited resources available in Phase II of this Marine Biodiversity Hub project the focus will be on:

- Identifying suitable sites for tidal bund removal in the Fitzroy region, in conjunction with natural resource management groups and the community;
- Using restoration sites as case studies, where available, to undertake a cost benefit analysis of the economic and ecosystem service benefits of coastal wetland repair

  If additional funding were available, research could be conducted to assess the use of different coastal wetland habitats by prawns and other fish species to estimate the relative productivity and connectivity of saltmarsh, mangrove, mud/sand flat and adjacent freshwater wetlands.

9. BUILDING THE KNOWLEDGE

Australia's saltmarshes – our knowledge

This report set out to provide both the context and state-by-state summary and analysis of knowledge on saltmarshes. Particularly the focus is on providing knowledge on the benefits of saltmarshes as input to the business case for greater investment in saltmarsh restoration and protection.

For Australia's saltmarshes and for seascape landscapes generally, information is readily available on vegetation types and the mix of species that make up the mosaic of wetlands from mangroves through the tidal height spectrum of inter-tidal, to supra-tidal and highest astronomic tides to the fresh water systems of sedges, reeds, and *Melaleuca* dominated wetlands. For most states, these vegetation types are reliably mapped and spatial data sets are readily available. Likewise, for most states the areas of wetland loss can be broadly estimated and the cause of loss detailed. Similarly, current threats to wetland integrity are well documented. In states such as New South Wales and Queensland, this information has also led to various mechanisms to protect remaining seascapes.

For all states, key sites for repair can be at least broadly identified. Likewise, the role of seascapes in marine net primary production, crustacean and fish nursery phases, carbon sequestration, nutrient assimilation, coastal foreshore protection, bird habitat and related ecological functions is broadly known and generally parallels that found globally. This synopsis has also found that Australia cannot yet categorically ascribe levels of net primary production to seascapes or indeed estimate the biomass of high value, fecund, annual and high profile species such as prawns, let alone quantify food chains and the equally complex issue of quantifying their role in fish populations.

In brief, the findings are:

- Saltmarshes and seascapes generally are undervalued by the Australian community, as demonstrated by their alteration and by the general lack of understanding as to their role in estuary productivity such as prawn biomass;
- Substantial areas of saltmarsh have been lost to agriculture;
- In some areas urban development planning (often infrastructure such as road and rail) has not accounted for the need for tidal flows to ensure ongoing saltmarsh function;
- The level of legal protection varies across states from substantial (e.g. Queensland and NSW) to nil (e.g. Tasmania);
- Mapping and spatial data sets have often focused on vegetation type rather than function. Definitions of vegetation type and wetland type are not always consistent across states;
- Changes such as % loss of saltmarshes since European settlement are well defined for some states such as Queensland, but not for others such as NSW;
- Ecosystem services will differ depending on the saltmarsh complex, the geography and estuary type;
- Likewise, articulating the key benefits of saltmarshes as an input to business cases for repair will need to vary across states and localities;
- Therefore a 'one size fits all' approach communicating the value of saltmarshes in terms of ecosystem services is unlikely to work;
- There are many sites for restoration for each state and there is value in continuing to develop benefit statements than can be used as part of the decision-making processes towards protection and repair;
- This work is probably best done at the seascape level – recognising the inter-dependence and inter-relationships of the various wetland vegetation types in estuary productivity from sub-tidal such as seagrasses to tidal such as mangroves, saltmarshes and mud flats to the fresh to brackish back swamps.

Australia's saltmarshes – building the business case for repair and protection

Given the above assessment, key knowledge gaps and priorities for research and management could be:

- Build a more seascapes-level scale of knowledge and appreciation on the role, function and benefits of coastal wetlands;
- Improve understanding of the different benefits provided by these seascapes in different regions (e.g. quantifying fish production, shoreline protection, carbon sequestration);
- Develop tailored communication media based on the benefits provided by these seascapes with their different suites of vegetation communities comprising the mosaic commonly known as coastal wetlands;
- Focus on benefits and functions that are directly relevant to coastal stakeholders such as recreational and commercial fishers. For example, promotion of saltmarsh role in fish production will most likely resonate with fishers and can be used to potentially engage these groups in seascapes conservation and protection. This also opens up resourcing opportunities to form public-private partnerships such as the various recreational fishing trust funds;
- Prioritise restoration sites in each state and undertake case studies on these priorities to foster an increase in repair investment;
- Develop other benefit statements as potential markets emerge (e.g. models for carbon sequestration that could be used in carbon markets).

Certainly, if a business case is to be devised for investment in seascape repair then quantification of their potential value and returns to the health and productivity of coastal and marine systems is essential. There are many competing demands on both public and private investment streams. Quantification of potential benefits using simple readily understood indices is essential so that the costs and benefits of investment in repair can be compared to other possible investment activities.

Readily identifiable and high value indicators of biomass such as prawns could be useful as an initial indicator of saltmarsh value. At a broader scale, quantification of all ecosystem services that these seascapes provide should be prioritised. However, this broader-scale quantification will require substantial resources. Accordingly, this project will focus first and foremost on quantifying high value and readily understood indicators of benefits.

Appendix I lists the proposed work program for the remaining period of National Environmental Science Program investment.

10. CONCLUSIONS

Much information is readily available on Australia's seascapes, particularly their spatial location, areas and vegetation types. What is not well known beyond general functional ecological understanding is their productivity and therefore the likely returns on investment in repair. For Australia to invest wisely in repair, substantially more information on their functional role, the likely levels of biomass that will accompany repair and how this compares to the costs of repair is essential.

As a suite of short to medium term knowledge needs the following is proposed as the priority for R&D:

Immediate – this project

- Develop basic indices like prawn productivity to communicate the business proposition towards investment in repair and protection.

Short term

- Working collaboratively with agencies, conservation and fishing groups to foster understanding of the role and benefits of seascape repair, key sites for repair and the business cases to attract investment.

Medium term

- Quantify other key ecosystem services such as carbon sequestration.

Medium to long term

- Seeking recognition of saltmarshes and indeed all elements of 'blue carbon' in Australia's National Carbon Accounts;
- Work through agencies to foster a series of consistent and comparable policies for protection, all states; and
- Provide information to support further assessment and consideration under the Environmental Protection and Biodiversity Conservation Act.

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APPENDIX 1: PRIORITY INVESTMENTS BY STATE

The next phase of work is to determine more precisely the value, the likely benefits of repair and protection and link these benefit statements to the costs of repair, thereby demonstrating to the community how the benefits of repair and protection can well outweigh costs. Reflecting the differences in States and their assets, the methods and activities will vary.

By necessity, given the limited resources available, under the National Environmental Science Program Marine Biodiversity Hub these activities must be focussed. It will be challenging. The end of each state chapter provided summary detail, in the context of the State findings, as to the next phase of activities. These are as follows:

Queensland – The task will be to focus on:

- Identifying suitable sites for tidal bund removal in the Fitzroy region, in conjunction with natural resource management groups and the community; and
- Using restoration sites as case studies, to undertake a cost benefit analysis of the economic and ecosystem service benefits of coastal wetland repair.
  If additional funding was available, possibly through an allied investment, then it would be very useful to assess the use of different coastal wetland habitats by prawns, other crustaceans and representative fish species to estimate the relative and cumulative productivity and connectivity of saltmarsh, mangrove, mud/sand flat and adjacent freshwater wetlands. This would deliver knowledge at the seascape level – essential if we are to ably communicate the extent and nature of repair activities required for priority marine systems such as the Great Barrier Reef.

New South Wales – Phase II of this Marine Biodiversity Hub project can most usefully contribute by developing an assumption-based set of metrics for the likely benefits of repair to school prawn productivity.

Within NSW fresh to brackish wetlands, saltmarshes and mangroves form a mosaic continuum of vegetation, water, diatoms, phytoplankton and shelter - all elements of the food chain towards school prawn productivity. This small research project will be based on the well documented life history of school prawns, be applied to a nominal representative mosaic of connected wetland ecosystems such as Lake Wooloweyah, Clarence estuary and provide estimates of the likely range of school prawn potential productivity that would accompany repair. This information can then be used as an input to the overall benefit assessments in any Business Case for the major estuaries of NSW including the companion HSBC funded project on *Mapping Ocean Wealth.*

Victoria – it is proposed to focus on the Corner Inlet-Nooramunga region of Gippsland and determine:

- Estimates of the $ value of this resource for commercially important species as a subset of their total value in ecosystems services; and
- The opportunities for repair, enhancement and protection of these coastal wetland systems, including re-establishing tidal hydrology and removing extensive grazing

Tasmania – it is proposed to focus on:

- Preparing, based on assumptions and known life history features of key fish and crustacean species a set of summary food chains that demonstrate coastal productivity benefits and estimates of the likely value per hectare of repaired saltmarshes;
- Apply these findings to both the Circular Head and Pitt Water sites to demonstrate the likely return on investment of repair activities; and, should supplementary funding become available; and

- Support the completion of State-wide assessment of saltmarsh loss and degradation so that a state-wide blueprint for repair can then be developed.

South Australia – it is proposed to focus on quantifying the direct link between repair and relative prawn abundance, through ecological modelling as a precursor to field validation of outputs as part of a trial restoration project.

In parallel with these activities the findings of this synopsis will be communicated widely, building greater understanding of the role of our seascapes in healthy and productive coastal landscapes.

These research projects will also link to a major initiative on *Mapping Ocean Wealth* being conducted through The Nature Conservancy. *Mapping Ocean Wealth* will use the results of this project in establishing saltmarsh values as one of the key inputs towards valuing coastal resources. *Mapping Ocean Wealth* will have case studies in Victoria (Port Phillip and Western Port) and NSW barrier estuaries (Richmond and Clarence) to ensure strong links and applicability between the two initiatives.