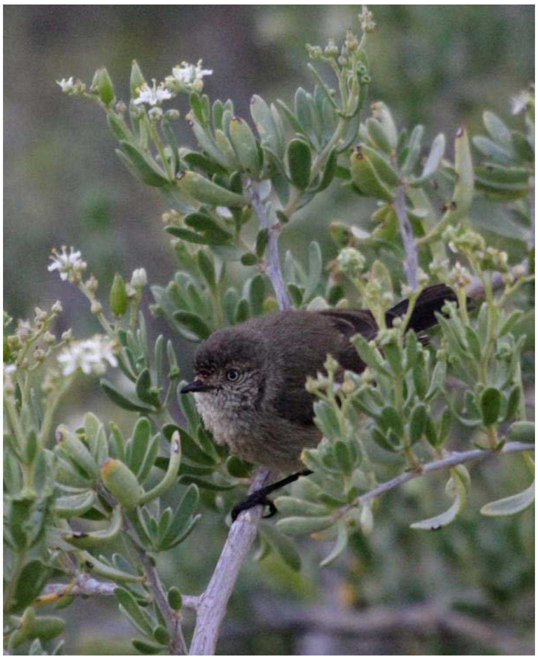
Thornbills, samphires & saltmarsh tipping points

A assessment of potential threats to Samphire Thornbill habitat

in the northern Adelaide & Mt Lofty Ranges Natural Resources Management region

27 July 2017



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LIMITATIONS STATEMENT

The sole purpose of this report and the associated services performed by Delta Environmental Consulting is to investigate the habitat of the Samphire Thornbill in the eastern Gulf St Vincent region in accordance with the scope of services set out in the contract between Delta Environmental Consulting ('Delta') and AMLR NRM BOARD ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Delta derived the data in this report primarily from visual inspections, examination of records in the public domain and interviews with individuals with information about the site. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data, analysis and a re-evaluation of the findings, observations and conclusions expressed in this report.

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EXECUTIVE SUMMARY

Prior to this report surveys have been undertaken to assess the distribution of Samphire Thornbill (*Acanthiza iredalei rosinae*) in the "Samphire Coast" area north of Adelaide (Carpenter 2015) in comparison to earlier surveys reported by Matthew (1994). Carpenter's recent thornbill surveys noted "die off" in the Shrubby samphire (*Tecticornia arbuscula*) at some locations. Loss or change of habitat values in *T. arbuscula* and the samphire sites assessed may have negative impacts on different bird taxa, including thornbills which are known to use *T. arbuscula* as a food or nesting resource (Matthew 2002).

The aim of this project, as defined in the brief, was to undertake an assessment of the potential differences in habitat condition at different sites used by the Samphire Thornbills and conduct a risk evaluation of habitat where Samphire Thornbill had previously been found in historical and recent surveys. The initial inspections identified a number of observed changes to sites which included die back and loss of Shrubby samphire *Tecticornia arbuscula* and changes to saltmarsh plant diversity, abundance, cover and distribution.

The potential loss of *T. arbuscula* as valuable habitat for thornbill and other bird taxa was estimated from initial inspections using windscreen and visual surveys of several sites. Based on these initial estimates of loss, *Tecticornia arbuscula* populations in eastern Gulf St Vincent in South Australia may have declined by 30-50%. Although actual habitat loss of *T. arbuscula* needs to be validated and quantified, such a loss could have considerable impacts to local biodiversity.

South Australia contains a third of the known population of Shrubby samphire. If dieback is occurring elsewhere, this loss could pose a substantial impact to the long-term viability of the species.

Observations (Table 1 on page 7), indicate the highest % loss of *T.arbuscula* occurs in areas known to support important breeding populations of the Samphire Thornbill for which *T.arbuscula* forms important and dependent habitat.

Samphire Thornbills use Shrubby samphires for perching and nesting (Matthew 2002), and the insects the birds feed on may include some species of samphire gall midges (Veenstra *et al* 2011, Higgins & Peter 2002). Whether these functions (shelter, perching, food source) could be filled by other species within the Temperate Saltmarsh Ecological Community is unknown. Similarly, it is not known whether other samphire species may change their growth habits to fill the niche vacated by the Shrubby samphire.

The loss of Shrubby samphire is likely the initial link in a chain of ecological changes, occurring as a result of reaching a tipping point with regards to sea level rise and other anthropogenic influences. Temperate saltmarsh ecological community is under threat, with changes occurring at an increasingly rapid pace.

This study has identified a number of short (3-5 years) to moderate term (10-15 years) management outcomes that may assist in maintaining or improving the habitat values of *T. arbuscula* and samphire communities which appear to be under threat. These include:

- constructing new coastal retreat zones,
- creating gentle slopes on existing embankments or seawalls to be selectively sown with Shrubby samphire seed,
- reducing other anthropogenic impacts (development, off-road vehicle use, weeds, pests, nutrient issues, water management) affecting this zone,
- reducing the degree of pest insect control in key marshes may also be of assistance to the Samphire Thornbill.

Table 1 - Observed losses of Shrubby samphire

Location	Visual estimate of % Shrubby samphire loss
South of Port Prime	**50-70%**
Light River Delta	*70%*
Middle Beach	*70%*
Port Gawler	*30-50%*
Saltfield birdwatching zone	*5-70%*
Torrens Island	**20%**
Thompson, Webb and Parham	**20-30%**
The Coorong	**20-30%**
Mid Coorong	20-50%
Cantara Lakes	<10%
Cortina wetlands	20-30%
Yorke Peninsula to Port Wakefield	**20-40%**
Macs Beach	10-15%
East of Price (mining lease)	15-20%
Wills Creek Conservation Park	20%
Port Clinton (Clinton Conservation Park)	50-70%
Port Arthur (Clinton Conservation Park)	30-50%
Port Wakefield (north of Wakefield River)	30-50%
Port Augusta	**10-15%**
Avalon Beach (VIC)	**Variable, not quantified**

INTRODUCTION

Natural Resources – Adelaide & Mt Lofty Ranges undertakes a range of conservation works along the northern coastal corridor of the NRM region. This review of the habitat used by the threatened Samphire Thornbill (*Acanthiza iredalei rosinae*) is being undertaken as part of the Australian Government supported Samphire Coast Icon Project, focused on saltmarsh and shorebird habitat conservation. The initial project focus was on potential differences between sites the Samphire Thornbill had recently been recorded, and other sites where it had not been recorded, containing the same habitat species (Shrubby samphire, *Tecticornia arbuscula*), and to identify risks to those sites. Initial site inspections identified a significant ecological change taking place within the saltmarsh habitats, particularly within areas of *Tecticornia arbuscula*, that was likely to impact on many species, including the Samphire Thornbill.

As a result, the focus of the report shifted. The report has been expanded beyond thornbill habitat, as a key "habitat structure" forming plant Tecticornia arbuscula, the Shrubby samphire, looks to be dying, en masse, along the shores of eastern Gulf St Vincent.

BACKGROUND

SLENDER-BILLED THORNBILLS

The Slender-billed Thornbill is a small bird with a short black bill, pale eyes, fine black and white scalloping on the forehead, and a blackish tail with paler tips (Pizzey and Knight, 1997).

The species *Acanthiza iredalei*, commonly known as the Slender-billed Thornbill has three subspecies that occur in the Adelaide Mount Lofty Ranges region. All subspecies are small insectivorous passerines, which occur in low shrublands, generally in coastal, arid or semi-arid parts of southern Australia (Matthew, 1994).

The three subspecies are;

- *Acanthiza iredalei iredalei* is the lightest colour form, which occurs in arid saltbush, bluebush and samphire flats in South Australia and Western Australia. This subspecies was listed as Vulnerable under the EPBC Act, but delisted as of 14th of December 2016. It is still listed as Rare in SA and extinct in the NT.
- *Acanthiza iredalei hedleyi* is the mid colour form, which occurs in heath habitats of the Upper South East of South Australia and North-West Victoria. It is listed as Near Threatened in SA.

- *Acanthiza iredalei rosinae* is the darkest colour form and is the subject of this report. This subspecies occurs in coastal saltmarsh (saltbush, samphire and mangrove) communities bordering northern Gulf St Vincent.

The combined distribution of the three subspecies is shown in the figure below. It is worth noting that many of these observations are more than 100 years old.

The species distribution (as a whole) covers much of South Australia's heathland, saltmarsh and saltbush habitats. Across all subspecies, there are 1928 records within the Atlas of Living Australia.

At a national level, the distribution of this species can be visually compared to the Bureau of Metrology Climatic Zone map, revealing the densest areas of observations are throughout the hot desert, warm summer, dry temperate and grassland zones.

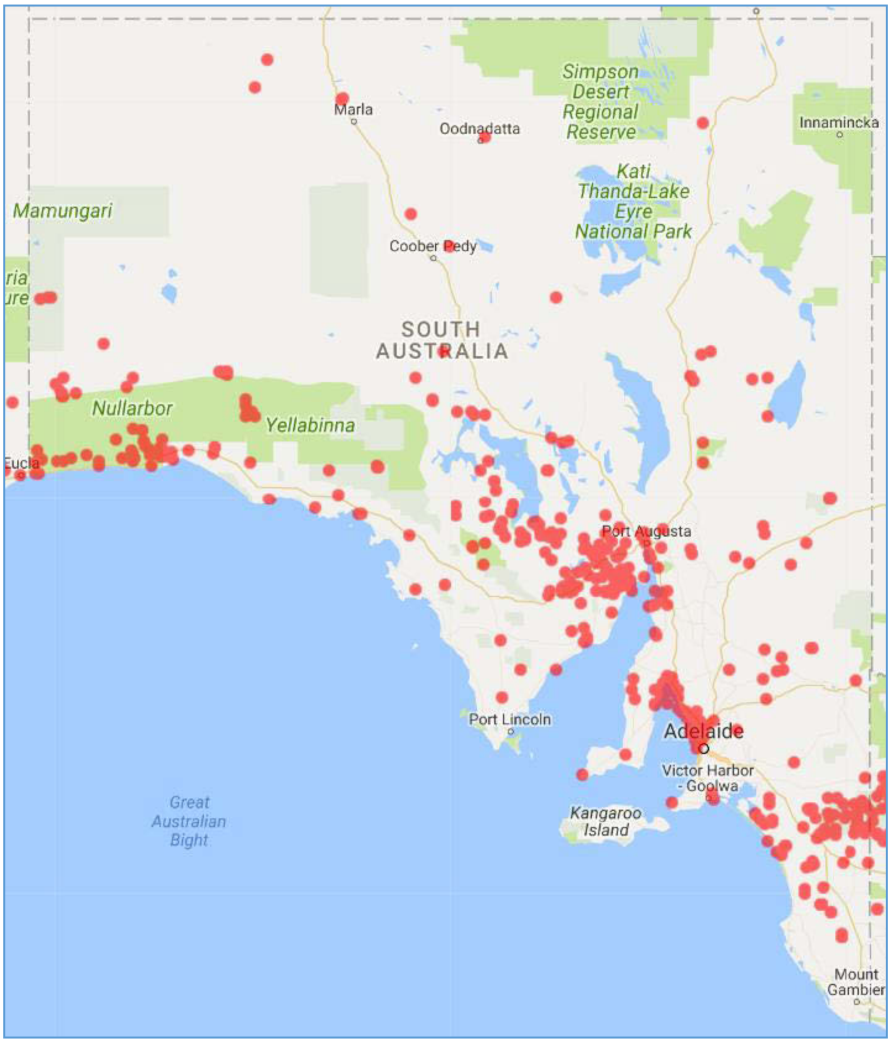


Figure 1 - *Acanthiza iredalei* distribution in SA (all subspecies)

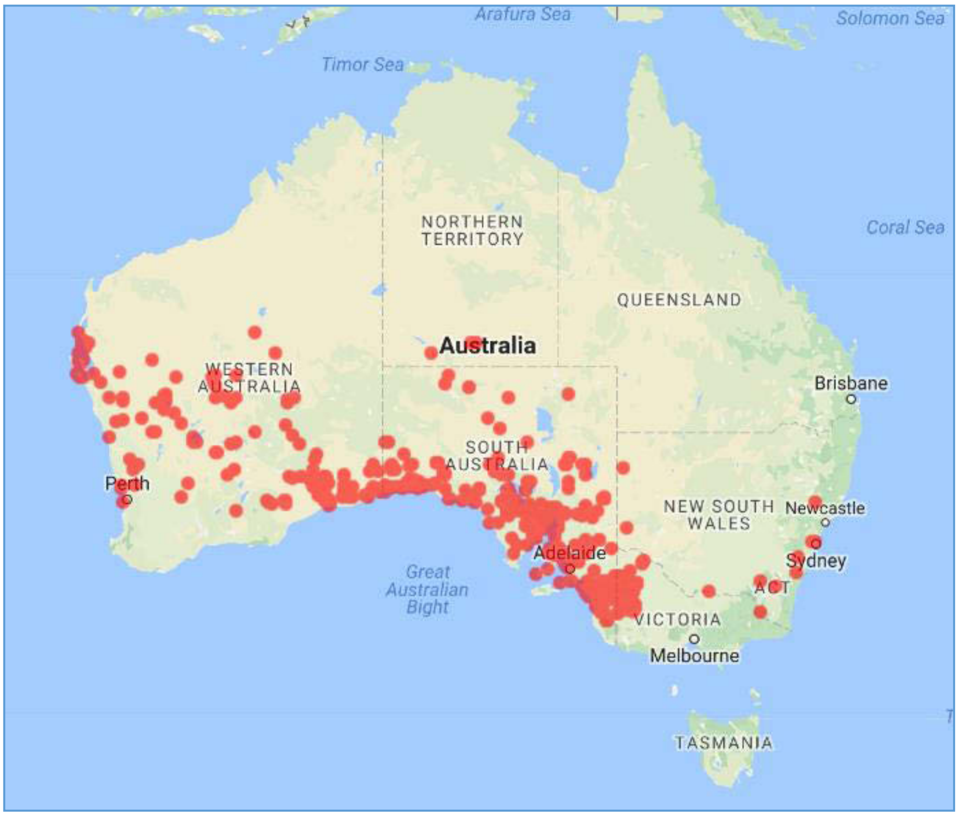


Figure 2 - *Acanthiza iredalei* distribution (all subspecies). Nationally.

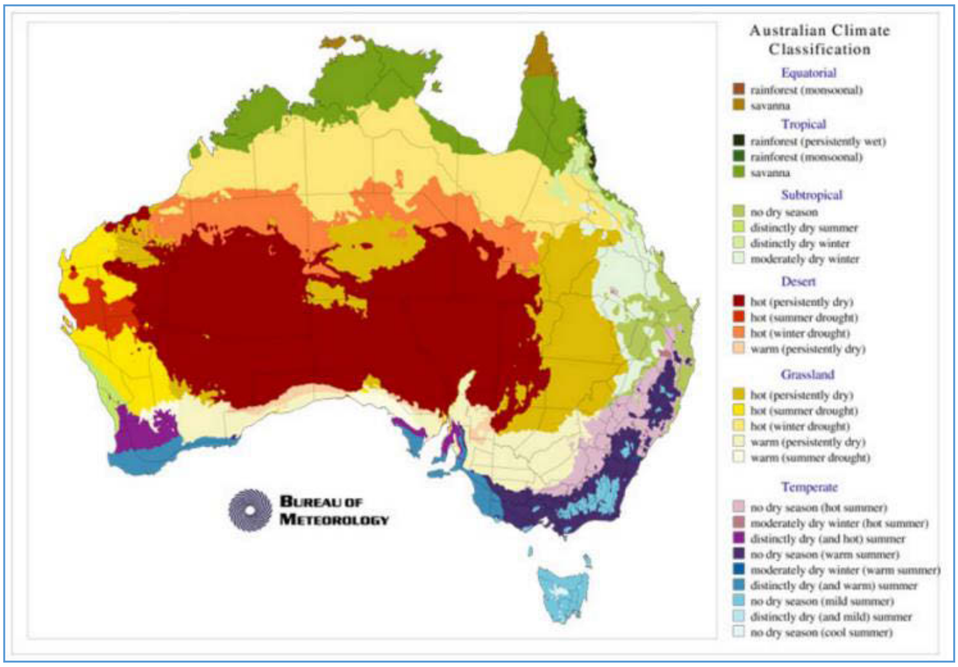


Figure 3 - BOM Australian climatic classification

SAMPHIRE THORNBILLS

The sub-species *Acanthiza iredalei rosinae* (Slender-billed Thornbill (Gulf St Vincent)) is, for the purposes of this report, distinguished from the rest of the Slender-billed Thornbills, by referring to them by their shorter common name of Samphire Thornbill. This is the subspecies least observed, with only 80 (4.1%) of Slender-billed Thornbill records. It is found in coastal saltmarshes, including saltbush habitats, samphire and mangrove communities. It is limited to those coastal saltmarshes bordering northern Gulf St Vincent.

The sub-species was described by Mathews, in 1913. This is currently the only EPBC Act listed sub-species of the Slender-billed Thornbills, with a rating of Vunerable (Threatened Species Scientific Committee 2015). In South Australia, this subspecies is rated as Endangered.

The Samphire Thornbill is olive-grey with a buff rump, grey-white underparts, and olive-buff flanks, while the other two subspecies (*Acanthiza iredalei iredalei* and *Acanthiza iredalei hedleyi*) have paler colouration (Pizzey & Knight, 1997).

According to records within the Altas of Living Australia, the Samphire Thornbill is found predominantly in patches along the shores of Gulf St Vincent, with the exception of seven vouchered records 8.6%) out of the eighty observations. These exceptions being the three reccords on the Nullabor, one 40km east of Meningie and three at Port Broughton (vouchered prior to development). While exceptions to the general prescribed area of distribution, these samples appear to have been, at time of collection, samphire shrubland.

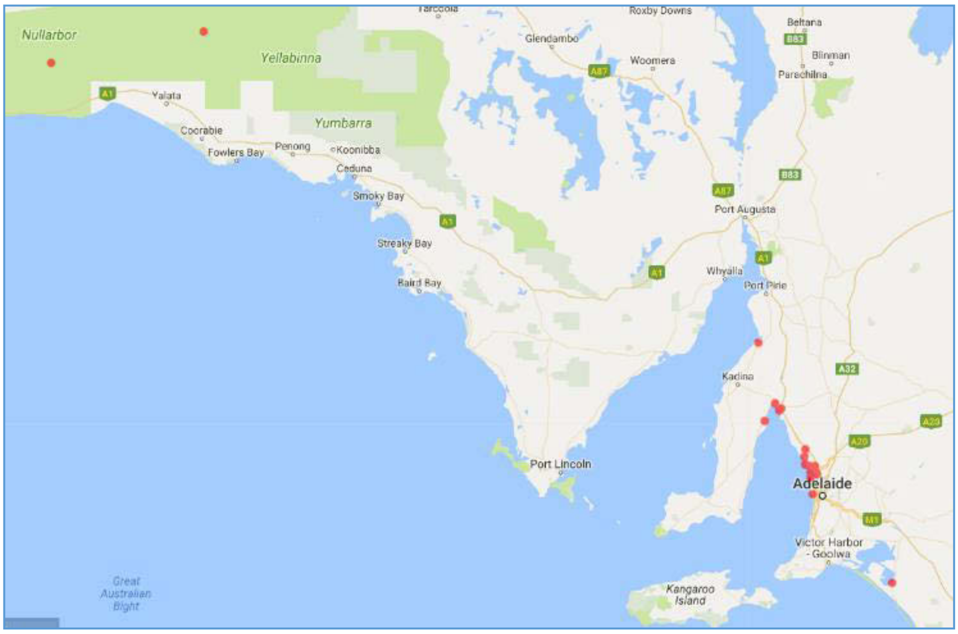


Figure 4 - Acanthiza iredalei rosinae distribution

Nests of this subspecies are dome-shaped and are constructed primarily from dry seagrass and spider egg sacks. These are placed less than a meter above the ground in samphire or low shrub such as salt bluebush (*Maireana oppositifolia*) (McGilp 1925 in Matthew 2002).

The Samphire Thornbill's estimated generation time is 12.3 years (BirdLife International, not dated). Birds breed in their first year and live for up to 23.5 years (Garnett *et al*, 2011).

Within the Clinton population, density estimates varied from 2.9 - 8.4 birds per hectare of suitable habitat (samphire). If unsuitable habitat (sandy rises or lakes) was included, the density was 1.5 - 4.3 birds per hectare.

According to Matthew (2002) the densest distributions of Samphire Thornbills within the Clinton population were within areas of one to three metre tall Srubby samphire *Tecticornia arbuscula* (<85% cover) with a Beaded glasswort *Sarcocornia quinqueflora* understory, within ten metres of tidal channels or lake edges.

Samphire Thornbill was present in lower densities across low open Grey samphire *Tecticornia halocnemoides* shrubland, further away from tidal channels and lake edges, however it appeared to provide only occasional forage habitat.

This matches with observations in Garnett *et al* (2011) which identified the prefered habitat to be chenopod shrublands, particularly samphire dominated by Shrubby samphire *Tecticornia arbuscula*, on narrow coastal saline mudflats, usually within 20m of a tidal channel or saline lake.

Individual birds within the Clinton area were found to move only small distances, with most being recapured within 100m of their original capture location (Matthew, 2002). The furthest resighting was just 650m, by a young bird (Higgins & Peter, 2002), suggesting that the home range of each bird is less than 25 hectares. The birds tend to be seen together in pairs or groups, with groups being more common once young had fledged (October). In January and Febuary all birds observed were in groups of ten or more.

Matthew (2002) often observed birds gleaning food (catching invertebrate prey by plucking them from foliage and the ground) from both *Tecticornia arbuscula* and *Tecticornia halocnemoides*, as well as occasionally from the mud surface. Birds would also hawk (catch flying insects by sallying out from a perch to snatch an insect and then returning to the same or a different perch) for small moths.

The flowers the White mangrove *Avicennia marina* and Nitre berries *Nitraria billardierei* were also regular prey item sources for the Clinton population of Samphire Thornbills. Stomach contents included small flies, fly larvae, beetles, spiders and caterpillars. While Samphire Thornbills predominantly feed on insects, they occasionally also feed on seeds and other vegetable matter (Higgins & Peter 2002, Garnett *et al* 2011).

THREATENED SPECIES CONSERVATION AND MANAGEMENT ACTIONS

The actions currently proposed to assist in the preservation of this sub-species are;

- Work with local government and the Coast Protection Board to secure and protect all remaining habitat, including abatement of current threats and restoration of habitat
- Secure or create new habitat inland from current range where salt marshes could develop as sea level rises, or manage existing marshes to retain habitat with dykes etc.
- Consider, depending on the outcome of research priority five, implementing a feral predator control program

MONITORING PRIORITIES

- Establish annual monitoring sites, particularly at fringes of the range
- Monitor populations and habitat to identify when action is needed to institute intensive management

INFORMATION AND RESEARCH PRIORITIES

- Assess population trends, particularly near developed areas
- Determine the extent of movement between subpopulations/regions
- Identify the impacts of proposed developments and emerging threats
- Determine genetic connectivity between subpopulations/regions
- Identify the impacts of feral predators on the Samphire Thornbill

SAMPHIRES

These unusual looking plants have jointed (articulated) branches that look like a string of beads. Articles function as both leaf and stem, providing the structure of the plant, the location for photosynthesis and a large water-holding capacity. The latter function allows these plants to live in very dry locations, or in tidally inundated areas that are "physiologically dry" because all the water present is saline.

The name "samphire" is a corruption of "Saint Pierre" or Saint Peter, the patron saint of fishers, and reflects the preference of these plants and their overseas relatives for growing near the coast.

The ash from burnt samphire is very alkaline and was used in glassmaking (hence "glasswort") and soap making in Medieval times. This use continued in less prosperous communities right up until the 1800s. In the early days of South Australian settlement a glassworker operated in the saltmarshes south of Saint Kilda. Small pieces of glass slag can still be found in the saltmarshes between St Kilda and the Little Para River.

The remarkable water-holding capacity and salinity tolerance of samphires results in them being the dominant plant species in temperate and Mediterranean saltmarshes, and around inland salt lakes and saline scalds.

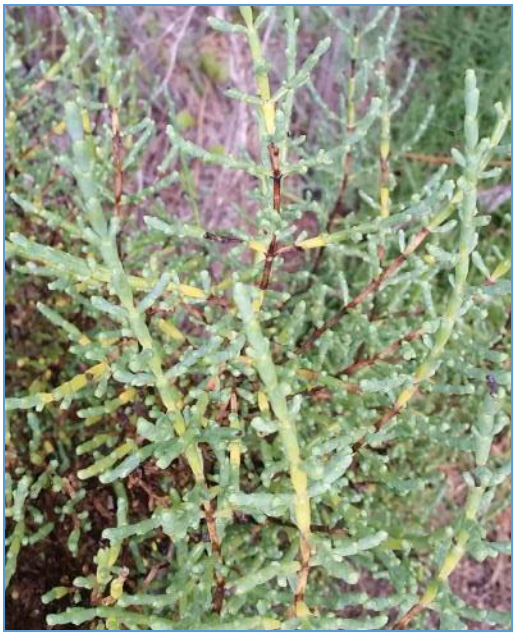
SHRUBBY SAMPHIRES

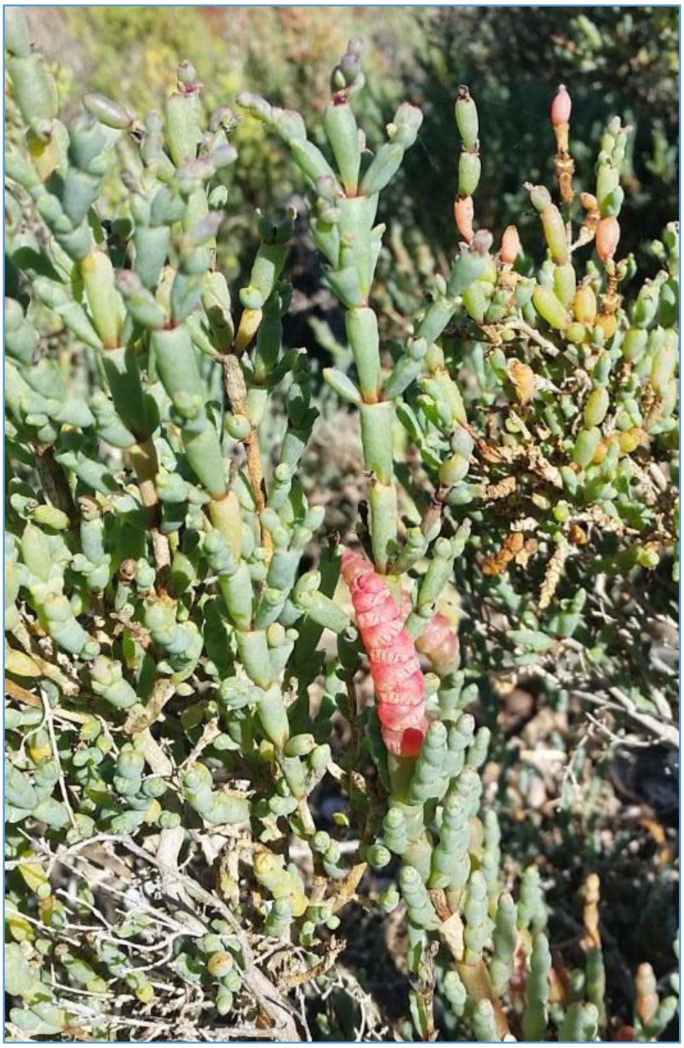
The Shrubby samphire *Tecticornia (Sclerostegia) arbuscula* often occurs directly adjacent to other samphire or glassworts. They are herbs to small shrubs belonging to the Salicornieae tribe, within the family Chenopodiaceae.

This species was originally published by Robert Brown under the name *Salicornia arbuscula*, it was renamed as *Arthrocnemum arbuscula*, then *Sclerostegia arbuscula* by Paul Wilson in 1980, before being merged into *Tecticornia* in 2007.

Shrubby samphire is the largest of the local samphires, growing up to 2 m high and wide, where it grows directly adjacent tidal creeks, often landward of any mangroves. In less than ideal conditions, it can grow to as little as 30cm tall.

Figure 5 - Shrubby samphires in various forms - Above, suffering die back, upper right with galls, lower right healthy but mixed with other species and lower left under the shade of a Teatree.





The dense branches and ascending form of Shrubby samphire results in the development of densely impenetrable shrub land where these bushes grow close together. This provides habitat for the Slender-billed or Samphire Thornbill (*Acanthiza iredalei rosinae*). The form of the Shrubby samphires are somewhat similar to that of South-east heathland plants, or the saltbushes and blue bushes that provide habitat for other sub-species of thornbill.

Identification of Shrubby samphire can be challenging, as true identification depends on the morphology of the flowering spike. The short (only a few articles long) flowering spikes are usually (but not always) terminal. They occur on both the main and small lateral branches, so can be oriented in all directions. The supporting bracts of the flowering spikes are continuous – the bracts go right around the spike and almost cover the triads of flowers. Each triad has only one bisexual flower – the central one.

The two flowers on either side of the central flower are male and can only be seen when their pollen anthers push out from between the bracts. The central female flower has a solid style with a divided stigma, which can easily be seen protruding on opposite sides of the flowing spike. The style hardens and persists in the fruiting spike and can be seen protruding long after the fruit has shrivelled to dryness. Fruits can be held on the plant for some time although the spike eventually breaks up into separate articles which fall away. A few old fruit can be found on the bushes at all times of the year. The protruding style in the flowering and fruiting spikes is the most obvious aid to recognition of Shrubby samphires.

Seeds of the Shrubby samphire are enclosed in a hard, vaguely pyramid-shaped pericarp which, once cracked, reveals the narrow seeds (more than twice as long as they are broad). About 1.5 mm long, the seeds are golden brown, transparent and unornamented. The embryo is almost straight and lies next to a large volume of perisperm.

SHRUBBY SAMPHIRE DISTRIBUTION

There are 1,215 records of Shrubby samphire, Australia wide. Of these, 403 (33%) are in South Australia. 105 (8.6%) are from within the AMLR NRM Region.

Shrubby samphires are found most commonly in the riparian of tidal creeks, just landward of the mangroves where inundation with fresh tidal water is regular, or landward of shelly ridges that allow percolation of seawater and rainwater.

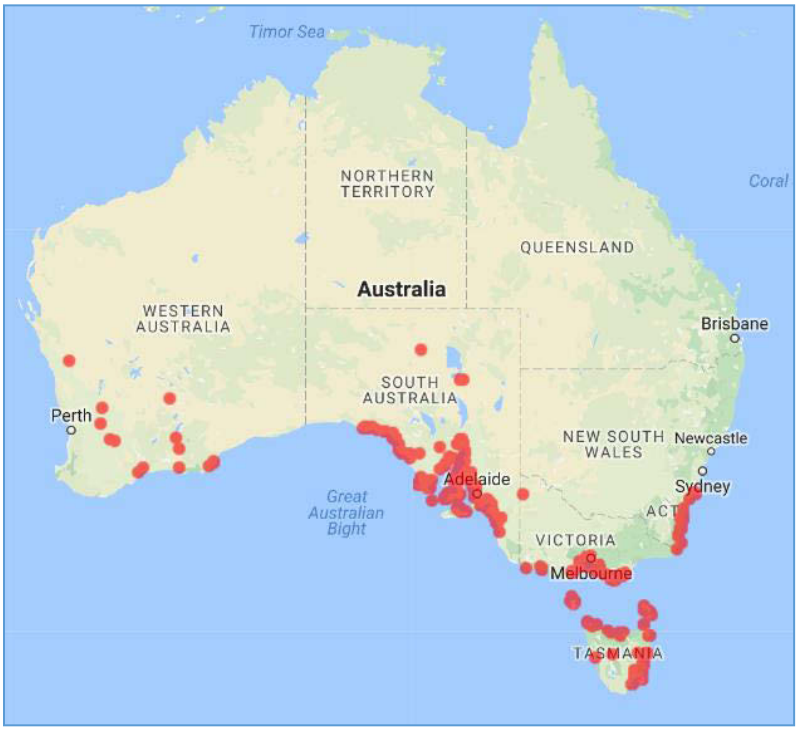


Figure 6 - Australia wide distribution of Shrubby samphire

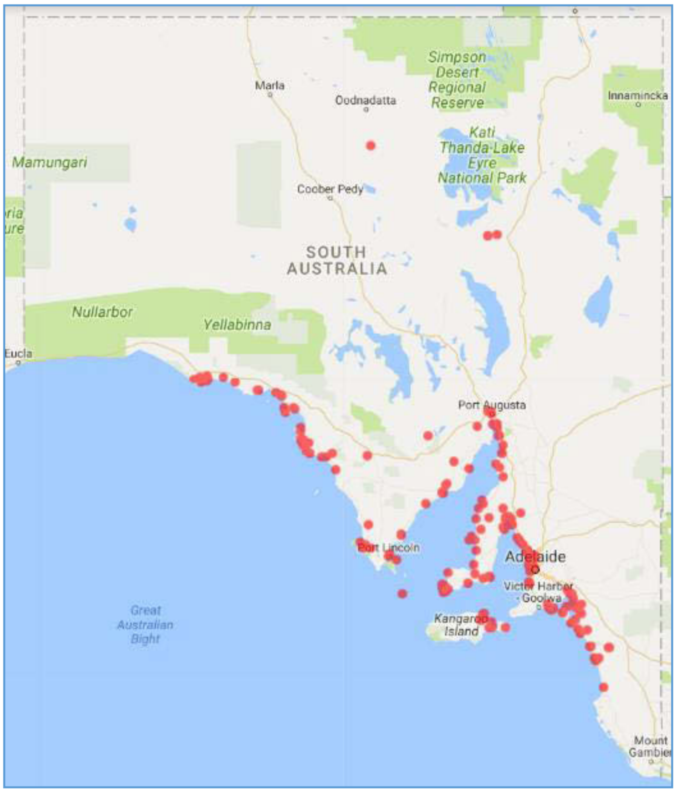


Figure 7 - South Australian distribution of Shrubby samphire

ECOLOGICAL VALUE OF SHRUBBY SAMPHIRES

Shrubby samphires are a foundation species of many temperate coastal saltmarshes. Australian Subtropical and Temperate Coastal Saltmarshes have been afforded protection under the Commonwealth's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) as a Vulnerable ecological community (Threatened Species Scientific Committee 2013).

As can be seen in the tables below, most Australian saltmarsh is distributed in the states with tropical areas, including Northern Territory, Queensland and Western Australia. Temperate saltmarshes, to which the Shrubby samphires are confined, are only a very small portion of the total area of saltmarsh (<3% or 407km^2).

Table 2: Estimates of the extent of Australian saltmarsh, based on Bucher & Saenger (1991)

State	**Length of shoreline (km)**	**Area of saltmarsh (km^2)**
Northern Territory	6,200	5,005
Queensland	7,400	5,322
New South Wales	1,900	57
Victoria	1,800	125
Tasmania	3,200	37
South Australia	**3,700**	**84**
Western Australia	12,500	2,965
Total	**36,735**	**13,595**

Table 3: Percentage of Australian saltmarsh area and comparable percentages of national saltmarsh flora, per state (Saintilan, 2009).

State	Saltmarsh area (%)	Saltmarsh flora (%)
Northern Territory	37	18
Queensland	38	29
New South Wales	<1	45
Victoria	<1	55
Tasmania	<1	53
South Australia	**<1**	**71**
Western Australia	22	72

Coastal saltmarshes are tidal wetlands. As such they function to settle land-sourced runoff into sediment so that water reaching the marine environment is clean. These tidal wetlands also contribute to fisheries productivity, as crab and gastropod larvae released from the populations living in the saltmarsh provide an excellent food source for juvenile fish (Mazumder *et al* 2006, 2008).

Along with helping stabilise coastal tidal creeks and chenier ridges, Shrubby samphires are also known to provide habitat for the critically endangered Orange-bellied parrot (*Neophema chrysogaster*) (Loyn *et al* 1986, OBPRT 1998). Shrubby samphire provides perching or roosting sites and the seeds are the major food source for the parrots. Shrubby samphires also host a range of species- or genus-specific gall midge (Veenstra *et al* 2011). Midges are prey items for the Samphire Thornbill.

Dense stands of Shrubby samphire are thought to slow mangrove encroachment into saltmarsh, by either shading the mangrove seedlings or by building up the marsh surface to exclude mangroves (Rogers *et al* 2005). Unfortunately, adult mangroves have been observed to exhibit allelopathic tendencies (Chen & Peng 2008), poisoning the ground around their roots to all other species, which means that once mangroves are established, Shrubby samphires can rapidly lose ground.

THREATS

Threats to Shrubby samphire include the draining and filling of marshes for use as industrial or residential land and dredging to form marinas. More localised impacts include dumping, grazing, use of the areas by off-road vehicles preventing expansion or retreat, mangrove allopathy and weed infestation.

Fragmentation and changes to tidal regime or tidal connection that result from development, land-use practices, land reclamation or infrastructure can lead to further habitat loss, invasion of 'problem species' or modification of ecological function (Laegdsgaard *et al* 2009, Williams *et al* 2011).

Pollution/litter - pollution and litter from stormwater or dumping of waste can smother coastal saltmarsh plants and introduce contaminants such as heavy metals or organic chemicals (Adam 2002, Laegdsgaard *et al* 2009). Oil spills are also a potential threat.

Coastal saltmarsh is susceptible to a range of impacts from excess nitrogen from sewage and land-derived sources. Nitrogen can change patterns of productivity and species distribution, stimulate algal growth, and encourages non-saltmarsh vegetation to invade (Rose and McComb 1992, Adam 2002)

Actual or potential acid sulfate soils are found along much of the Australian coastline and therefore pose a threat to all coastal samphires (e.g. Adam 2009, VSS 2011). Acidification can have significant impacts on habitat quality, the health of aquatic organisms and biodiversity. Typical examples of such impacts include fish and shellfish kills, outbreaks of disease in fish, scalding of vegetation, and increases in nuisance algae (Watkinson *et al* 2000, ASEC 2001, NRME 2003, Fitzpatrick *et al* 2009).

Large-scale grazing by introduced farm animals is likely to impact on coastal saltmarsh vegetation, potentially changing composition and structure (Adam 1990, Laegdsgaard *et al* 2009). Shrubby samphires do not stand up well to regular soil compaction or breaking of slow-growing branches.

Controlling nuisance insects in saltmarshes often involves habitat modification such as runnelling, which alters drainage and tidal inundation patterns, or the construction of access tracks (Balla 1994, Adam 2002).

Solar evaporative salt ponds are often constructed on saltmarshes, thereby destroying vast areas of natural habitat (Adam 2002, Bromberg Geden *et al* 2009). In South Australia, where the highest biodiversity of coastal saltmarsh occurs, vast areas were under lease for potential salt mining in the future (Fotheringham and Coleman 2008) and there is ongoing debate over the future uses of the mining leases. Shell-grit mining also occurs in South Australian coastal saltmarshes. Some undeveloped areas north of Adelaide that were previously under mining tenure have now been incorporated into national park and conservation land as part of the Adelaide International Bird Sanctuary.

Changes in rainfall patterns, due to climate change, come with risks that with increased summer rainfall, areas will freshen beyond their normal range. Crain *et al* (2004) demonstrated that although most saltmarsh species initially thrive in fresher summer conditions, they quickly succumb to increased competition, due to fresher water taxa invading.

While Shrubby samphires are unlikely to burn, they are poorly adapted when fire does occur. The increased presence of flammable vegetation, generally in the form of introduced weeds, can cause an otherwise stressed saltmarsh to reach a tipping point (Kirkpatrick and Glasby 1981, VSS 2011).

Climate change in Australia has been accompanied by measurable sea level rise over the past half century and mangroves both in the local region (Coleman 1998) and around Australia have begun to colonise across the saltmarsh, which is being squeezed between the mangroves and developed areas (Saintilan & Williams 1999).

The tendency of Shrubby samphires to occur in very tidally wet areas, forming dense shrub lands, gives them some protection from off-road vehicle disturbance and weed invasion. However, their closeness to the mangroves means they are amongst the first samphire species to be impacted as mangroves move inland as a result of sea level rise.

CONSERVATION AND MANAGEMENT ACTIONS

At present, while Recovery and Threat Abatement Plans are required for Subtropical and Temperate Coastal Saltmarshes, on the recommendation of the Threatened Species Scientific Committee (5/08/2013), there is no plan in progress that can be adopted or is relevant for this species within the wider ecological community.

Natural Resources AMLR have a number of plans centred around establishing coastal retreat zones for saltmarsh species within the Northern Adelaide Plains coastline, however many of these plans are dependent on progress with decommissioning of the Dry Creek Saltfields.

FIELD OBSERVATIONS

TECTICORNIA ARBUSCULA HEALTH AND LOSS

The initial scope of this project was to visit sites identified by Matthews (1994) as habitat where Samphire Thornbills were historically known to occur. Additional sites where thornbills had been identified later by Carpenter (2015) were also to be assessed. This study was to identify whether there were differences in the habitats that may explain the presence or lack of birds. In passing, Carpenter notes that some areas of *T. arbuscula* were under stress and some die back was noted.

The first site visit to the Light River delta indicated *T. arbuscula* appeared in poor condition and was in a state indicative of mass die-off. Adult, well-established stands of T. arbuscula (~70%) were either dead or dying supporting comments by Carpenter (2015) for the area in 2014. Based on the level of die-off, the search area was increased beyond the few hectares of the Light River Delta immediately adjacent to the river where Carpenter had recorded thornbill presence, to include areas of Shrubby samphire that occur more widely across the plain of the delta and adjacent to the mangroves. An area of approximately a square kilometre, south of the river, was traversed. Further condition surveys of *T.arbuscula* were conducted at other locations in eastern Gulf St Vincent where Shrubby samphire are known to occur. Outside eastern Gulf St Vincent sites in the Coorong, Yorke Peninsula, and Port Augusta in South Australia were examined. Condition of *T.arbuscula* was also determined in Corio Bay, Victoria.

Other sources of information such as quadrat photopoints from Torrens Island, Port Adelaide (Doug Fotheringham, Honorary Research Associate, Adelaide Herbarium) were used for a comparative habitat analysis between 1989 and 2015. Anecdotal reports from saltmarsh specialists were also used as lines of evidence. Some areas of saltmarsh habitat in eastern Gulf St Vincent had been mapped in the previous decade (EBS 2012, Durant 2007 & 2007a, Coleman & Cook 2007 & 2008, Coleman & Eden 2005). Die off had not been noted in these surveys, suggesting it is recent.

SOUTH OF PORT PRIME – LOSS OF A MAJOR LANDSCAPE COMPONENT

Site visits to the Light River delta, Middle Beach, Port Gawler and the Dry Creek saltfields between Port Gawler and St Kilda revealed extensive loss of *Tecticornia arbuscula*.

Figure 8 - L: Individual Shrubby samphire R: Area of dieback (Light River Delta)

At the Light River a family group of Samphire Thornbills were observed using boxthorns and lignum in the riparian of the river, in an area where fresh water from recent flooding had been held in a brackish pool. About 100m downstream the first Shrubby samphires *Tecticornia arbuscula* were observed as isolated plants growing in the riparian near mangrove plants (*Avicennia marina*). The plants were looking very stressed with many dead branches and with heavy gall infestations of the remaining green shoots. Galls are often found in greater numbers when plants are suffering from environmental stresses. A typical example of a riparian shrubby samphire is illustrated in the left hand photograph in Figure 8. Closer to the main deltaic mangrove forest (as distinct from where mangroves are penetrating upstream along the riparian) Shrubby samphires grow as an extensive, though shorter, dense shrubland. The right-hand photograph in Figure 8 has a red outline showing where the Shrubby samphires occur. These extensive shrublands show marked dieback, with nearly 70% (estimated by eye –

no transects or quadrat measurements have been taken for this initial investigation) of shrubs dead or close to dead. Closer to the observers the saltmarsh is very green – this is a dense mixed stand where *Atriplex paludosa, Maireana oppositifolia* and *Tecticornia halocnemoides* are being actively overgrown by *Sarcocornia quinqueflora*, *Suaeda australis, Samolus repens* and *Hemichroa* sp.

Figure 9 - Shrubby samphire dieback near the Samphire Trail (Middle Beach N)

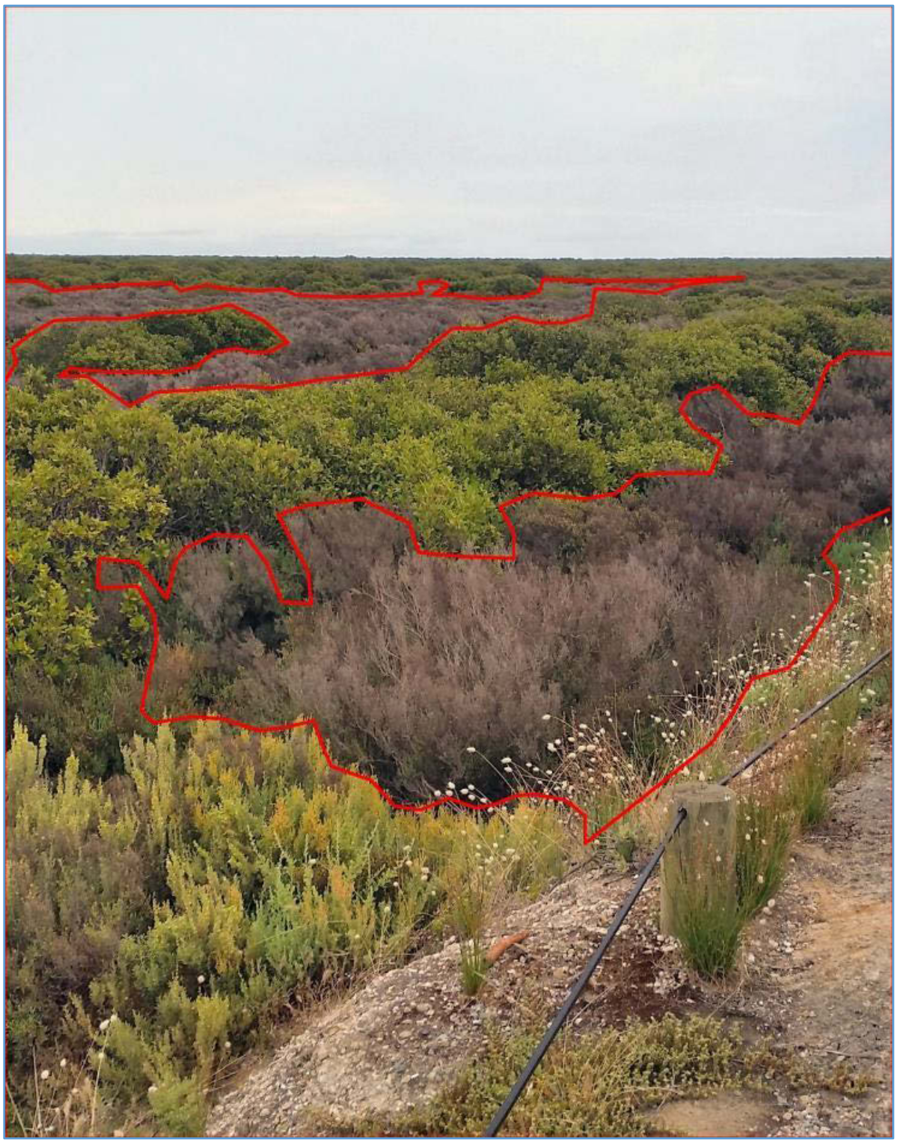


Figure 10 - Shrubby samphires losing ground to mangroves (Middle Beach North)

At Middle Beach Shrubby samphires were observed where they grow between the advancing mangrove edge and the embankment of the Samphire Trail (north of the settlement). Once again, close to 70% of the shrubby samphires were dead or dying. In this location mangroves were growing through and over the skeletons of *Tecticornia arbuscula* (Figures 9 & 10).

Salt Creek marks the southern boundary of Middle Beach. The sabkha behind the township drains to the creek and a similar level of dieback was visible in the Shrubby samphires adjacent Salt Creek, as further north.

Figure 11 - Shrubby samphire dieback at Salt Creek (Middle Beach)

One noticeable feature is the lack of regrowth or migration of *Tecticornia arbuscula* in areas where dieback is occurring. However, at Middle Beach we came across the first indications of re-establishment of the samphire. Several young plants were observed in an area that had been illegally cleared. Although the area was rapidly being colonised by *Sarcocornia*, several young Shrubby samphires had sprouted in the bare. A detailed discussion of all observations of successful migration or adaptation is provided in the section of the report entitled “Surviving against the odds”.

South of Middle Beach the next access to the coast is along Port Gawler Road. Port Gawler Road is effectively a traverse through the saltmarshes and mangrove forests. Alongside the road is a drain that carries overflow from Buckland Park Lake and its surrounds. Landward of the mangroves the drain’s riparian includes shrubs of *Myoporum insulare*, and it was in these shrubs another family of thornbills was observed.

Shrubby samphire (*Tecticornia arbuscula*) was present nearby as healthy isolated plants – but most of the bushy-looking samphires growing in this area are *Tecticornia* *indica*, the brown headed samphire, which prefers the fresher conditions. The Shrubby samphires become dominant at about the same location as the first mangroves are seen. Shrubby samphires growing on flat land behind the mangroves exhibit similar dieback rates to the other areas visited. They are less noticeable because the road embankment at this point supports a number of healthy Shrubby samphires that are growing at a higher elevation than the dieback-affected plants on the far side of the drain (Figure 12).

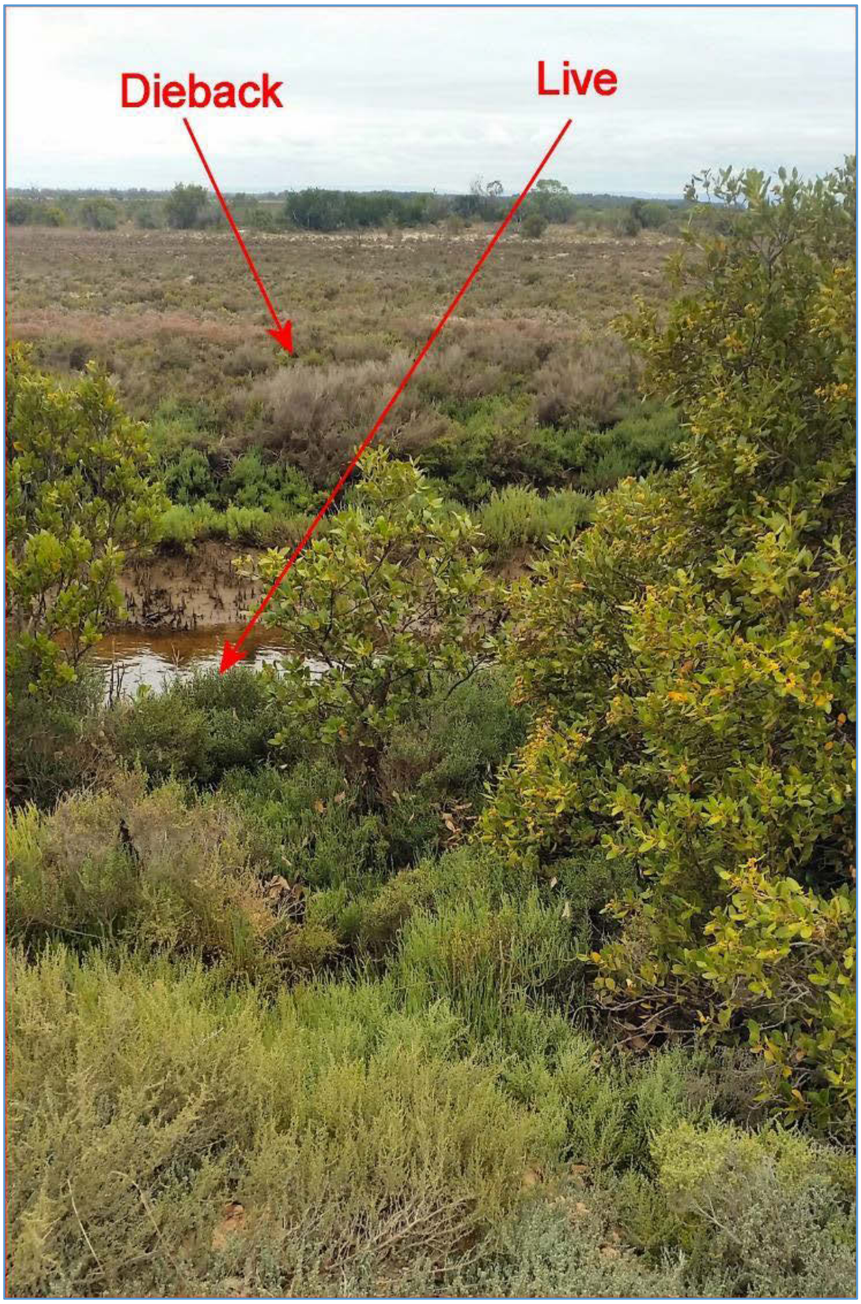


Figure 12 - Saltmarsh/mangrove interface, Port Gawler Rd

An interesting observation is that *Tecticornia arbuscula* appears to tolerate freshwater inundation. Where the drain has an overbank floodplain that had been denuded of vegetation by freshwater flooding, there were several young Shrubby samphires.

Further seaward, Shrubby samphire is present along the road embankment where it passes through the mangrove forest. These shrubs have historically been amongst the largest of this species, some reaching 2m tall. Between 30-50% exhibit dieback.

Figure 13 - Very large Shrubby samphires dying back

The higher survival rate here seems to be comprised of two types of plants – those that are growing on the highest elevations of the embankment, and some lower down the slope that have received a recent donation of sediment in the form of road base that has washed down over their roots in a recent upgrading of the road (Figure 14).

Figure 14 - Healthy large Shrubby samphires at Port Gawler

South of Port Gawler Road the bare sabkha adjacent the Dry Creek Saltfields is gradually being colonised by *Sarcocornia quinqueflora*. The embankment plants immediately adjacent the road are all bushy *Tecticornia indica*.

Tecticornia arbuscula (Shrubby samphire) is present further south, on the seaward embankments of the "sacrificial ponds" XE6 and XE6A, where it is growing near shrubs of *Myoporum insulare*. The Shrubby samphires on these embankments are generally healthy. The plants are growing on the wrack line within and on top of a deep deposit of driftwood, seagrass wrack and other organic detritus. Another family group of thornbills was present at this location (Figure 15).

Figure 15 - Healthy Shrubby samphires and Myoporum growing on wrack deposit, on edge of embankment.

At the Buckland Park Lake Gawler River crossing an area of Shrubby samphires occurs on a saltfield embankment and the adjacent saltmarsh plain landward of the mangroves.

Figure 16 - Buckland Park Lake Gawler River crossing

The narrow band of tall shrubby samphires immediately landward of the mangroves displayed a high level of dieback (approaching 70%). The marsh plain further from the mangroves was lush with *Sarcocornia quinqueflora* and *Suaeda australis*. These plants were growing right over the shorter form of *Tecticornia arbuscula* that grows further from the watercourses, with only a few shrubby samphires managing to maintain their canopies above the competition. However, without photographs from earlier times it was not possible to estimate what degree of loss of shrubby samphire may have occurred from the overgrowth by other species. On the saltfield embankment the survival rate of shrubby samphires was much higher than survival of shrubby samphire in the band next to the mangroves – only occasional plants on the embankment were dead. Samphire Thornbills were heard in the edges of the mangrove forest at this location but not sighted.

Shrubby samphires do not appear to penetrate along the Gawler River/Chapman Creek bypass drain at Buckland Park Lake. The bushy-looking samphires along the XD1 pond embankment next to Buckland Park Lake are *Tecticornia indica, Tecticornia pruinosa* and *Tecticornia pergranulata*.

Where Fork Creek passes between Pond XB3 and the Bolivar outfall drain the shrubby samphires in the creek vary in health from relatively good at the eastern ends of the ponds to heavily impacted by dieback (over 50%) next to the western end of the ponds. *Sarcocornia quinqueflora* is growing very densely in the creek from the seaward end, inland to well past any shrubby samphires. Even where there are large healthy shrubby samphires in the creek, the *Sarcocornia* is overgrowing smaller shrubs.

Figure 17 - Fork Creek, large shrubby samphire (foreground), smaller ones overgrown

Along the seawall south to St Kilda the pattern continued of larger losses of shrubby samphire where the species was growing on flat plains of mineral clay soils and much lower losses where the plants were growing on chenier ridges, beach berms and embankments where flotsam and jetsam was accumulating. Areas with significant variation in topography and high levels of detrital accumulation may have as little as 5% losses evident at present. Extensive plains with little elevation variation and next to no accumulation of driftwood, sandy shells or other material had losses in the vicinity of 50-70%.

TORRENS ISLAND – MEASURED LOSSES

Over several decades Doug Fotheringham established vegetation quadrats in salt marshes across much of South Australia. He took photographs of forty-five quadrats on Torrens Island in 1989 and photographed and resurveyed several of them again in 2015 and 2016. The data from the resurveyed sites is currently being processed, however the researcher has made the photographs available for this report, along with the data from Quadrat 9, which has been processed.

The quadrats are 10m x 10m. While this size is useful for the quantitative estimation of cover for smaller, closer growing species like *Sarcocornia*, it has limitations when it comes to picking up landscape-scale changes of larger species. Quadrats containing the larger shrubby samphires may provide variable results - for example, if a quadrat has one large shrub, and it has survived, very little change is apparent. Of course, if it has died and the rest of the area has only patchy deaths, the loss looks more significant than it is, as well. In the absence of larger quadrats, or many more quadrats, landscape photographs are valuable because they include the wider scene, allowing the quadrat result to be compared to the wider view.

Photographs show that on Torrens Island, which has no watercourses and is not subject to riverine flooding:

- Mangroves have encroached across many salt marsh sites (Quadrats 23, 31 and 33),
- *Sarcocornia quinqueflora* has become denser where it was sparse, is now co-occurring with permanent pannes of water rather than pannes that are filled only at high tide (Quadrats 8 & 6), and has invaded across bare sabkha surfaces (Quadrat 9),
- Shrubby samphire has become less common (Quadrats 8, 9, 13 & 30)
- High marsh sites supporting *Atriplex paludosa* and *Wilsonia humilis* are not yet showing distinct vegetation association changes (Quadrats 2 & 14) on Torrens Island, although some abundance changes are apparent. These may be a result of rabbit control or rainfall patterns.

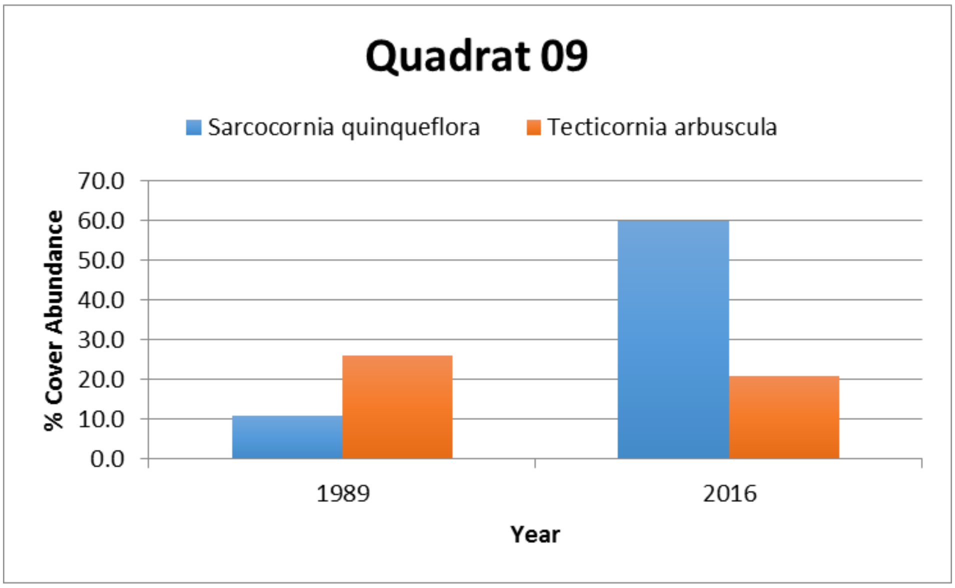


Figure 18 - Quadrat 9 vegetation changes

The elevation data collected for the Torrens Island transects and quadrats indicates a relative sea level rise on the island of approximately 15cm since 1989 (Fotheringham, *pers comm*). The rise is a combination of approximately 5.2mm per year sea level rise for Gulf St Vincent recorded at Port Stanvac (DEWNR 2013) combined with subsidence.

The processed vegetation data from Quadrat 9 shows an increase in *Sarcocornia quinqueflora* cover from 11% of the quadrat to 60%, nearly a 5-fold increase. At the same time *Tecticornia arbuscula* has reduced from 26% of the quadrat to 21%, a relative dieback of about 20%. Keeping in mind the limitations of using such a small quadrat (outlined above), and viewing the photographs, one is led to the assertion that this is likely to be an underestimation of the loss of this species across Torrens Island.

Although the measured data from other quadrats has yet to be processed, the comparative site photographs are revealing. **Figure 19** contains paired photographs of those quadrats where mangrove incursion is the major feature, **Figure 20** displays the changes in dominance of *Tecticornia arbuscula* and *Sarcocornia quinqueflora*, while **Figure 21** illustrates the high marshes, where patterns of change are not yet clear.

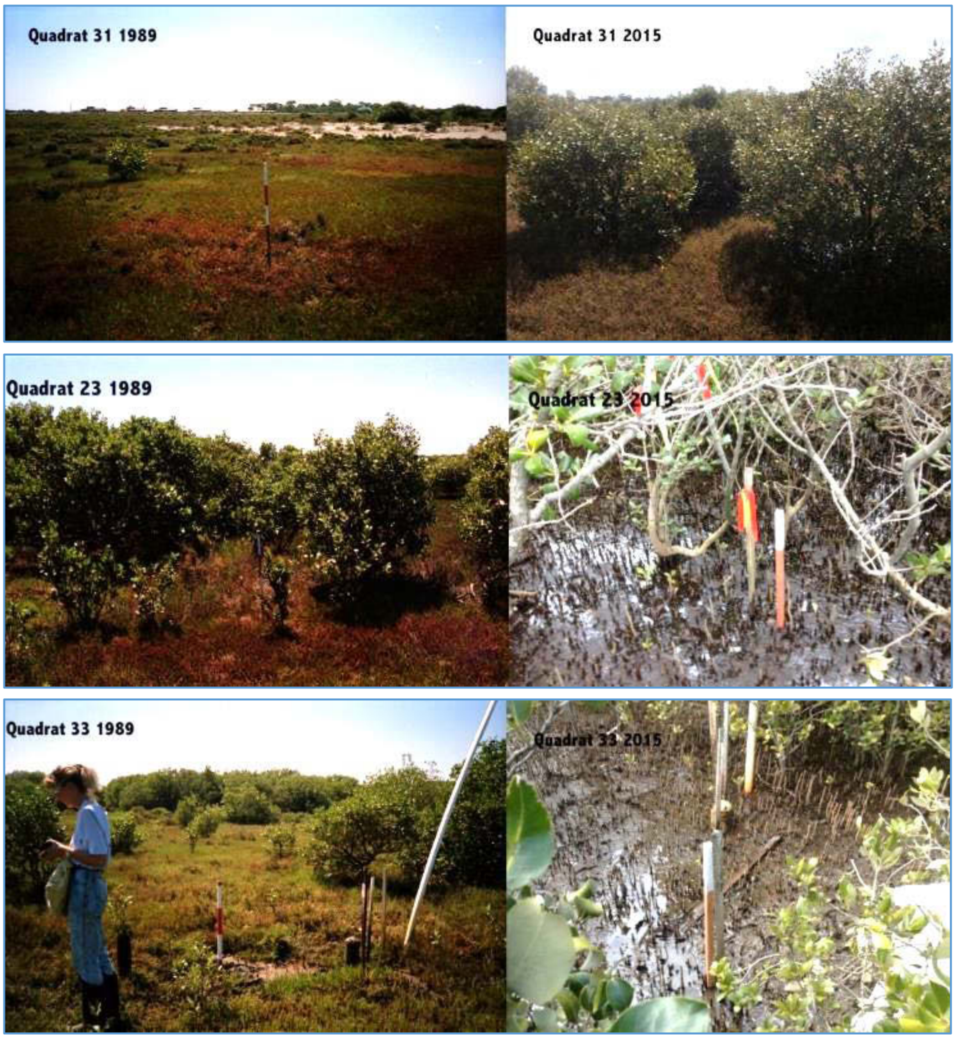


Figure 19 - Mangrove incursion at Torrens Island

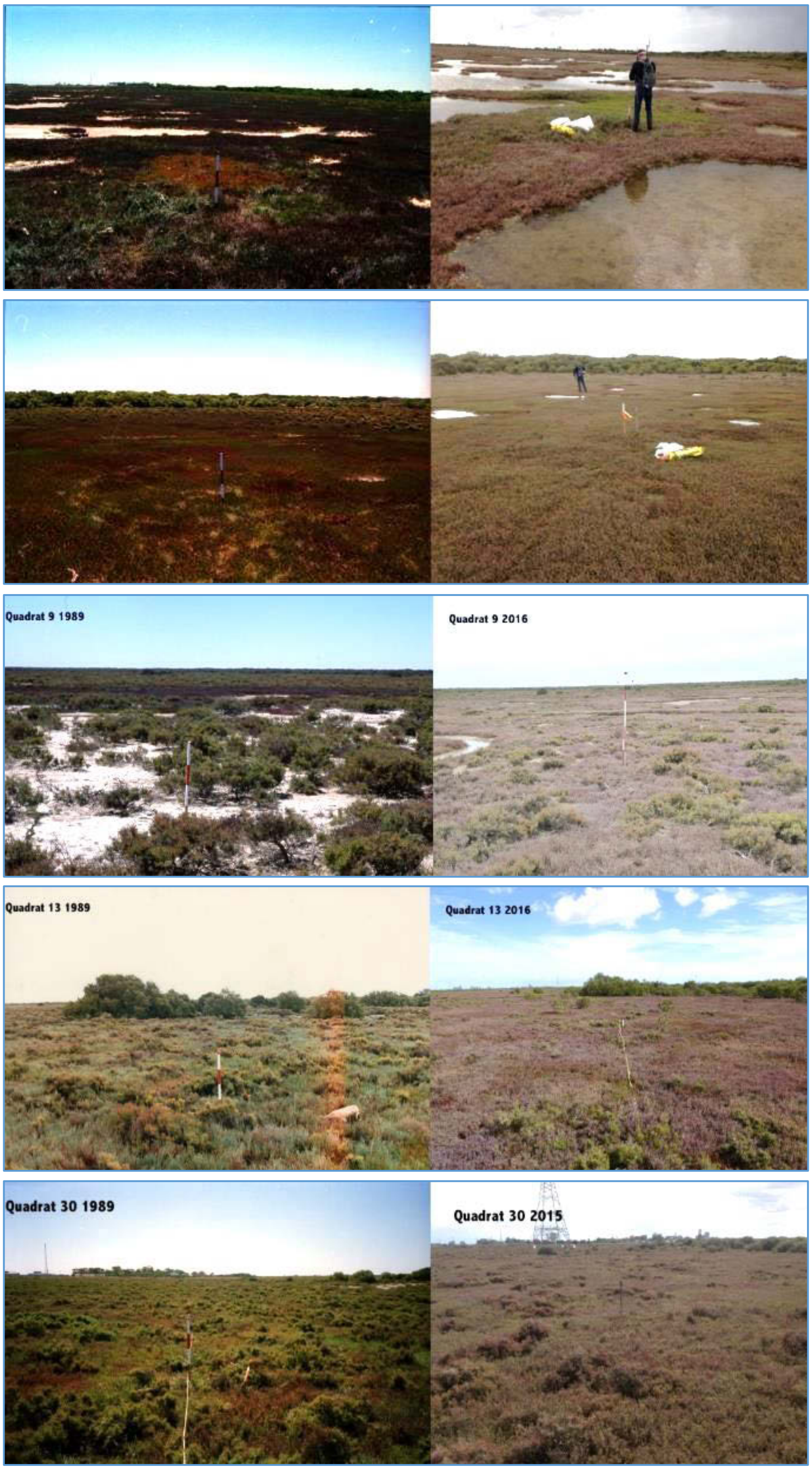


Figure 20 Changes to T arbuscula & S quinqueflora, Torrens Island

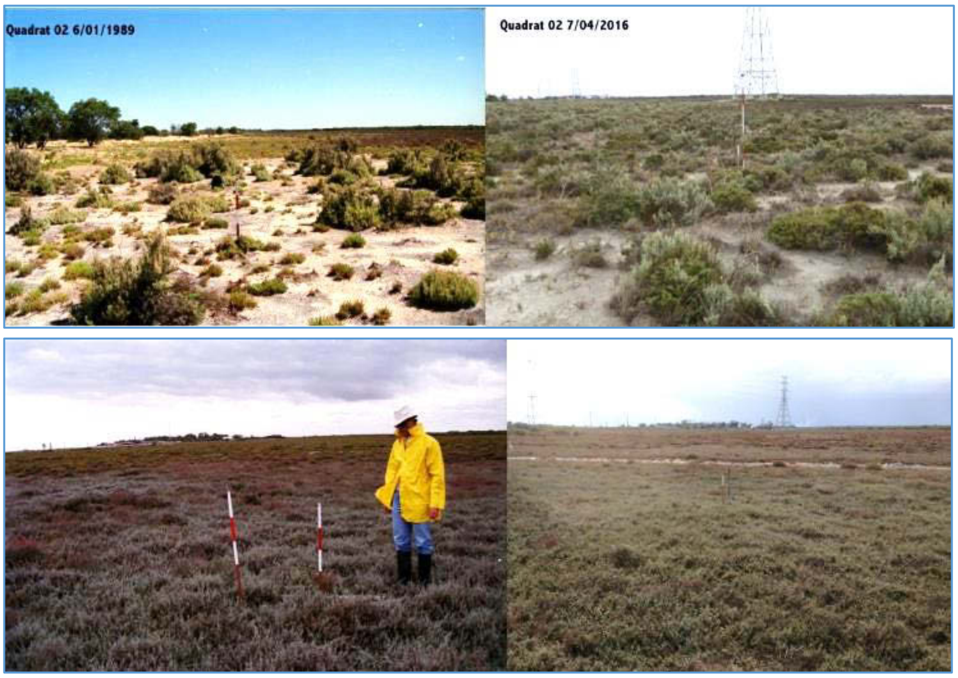


Figure 21 - High marshes not yet affected, Torrens Island

NORTHERN GULF ST VINCENT - THOMPSON, WEBB AND PARHAM

The northern parts of Gulf St Vincent are dominated by sabkhas that have restricted tidal connections. Thus far, that restriction seems to have minimised the changes to the hydrology of these large areas. *Tecticornia arbuscula* occurs in relatively small areas close to the tidal creeks and is displaying smaller quantities of loss (~20-30%) than evident at the River Light delta.

Figure 22 - Between Webb Beach and Parham

THE COORONG – MIXED HEALTH

Shrubby samphire throughout the middle reaches of the Coorong (Parnka Point and northern parts of the Southern Lagoon) are displaying losses of approximately 30% (20-50%) with the remaining plants looking variably stressed.

Figure 23: Adjacent Parnka Point boat ramp.

Figure 24: Southern side of Parnka Point, near highway. Photo shows *Sarcocornia* encroachment.

Figure 25: Spiny Rush (*Juncus acutus*) forming barrier to migration of Shrubby Samphire. Southern Lagoon, near Hacks Point.

Figure 26: Understory Shrubby samphire, with a dense upper canopy of Melaleuca and understory of *Sarcocornia*.

Further south, at Cantara Lakes, tidal influence is negligible and the Coorong becomes a separated series of large salt lakes. Shrubby samphire does not occur within the main water body (due to hypersalinity), but occurs in small areas alongside the lakes on shellgrit ridges, under stands of *Melaleuca halmaturorum*. These stands and nearby divaricate coastal shrubbery (shrubbery with densely interlaced stems where the branches spread apart at wide angles) are where Blue-winged Parrot and other *Neophema* species have previously been spotted (photos by John Gitsham and others, published on Bird Nerds). These “understory” stands of *Tecticornia arbuscula* are scattered but appear to be healthy.

Further back from the Cantara Lakes, within the Cortina wetland complex, between the Old Coorong Road and the Princes Highway, more extensive, denser stands of Shrubby samphire exist. These seem to be dependent on groundwater discharge, subsurface Coorong / seawater intrusion and localised flooding. Potential threats to *T.arbuscula* in this area include dryland salinity and groundwater level change as a result of sea level rise and drainage projects.

Initial observations suggest that dieback has occurred 20-30% of these plants, with a disproportionate number of the dead Shrubby samphire being the taller plants. The remainder of the plants ranged from healthy to stressed.

Figure 27: Cortina wetland Shrubby Samphire stands

YORKE PENINSULA & PORT WAKEFIELD

Mac's Beach, on the eastern side of the Yorke Peninsula has significant stands mixed *Tecticornia* spp., in a swale behind a low series of coastal dunes. These areas are separated from tidal influence. While very low in number, the Shrubby samphires within this mixed habitat appear to be healthy, although approximately dieback has occurred in 10-15% of the stand observed from the road.

Figure 28: Mac's Beach swale

There are some healthy isolated Shrubby samphires, mixed with other samphires in, and adjacent to, the drains running alongside the western portions of the Price Saltfield. It was difficult to identify the samphire down to species due to limited access, however, a number of adult *T.arbuscula* appeared to have died.

Figure 29: Price Saltfield drains

The extensive Shrubby samphire association on the saltpans east of the Price township (on Saltfield mining lease) appear to have 15-20% dieback. The seaward portions of these flats, closest to the Wills Creek Conservation Park, are experiencing encroachment by *Sarcocornia quinqueflora.*

Figure 30: Saltflats adjacent and east of Price township.

The stands of Shrubby samphire within the Wills Creek Conservation Park indicate an ~20% loss of the current stand. The Price to Port Wakefield area is a location where accretion has been occurring, with studies showing seaward mangrove colonisation and land building (Coleman and Cook 2007). Mangroves at Wills Creek have colonised seaward in a band about 70-90 meters wide for several kilometres of coast.

Figure 31: Wills Creek Conservation Park

Figure 32: Creekline alongside road in Wills Creek Conservation Park

Explanations for this land building include the impacts of uplift and sediment supply. The recent geological highstand of the sea resulted in an increasing volume of water overlying the continental shelf. This caused differing degrees of coastal warping and resulted in a geographically variable, apparent sea-level fall around the much of the state's shoreline over the past 6,000 years (Drexel and Preiss, 1995). In the northern Gulf St Vincent the apparent sea-level fall over that period was in the order of 3-5 metres, or 0.05-0.08mm per year. Sea level rise as the result of global warming is rapidly negating uplift however, even in the northern ends of the South Australian Gulfs. The rate of sea level rise is two orders of magnitude greater than uplift in most areas.

As well as uplift, the northern Gulf receives many tonnes per day of fine carbonate material carried in by the tidal current from the south (Shepherd and Sprigg 1976) This fine milky material settles out in the quieter waters of the northern Gulf and is one of the reasons that waters of the northern Gulf are slightly turbid. Over geological time, should no other changes intervene, the top portions of the Gulf would gradually become shallower, eventually transforming into coastal wetlands. Shepherd and Sprigg (1976) also identified other sources of sediments that accumulate in the northern Gulf, including discharges from quarries at Rapid Bay, Kleins Point and Christies Beach, from the dredging at Outer Harbor and from the resuspension of settled sediments by tidal rips near Cape Jervis and North Spit.

Settled sediment is stabilized by seagrass. The seagrass provides a sheltered area for more sediment to settle out and the coralline algae that grow amongst the seagrass also contribute to the enlargement of the seagrass beds. Shepherd and Sprigg (1976) discuss several studies in Gulf St Vincent that show these seagrass banks have caused the shoreline of the northern Gulf to migrate seaward several kilometres since the sea level stabilized about 6,000 years ago.

Within this area of accretion and uplift, Shrubby samphire populations growing in areas such as Wills Creek show fewer dead plants than those on the Samphire Coast. Many of the larger plants are showing signs of dieback suggesting deaths may increase over the next few years if sea level rise continues at current rates. Open areas of sabkha are being rapidly colonised by *Sarcocornia quinqueflora*.

In Port Clinton, there are very few historical stands of samphires of any species remaining along the foreshore, as mangroves are encroaching rapidly. Further north, in the protected embayment adjacent Manwurta Street (Clinton Conservation Park) there is a substantial area of Shrubby samphire. Shrubby samphires in this discrete area appear to have 50-70% dieback and *Sarcocornia* are rapidly colonising here. A combination of land filling, drainage, stormwater discharge and sea level rise are possible threats to the samphire community in this location.

Adjacent this part of the conservation park there are key areas that could provide Shrubby samphire retreat, if carefully land-formed, weeded and sown appropriately.

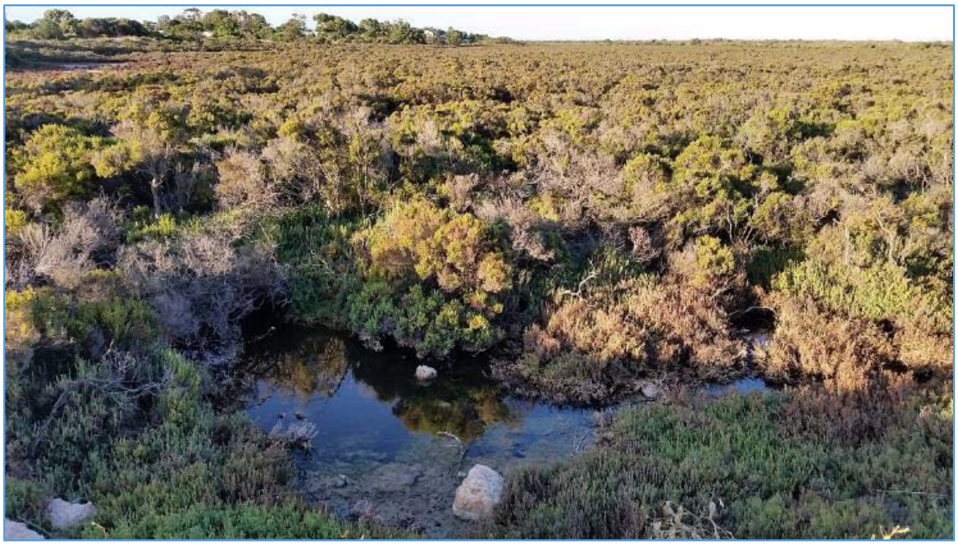


Figure 33: Looking north from Manwurtha Street

Figure 34: Looking north west from track along sand dune, near Manwurta Street.

At Port Arthur, *T. arbuscula* appears to have experienced ~30-50% dieback in areas of close proximity to the mangrove forests. *T.arbuscula* found at a distance from *Avicennia marina* appear to be healthy. This site has fewer anthropogenic impacts beyond sea level rise.

Figure 35: Port Arthur, closer to mangroves

Figure 36: Port Arthur, further from mangroves

Port Wakefield supports extensive areas of Shrubby samphire. There are formed paths through the association that join up with the Walk the Yorke Trailhead and the Clinton Conservation Park. Dieback in this area varies from 30-50% or more, with significant areas of dieback being overgrown by *Sarcocornia* and *Wilsonia humilis* meadows.

Figure 37: Port Wakefield, looking back toward the caravan park.

Figure 38: Port Wakefield. Same location as Figure 37, looking west.

PORT AUGUSTA – A DISJUNCT DISTRIBUTION

The Shrubby samphire *Tecticornia arbuscula* occurs in two relatively restricted and disjunct niches at Port Augusta. The first niche is behind mangroves that are very close to open Gulf waters. Inland, at the head of the tidal creeks, Shrubby samphire is replaced by an unusually large form of *Tecticornia halocnemoides* (Grey samphire) that is filling the niche of *T. arbuscula.* This possibly reflects the two species' salinity tolerances, as tidal creeks in this arid area become hypersaline as they penetrate landward.

Wilson's (1980) description of Grey samphire as being a subshrub less than 50cm high is clearly confounded, as these plants can reach 1.2m tall. Chinnock (1980) recorded large *Tecticornia halocnemoides* immediately behind the mangrove zone at Chinaman's Creek south of Port Augusta, and both Wilson (1980) and Datson (2002) have recognised that the *Tecticornia halocnemoides* species complex contains some much larger plants than are currently defined in the species' and subspecies' descriptions.

The second niche occupied by Shrubby samphire (*Tecticornia arbuscula*) at Port Augusta is in the high marsh, on land not subject to daily flooding. Rain washes out salts in the soil at this elevation. Once again, this observation is supported by Chinnock's (1980) survey of Chinaman's Creek.

The Shrubby samphires at Port Augusta appeared to be healthy, although in this habitat they are not a dominant component of the landscape. There are some small stands of stressed and dead Grey samphire, but the ground between the plants is sparsely vegetated and juvenile *T. halocnemoides* are sprouting next to those that have died.

AVALON BEACH – NICHES IN THE LANDSCAPE

Avalon Beach is located on Corio Bay in Victoria. Shrubby samphires are found in several distinct habitats here:

- very large healthy looking old shrubs grow in a coastal tussock grassland in the gardens of the residences, on a shelly substrate above the high tide;
- tidal drains host a riparian of *Tecticornia arbuscula* and about 30-50% of these plants exhibit dieback; and
- a third group are growing on the embankments and on islands within the marine ponds of the abandoned Lara saltfield. These latter appeared to include areas that were healthy and areas that looked stressed. The saltworks has been abandoned for some years and minimal pumping of seawater is occurring into the ponds. It is not known whether there are water level and salinity variations occurring.

Figure 39 – L: Shrubby samphires at Avalon Beach R: Mixed health in the tidal drains

DISCUSSION

AN EXPLANATION FOR THE LOSSES?

The first indication of die-off in *T. arbuscula* in Gulf St Vincent was Carpenter's report of the thornbill surveys undertaken in winter and spring of 2014. In that study Carpenter observed areas of shrubby samphire that appeared stressed and subject to die-off. Carpenter suggested stress in *T. arbuscula* may be the result of exposure to wetter conditions during abnormal winter or impacts from sea level rise. Changes to the health and condition of *T. arbuscula* prompted this survey of samphire thornbill habitat, of which *T. arbuscula* forms an important plant and habitat species for breeding and food resources.

There are number of hypotheses about factors that may be contributing to the die-off of *T.arbuscula* in South Australia and Victoria, including disease, anthropogenic impacts, salinity ingression and sea level rise. There have been widespread stressors such as the Millennial Drought, and then several wettish winters. However, the dieback seems to have occurred since the end of the drought, and in Gulf St Vincent seems to have occurred both in areas that received winter flooding (the River Light delta) and in those that did not (Torrens Island).

MOST LIKELY CAUSE

Sea level rise could bring about high stress loads for *T.arbuscula* which may supress reslience and could increase disease risk in the species. Another theory is that sea level rise severely increases stress on *T. arbuscula* and has pushed the species to its inundation tolerance limits.

Dieback of *T. arbuscula* occurring concurrently with landward expansion of *Avicennia marina* and *Sarcocornia quinqueflora* is consistent with observations reported by Vanderzee (1988) within subsiding salt marshes in Corner Inlet in Victoria. Vanderzee used those observations to develop a model of potential saltmarsh vegetation changes in response to predicted sea level rise. More recently, Mount *et al* (2010) reported the loss of *T. arbuscula* in saltmarsh at Circular Head in Tasmania as a “sea level rise signature”.

There has been nearly 10cm of sea level rise in the Barker Inlet and Gulf St Vincent since the mid 1990’s. When Fotheringham (1994) examined saltmarsh species in the Gulf he found that most species had a wide tolerance for dryness, with many species being capable of surviving in areas that were only tidally inundated once or twice a year despite being generally distributed in wetter zones. However, his data also showed that the majority of species had a much more definite lower limit to their distribution. Species had maximum percentages of time they could tolerate being submerged.

Using the Average Return Interval tables for Outer Harbor and Fotheringham’s 1994 maximum inundation percentage for a range of mangrove and saltmarsh species, we added a 10cm quantum of sea level rise to obtain the following inundation percentages for plant communities in the Gulf St Vincent saltmarshes:

Table 4 - Inundation preferences of saltmarsh species

1990's species or association	Max % inundation, 1990s	Derived new % inundation regime
Avicennia marina	18.7	23.5
Sarcocornia quinqueflora	18.7	23.5
Tecticornia arbuscula	17.3	21.9
Suaeda australis	7.8	10.7
Wilsonia humilis	7.8	10.7
T. halocnemoides	7.51	10.4
T. indica	7	9.3
Samolus repens	4.7	6.9
Hemichroa pentandra	4.4	6.4
Maireana oppositifolia	2.2	3.5

Based on the data in Table 4, most saltmarsh plant communities would probably attempt to migrate inland across several vegetation associations to avoid increased saltwater inundation. For example, *Avicennia marina, Sarcocornia quinqueflora* and *Tecticornia arbuscula* are continuing to survive outside their upper limits of inundation tolerance. It is worth keeping in mind that some degree of sea level rise had also occurred prior to the 1990s, and so Fotheringham's maximum inundation percentages may be close to the point where stress becomes apparent for some of these species.

DIFFERENT RESPONSES BY DIFFERENT SPECIES

Different intertidal plant species have different growth habits, tolerance ranges for salinity and inundation hydroperiod, methods of reproduction and adaptation strategies.

Four plant species that occur in the tidal inundation zone most immediately affected by sea level rise are White mangroves (*Avicennia marina*), the Bearded glasswort (*Sarcocornia quinqueflora*), the Shrubby samphire (*Tecticornia arbuscula*) and the Grey samphire (Tecticornia *halocnemoides*).

Other saltmarsh plant species such as the Brown-headed samphire (*Tecticornia indica*), Creeping brookweed (*Samolus repens*), Saltmarsh grass (*Puccinellia stricta*), Silky wilsonia (*Wilsonia humilis*) and *Hemichroa* spp have the potential to be affected, or may already be affected, by sea level rise. However, there is little known of the adaptation response of these and other saltmarsh species to anthropgenic or climate change pressures.

White mangroves have a number of methods for adapting to changing inundation regimes. *Avicennia marina* is a land builder species (Howe *et al*, 2009) which may ameliorate the impacts of sea level rise by accumulating sediment in the plants' root zones. Sediment accumulation may allow individuals to migrate "upwards" while successfully establishing new trees landwards. Sediment accumulation and establishment of individual mangrove trees may mitigate some of the impacts of sea level rise.

Ashford and Allaway (1995) found that young mangroves are plastic in their response to inundation regimes. There is a continuum of gas space in *Avicennia marina* seedlings that allows them to obtain oxygen for their root system before they develop pneumatophores (peg roots) and to also determine the typical inundation regime they are growing within. During the juvenile period the pneumatophores will develop to an appropriate length for that inundation regime. In dry conditions the pneumatophores are very short, or even non-existent. In permanently ponded locations the pneumatophores are much longer. Once the pneumatophores have developed, changes to the inundation regime may result in the death of that individual plant. When such deaths occur from hydrological change, new seedlings sprout in the same location, but they develop different lengths of pneumatophores to cope with the changed environmental conditions.

Mangroves growing closer to the land send roots landward, underneath the plants growing immediately "uphill" of them. Chen and Peng (2008) found that mangrove roots release allelopathic substances that cause other species of plants to retreat, leaving a relatively bare strip of sediment on the "uphill" side of young mangrove saplings. Upright pneumatophores that are present within the strip capture young mangrove propagules facilitating the establishment of new mangroves.

Avicennia marina also produces propagules rather than seeds. These propagules are fully formed immature plants comprising roots and cotyledon leaves. This method of propagation assists mangrove trees to rapidly establish in new environments, which presents advantages over other colonising species that require seed development to establish.

Mangroves in Gulf St Vincent have been reported migrating landward (Burton 1982, Fotheringham 1994, Coleman 1998 & 2013). The River Light Delta has changed since European settlement and recent evidence of sea level rise can be seen in the changing vegetation patterns. Burton reported in 1949 the most prominent feature of the delta was a huge mud bank to the seaward of a line of cheniers, that may have marked the original coastline, and a narrow fringe of mangroves. The mud bank's sudden appearance may well have been related to post-European settlement catchment clearance. Mangroves colonised across the mud bank over the next thirty years however, simultaneously, landward colonisation of the mangroves at the River Light was also occurring, in response to sea level rise.

An east-west transect undertaken by Coleman and Taylor in Dec 2011 found that mangroves had penetrated east of the line of cheniers. Some of the cheniers had eroded away and mangroves were starting to penetrate into the old chenier footprints.

Significantly, on aerial photography numerous small dendritic drainage lines could be seen to have formed along the main creeks in response to the flow requirements from more regular tidal inundation across the saltmarsh. These dendritic creek patterns are typical of low to middle marsh, compared to the smoother, more linear creek patterns found in high marsh and sabkha areas.

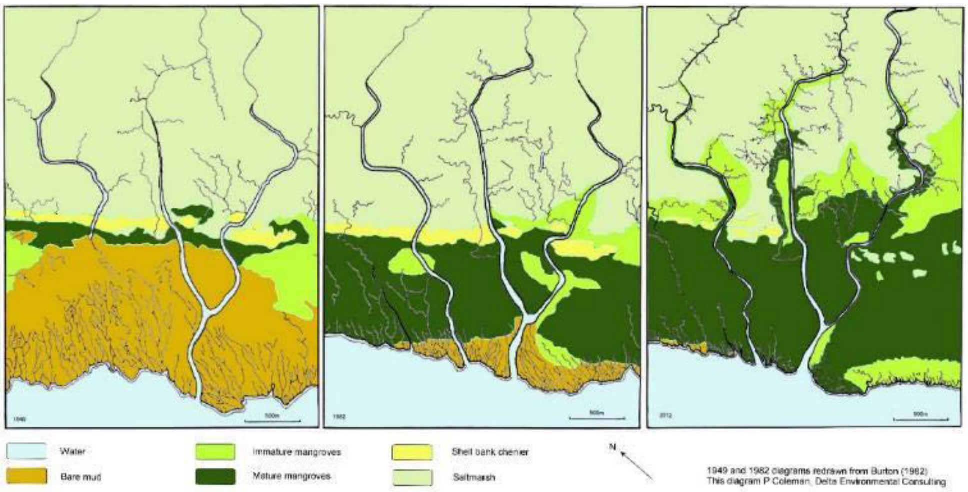


Figure 40 - Changes at the River Light delta

While these changes to mangroves were visible, and remarked upon, the rapidity of impacts to *Tecticornia arbuscula* in the delta was unexpected.

Sarcocornia quinqueflora (Bearded glasswort) occurs just landward of the mangroves. This species is also a land builder species similar to *A. marina* (Howe *et al*, 2009).

Coleman, Cook & Eden (2005 unpub) undertook studies of natural (ancient) saltmarshes and subsided, rehabilitating saltmarshes containing *Sarcocornia quinqueflora* in the Barker Inlet and Port River estuary. The study aimed to characterise the soil parameters in these marshes, to determine the distribution of zones of saltmarsh flora. Sands and loamy sands appeared to be the dominant soil types underlying *Sarcocornia* stands in un-subsided marshes and in subsided marshes in Gulf St Vincent that had only recently been reconnected to tidal inundation. However, in subsided marshes that had been reconnected to tidal inundation for many decades there was a thick deposit of fibric and hemic peats underlying the *Sarcocornia* swards. This accumulation of organic material (mostly earlier existing plants) allows *Sarcocornia* to migrate upward and remain in place, even in the face of a very rapid increase in inundation regime.

Sarcocornia quinqueflora reproduces both sexually by seed and clonally by producing rooted runners. Clonal plants can be amongst the largest organisms on Earth (for example Pando, a clonal quaking aspen colony in the USA is over 43ha in extent) and clones are notoriously difficult to kill because "bits" of them can survive to re-establish. In GSV one can frequently determine how many specific clones of *Sarcocornia* are present in a particular glasswort sward by observing the patches of colour.

Clonal reproduction by runner allows individual clones to migrate rapidly both upward (by growing on top of itself) and across a landscape (Liu *et al* 2016). While *Sarcocornia* retreats from allelopathic mangrove roots, it simultaneously moves inland, outflanking *T.arbuscula*. In the River Light delta *Sarcocornia quinqueflora* is now found growing over mats of *Samolus repens* and *Hemichroa* spp., and amongst *Maireana oppositifolia* in the high marsh.

Some plant species have naturally higher tolerance of changing environmental conditions. This may occur where a uniform species has a wide tolerance of specific environmental stressors. Alternatively, individuals within a species may exhibit phenotypic response environmental stressors, such that few individuals may survive in adverse conditions while other may perish (Richards *et al* 2005). *Tecticornia halocnemoides* (the Grey samphire) is a resilient species occurring on arid hypersaline sabkhas in Gulf St Vincent and in the intertidal areas at Port Augusta immediately landward of mangroves. Individuals of this species can withstand extreme environmental conditions including extended dry periods and those associated with flooding and prolonged water inundation. The plants produce copious wind dispersed seeds. Mature shrubs have gnarled low woody trunks and tolerate varying and extreme hydrological conditions. This species currently occupies the high ground, preventing any expansion inland of *T. arbuscula*.

T. halocnemoides also seems to have a very variable growth form (detailed in the previous section), which noted the very tall Grey samphires at Port Augusta. However, there is currently no information on the temporal change in growth form of *T. halocnemoides* and whether larger shrubs of this species occupy the same ecological niches as *T. arbuscula*.

T. arbuscula is a large, long lived samphire (Mount *et al* 2010). It occurs in areas where it has established during a period of stability and a very regular inundation regime. It is possible that older plants have lower resilience to changing environmental conditions than younger more adaptable plants. *Tecticornia arbuscula* seems to be sensitive to hypersalinity (Boon *et al* 2016) as well as to increased inundation. It displays a disjunct distribution at Port Augusta, where it is observed to grow adjacent the mangroves closest to the Gulf but not adjacent to mangroves further from the sea where the tidal creeks and soils are hypersaline. The second niche occupied by *Tecticornia arbuscula* at Port Augusta occurs in the high marsh on slopes where salt is leached by rainfall. This "high land" niche is also utilised by the Shrubby samphire in other localities, for example adjacent the Cantara Lakes (Coorong National Park) and at Avalon in Victoria.

As well as being individually sensitive to increased inundation, *T. arbuscula* does not have a method of rapid dispersal that enables it to easily colonise new environments. The species' low dispersal and slow and limited reproduction is characteristic of a Kstrategist. *T. arbuscula* has one fertile seed per floret, rather than three or more as most other samphires do, and the species holds the seed in the flesh of their stems, limiting distribution into the environment until the plants' branches are broken up. This is most likely to occur in winter storms, during the period of the highest tides each year. Broken branches float in the tide to an appropriately elevated location. In many places we observed, this location is occupied by *T. halocnemoides* or *S. quinqueflora* which may be limiting the current dispersal of *T. arbuscula* to new environments. In situations where freshwater was observed entering the marsh, there is likely to be competition for space, also. For example, shrubby lignum at the River Light form an impenetrable riparian band.

OBSERVED DIFFERENCES BETWEEN SHRUBBY SAMPHIRES - SURVIVING AGAINST THE ODDS

So where is *Tecticornia arbuscula* surviving, and how? Are there areas of Shrubby samphire that are coping, or doing better? Any sign of successful retreat? There are some plants doing better than others within areas of strong dieback and there are locations where dieback is not as pronounced.

A few very large, ancient plants at Port Gawler are coping well where the Council has added extra road base to Port Gawler Road. Where several centimetres of soil have washed down from the road to cover the roots of the bushes, it appears their roots may have been able to migrate upwards into the new, less waterlogged soil and into a zone where the frequency of tidal inundation was more congenial. This suggests that in some river catchments, if the sediment supply is large enough and sea level rise is slow enough, Shrubby samphire may be able to keep ahead of the water rise. This is reassuring in one way, as it means that in the northern parts of the South Australian Gulfs and much of southern Western Australia where uplift is occurring, the species may retain some populations.

A second group that appear to be doing better are the patches of Shrubby samphire that were cleared and mildly land-formed for boat hardstanding at Middle Beach. The area is gradually recolonising and because the mud flat was scraped bare, all species had an equal chance of colonising. New Shrubby samphires have sprouted and the young plants are adjusted to the current hydrological conditions. Whether they will have as long a life as their forebears remains to be seen – this will probably depend on the speed that sea level rise progresses.

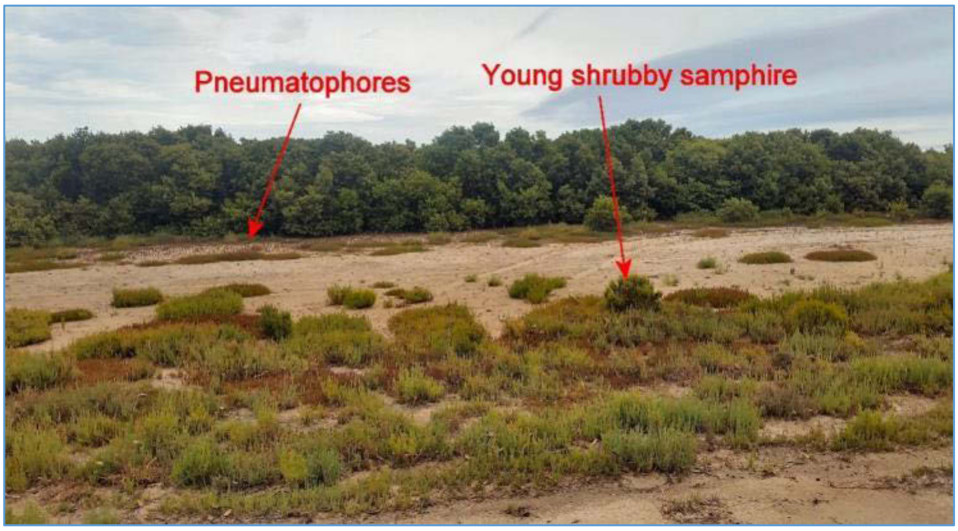


Figure 41 - Regrowth at Middle Beach

A third group of young plants were observed growing in the drain alongside Port Gawler Road. Regular flooding down the drain strips vegetation away from the “overbank flow” zone. Several young, but healthy *Tecticornia arbuscula* were visible in that zone.

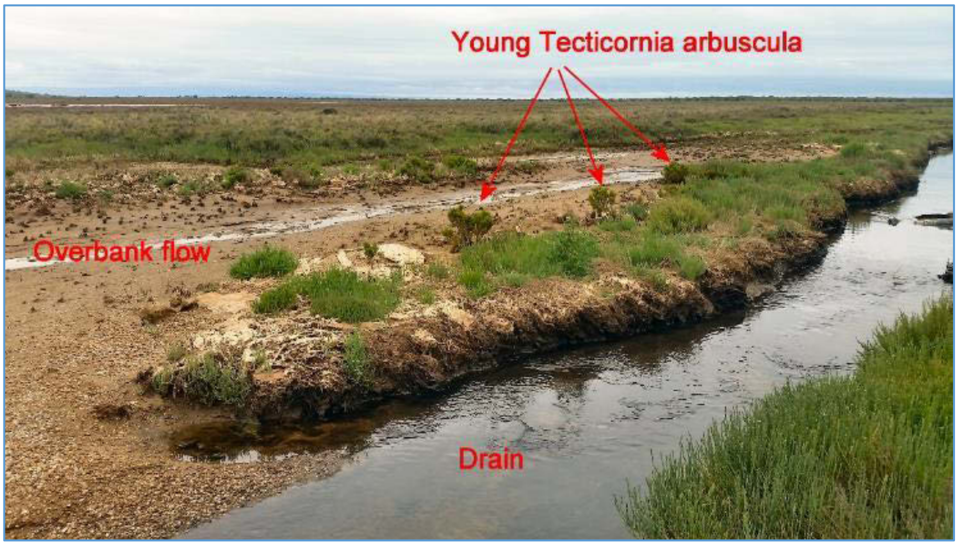


Figure 42 - Young plants at Port Gawler

Flotsam and jetsam including seaweed wrack is an intrinsic component of seashores that enable sediments to accumulate. Where shelly sand cheniers have accumulated (and are continuing to accumulate) and along embankments, the generous wrack deposits provide a drier, well aerated medium for the roots of the Shrubby samphire.

Where Shrubby samphire has grown on shelly ridges away from tidal inundation, they are likely to remain healthy for substantial periods until sea level rise causes measurable alterations in groundwater levels. Such locations occur in Avalon and Cantara Lakes where *T. arbuscula* remains healthy. Similarly, where the rate of sea level rise is lower or being offset by uplift, or where restricted tidal prisms may have reduced the full impact of sea level rise (the Coorong, some sabkha tidal creeks) it is likely that dieback will progress more slowly.

T.arbuscula will also likely thrive in open space landward of existing plant communities (for example the overflow bench of Port Gawler Road flood drain). Similarly, *T.arbuscula* may also remain healthy and colonise elevated inland sites that have limited salt ingression. Such sites however, across South Australia are limited. Such examples suggest *T. arbuscula* can adapt to new environments if the right conditions are available for colonisation.

Figure 43 - Shrubby samphire (top of photo) on wrack deposits

UNPREDICTABLE OUTCOMES WITH SEA LEVEL RISE IN SALTMARSHES

Species mechanisms for coping with sea level rise vary. That saltmarsh species will all migrate inland together and the same associations will occur at slightly higher elevations than currently is confounded. Some species will be more successful than others. And some species will be more successful in some places, than they are in other places. Other species may change from being a dominant landscape element to being occupiers of tiny niches, or may disappear altogether.

Dryland salinity issues and rising unconfined aquifer levels due to sea level rise are likely to be unpredictable and their impacts on Shrubby samphires that occupy near-coastal saline wetland systems as refugia is unknown.

Changes in ecosystem structure such as the decline or complete loss of *T.arbuscula* as a key samphire species may have cascade effects on reliant species for example, the Samphire Thornbill. In Gulf St Vincent, Barker Inlet/Torrens Island, *Tecticornia arbuscula* has limited adaption and resilience to sea level rise resulting in the reduction and die off of many individuals and limited recruitment. This long lived, slowly reproducing species could be considered the 'canary in the coalmine', indicating saltmarshes within this area may be changing in composition as a result of sea level rise.

The results of the surveys conducted across South Australia and in Victoria suggest *T. arbuscula* may become a minor saltmarsh species in areas where it cannot adapt to changing environmental conditions. In Gulf St Vincent, the colonisation and recruitment of *T. arbuscula* appears constrained by the availability of uphill, or elevated locations, which are currently occupied by other samphire species.

STATEWIDE SALTMARSH BASELINE DATA

The existing photopoints, quadrats and transect data collected in the 1990s by DEWNRs Coastal Management Branch will provide very important saltmarsh baseline data, once the data are processed. Budgetary constraints meant that the data was archived unprocessed when it was collected. The processing and analysis is currently being undertaken on a voluntary basis at the Herbarium by Doug Fotheringham.

Once the data is processed, it is only useful if it can be compared to something. The current study provides a snapshot of the current health of saltmarsh and samphire species in Gulf St Vincent and a limited number of other locations. Revisiting the Coastal Management Branch's state-wide transect sites will provide a better understanding on how different samphire and saltmarsh species adapt to a changing environment. Given the dependence of other species (including EPBC Act listed species) on saltmarsh habitats, such information is necessary to support future biodiversity management and conservation planning across the State.

At a minimum, sites used by thornbills surveyed in the current study should be revisited and rephotographed at regular intervals.

MITIGATION OPPORTUNITIES FOR *TECTICORNIA ARBUSCULA* IN GSV

Restoration of the ponds of the Dry Creek Saltfield may provide some opportunities for *Tecticornia arbuscula* to recolonise and establish, where remediated ponds with embankments are utilised for the treatment of stormwater (as suggested by the Cities of Salisbury and Playford, for ponds near St Kilda). Similarly, where ponds are reopened to tidal inundation, there is an opportunity for Shrubby samphire to be used as the key species for revegetation programs. In both examples the salinity of the adjacent water body should not be in excess of normal Gulf water salinity.

T.arbuscula is not currently well propagated and there are limited seed volumes available for revegetation. It would be prudent to establish a seed bank and seedling program to assist in any revegetation program using *T. arbuscula*. The State's regulations for appropriate harvesting percentages may need reviewing in the light of *Tecticornia arbuscula*'s dramatic population collapse.

Embankments produce very narrow bands that are suitable for each species, in relation to the tide (reconnected saltmarsh) or to a constant water level (pond). Adding extra material to create a longer slope would maximise the opportunity to grow a wider band of *Tecticornia arbuscula*. Material that drains well may also be beneficial (sand, seagrass wrack) as it does not stay waterlogged as long as clay soils do, so may extend the width of the embankment zone that is appropriate for the establishment of Shrubby samphire.

Estimating the appropriate elevation along an embankment for seeding is problematic as different soils hold water for different periods of time. Establishing trial plots may assist in understanding the requirements and successful reintroduction of *T. arbuscula* to new environments. The more usual approach would be to seed widely on the embankment and assume that those seeds that fall too far down the embankment will be picked up by the water and redeposited at an appropriate elevation.

Remediation of the saltfield ponds to other uses that rely on hypersaline water (for example, the commercial development of a smaller saltfield or SA Water's saltwater evaporation ponds) would appear to provide less opportunity for developing niches for Shrubby samphire.

Reducing other stresses on these saltmarsh communities, such as off-road vehicle use, weeds, hydrological changes, nutrient enrichment and pest incursions will also assist, by ensuring the impacts of sea level rise are not compounded by other issues.

SAMPHIRE THORNBILL OR COASTAL SHRUB THORNBILL?

The Slender-billed Thornbill (*Acanthiza iredalei*) species, of which Samphire Thornbill (*Acanthiza iredalei rosinae*) is a subspecies, is primarily an insectivorous species. The species utilises diverse and divaricate shrubbery, mostly of the chenopod family. While Slender-billed Thornbills use isolated larger shrubs and trees, they are usually only observed on the fringes of areas with a dense tree canopy. The species appears to be dry temperate zone specialists, with the Samphire Thornbill subspecies predominately using coastal microclimates.

Acanthiza iredalei rosinae uses seagrass and spider webs to form its dome-shaped nests, which it builds into the middle of shrubs at a height of 0.5-1.0m from the ground (McGilp 1925 in Matthew 2002). The primary shrub species used for nesting is the Shrubby samphire, however other species of divaricate shrubs of the appropriate height, are occasionally used. The preferred height for these nesting bushes is 1-3m tall. The birds have a preference for shrubs within 20m of a tidal creek or saline lake.

Samphire Thornbills have very small territories, with a total home and range area of less than 25 hectares.

Samphire Thornbills have been observed predominantly gleaning insects from a range of *Tecticornia* species (particularly plants infested with galls). As a secondary but still important food source, they have been seen gleaning from Nitre bushes, as well as from the mud surfaces, air and from mangrove flowers, at the fringes of the mangrove woodland. Prey items included small flies, midges, larvae, beetles, spiders and caterpillars.

While it is obvious that they have an ecological dependence on the larger *Tecticornia* species in particular the Shrubby samphire, for nesting, as a source of gall insects and a perch from which to sally forth, it appears that there may be some scope for exploring and enhancing alternative habitats for the Samphire Thornbill, in addition to work to preserve the Shrubby samphires.

Alternative habitat development could include identifying other coastal species that may currently be used as nesting sites or that attract insects through their production of nectar and selectively planting these species near areas of extensive Shrubby samphire dieback.

Reducing pest insect control within areas of known value to Samphire Thornbill and increasing pest predator management may also assist with reducing overall stress to this subspecies.

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