VEGETATION MONITORING, KARAAF WETLANDS, YEAR 2 (NOVEMBER 2024)

PATHWAYS
BUSHLAND & ENVIRONMENT

Report to Surf Coast Shire, by Doug Frood (Pathways Bushland and Environment, Marraweeney, Victoria), January 2025.

ACKNOWLEDGEMENTS

The Karaaf is located on the lands of the Wadawurrung People of the Kulin nation. The author acknowledges them as the Traditional Owners of this place and pays respect to their Elders past, present, and future.

The author wishes to extend his appreciation to the staff of Surf Coast Shire for their support for this project, in particular to Robyn Neville. Thank you also to Jamie McMahon of ABZECO Pty Ltd for preparation of the aerial photography for use in the field and Surf Coast Shire for digitizing the supporting mapping information.

EXECUTIVE SUMMARY

The Karaaf is a 130 ha site managed by Parks Victoria and has a catchment that straddles two local government areas. The Surf Coast Shire Council (Council) is the stormwater drainage authority for the majority of the Karaaf and Thompson Creek catchments to the north and west of the site. The Karaaf is part of the Thompson Creek estuary and is a subsection of the broader Breamlea Flora and Fauna Reserve saltmarsh system. The Karaaf lies within Wadawurrung Country and is noted to be of high environmental, community and living cultural heritage significance.

Previous work (Frood, 2022) was commissioned by Council to provide assessment of the extent and quality of existing vegetation at the Karaaf, and identify the impacts resulting from stormwater flows from the western outlets connected to residential development. Following on from this work, Pathways Bushland and Environment was commissioned by Council to initiate a monitoring program for the vegetation of the Karaaf. The monitoring program considers two components, these being sampling of vegetation and soils. While the vegetation component is the main focus of the monitoring, the design of the program includes analysis of some soil samples to establish baseline values for salinity, comparing sites with more modified vegetation to some supporting relatively intact shrubby saltmarsh communities.

The vegetation component involves strategically placed 10 x 10 metre square quadrats, recording the estimated covers provided by individual plant species within the sampling area as well as general notes on other features of the locations. The purpose of this monitoring is to provide clear indications of progressive changes in the structure or floristics within the local vegetation. Twenty-one quadrats were selected for the initial sampling in 2023, to provide coverage of the plant communities modified by stormwater inputs, and also the range of proportional extent of dieback of saltmarsh shrubs. The current report provides information from follow-up monitoring conducted during November 2024.

Soils were sampled at eight locations, with sections of cores from between 15 and 20 cm depth sent for laboratory measurement of the Electrical Conductivity (EC) as an indicator of relative salinity. The eight locations were selected to include tidally influenced parts of the saltmarsh and healthier shrubby glasswort dominated

vegetation outside of normal tidal inundation (e.g. near the central southern boundary), to enable comparison with areas where the vegetation has been converted to brackish wetland and sites where there has been comprehensive dieback of glasswort shrubs. Brief descriptions of the soil sample sites and associated EC determinations are provided.

The first years monitoring data indicated that soil salinity levels were substantially lower at the sites where the saltmarsh vegetation has been converted to Brackish Wetland by stormwater inputs. In 2023 the relationship between soil salinity and various levels of dieback of the saltmarsh shrubs appeared to be less meaningful, with only relatively small differences between sites of vastly different condition. However in 2024 a direct correlation between reduced soil salinity and both conversion to vegetation indicative of brackish conditions and levels of dieback was apparent.

The vegetation quadrat data from 2023 was hand-sorted into a two-way table to indicate species groups and their representation within the relevant quadrats. This table was presented in Frood (2023). Four groups were delineated in this table – these are to some extent loosely defined as they represent sections of a more or less continuous ecological gradient. The groups are defined by the progressive replacement of saltmarsh species by those of sequentially less saline wetland habitats, i.e. the conversion of Coastal Saltmarsh to adventive Brackish Wetland and ultimately opportunistic assemblages of freshwater wetland species.

While all quadrats remained in the same groups as identified in 2023, increases in the abundance of species indicative of brackish to fresh conditions are apparent at some sites, notably those on the periphery of the vegetation previously noted as modified by stormwater. These changes indicate the progressive expansion of the area identified as impacted by stormwater in 2022. A substantial recent increase in the extent of *Typha* spp. in the western Karaaf was also noted during the current field assessment.

In areas where dieback of the saltmarsh shrubs has been less extreme, shrub regeneration was noted at a number of sites, largely appearing to be from root suckers, but also with small seedlings occasionally noted. No additional shrub mortality since 2023 was observed at any of the sites.

CONTENTS

1. INTRODUCTION AND BACKGROUND

The Karaaf is a 130ha site, including approximately 95 ha of saltmarsh vegetation (Map 1). It is managed by Parks Victoria and has a catchment that straddles two local government areas. The Surf Coast Shire Council (Council) is the stormwater drainage authority for the majority of the Karaaf and Thompson Creek catchments to the north and west of the site. The Karaaf is part of the Thompson Creek estuary and is a subsection of the broader Breamlea Flora and Fauna Reserve saltmarsh system. The Karaaf lies within Wadawurrung Country and is noted to be of high environmental, community and living cultural heritage significance.

Previous work (Frood, 2022) was commissioned by Council to provide assessment of the extent and quality of existing vegetation at the Karaaf, and identify the impacts resulting from stormwater flows from the western outlets connected to residential development. Key conclusions of that study included the following:

- While saltmarsh plants of the intertidal zones are adapted to regular inundation to a particular depth, sustained and deeper inundation can exceed their tolerances. Species adapted to highly saline conditions can be intolerant of sustained conditions of low salinity, further increasing their vulnerability to freshwater inputs.
- Inflows from stormwater have dramatically altered the environmental conditions, particularly where they have led to unnaturally wet conditions over summer.
- The vegetation in a zone abutting the western boundary of the Karaaf has been transformed by the expansion of an adventive Brackish Wetland community and colonisation by patches of Cumbungi (*Typha* spp.), as a consequence of stormwater inputs from adjacent development.
- In addition to an ecological shift towards wetland species indicative of less saline habitats in the western section of the reserve, there has been substantial mortality of the succulent shrubby glasswort species which dominate much of the extent of the Karaaf saltmarsh.
- Dieback of these shrubby saltmarsh species occurs when the saltmarsh experiences flooding over prolonged periods as part of the cycle of intermittent closing of the Thompson Creek estuary.

- Impoundment and harvesting of water for agricultural use, in conjunction with climate change, may be influencing the natural cycles of stream opening and closure.
- Evidence such as the remains of algal growth attached to the stems of dead glasswort shrubs indicates that these plants have been subject to prolonged inundation well above the depth reached by normal tidal inflows. As evidenced by the frequent retention of finer branch structures on dead plants, much (but not all) of this impact is relatively recent, apparently within the last few years.
- Mortality rates of glasswort shrubs were particularly high in the western section of the Karaaf, with broad areas of virtually total stand death evident.
- It is considered highly probable that, in this western section, stormwater inputs have compounded the deleterious effects of ponding in the saltmarsh during intermittent periods of estuary closure.
- Comparative observations from previous studies indicated that both the extent of dieback of saltmarsh shrubs and the area dominated by species indicative of less saline conditions in the western part of the Karaaf had expanded substantially over the preceding five years.

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Following on from this work, Pathways Bushland and Environment was commissioned by Council to initiate a monitoring program for the vegetation of the Karaaf. This program is intended to be conducted in conjunction with the implementation of infrastructure management actions designed to regulate stormwater inputs into the Karaaf. This report presents the data from the second year of the monitoring program.

MAP 1. THE KARAAF WETLANDS STUDY AREA AND SURROUNDS

2. METHODS

The monitoring program considers two components, these being sampling of vegetation and soils. While the vegetation component is the main focus of the monitoring, the design of the program includes analysis of some soil samples to establish baseline values for salinity, comparing sites with more modified vegetation to some supporting more intact shrubby saltmarsh communities. The GPS locations of both the vegetation and soil sampling sites as outlined below are included as Appendix 1.

2.1 VEGETATION SAMPLING

The vegetation component involves strategically placed quadrats, recording the estimated covers provided by individual plant species within the sampling area as well as general notes on other features of the locations, as described below. The purpose of the monitoring is to provide clear indications of progressive changes in the structure or floristics within the local vegetation. Due to the magnitude of the impacts on the vegetation caused by hydrological events that have occurred within the wetlands, there was no perceived need for analysis of a statistical nature in order to track any significant changes, such as regeneration of saltmarsh species into either areas of dieback or modified brackish vegetation. Sampling during late spring to early summer was considered optimal to capture the maximum expression of annual species (both native and introduced) where these are present.

10 x 10 metre square quadrats have been previously found to be of a practical size for the monitoring of vegetation within wetlands and were adopted for this study. Twenty-one quadrats were selected for the vegetation sampling, to provide coverage of the plant communities modified by stormwater inputs and also the range of proportional extent of dieback of saltmarsh shrubs. Depending on observed vegetation responses, the optimal number of sample sites may warrant review over a longer period of monitoring. The spread of quadrats across the range of variation in the vegetation as mapped by Frood (2022) is outlined below.

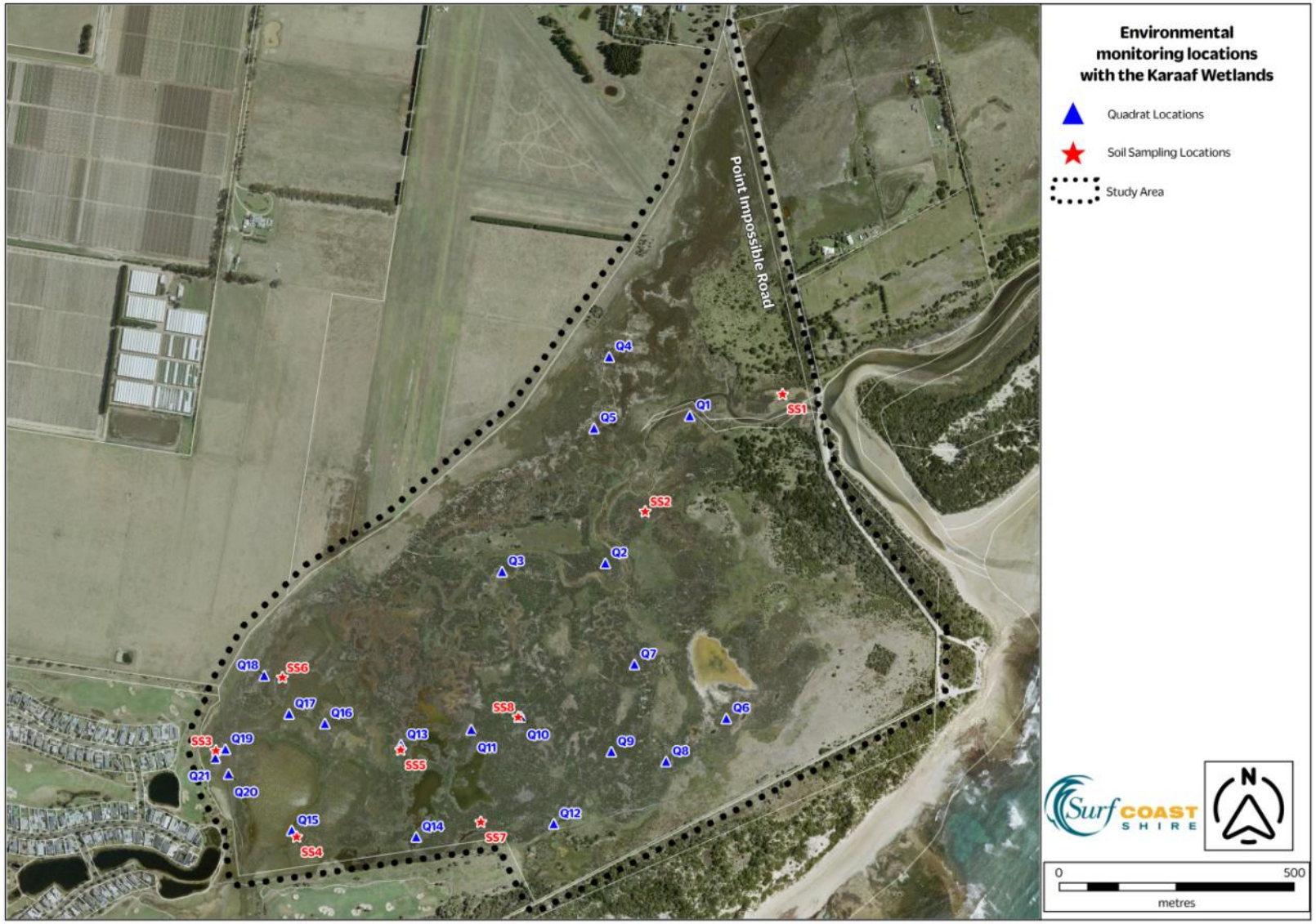
2.2 TARGETED QUADRAT SAMPLING STRATEGY

Strategic placement of the 21 quadrats was based on the condition zones as outlined by Frood (2022), with planned sampling locations selected prior to field work, through consideration of suitable vegetation patches identified from the mapping of that project. The attributes of the selected sites were as follows:

- Adventive Brackish Wetland: 3 sites
- Claypan fringes with signs of transition, to west of main area of Brackish Wetland: 1 site
- Abutting *Typha* patches at ecotone with fringing brackish wetland: 2 sites
- Dieback Condition 5 (90 - 100% mortality): 5 sites (2 in prior Shrubby Glasswort on flats, 2 in prior mixed woody glasswort species stands in shallow depressions, 1 in mixed woody glasswort species with Beaded Glasswort colonisation)
- Dieback Condition 4 (60 - <90% mortality): 4 sites (2 in Shrubby Glasswort, 2 in mixed woody glasswort species)
- Dieback Condition 3 (40 - <60% mortality): 3 sites (2 in Shrubby Glasswort on flats, 1 in mixed woody glasswort species)
- Dieback Condition 2 (10 - <40% mortality): 3 sites (1 in Shrubby Glasswort on flats, 2 in mixed woody glasswort species)

The locations and quadrat identifiers of the relevant sites are indicated on Map 2.

MAP 2. MONITORING QUADRAT AND SOIL SALINITY LOCATIONS



2.3 QUADRAT CHARACTERISTICS AND INFORMATION TO BE RECORDED

The 10m x 10m square quadrats have been oriented along the major compass directions and the GPS location of the north-west corner recorded (using datum GDA). The north-west corners of the quadrats were marked using builder's hardwood pegs with cross-sectional dimensions of ca. 2.2 x 5 cm. The estimated projected cover provided by all vascular plant species observed as attached within or overhanging the quadrat was recorded using the following cover/abundance (C/A) scale:

+: <1% cover, very few (<5) individuals

1: <1% cover, at least several (5 or more) individuals

2: 1-<5% cover, any number of individuals

Cover equal to or greater than 5%: Estimate of cover to nearest 5%.

In the case of plants with both dead and live branches, the total projected cover was included as cover for the respective species. The estimated percentage cover of other relevant features including that provided by the stems of dead saltmarsh shrubs still attached to the ground, detached plant debris, bare ground, and filamentous algae was also recorded. Notes were also made on any observed regeneration of saltmarsh species (including identification of species and approximate numbers). Reference photos were taken diagonally across the quadrats from the north-west corner. Notes on degree of saturation and extent and depth of inundation were also recorded where relevant. The quadrat data from both the 2023 sampling and the current assessment, including GPS location and reference photos, is included as Appendix 2.

2.4 SOIL SALINITY MONITORING

The evaluation of salinity levels in the soil at selected locations through the Karaaf wetlands was considered to be informative to provide some baseline perspective of salinity levels within the saltmarsh shrublands, to aid monitoring of the impacts of

stormwater on the saltmarsh habitat, and also to contribute to understanding of the potential for vegetation recovery in impacted sites.

Soils were sampled at eight locations using a 33mm diameter stainless steel corer. Several sections of core from between 15 and 20 cm depth were sampled, from within a zone of 10 cm diameter, to ensure sufficient material for laboratory analysis. This depth, while determined by the capacity of the corer, is presumed to provide an indication of underlying site conditions, minimizing the influence of either recent surface inundation or salt accumulation at the soil surface due to evaporation under dry conditions.

Soil salinity was evaluated through measurement of the Electrical Conductivity (EC) of samples collected during the field assessment and sent to ALS Environmental Services, Geelong, for analysis.

The eight locations were selected to include tidally influenced parts of the saltmarsh and healthier shrubby glasswort dominated vegetation outside of normal tidal inundation (e.g. near the central southern boundary), to enable comparison with areas where the vegetation has been converted to brackish wetland and sites where there has been comprehensive dieback of glasswort shrubs. The locations and identifiers of the relevant sampling sites are indicated on Map 2. Brief site descriptions and measured soil EC readings (uS/cm at 25^{o} C) for the eight selected sites from both sampling events are provided in section 3.2 of this report.

3. RESULTS

Field work for the project was undertaken during the 20th-25th November 2024. The vegetation quadrat data is included as Appendix 2. Species scientific names follow RBG (2024) and common names follow DEECA (2024). An asterisk before a species name indicates that it is considered introduced in Victoria. Brief descriptions of the soil sample sites and associated EC determinations are also provided.

3.1 VEGETATION DATA ANALYSIS

3.1.1 Analysis of 2023 data

The vegetation quadrat data from 2023 was hand-sorted into a two-way table to indicate pattern in the floristic variation in the vegetation. This table was presented in Frood (2023). Four groups were delineated in this table – these are to some extent loosely defined as they represent sections of a more or less continuous ecological gradient. The groups are defined by the progressive replacement of saltmarsh species by those of sequentially less saline wetland habitats, i.e. the conversion of Coastal Saltmarsh to adventive Brackish Wetland and ultimately opportunistic assemblages of freshwater wetland species.

The first group (including twelve of the quadrats) is characterised by halophytic saltmarsh species, with varying levels of dieback of the shrubby dominants.

The second group (including four quadrats) retains a component of the characteristic saltmarsh flora, notably a high cover of *Salicornia quinqueflora* (Beaded Glasswort), but has an increased component of introduced salt tolerant annuals, with **Cotula coronopifolia* (Water Buttons) in particular potentially providing substantial covers. These sites are also characterised by a gradient of increased presence of species characteristic of wetter sub-saline sites, notably *Bolboschoenus caldwellii* (Salt Club-sedge), *Isolepis cernua* (Nodding Club-sedge) and *Triglochin striata* (Streaked Arrow-grass).

The third group (including three quadrats) includes only a minor component of residual saltmarsh species, with most species present indicative of wet brackish conditions. It is

also characterised by the presence of the mat-forming semi-aquatic *Lilaeopsis polyantha* (Australian Lilaeopsis).

The fourth group (two quadrats) is characterised by the presence of a range of essentially freshwater wetland species, a high cover of *Eleocharis acuta* (Common Spike-sedge) and the effective absence of the saltmarsh flora.

3.1.2 Results from 2024 data

In areas where dieback of the saltmarsh shrubs has been less extreme, regeneration was noted at a number of sites in group 1, largely appearing to be from root suckers, but also with small seedlings occasionally noted. No additional shrub mortality since 2023 was observed at any of the 21 quadrat sites.

While all quadrats remained best placed in the same groups as identified in 2023, increases in the abundance of species indicative of wetter and brackish to fresh conditions are apparent at some sites, but not from sites included in group 1. The most substantial changes were evident at sites from the second group. These sites were located on the periphery of the vegetation previously noted as substantially modified by stormwater. Notable floristic changes included the presence of *Lilaeopsis polyantha* and increases in the local cover of *Bolboschoenus caldwellii* at three of the four sites in the second group. These differences indicate the progressive expansion of the area identified in 2022 as impacted by stormwater. A more detailed comparison of the quadrat data from the two sampling events is provided as Appendix 3, with sites listed according to the floristic groupings they were assigned to.

Vegetation representative of the third and fourth group is susceptible to colonisation of *Typha* spp. (Cumbungi). While low covers of *Typha* spp. are frequently present in the quadrats allocated to these groups, denser vegetation dominated by more established patches of Cumbungi was not sampled. The extent of patches of *Typha* dominated vegetation was indicated in Frood (2022), and changes in the extent of this vegetation could be evaluated by review of the relevant mapping. A further general expansion of *Typha* spp. was evident during the 2024 field inspection, both through expansion of existing patches and development of new clones. In a few instances, such increases

are apparent in the site photos in Appendix 2, either within the quadrat or in the background.

3.2 SOIL SAMPLE SITES

The 2024 soil samples were collected from close proximity to the 2023 sites (within GPS error). Minor differences in soil profile occurring at a local scale between the successive samples were noted at some sites, as were some changes in the local character of the vegetation since collection of the initial samples. Comparative descriptive summaries of the soil sampling sites and their salinity readings follow. The initial descriptions of the sites are from Frood (2023).

Site 1. 55H 0270267 / 5757634 (+/- 3 m): Mudflat abutting Mullet Creek, in the intertidal zone when the Thompson Creek entrance is open. Gap in vegetation, with *Salicornia quinqueflora* and dead *Tecticornia arbuscula* adjacent.

2023 (7th November): EC 3400 uS/cm. The soil was damp, comprising a clay and sand mix, grey in colour.

2024 (20th November): EC 3500 uS/cm. The soil comprised pale sand under ca. 10 cm of water – it appears that some recent local deposition of sand has occurred.

Site 2. 55H 0269982 / 5757379 (+/- 4 m): Shrubland of *Tecticornia* spp., with ca. 50% of plants dead.

2023 (7th November): EC 4400 uS/cm. The soil was damp, consisting of a yellow-grey clay.

2024 (20th November): EC 5400 uS/cm. The soil comprised heavy yellow-grey clay with an organic surface layer, and was superficially inundated to <5 cm depth.

Site 3. 55H 0269083 / 5756850 (+/- 5 m): Brackish Wetland (modified vegetation), with *Bolboschoenus caldwellii*, **Cotula coronopifolia* and *Senecio pinnatifolius*.

2023 (7th November): EC 1800 uS/cm. The site was inundated to ca. 10 cm depth. The soil consisted of a sloppy black organic layer over greyish clay with yellow touches.

2024 (21st November): EC 1800 uS/cm. The vegetation was dominated by *B. caldwellii* with *Eleocharis acuta*, *Epilobium hirtigerum*, *Epilobium billardierianum* subsp. *billardierianum*, **Cotula coronopifolia*, *Lilaeopsis polyantha*, *Lythrum hyssopifolia*, **Holcus lanatus* and *S. pinnatifolius*. The site was locally saturated, with the soil comprising heavy clay with a shallow organic surface layer.

Site 4. 55H 0269260 / 5756674 (+/- 5 m): Largely bare mudflat, adjacent to Brackish Wetland (modified vegetation) with *Bolboschoenus caldwellii*, *Eleocharis acuta*, **Cotula coronopifolia* and *Thyridia repens* providing a total of ca. 5% cover.

2023 (7th November):: EC 2800 uS/cm. The site was saturated, with soils consisting of a black anaerobic organic silty layer over yellow-grey clay.

2024 (21st November): EC 2200 uS/cm. The site was locally saturated to inundated to <5 cm depth.

Site 5. 55H 0269475 / 5756863 (+/- 5 m): *Tecticornia* spp. shrubland with most plants (>90%) dead, with *Salicornia quinqueflora*, **Cotula coronopifolia*, *Triglochin striata*, **Polypogon monspeliensis* and incidental *Bolboschoenus caldwellii*.

2023 (7th November): EC 3700 uS/cm. The site was more or less saturated, with the soil consisting of grey clay.

2024 (21st November): EC 2100 uS/cm. The site supported brackish wetland with dead *Tecticornia* spp., and dominated by *T. striata* with *B. caldwellii*. *Senecio pinnatifolius* and **Rumex crispus*. The soil comprised clay with an organic surface layer. The site was saturated, with local superficial to shallow inundation.

Site 6. 55H 0269220 / 5757008 (+/- 5 m): Shrubland with dead and regenerating *Tecticornia* sp. (Connewarre), dominated by *Salicornia quinqueflora* and with *Isolepis*

cernua, *Apium annuum* and **Cotula coronopifolia*. The site was located on a narrow tongue of slightly higher ground between adjacent ponds on both sides.

2023 (7th November): EC 3800 uS/cm. The top soil was wet but not inundated. The soil comprised yellow-grey clay, with a loose flaky gravelly layer and watertable present below ca. 15 cm depth.

2024 (21st November): EC 2700 uS/cm. The vegetation was dominated by *S. quinqueflora* with *Lilaeopsis polyantha*, and *Bolboschoenus caldwellii* and *Typha* sp. adjacent. The site was saturated to shallowly inundated (to <10 cm depth). The soil comprised clay, with a gravel layer present between ca. 10-15 cm depth.

Site 7. 55H 0269651 / 5756716 (+/- 6 m): *Tecticornia arbuscula* shrubland, with *Salicornia quinqueflora*, *Frankenia pauciflora* and **Polypogon monspeliensis*. The shrubs were mostly living, with ca. 90% of the canopy healthy.

2023 (8th November): EC 4800 uS/cm. The soil was moist, with a layer of peaty sand over yellow-grey clay.

2024 (21st November): EC 6800 uS/cm. The site was effectively dry (damp soil, but not locally saturated), with an organic surface layer over very heavy clay. A layer of pale grey sandy-clay was contacted at the lower extent of the core.

Site 8. 55H 0269274 / 5756939 (+/- 5 m): *Tecticornia* spp. shrubland (<1 m tall), locally in the range of 10-40% mortality, with *Salicornia quinqueflora*, *Frankenia pauciflora*, *Apium annuum*, **Polypogon monspeliensis* and **Melilotus indica*.

2023 (8th November): EC 3900 uS/cm. The soil was moist but not saturated, with ca. 10 cm of peaty sand over a layer of yellow-grey clay, then pale sand at ca. 18 cm depth.

2024 (21st November): EC 5500 uS/cm. The site was effectively dry (damp soil, but not locally saturated), with a sandy-organic layer over heavy clay, with pale grey sandy-clay at the lower extent of the core.

4. INTERPRETATION OF INFORMATION AND DISCUSSION

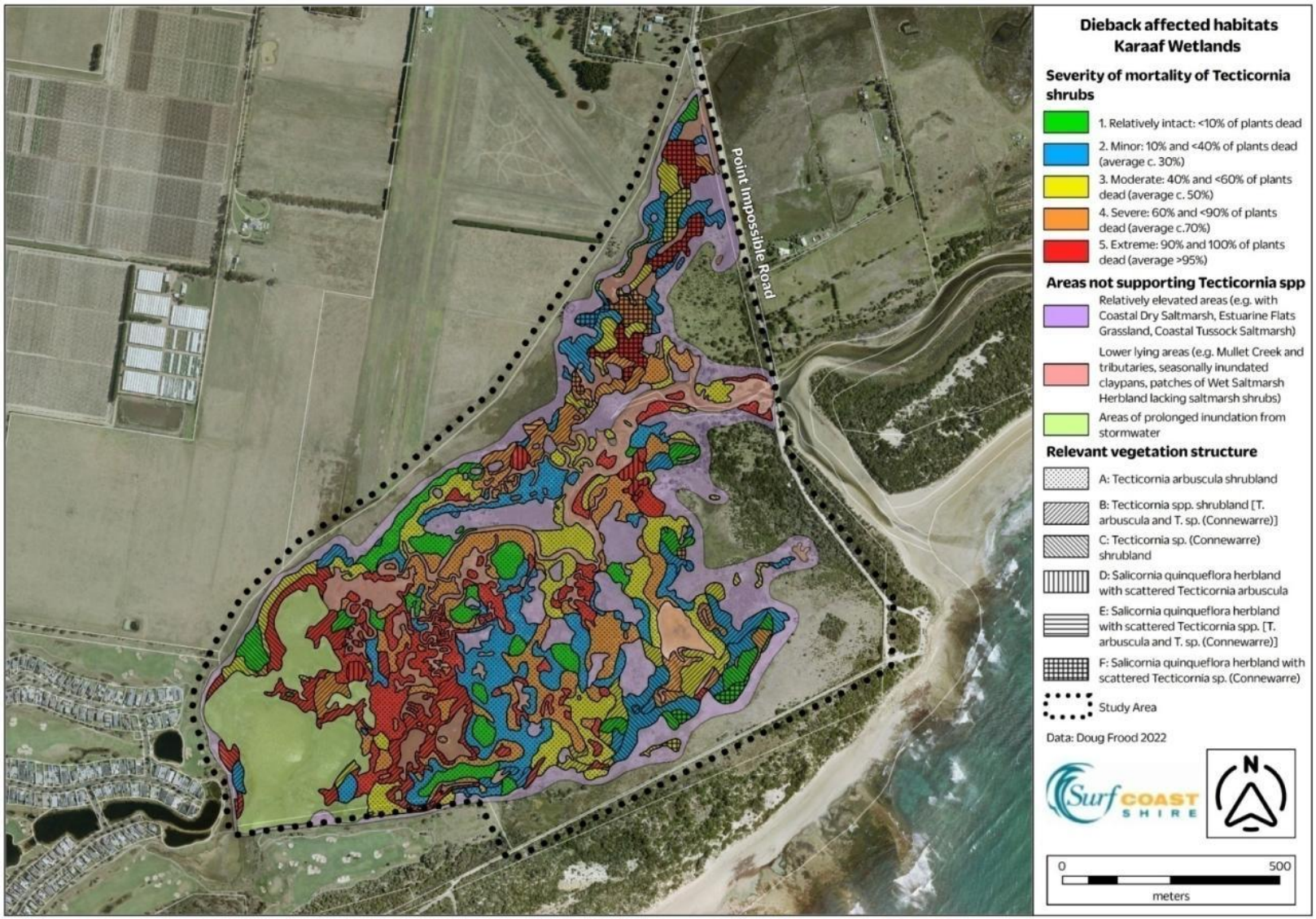
4.1 VEGETATION: BACKGROUND AND 2023 MONITORING

Frood (2022) mapped levels of mortality of saltmarsh shrubs into classes based on dominant species and ranges of proportion of plants killed (see Map 3 on the following page). This map also indicates the broader area where the floristics of the vegetation had been substantially altered by the impacts of stormwater, principally the conversion of prior saltmarsh into Brackish Wetland vegetation and the establishment of patches of *Typha* spp.

In many cases, little if any associated flora was evident in the shrubland vegetation during the winter survey of Frood (2022), particularly in those stands of *Tecticornia* spp. where the greater majority of individual plants had died (following photo and caption from that report).

Broad-scale death of Shrubby Glasswort towards the western side of the Karaaf. Remnants of algae attached to the stems are indicative of a sustained inundation event (image from winter 2022)

MAP 3. DIEBACK OF SALTMARSH SHRUBS (from Frood, 2022).



Frood (2023) noted that the quadrats from highly impacted saltmarsh sites often displayed a greater diversity of species locally present than was the case in 2022. Rather than just dead stems of *Tecticornia* spp. with scattered living individuals, associated species such as *Salicornia quinqueflora* (Beaded Glasswort), *Suaeda australis* (Austral Seablite) and *Apium annuum* (Annual Celery) were often conspicuous in such impacted sites. It was suspected that recent deep ponding occurring during estuary closure had suppressed the associated flora in 2022, but that rootstocks of *S. quinqueflora* had survived and subsequently resprouted, and that other species had germinated from the soil-stored seedbank.

In 2023 it was noted that regeneration of *Tecticornia* spp. was largely restricted to sites with a lower percentage of mortality (generally <50%), and at least in the case of *T. arbuscula*, appeared to largely comprise root suckers from surviving plants. At the time it was noted that the potential longer term responses of more heavily impacted sites was not yet apparent.

It was also evident in 2023 that at least some of the *Typha* patches had increased in extent since the 2022 assessment. It also appeared that *Eleocharis acuta* (Common Spike-sedge) had increased in extent within the Brackish Wetland on the western margins of the Karaaf, indicative of a shift towards more freshwater conditions arising from stormwater inputs.

*Opportunistic colonisation of Cumbungi around the verges of a shallow lagoon in the western portion of the Karaaf wetlands. The smaller mat-forming plant in the foreground is Water Buttons [*Cotula coronopifolia] (Image and caption from Frood, 2022).*

Brackish Sedgeland component of the Brackish Wetland Aggregate, dominated by Salt Club-sedge, developed on the margins of a shallow lagoon near the western margins of the Karaaf wetlands (Image and caption from Frood, 2022).

Extensive displacement of prior saltmarsh vegetation by adventive Brackish Wetland at the western end of the Karaaf (Image and caption from Frood, 2022).

4.2 VEGETATION: 2024 MONITORING

Different hydrological conditions were evident during each season of the investigations into the vegetation of the Karaaf. These ranged from wet due to high rainfall and increased stormwater inputs plus tidal influences with the estuary open (2022), to dryer with the estuary closed, with (2024) or without (2023) substantial backfilling of inundation. Locations in the eastern vicinity of the seasonally inundated claypans in the west of the Karaaf were wetter in 2024 than in 2023 – this was presumed to be from backfilling from the estuary rather than stormwater inputs.

At the time of the 2024 sampling, the estuary was closed, with the tidal marker at 1.0 m. This depth had been between 1.0 and 1.15 m for a prolonged period (Glenda Shomaly pers. comm.). The ponding at 1.0 m reached the level of the upper reaches of Mullet Creek, with only a small elevational difference to the adjacent claypans and indications that water had relatively recently flowed across the intervening gap.

While tidal peaks frequently exceed this height, it is surmised that tidal pulses generally don't have sufficient time between phases to inundate the claypans in the

south-western section of the Karaaf, given that they are reported to have been seasonally dry. While the marker pegs at a number of quadrats that were dry in late November had water marks at various heights, this is interpreted as local ponding following previous rainfall event s, which had since dried up. Given that a sustained period of low rainfall had led to an interruption in stormwater runoff into the Karaaf, it appears that the inundation levels observed within the Karaaf were due to backfilling from the estuary rather than inputs from immediately local rainfall or stormwater runoff.

Progressive regeneration of saltbush shrubs and other saltmarsh species was noted in a range of quadrats from sites lacking intrusion of the brackish wetland flora (Group 1). Floristic differences at the saltmarsh quadrat sites, between the two monitoring occasions, were otherwise minor. These included differences in the abundance and range of annual species that were recorded at some sites. One notably difference was that, compared to 2023, the native *Apium annuum* (Annual Celery) was greatly decreased in abundance and size where germinated, presumably reflecting the very dry winter-spring conditions of 2024. *Spergularia marina* (Salt Sand-spurry) was occasionally detected during the quadrat surveys in 2023, but not in 2024, presumably also as a response to the seasonal conditions.

At the time of sampling, no additional mortality of saltbush shrubs (since 2023) was observed at any of the monitoring sites. In highly impacted areas in the western portion of the Karaaf, there has been further expansion of the brackish wetland vegetation into the prior saltmarsh shrubland, without any regeneration of the shrub species. The cover provided by remnant dead *Tecticornia* plants was also noted to have declined at some of the wetter sites as a consequence of decomposition of older stems. In this part of the Karaaf, the area occupied by *Typha* spp. (Cumbungi) has also considerably expanded as a response to sustained inputs of stormwater over previous seasons

In summary, signs of recovery of the saltmarsh vegetation are apparent outside of the area directly impacted by stormwater, though this process may be negated if deeper ponding occurs under conditions of estuary closure, particularly if there are substantial contributions from stormwater. In the western portion of the Karaaf, the

extent of modified vegetation has continued to expand as a consequence of stormwater inputs.

Recent extended colonisation of Cumbungi into Brackish Wetland vegetation at the Karaaf, November 2024.

4.3 SOIL SALINITY

The following table lists the soil sampling sites in order of highest to lowest salinity readings from the current monitoring.

Table 1. Comparison of soil salinity data.

Sample No.	EC (uS/cm)		Saltmarsh Shrub Condition (Frood, 2022)	Vegetation in immediate vicinity (Frood, 2023)	Vegetation description. 2024
	2023	2024			
7	4800	6800	Class 1 (<10% mortality)	*Tecticornia arbuscula* shrubland	*Tecticornia arbuscula* shrubland
8	3900	5500	Class 2(10-<40% mortality)	*Tecticornia* spp. shrubland	*Tecticornia* spp. shrubland
2	4400	5400	Class 3(40-<60% mortality)	*Tecticornia* spp. shrubland	*Tecticornia* spp. shrubland
1	3400	3500	Adjacent to Class 5	Mudflat adjacent to dead *T. arbuscula*	Mudflat adjacent to dead *T. arbuscula*
6	3800	2700	Class 5 (90-100% mortality)	Prior *Tecticornia* sp. (Connewarre) shrubland, dominated by *Salicornia* herbland	*Salicornia* herbland, with Brackish Wetland and *Typha* encroaching
4	2800	2200	NA	Mudflat, adjacent to Brackish Wetland	Mudflat, adjacent to Brackish Wetland
5	3700	2100	Class 5	Prior *Tecticornia* spp. shrubland, dominated by *Salicornia* herbland	Prior *Tecticornia* spp. shrubland, dominated by *Bolboschoenus* Brackish Wetland
3	1800	1800	NA	Brackish Wetland	Brackish Wetland

As noted in Frood (2023), it is evident that the salinity levels are substantially lower at the sites where the saltmarsh vegetation has been converted to Brackish Wetland by stormwater inputs, with the shallowly inundated site 3 recording the lowest salinity reading on both occasions. In 2023, the relationship between salinity and various levels of dieback of the saltmarsh shrubs appeared to be less meaningful, with only relatively small differences between sites of vastly different condition (e.g. sites 6 and 8). In 2024, the salinity readings more directly correlated with the more extreme levels of dieback, with site 6 having shown a substantial decrease in salinity and site 8 a substantial increase in salinity.

It appears likely that there is a recalibration effect occurring in the soil salinity levels, in response to the sustained inputs of stormwater into the western side of the Karaaf and expansion of the zone of associated transformation of the vegetation. It is important to appreciate that vegetation responses reflect preceding ecological conditions, e.g. observable colonisations by sedges and cumbungi have a lag phase, having been triggered by recruitment during preceding years. The presence of permeable layers at relatively shallow depth at the above two sites (6 and 8) was noted in the 2023 monitoring report as indicating potential for complexity in the local groundwater interactions.

It was noted in Frood (2023) that while most of the saltmarsh soils distant from the stormwater inputs were damp rather than wet, the soils at site 5 were saturated. In 2023, the salinity recorded at site 5 was only slightly lower than that recorded at other highly impacted shrubland sites, but it was noted that this was in close proximity to shallow claypans and the outer edge of the zone supporting brackish wetland. The 2023 monitoring report include comment that this site may provide useful indication as to whether a zone of reduced salinity was expanding due to stormwater inputs: The substantially lower salinity recorded in 2024 and the encroachment of *Bolboschoenus caldwellii* confirm an active front of expansion of stormwater impacts. The 2023 report noted that if stormwater inputs can be controlled, sites 3 and 4 may provide indications of the potential for recovery of salinity levels in the western section of the Karaaf.

5. REFERENCES

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APPENDIX 1. VEGETATION AND SOIL SAMPLING SITE LOCATIONS

VEGETATION QUADRAT LOCATIONS (ZONE 55H, GDA)

Quadrat 01: Easting: 0270071, Northing: 5757581

Quadrat 02: Easting: 0269900, Northing: 5757266

Quadrat 03: Easting: 0269681, Northing: 5757242

Quadrat 04: Easting: 0269896, Northing: 5757700

Quadrat 05: Easting: 0269868, Northing: 5757549

Quadrat 06: Easting: 0270167, Northing: 5756947

Quadrat 07: Easting: 0269968, Northing: 5757055

Quadrat 08: Easting: 0270041, Northing: 5756853

Quadrat 09: Easting: 0269924, Northing: 5756870

Quadrat 10: Easting: 0269730, Northing: 5756938

Quadrat 11: Easting: 0269625, Northing: 5756908

Quadrat 12: Easting: 0269806, Northing: 5756715

Quadrat 13: Easting: 0269476, Northing: 5756872

Quadrat 14: Easting: 0269514, Northing: 5756679

Quadrat 15: Easting: 0269249, Northing: 5756685

Quadrat 16: Easting: 0269313, Northing: 5756912

Quadrat 17: Easting: 0269236, Northing: 5756930

Quadrat 18: Easting: 0269181, Northing: 5757009

Quadrat 19: Easting: 0269103, Northing: 5756852

Quadrat 20: Easting: 0269111, Northing: 5756800

Quadrat 21: Easting: 0269082, Northing: 5756833

SOIL SALINITY SAMPLING SITE LOCATIONS

Soil Sampling Site 1: Easting: 0270267, Northing: 5757634

Soil Sampling Site 2: Easting: 0269982, Northing: 5757379

Soil Sampling Site 3: Easting: 0269083, Northing: 5756850

Soil Sampling Site 4: Easting: 0269260, Northing: 5756674

Soil Sampling Site 5: Easting: 0269476, Northing: 5756863

Soil Sampling Site 6: Easting: 0269220, Northing: 5757008

Soil Sampling Site 7: Easting: 0269651, Northing: 5756716

Soil Sampling Site 8: Easting: 0269724, Northing: 5756939

APPENDIX 2. QUADRAT DATA

An asterisk preceding a species name indicates that it is considered to be introduced in Victoria.

QUADRAT NUMBER: 01

DATES: 8/11/23, 20/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0270071 / 5757581 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION (2023): Prior *Tecticornia arbuscula* shrubland, with nearly all plants dead. Fringed by healthy *Salicornia quinqueflora* to north, with *Austrostipa stipoides* grassland with *Gahnia filum*, *Suaeda australis* and living *Tecticornia arbuscula* to south. With plentiful crab burrows present, but algal mats not evident. The soil comprised grey clay, and was damp but not inundated.

SPECIES AND COVERS:

	2023	2024
Salicornia quinqueflora subsp. *quinqueflora* [dead stems]	2	
Tecticornia arbuscula [live plants]	2	2
Tecticornia arbuscula [dead plants]	30	25
Bare ground (%)	90	10
Plant litter (%)	5	5
Algal mat (%)	0	85

Additional species observed nearby: *Austrostipa stipoides*, *Gahnia filum* and *Suaeda australis* (2023, 2024)

NOTES:

2023: The soil was damp but not inundated. No regeneration of *T. arbuscula* was evident.

2024: The site was100% inundated due to estuary closure, with water depth of ca. 10-20 cm. Crab holes were evident on adjacent damp edges. No regeneration of *T. arbuscula* was observed.

Quadrat 1, 2023.

Quadrat 1, 2024.

QUADRAT NUMBER: 02

DATES: 8/11/23, 25/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269900 / 5757266 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION (2023): *Tecticornia arbuscula* shrubland, plants mostly living. The soil was dry, with organic sand overlying clay. Kangaroo trails with droppings were present, but were not deeply pugged or incised.

SPECIES AND COVERS:

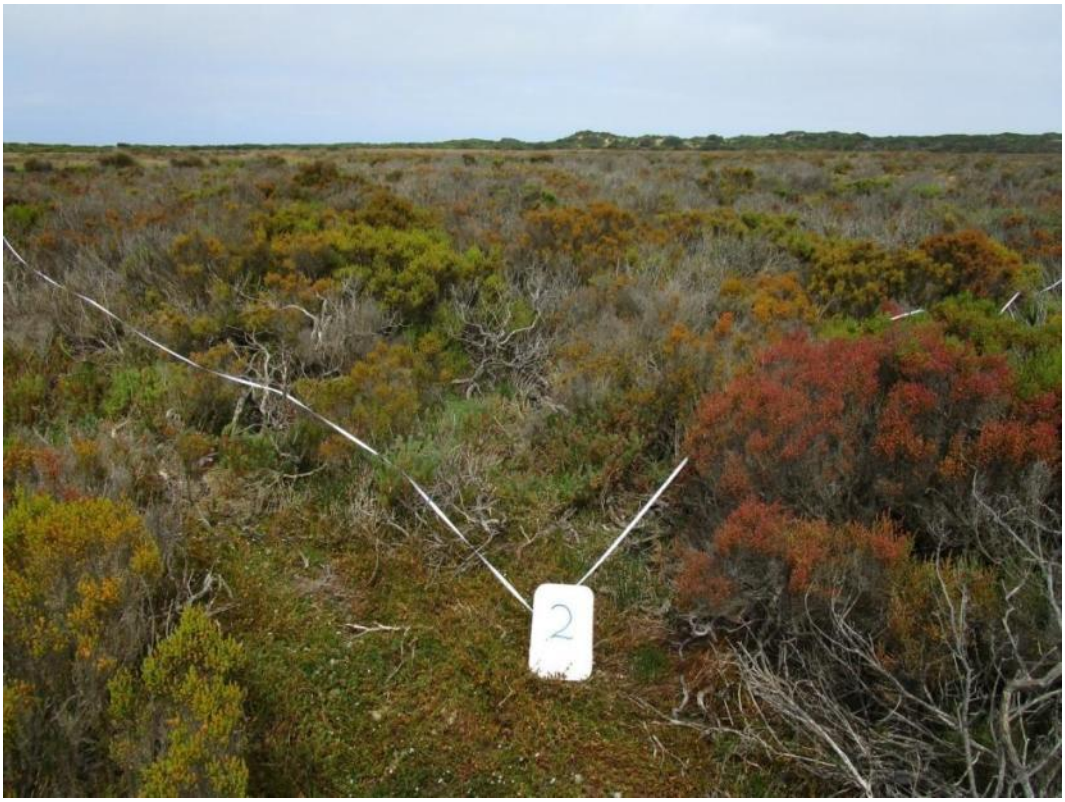
	2023	2024
Disphyma crassifolium subsp. *clavellatum*	1	1
Frankenia pauciflora var. *gunnii*		+
Salicornia blackiana		+
Salicornia quinqueflora subsp. *quinqueflora*	2	2
Samolus repens	1	1
Suaeda australis	10	10
Tecticornia arbuscula [live plants]	60	60
Tecticornia arbuscula [dead plants]	2	2
Bare ground (%)	15	15
Plant litter (%)	5	5
Algal mat (%)	-	-

Additional species observed nearby: *Frankenia pauciflora* var. *gunnii* and *Spergularia marina* (2023); *Apium annuum* and **Plantago coronopus* (2023, 2034), **Parapholis incurva* [along kangaroo paths] (2024).

NOTES:

2023: The soil was dry. Seedlings of *T. arbuscula* were not evident, but the vegetation was generally lacking gaps for colonisation. Detailed inspection of the vegetation was restricted to available viewpoints in order to minimise damage to the relatively intact and fragile vegetation – covers may be coarser estimates than for other sites. It is recommended that any follow-up sampling of this site is both Infrequent and very carefully conducted.

2024: The site was dry (soils damp), with evidence of recent inundation not apparent. Crab holes were evident in part of the site, which is in close proximity to the channel of Mullet Creek. Some of the *T. arbuscula* plants included in the cover of living plants had very limited branches supporting green tissue. Incidental juvenile plants of *T. arbuscula* were observed, including seedlings to 5 cm.



Quadrat 2, 2023.

Quadrat 2, 2024.

QUADRAT NUMBER: 03

DATES: 8/11/23, 24/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269681 / 5757242 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION (2023): Patch dominated by *Suaeda australis*, with the associated plants of *Tecticornia* spp. mostly dead. This vegetation was locally occurring in mosaic with open ground with algal mats, forming a reticulate pattern. The soil was dry, with variable surface texture (variously organic silt, sand veneer, decomposing algae or surface clay) overlying yellow-grey clay. Kangaroo trails were present through the vegetation and deeply pugged.

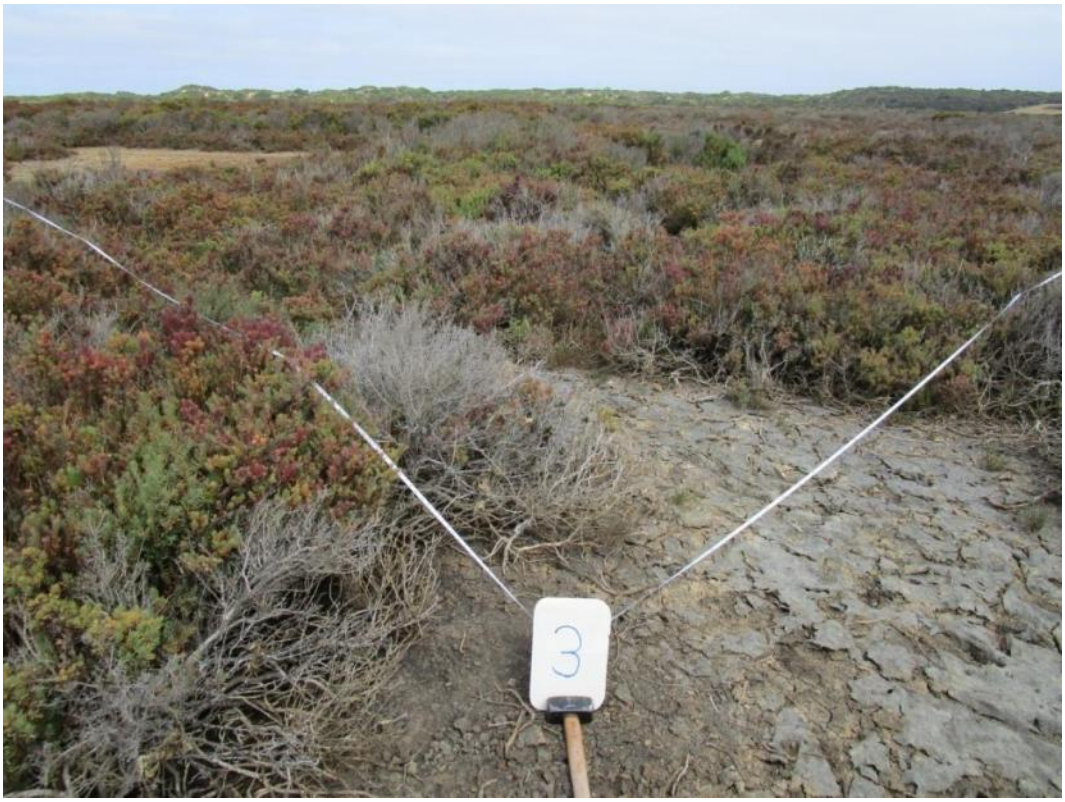
SPECIES AND COVERS:

	2023	2024
Althenia preissii		1
Salicornia quinqueflora subsp. *quinqueflora*	10	5
Suaeda australis	60	60
Tecticornia arbuscula [live plants]	2	2
Tecticornia arbuscula [dead plants]	2	2
Tecticornia sp. (Connewarre) [live plants]	2	2
Tecticornia sp. (Connewarre) [dead plants]	10	10
Bare ground (%)	10	-
Plant litter (%)	10	?
Algal mat (%)	20	95

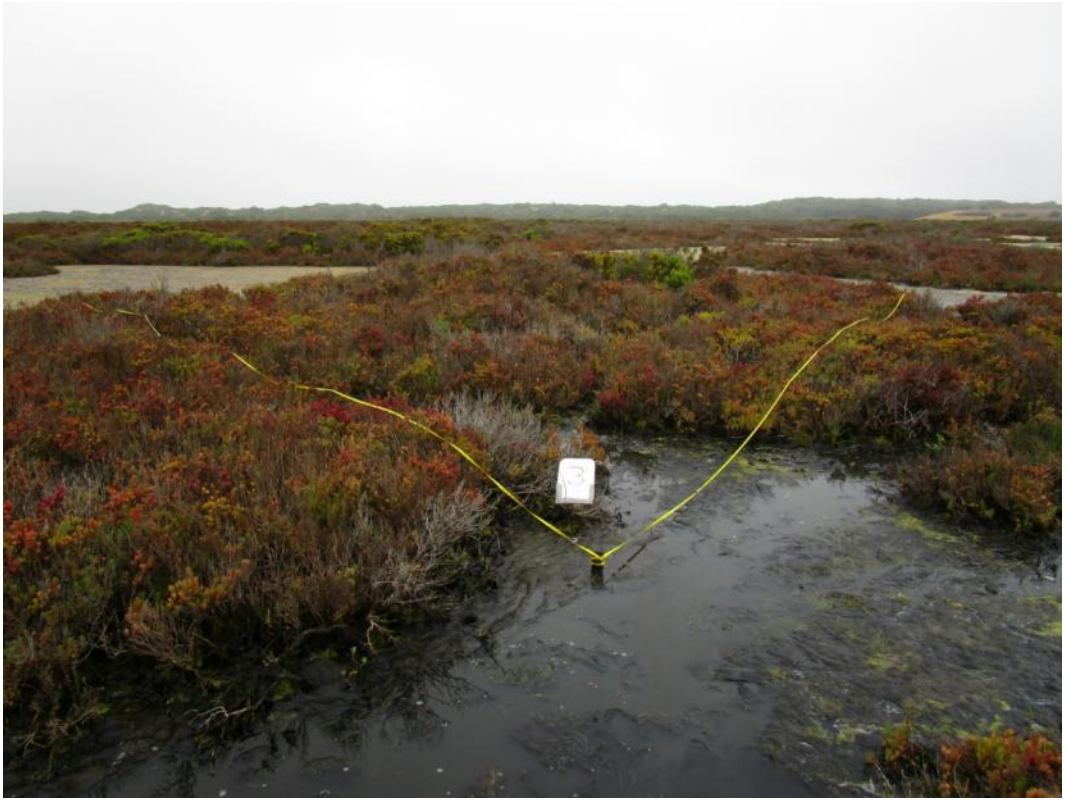
NOTES:

2023: The soils were dry. Seedlings of *Tecticornia* species were not evident.

2024: 100% of the site was inundated, with water depth of 10 - 25 cm. Underlying bare ground and potential litter cover were obscured by the comprehensive cover provided by the algal mat. Gaps in the terrestrial vegetation cover comprised a network of shallow ponds. Some emergent young *Tecticornia* plants (presumably suckers) were present.



Quadrat 3, 2023.



Quadrat 3, 2024.

QUADRAT NUMBER: 04

DATES: 8/11/23, 23/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269896 / 5757700 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION (2023): Open shrubland of *Tecticornia* sp. (Connewarre) with relatively low mortality, with *Salicornia quinqueflora* mats nearby, and bare gaps occurring in a mosaic. The soil was dry, with a peaty layer over clay. With light kangaroo pugging only.

SPECIES AND COVERS:

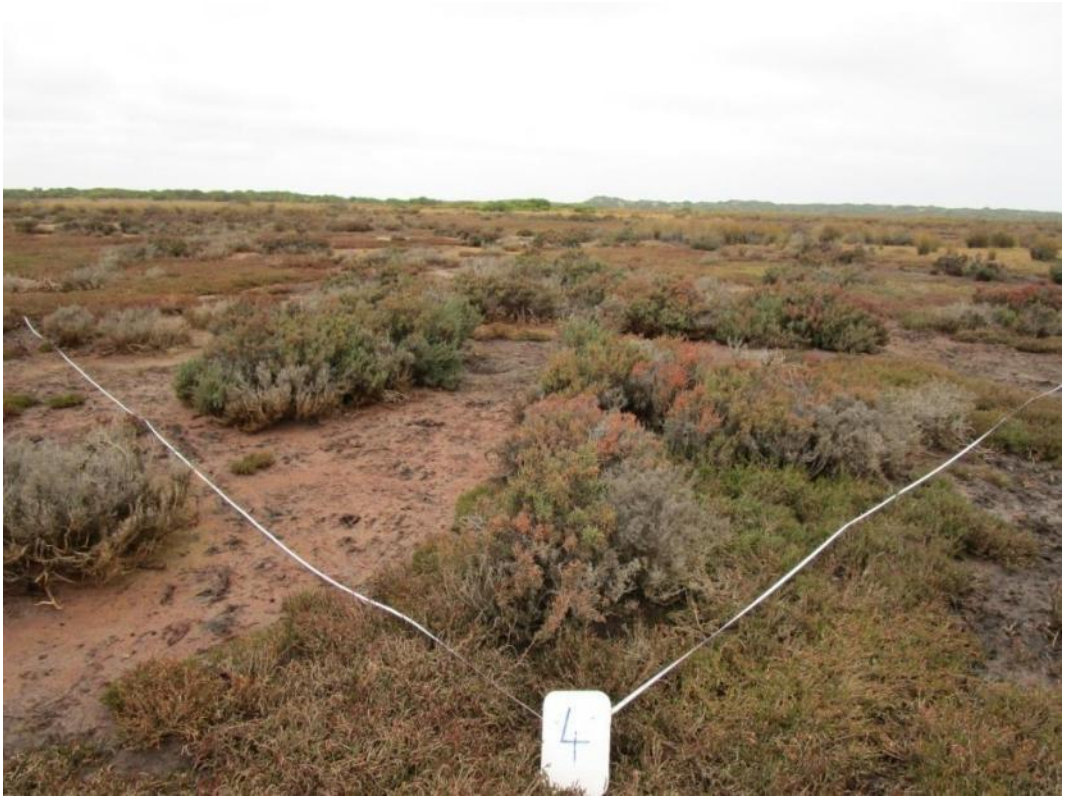
	2023	2024
Frankenia pauciflora var. *gunnii*	+	+
Salicornia quinqueflora subsp. *quinqueflora*	5	5
Tecticornia sp. (Connewarre) [live plants]	20	20
Tecticornia sp. (Connewarre) [dead plants]	5	5
Bare ground (%)	60	50
Plant litter (%)	3	30
Algal mat (%)	15	-

NOTES:

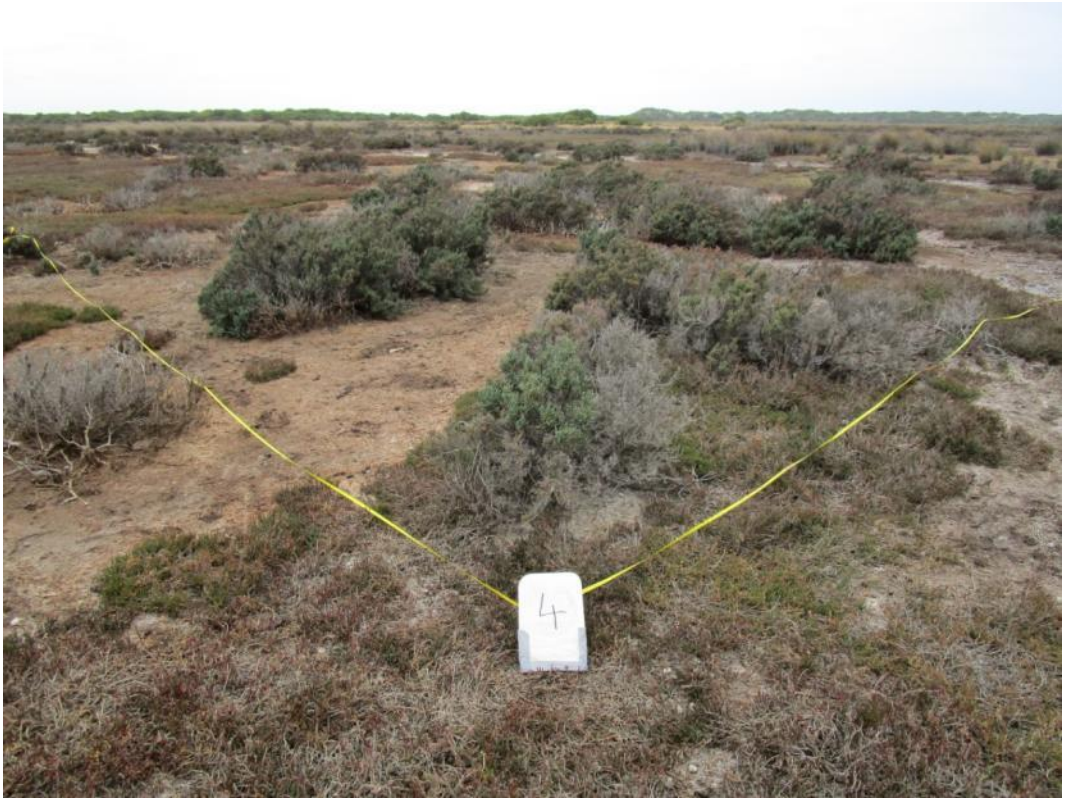
2023: The site was dry. The full extent of the algal crust was becoming somewhat ambiguous due to decomposition. Seedlings of *Tecticornia* sp. were not evident.

2024: The site was dry, lacking evidence of recent inundation apart from shallow puddles in low lying spots. Extent of cover provided by bare ground was ambiguous, variously with salt crust and superficial cover of non-problematic species

of blue-green algae. Litter cover was also ambiguous, with the surface layer incorporating numerous small fragments of *S. quinqueflora*. Scattered juveniles (suckers?) of *T.* sp. (Connewarre) were present, arising in the vicinity of plants whose aerial parts had died



Quadrat 4, 2023



Quadrat 4, 2024.

QUADRAT NUMBER: 05

DATES: 8/11/23, 23/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269868/ 5757549 (+/- 5 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION (2023): Open shrubland of *Tecticornia* spp. with *Salicornia quinqueflora*, with small bare gaps in mosaic, abutting *Gahnia filum* sedgeland. The quadrat area was dry, but with residual small ponds present nearby. The soil consisted of a loamy friable layer over clay. Algal mats extended across much of the surface, mostly at ground level, but including older remnants elevated up to ca. 40 cm on shrub stems. Kangaroo trails with deep pugging were present. Mortality of *T. arbuscula* had arisen from multiple events (including older more decomposed stems as well as relatively recently killed plants).

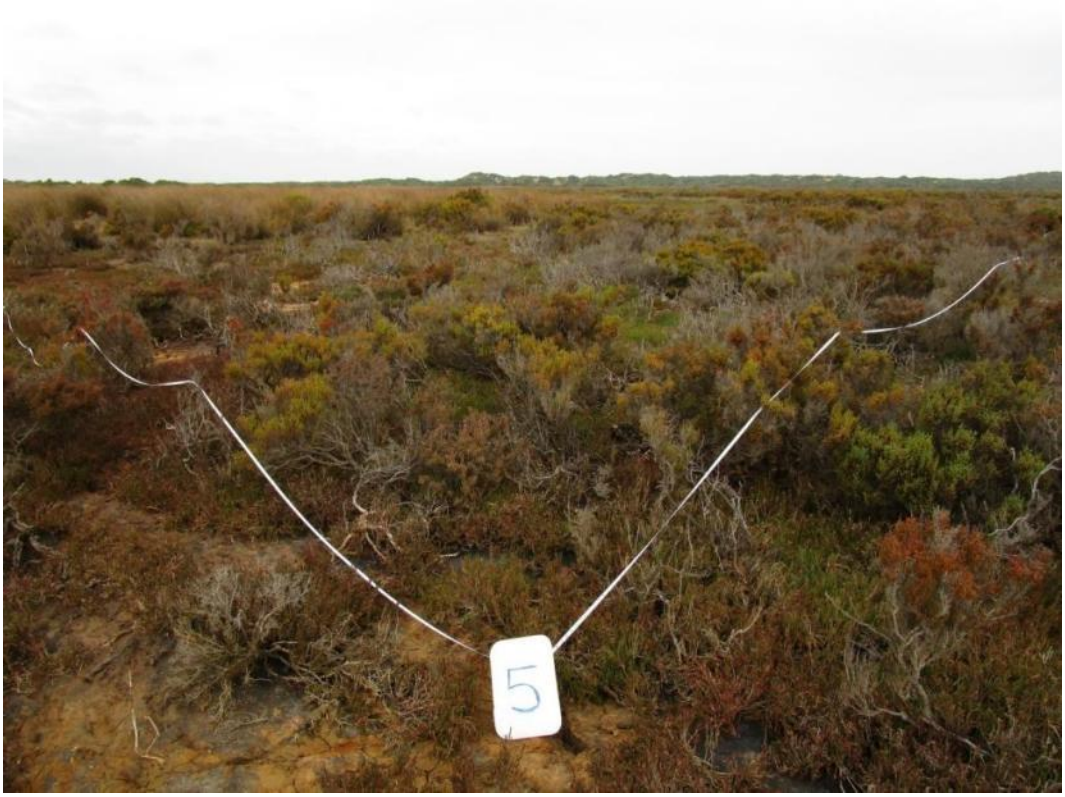
SPECIES AND COVERS:

	2023	2024
Frankenia pauciflora var. *gunnii*		+
Salicornia quinqueflora subsp. *quinqueflora*	70	70
Tecticornia arbuscula [live plants]	10	10
Tecticornia arbuscula [dead plants]	5	5
Tecticornia sp. (Connewarre) [live plants]	2	2
Tecticornia sp. (Connewarre) [dead plants]	2	2
Bare ground (%)	5	10
Plant litter (%)	2	5
Algal mat (%)	50	40

NOTES:

2023: The site was dry, but with residual small ponds present nearby. The full extent of the algal crust was somewhat ambiguous as it extended beneath the S. quinqueflora cover). Bare ground was primarily due to pugging along kangaroo paths. Seedlings of *Tecticornia* species were not evident.

2024: The site was dry (soil damp), with an inundation line on the marker post at ca. 10 cm, and clay in the gaps within the vegetation pugged. Suckering or seedlings of *Tecticornia* species were not observed.



Quadrat 5, 2023.

Quadrat 5, 2024.

QUADRAT NUMBER: 06

DATES: 9/11/23, 24/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0270167/ 5756947 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Open shrubland of *Tecticornia* spp., relatively diverse. Plants of *Tecticornia* species were of mixed age and condition, with scattered young plants 20-40 cm, presumably including root suckers, but lacking mass regeneration. Also with the *Suaeda australis* plants being of mixed age and patches of *Spergularia marina* seedlings present. The quadrat area was dry, with a thin salt crust present on the soil surface. The soil consisted of an organic sandy surface over grey clay. The site was traversed by pugged kangaroo trails.

SPECIES AND COVERS:

	2023	2024
Apium annuum	2	
**Atriplex prostrata*	1	
**Cotula coronopifolia*	1	
Disphyma crassifolium subsp. *clavellatum*	+	+
Frankenia pauciflora var. *gunnii*	2	2
**Hordeum marinum*	1	
**Parapholis incurva*	1	1
**Polypogon monspeliensis*	1	
Salicornia quinqueflora subsp. *quinqueflora*	5	5
Senecio halophilus	1	
Spergularia marina	1	
Suaeda australis	15	15

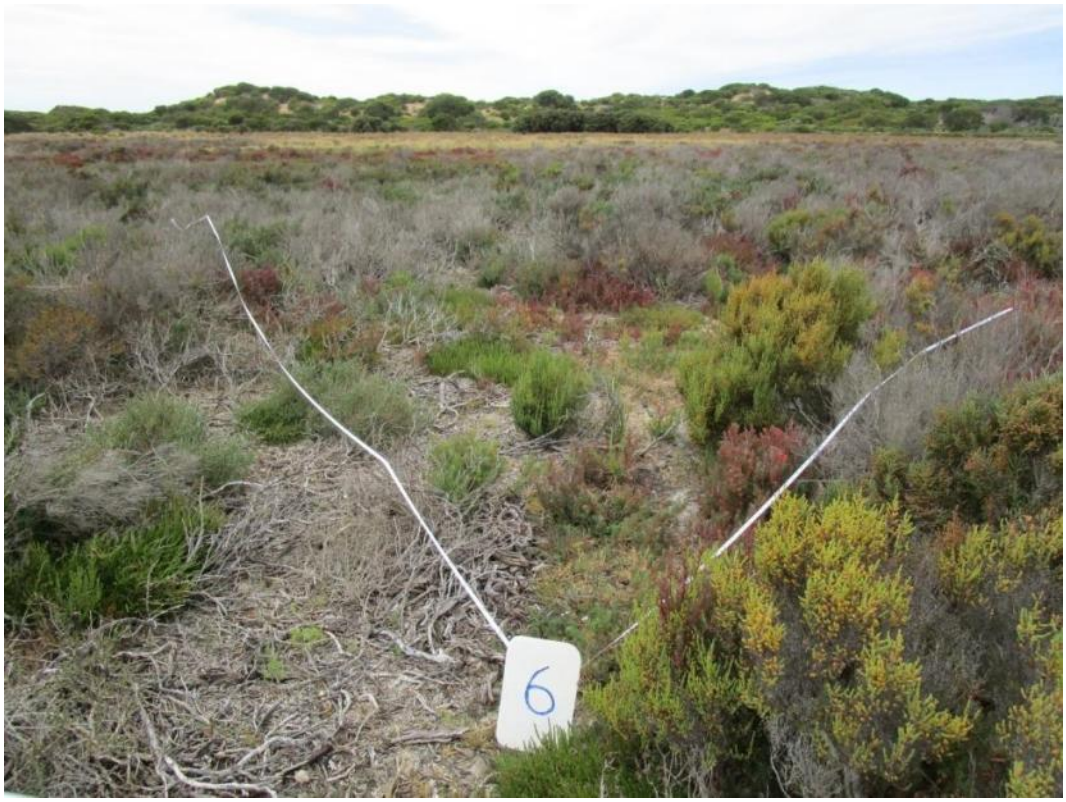
Tecticornia arbuscula [live plants]	10	10
Tecticornia arbuscula [dead plants]	10	10
Tecticornia sp. (Connewarre) [live plants]	10	10
Tecticornia sp. (Connewarre) [dead plants]	10	10
Bare ground (%)	25	25
Plant litter (%)	35	35
Algal mat (%)	-	-

Additional species observed nearby: *Samolus repens* (2023)

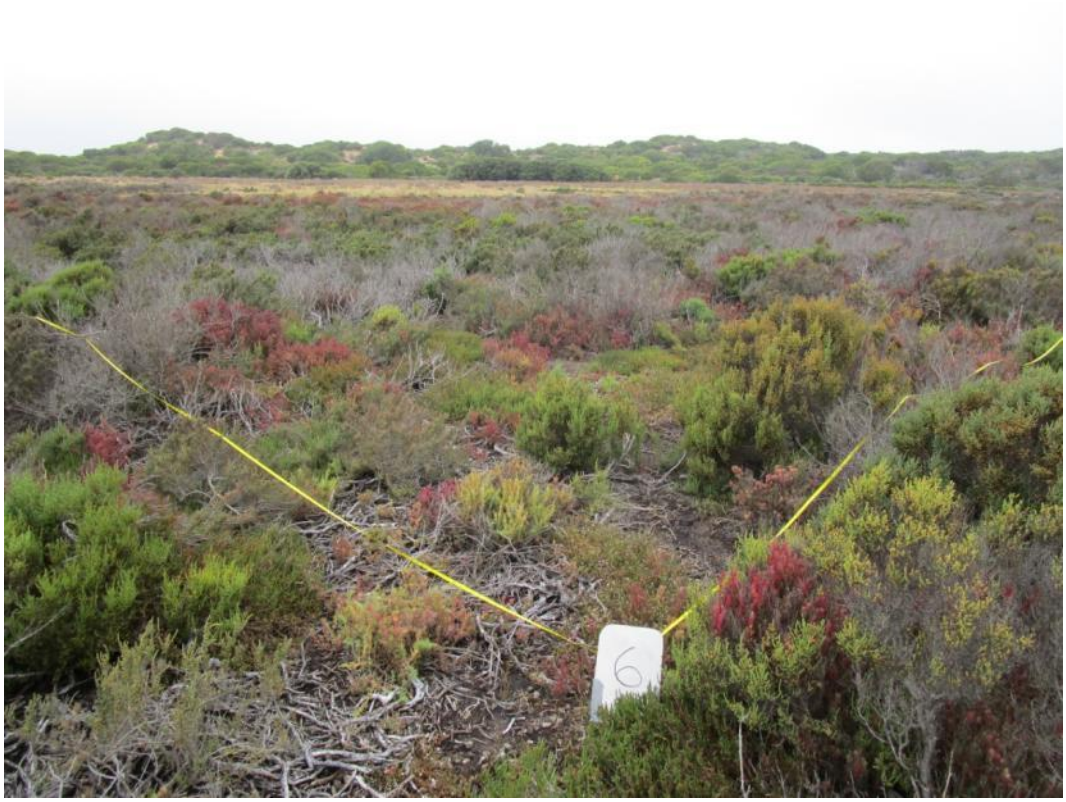
NOTES:

2023: The quadrat area was dry, with a thin salt crust present. Scattered young plants of *Tecticornia* species 20-40 cm tall were present, presumably including root suckers, but mass regeneration was lacking.

2024: The quadrat was dry (damp soil), with signs of recent inundation not evident. Occasional patches of a very superficial film of non-problematic native blue-green algae were included within the bare ground cover. Small (to 5-20 cm) plants of *Tecticornia* species were relatively frequently present in the vicinity of the bases of plants with dead aerial parts, and are presumed to be suckers from surviving root systems.



Quadrat 6, 2023.



Quadrat 6, 2024.

QUADRAT NUMBER: 07

DATES: 9/11/23, 24/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269968/ 5757055 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Open shrubland of *Tecticornia* spp. The quadrat area was not inundated, but the soil was still damp and with localised patches of salt crust. The soil surface was peaty with a minor component of sand, over grey clay. Pugged kangaroo trails were locally present, but only of minor occurrence within the quadrat area.

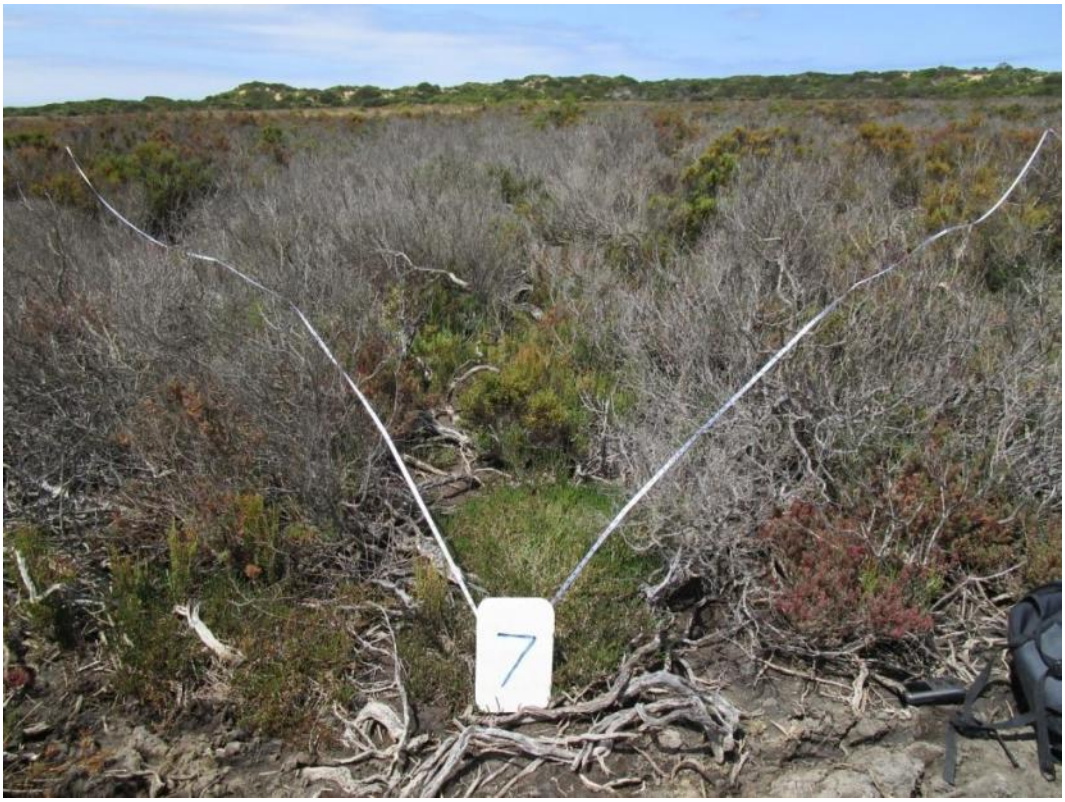
SPECIES AND COVERS:

	2023	2024
Frankenia pauciflora var. *gunnii*	2	5
Salicornia blackiana		+
Salicornia quinqueflora subsp. *quinqueflora*	5	10
Suaeda australis	10	15
Tecticornia arbuscula [live plants]	15	20
Tecticornia arbuscula [dead plants]	10	10
Tecticornia sp. (Connewarre) [live plants]	1	1
Tecticornia sp. (Connewarre) [dead plants]	1	1
Bare ground (%)	40	30
Plant litter (%)	35	30
Algal mat (%)	-	1

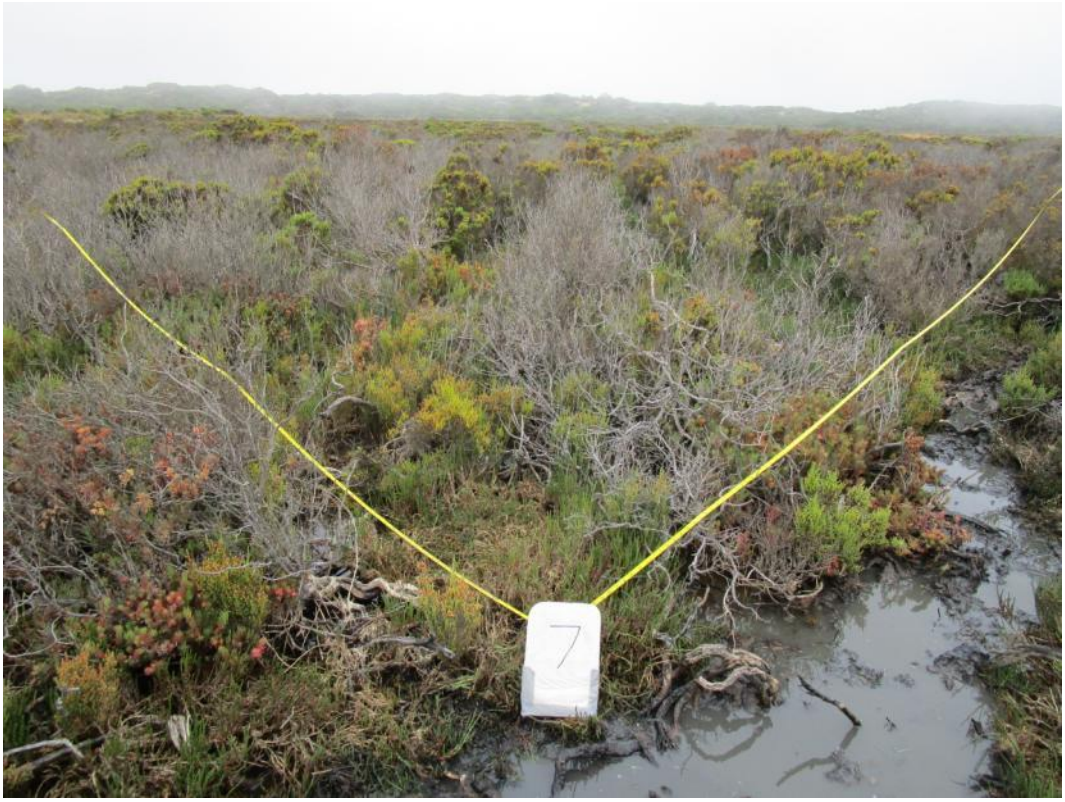
NOTES:

2023: The quadrat area was not inundated, but the soil was still damp and with localised patches of salt crust. The quadrat included abundant (100s of plants) regeneration of *Tecticornia arbuscula* ca. 10-40 cm in height, with more or less full regeneration present in gaps (recruitment estimated at ca. 7% cover, mature plants at ca. 10%).

2024: Approximately 3% of the quadrats was inundated to 15 cm (along kangaroo paths), otherwise the quadrat was mostly dry (damp soil) to saturated. Shallow ponding was persisting immediately adjacent to the quadrat. The relative cover of bare ground and plant litter was ambiguous. Healthy patches of regeneration to ca. 40 cm tall (presumably suckers) of *Tecticornia* species were evident, indicative of substantial recovery of the shrub layer.



Quadrat 7, 2023



Quadrat 7, 2024.

QUADRAT NUMBER: 08

DATES: 9/11/23, 24/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0270041/ 5756853 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Denser shrub canopy of *Tecticornia* sp. (Connewarre). The condition of the canopy of mature plants was very intact. Dead plants were mainly immediately adjacent to kangaroo trails. The quadrat area was dry, with a salt and algal crust present along these trails. The soil included a sandy layer, over grey clay with a sand fraction evident in at least in the upper portion. Shells of Mediterranean Snail were locally conspicuous. Kangaroo trails in the vicinity were variously entrenched.

SPECIES AND COVERS:

	2023	2024
Apium annuum	1	
**Cotula coronopifolia*	+	
Disphyma crassifolium subsp. *clavellatum*		1
Frankenia pauciflora var. *gunnii*	+	1
**Lolium rigidum*		+
**Melilotus indica*		2
**Parapholis incurva*	1	1
**Polypogon monspeliensis*	1	+
Salicornia quinqueflora subsp. *quinqueflora*	+	+
**Sonchus oleraceus*	1	
Tecticornia arbuscula [live plants]	2	2
Tecticornia arbuscula [dead plants]	+	+

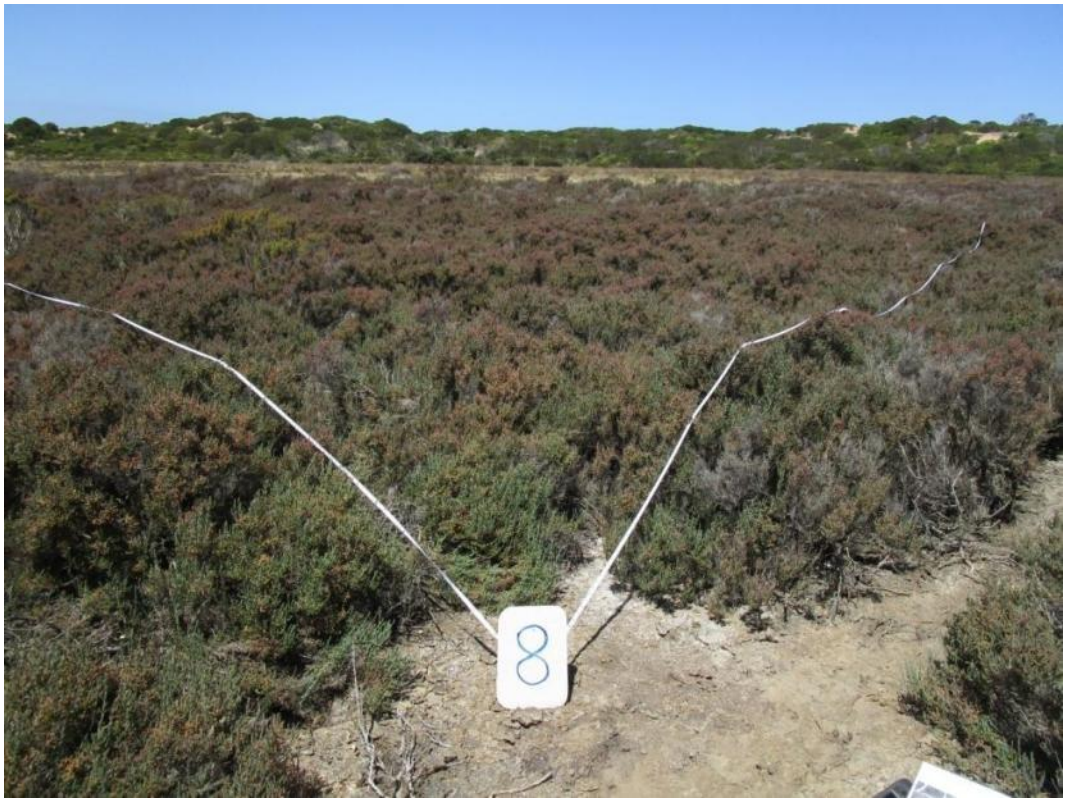
Tecticornia sp. (Connewarre) [live plants]	70	70
Tecticornia sp. (Connewarre) [dead plants]	2	2
Bare ground (%)	20	30
Plant litter (%)	30	20
Algal mat (%)	1.5	0.5

Additional species observed nearby: *Puccinellia stricta* (2024).

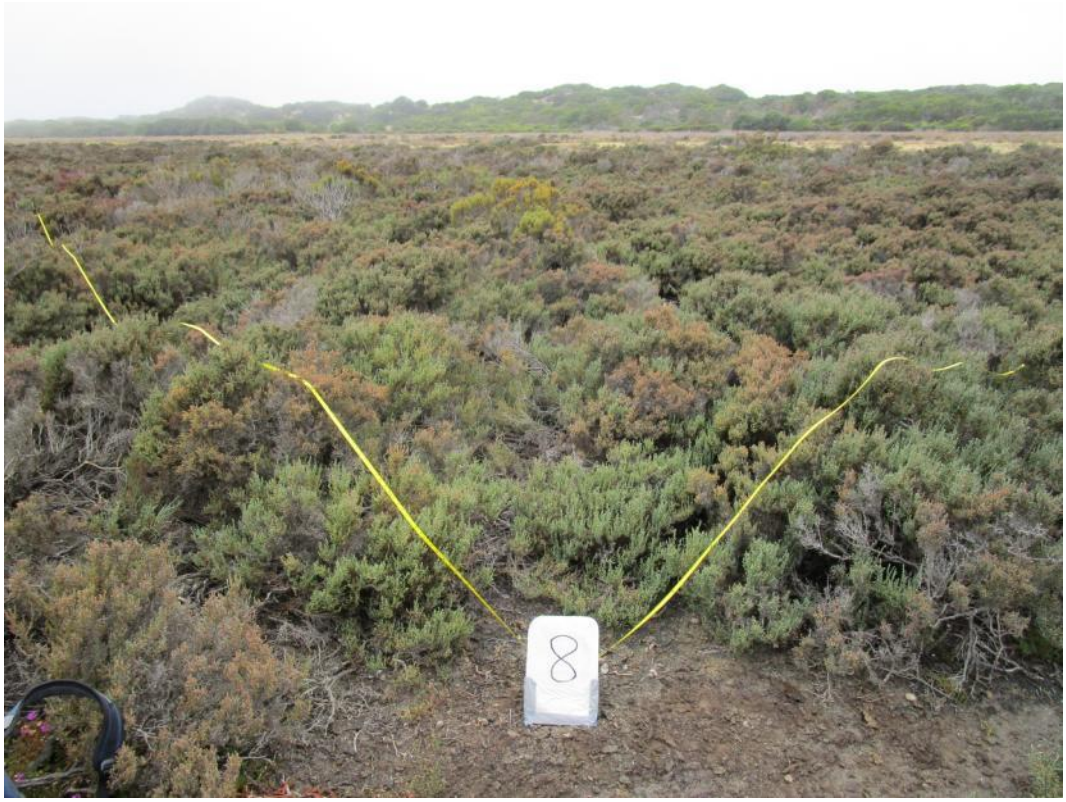
NOTES:

2023: Bare ground cover was a coarse estimate – the extent under the shrub cover was ambiguous. No regeneration of *Tecticornia* species under the very intact canopy of mature plants was evident.

2024: The site was dry, with a watermark representing superficial inundation present at the base of the marker post. The annual species primarily occurred along kangaroo paths. The cover of bare ground comprised a coarse estimate – its extent under the shrub canopy was ambiguous. No regeneration of *Tecticornia* species was evident



Quadrat 8, 2023.



Quadrat 8, 2024.

QUADRAT NUMBER: 09

DATES: 9/11/23, 24/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269924/ 5756870 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Moderately dense canopy of *Tecticornia arbuscula* with considerable plant mortality. Mortality of *T. arbuscula* had arisen from multiple events (including older more decomposed stems as well as relatively recently killed plants). The quadrat area was dry. A very superficial salt crust was present, but algal crust was not evident within the vicinity of the quadrat. The soil included a layer of loamy sand over clay, similar to that of quadrat 8. Major kangaroo trails in the vicinity were pugged or variously entrenched, but not as deeply as in wetter areas.

SPECIES AND COVERS:

	2023	2024
**Cotula coronopifolia*		+
**Polypogon monspeliensis*	1	
Salicornia quinqueflora subsp. *quinqueflora*	1	1
Tecticornia arbuscula [live plants]	35	40
Tecticornia arbuscula [dead plants]	15	15
Bare ground (%)	20	30
Plant litter (%)	60	50
Algal mat (%)	-	0.5%

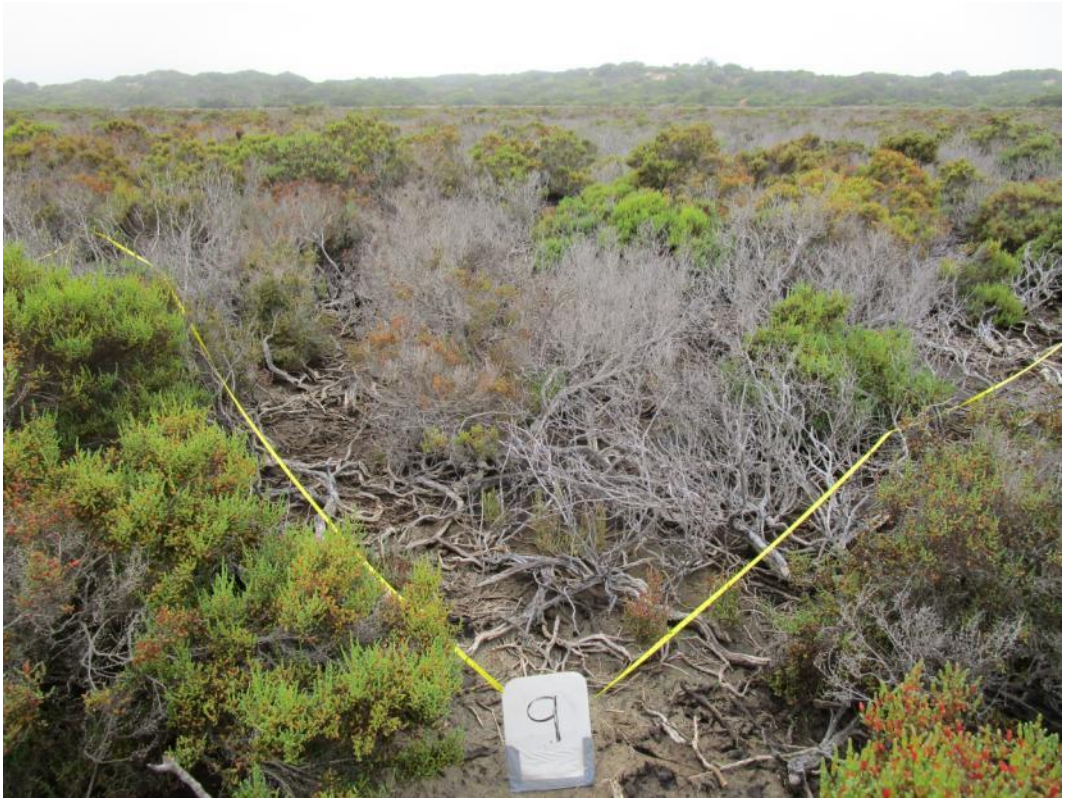
Additional species observed nearby: *Apium annuum* (2024), *Frankenia pauciflora* var. *gunnii* (2023, 2024)

NOTES:

2023: The quadrat area was dry, with a very superficial salt crust present. Litter cover was somewhat ambiguous as to when it represented detached litter and when it comprised older dead stems of *T. arbuscula*. The quadrat included patches of regeneration of *T. arbuscula* ca. 15-40 cm tall in gaps, totalling ca. 200 plants and presumed to include at least a component of suckers (ca. 5% cover juveniles, 30% mature plants).

2024: The site was dry (with damp soil), with an inundation line on the marker post at ca. 12 cm. The actual cover of bare ground was ambiguous, with a thin film of non-problematic species of blue-green algae variously present. The shrub layer was undergoing recovery, with patchy regeneration of *T. arbuscula* (presumably suckers), 10-40 cm or more in height present.

Quadrat 9, 2023.



Quadrat 9, 2024.

QUADRAT NUMBER: 10

DATES: 9/11/23, 23/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269730/ 5756938 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Relatively open shrub canopy of *Tecticornia arbuscula*. Mortality of *T. arbuscula* had arisen from multiple events (including much older more decomposed stems as well as relatively recently killed plants). The quadrat area was dry, with a superficial salt crust but algal crusts were not locally evident. A very small patch of a moss species was present. The soil included a shallow layer of loamy sand over grey clay. The extent of pugging along kangaroo trails in the vicinity was variable according to microtopography.

SPECIES AND COVERS:

	2023	2024
Apium annuum	1	1
**Cotula coronopifolia*		+
Disphyma crassifolium subsp. clavellatum	1	1
Frankenia pauciflora var. *gunnii*	2	2
**Parapholis incurva*	1	1
**Polypogon monspeliensis*	2	2
Salicornia quinqueflora subsp. *quinqueflora*	2	+
Tecticornia arbuscula [live plants]	30	35
Tecticornia arbuscula [dead plants]	5	5
Bryophytes (%)	0.02	-
Bare ground (%)	40	10
Plant litter (%)	40	20
Algal mat (%)		40

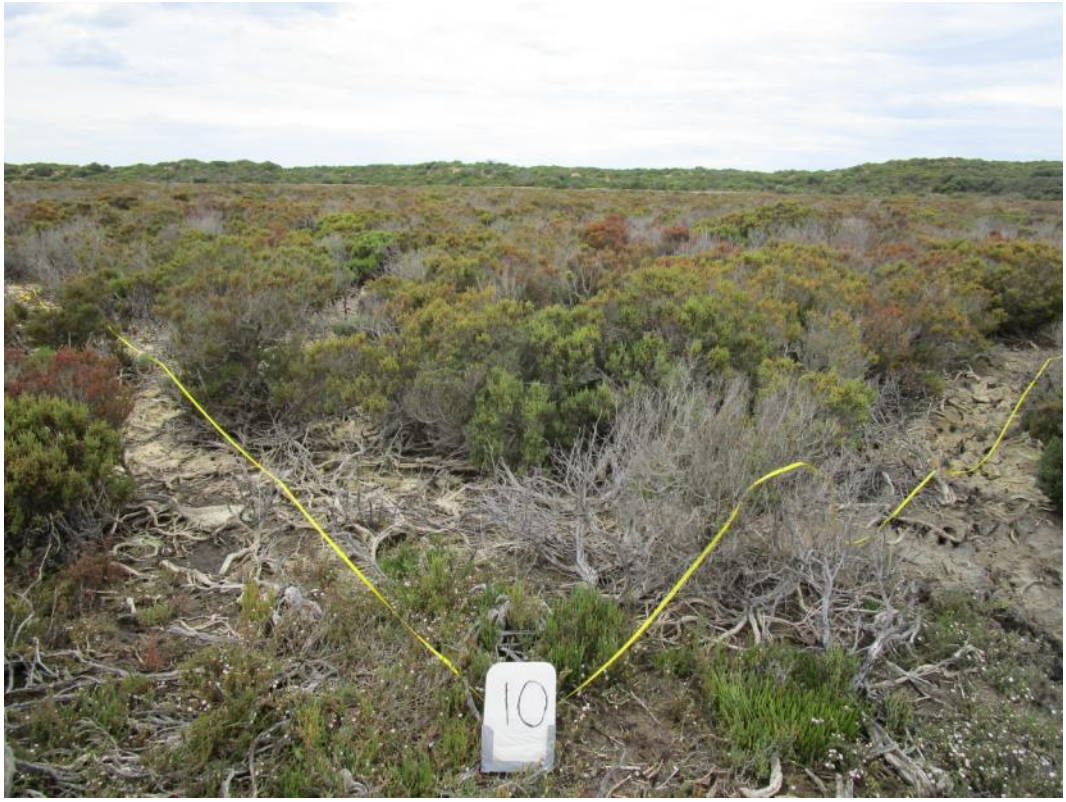
Additional species observed nearby: *Puccinellia stricta*, *Suaeda australis* (2023)

NOTES:

2023: The site was dry, with a superficial salt crust. The quadrat included several localised patches of juvenile *T. arbuscula* ca. 10-30 cm tall, presumed to mainly comprise suckers, totalling ca. 50 plants.

2024: The site was dry (damp soil), with an inundation line on the marker post at ca. 5 cm. The algal mat primarily comprised a green alga with relatively coarse filaments (a species of *Chaetomorpha*?). A smaller component of non-problematic filamentous blue-green algae was present. The litter cover was ambiguous, primarily comprising woody fragments of *T. arbuscula*. Occasional very young *Tecticornia* seedlings were present. *Apium annuum* was present as recently germinated seedlings.

Quadrat 10, 2023.



Quadrat 10, 2024.

QUADRAT NUMBER: 11

DATES: 9/11/23, 23/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269625 / 5756908 (+/- 3 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Relatively open shrub canopy of *Tecticornia* sp. (Connewarre) with high plant mortality and a high cover of *Salicornia quinqueflora*. The soils included a dark organic surface layer over wet grey clay. An adjacent open area included algal cover, with the quadrat area still saturated and deeply pugged by sparse kangaroo tracks.

SPECIES AND COVERS:

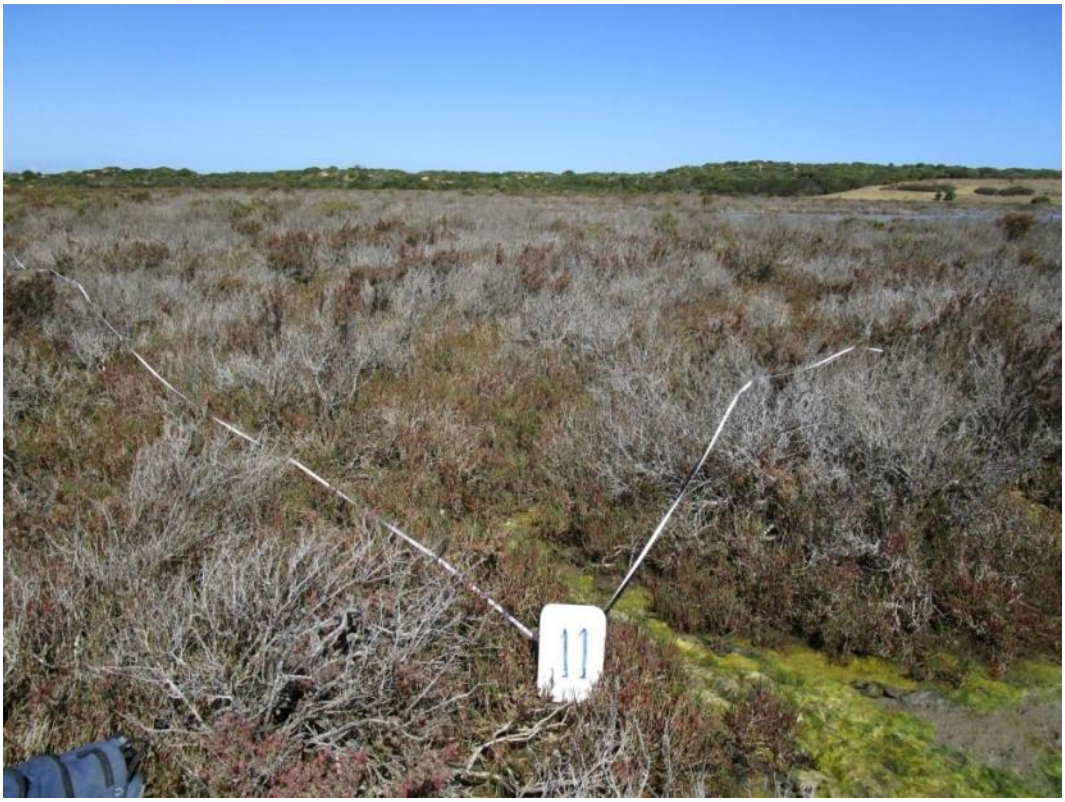
	2023	2024
Althenia bilocularis		2
Salicornia quinqueflora subsp. *quinqueflora*	65	65
Suaeda australis	2	1
Tecticornia sp. (Connewarre) [live plants]	15	15
Tecticornia sp. (Connewarre) [dead plants]	20	20
Bare ground (%)	15	?
Plant litter (%)	15	?
Algal mat (%)	5	40

Additional species observed nearby: *Puccinellia stricta*, *Suaeda australis* (2023)

NOTES:

2023: The quadrat area was saturated. No regeneration of *Tecticornia* sp. was evident.

2024: The quadrat was 100% inundated, at 10-25 cm depth. Algal mat cover refers to the exposed component. Total litter and bare ground covers were ambiguous due to the overlaying algal mat and depth of inundation. No regeneration of *Tecticornia* sp. was evident.



Quadrat 11, 2023.

Quadrat 11, 2024.

QUADRAT NUMBER: 12

DATES: 9/11/23, 23/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269806/ 5756715 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION:

Primarily open low-lying area, with sparse dead plants of both of the *Tecticornia* spp. present, with dead *T. arbuscula* plants structurally more intact and consequently having died more recently than those of *T*. sp. (Connewarre) plants. Only minimal cover of live *Tecticornia* species was evident within the low-lying land feature. The quadrat area was currently dry with a salt crust. The soils consisted of a yellowish-brown sandy loam, presumed to be overlying clay at a deeper level. Abundant rabbit sign (droppings and scratching) and some fragments of marine shells were evident in the quadrat area. Pug marks associated with kangaroo tracks were not very deep or well preserved, due to the sandy character of the soil.

SPECIES AND COVERS:

	2023	2024
**Atriplex prostrata*	+	
Disphyma crassifolium subsp. *clavellatum*	+	1
Frankenia pauciflora var. *gunnii*	2	2
**Polypogon monspeliensis*	1	
Puccinellia stricta		1
Salicornia quinqueflora subsp. *quinqueflora*	30	60
Senecio halophilus	+	+
Tecticornia arbuscula [live plants]	+	+
Tecticornia arbuscula [dead plants]	2	2

Tecticornia sp. (Connewarre) [dead plants]	2	2
Bare ground (%)	70	35
Plant litter (%)	5	5
Algal mat (%)	-	-

Additional species observed nearby: *Senecio glomeratus* and *Spergularia marina* (2023).

NOTES:

2023: The quadrat was dry with a salt crust present. The litter cover was somewhat ambiguous in relation to disintegrating *Tecticornia* plants. Within the quadrat, colonisation by small plants of *Salicornia quinqueflora* was present, but regeneration of *Tecticornia* species was lacking.

2024: The quadrat was dry (damp soil) - while apparently not recently inundated, the marker peg has a waterline at ca. 15 cm, indicating parts of quadrat would have been inundated to over 30 cm depth. Scattered suckers of *Tecticornia arbuscula* <30 cm tall were present, arising from around the bases of nearly-dead looking plants bearing very little green tissue.

Quadrat 12, 2023.

Quadrat 12, 2024.

QUADRAT NUMBER: 13

DATES: 10/11/23, 23/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269476/ 5756872 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Prior *Tecticornia* species shrubland, with majority of individuals dead and *Salicornia quinqueflora* dominated ground layer. Mortality of *Tecticornia* species was from mixed time frames, but primarily recent. The soil was saturated, with algal crust present along kangaroo trails. The top soil comprised a dark organic layer over yellow-grey clay. Kangaroo tracks were deeply pugged.

SPECIES AND COVERS:

	2023	2024
Apium annuum	2	-
**Atriplex prostrata*	2	+
Bolboschoenus caldwellii	+	1
**Cotula coronopifolia*	2	2
Frankenia pauciflora var. *gunnii*	2	2
Isolepis cernua s.s.	2	1
Lachnagrostis sp. aff. *filiformis* (glabrous lemmas)	1	-
Lilaeopsis polyantha	-	2
**Plantago coronopus*	1	1
**Polypogon monspeliensis*	5	2
**Rumex crispus*	1	1
Salicornia quinqueflora subsp. *quinqueflora*	60	60
Senecio pinnatifolius var. *lanceolatus*	1	1

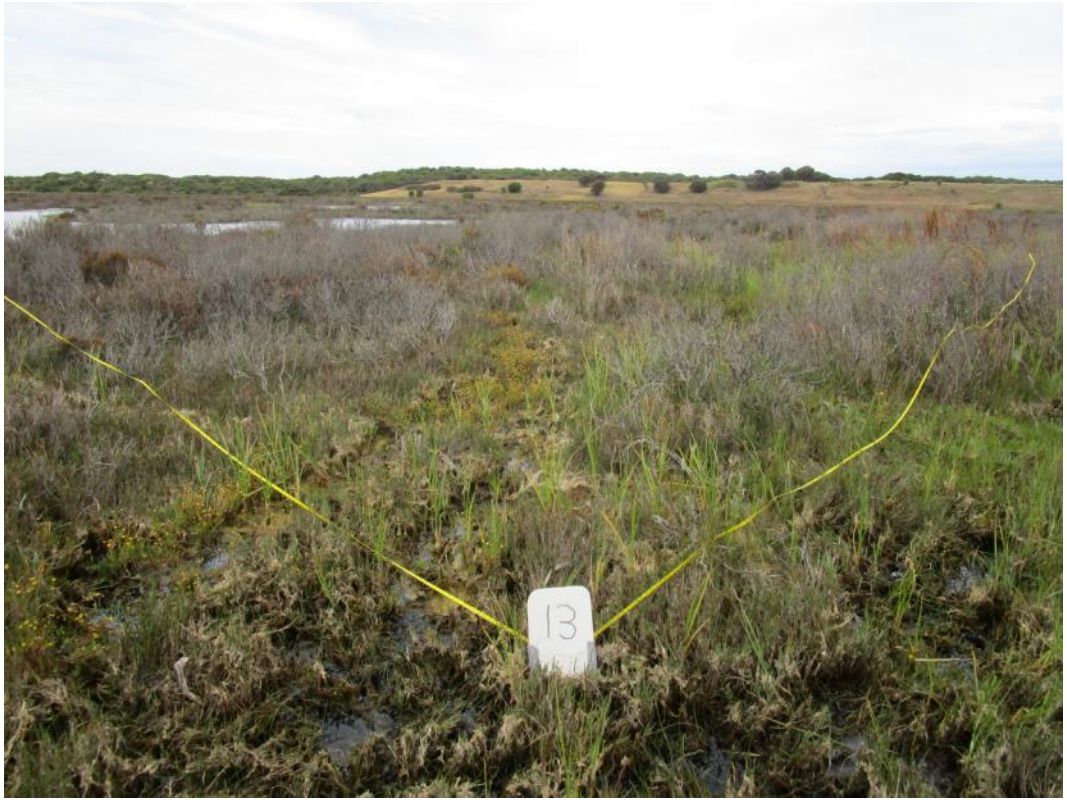
**Sonchus oleraceus*	1	-
Spergularia marina	1	-
Suaeda australis	2	2
**Symphyotrichum subulatum*	1	+
Tecticornia arbuscula [live plants]	2	2
Tecticornia sp. (Connewarre) [live plants]	+	+
Tecticornia spp. [dead plants]	20	20
Triglochin striata	2	5
Bare ground (%)	5	1
Plant litter (%)	10	10
Algal mat (%)	5	20

NOTES:

2023: The soil was saturated. The extent of litter cover was ambiguous in relation to interpretation of disintegrating dead *Tecticornia* plants. No regeneration of *Tecticornia* spp. was evident.

2024: With ca. 50% of the quadrat area inundated to 15 cm and the residue damp to saturated. No regeneration of *Tecticornia* spp. was evident.

Quadrat 13, 2023.



Quadrat 13, 2024.

QUADRAT NUMBER: 14

DATES: 10/11/23, 23/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269514/ 5756679 (+/- 5 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Open shrubland of *Tecticornia arbuscula* with the majority of plants dead, and *Salicornia quinqueflora* and **Cotula coronopifolia* co-dominant in the ground layer. The quadrat was adjacent to a small pond. Within the quadrat, the soil moisture ranged from saturated to very damp. The top soil comprised sandy peat over a clayey-sandy layer with high organic content. Kangaroo tracks were sparse but deeply pugged where present.

SPECIES AND COVERS:

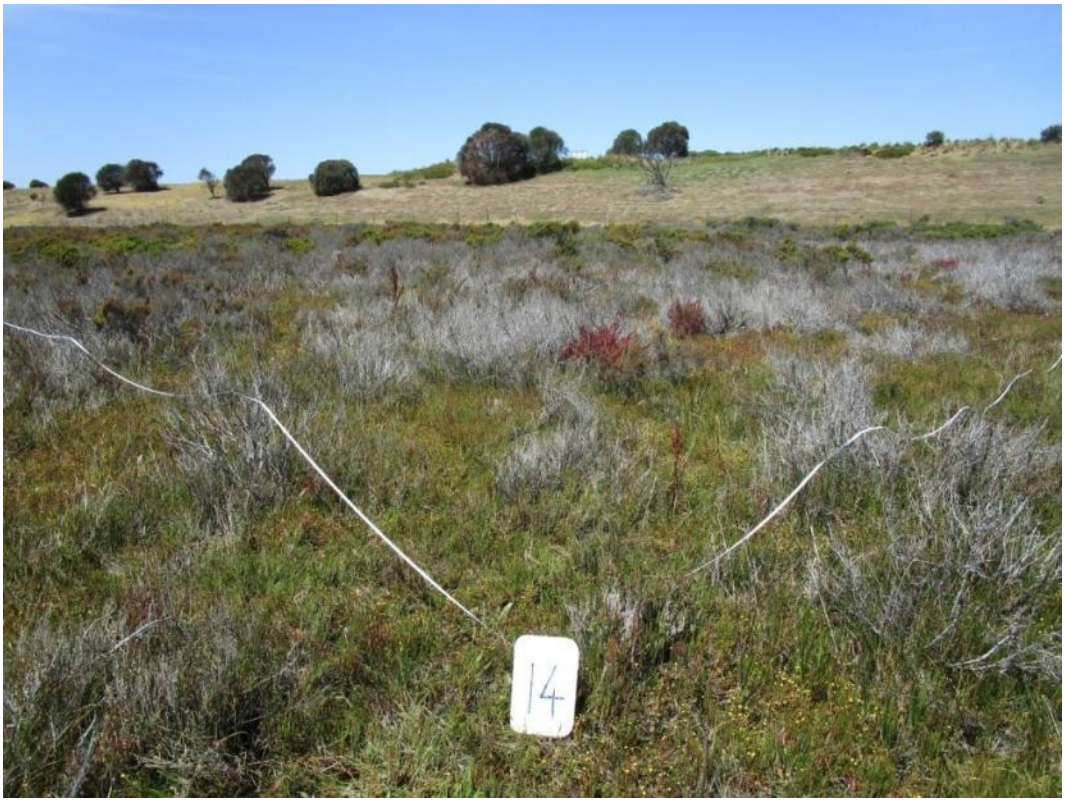
	2023	2024
**Atriplex prostrata*	+	
Bolboschoenus caldwellii	2	15
**Cotula coronopifolia*	40	20
Isolepis cernua s.s.	1	
Lilaeopsis polyantha		5
**Polypogon monspeliensis*	1	1
**Rumex crispus*	1	+
Salicornia quinqueflora subsp. *quinqueflora*	40	30
Suaeda australis	2	2
Tecticornia arbuscula [live plants]	2	2
Tecticornia arbuscula [dead plants]	2	2
Tecticornia sp. (Connewarre) [live plants]	5	5
Tecticornia sp. (Connewarre) [dead plants]	10	10

Triglochin striata	2	5
Bare ground (%)	2	-
Plant litter (%)	7	2
Algal mat (%)	10	60

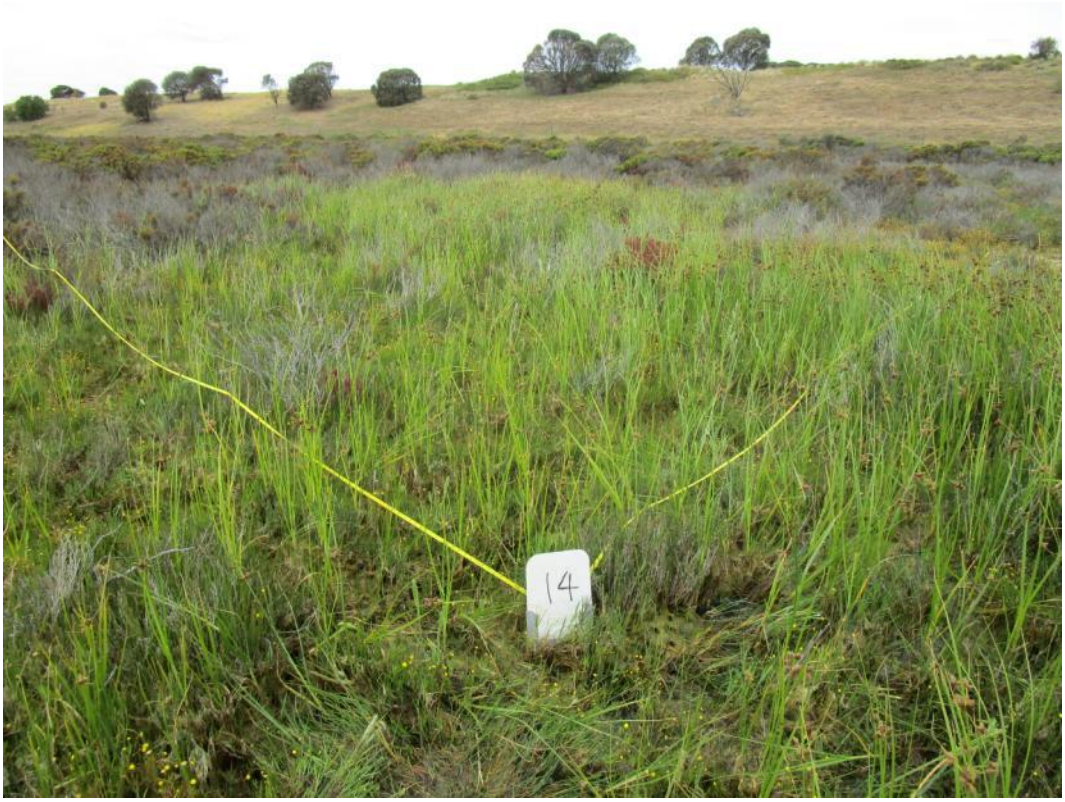
NOTES:

2023: The soil was saturated to very damp. No regeneration of *Tecticornia* spp. was evident.

2024: The quadrat was with 100% shallow inundation < 10 cm depth. The litter cover was the ambiguous due to the algal mat – the visible component only was estimated. No regeneration of *Tecticornia* spp. was evident.



Quadrat 14, 2023.



Quadrat 14, 2024.

QUADRAT NUMBER: 15

DATES: 10/11/23, 22/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269249/ 5756685 (+/- 5 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION: Mudflat with scattered dead *Tecticornia* species and patchy Brackish Wetland species, surrounded by patches of *Typha* spp. *Salicornia quinqueflora* was mainly present as small seedlings. *Bolboschoenus caldwellii* shoots were still emerging. Within the quadrat, the surface ranged from being saturated to superficially inundated. The soil comprised black anaerobic ooze over yellow-grey clay (as for soil collection site 4).

SPECIES AND COVERS:

	2023	2024
Apium annuum	1	
**Atriplex prostrata*	1	+
Azolla rubra		1
Bolboschoenus caldwellii	5	10
**Cotula coronopifolia*	10	50
Crassula helmsii	1	5
Eleocharis acuta	+	1
Epilobium billardierianum subsp. *intermedium*	1	+
Lemna disperma	2	
Lachnagrostis sp. aff. *filiformis* (glabrous lemmas)		+
Lilaeopsis polyantha	15	20
Lythrum hyssopifolia	+	
**Plantago coronopus*		+

**Polypogon monspeliensis*	1	2
Puccinellia stricta		1
**Rumex crispus*	+	2
Ruppia polycarpa		2
Salicornia quinqueflora subsp*. quinqueflora*	1	
Senecio pinnatifolius var*. lanceolatus*	1	2
**Symphyotrichum subulatum*	1	+
Tecticornia spp. [dead plants]	5	2
Thyridia repens	+	2
Triglochin striata	1	5
Typha spp.	+	2
Bare ground (%)	65	2
Plant litter (%)	1	1
Algal mat (%)	10	10

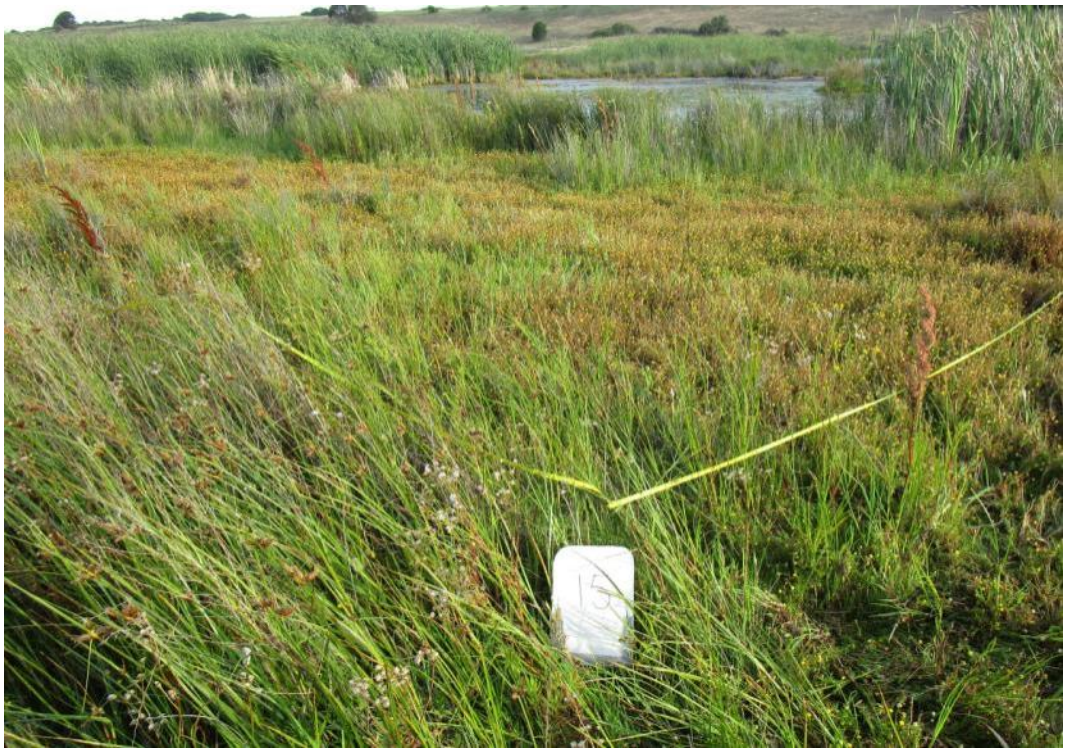
Additional species observed nearby: *Sonchus hydrophilus* (2024)

NOTES:

2023: Bare ground (mud) 65%. No regeneration of *Tecticornia* spp. was evident.

2024: Saturated, with sloppy mud and ca. 5% inundated to 20 cm. The marker peg was not relocated, with the GPS point used as corner point – a new peg is required next sampling occasion. No regeneration of *Tecticornia* spp. was evident.

Quadrat 15, 2023.



Quadrat 15, 2024.

QUADRAT NUMBER: 16

DATES: 10/11/23, 22/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269313/ 5756912 (+/- 3 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION:

Prior shrubland of *Tecticornia arbuscula* with nearly all plants dead. *Salicornia quinqueflora* and **Cotula coronopifolia* were co-dominant in the ground layer with Brackish Wetland species. The soil variously comprised peaty loam or black ooze over grey clay. Deep pugging was present along incidental kangaroo paths in the vicinity.

SPECIES AND COVERS:

	2023	2024
Apium annuum	2	1
**Atriplex prostrata*	+	1
Bolboschoenus caldwellii	10	40
**Cotula coronopifolia*	20	10
Frankenia pauciflora var. *gunnii*	+	+
Isolepis cernua s.s.	1	1
Lilaeopsis polyantha		5
**Lolium rigidum*	+	
**Plantago coronopus*		+
**Polypogon monspeliensis*	10	10
Puccinellia stricta	+	
**Rumex crispus*	1	+

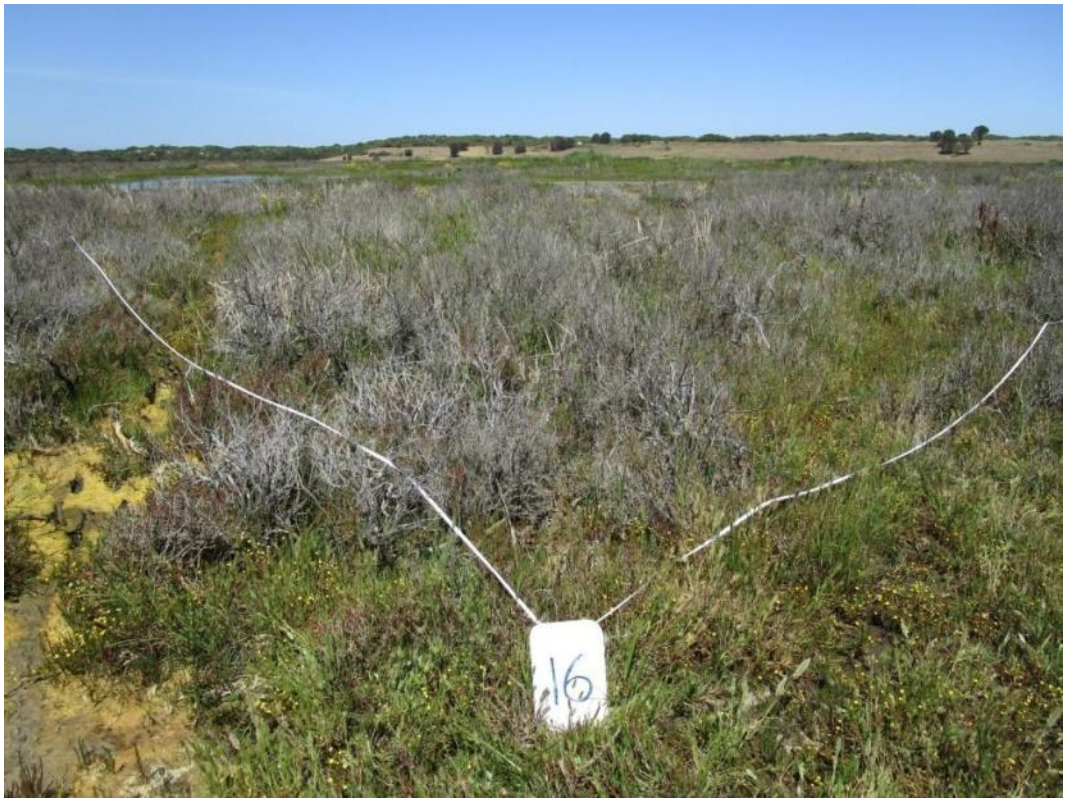
Salicornia quinqueflora subsp. *quinqueflora*	30	30
Senecio pinnatifolius var. *lanceolatus*		1
Sonchus hydrophilus	+	
**Symphyotrichum subulatum*	1	1
Tecticornia arbuscula [live plants]	+	+
Tecticornia spp. [dead plants]	15	15
Thyridia repens	1	1
Triglochin striata	5	5
Typha spp.	1	2
Bare ground (%)	15	1
Plant litter (%)	5	5
Algal mat (%)	5	10

Additional species observed nearby: *Senecio pinnatifolius* var. *lanceolatus* (2023)

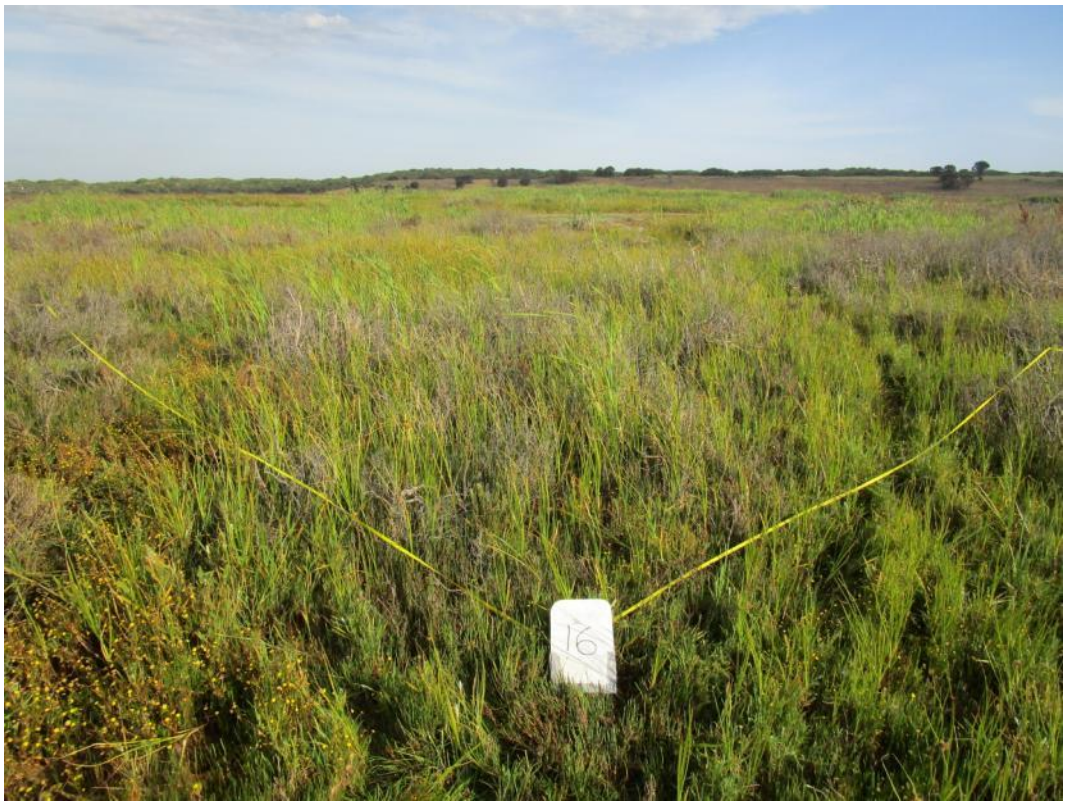
NOTES:

2023: Within the quadrat, the soil was saturated with an algal crust in gaps. No regeneration of *Tecticornia* spp. was evident.

2024: ca. 50% of the quadrat was inundated to <10 cm, with the remainder saturated. No regeneration of *Tecticornia* spp. was evident.



Quadrat 16, 2023.



Quadrat 16, 2024.

QUADRAT NUMBER: 17

DATES: 10/11/23, 22/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269236/ 5756930 (+/- 5 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION:

The quadrat was located on a mudflat between two ponds and included a portion of shallow fringing pond. The main vegetation comprised a dwarf herbland of Brackish Wetland species. A sparse component of dead *Tecticornia* spp. from an earlier dieback event was also present. The covers of species occurring as intermixed components within the dwarf herbland vegetation were difficult to interpret accurately. The soil consisted of silty black ooze over grey clay.

SPECIES AND COVERS:

	2023	2024
Althenia bilocularis	1	2
Apium annuum	2	
**Atriplex prostrata*	1	+
Bolboschoenus caldwellii	2	5
**Cotula coronopifolia*	2	2
Crassula helmsii		1
Frankenia pauciflora var. *gunnii*	+	
Isolepis cernua s.s.	1	1
Juncus bufonius	1	
Lilaeopsis polyantha	10	10
**Parapholis incurva*		1
**Plantago coronopus*	1	+

**Polypogon monspeliensis*	2	1
Ruppia polycarpa	2	2
Salicornia quinqueflora subsp*. quinqueflora*	2	+
Senecio pinnatifolius var*. lanceolatus*	1	1
**Symphyotrichum subulatum*	1	1
Tecticornia spp. [dead plants]	5	2
Thyridia repens	2	2
Triglochin striata	2	1
Typha spp.	1	2
Bare ground (%)	65	75
Plant litter (%)	2	2
Algal mat (%)	10	2

NOTES:

2023: Within the quadrat, the soil was saturated, with ca. 10% inundated to up to around 10 cm depth. No regeneration of *Tecticornia* spp. was evident.

2024: ca. 70% of the quadrat was inundated to up to 20 cm depth, over soft anoxic mud, with the remainder saturated. The site was considerably wetter than the previous year. Mud shoes may be desirable for future sampling events if the location has experienced prolonged wetness. No regeneration of *Tecticornia* spp. was evident.

Quadrat 17, 2023.

Quadrat 17, 2024.

QUADRAT NUMBER: 18

DATES: 10/11/23, 22/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269181/ 5757009 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION:

Prior shrubland of *Tecticornia* spp., with a high proportion of these plants dead and with a ground layer dominated by a dense cover of *Salicornia quinqueflora*. Incidental juvenile plants of *Tecticornia* spp. were present. Algal crusts were not evident. The top soil was peaty, grading into clay with an organic component. Deep pugging was localised along occasional kangaroo trails.

SPECIES AND COVERS:

	2023	2024
Apium annuum	1	1
**Atriplex prostrata*	1	+
**Cotula coronopifolia*	5	5
Disphyma crassifolium subsp. *clavellatum*	1	+
Frankenia pauciflora var. *gunnii*	2	2
**Hordeum hystrix*	+	+
Isolepis cernua s.s.	1	2
**Polypogon monspeliensis*	1	1
Puccinellia stricta		1
Salicornia quinqueflora subsp. *quinqueflora*	85	85
Spergularia marina	1	
Tecticornia arbuscula [live plants]	2	2

Tecticornia arbuscula [dead plants]	5	5
Tecticornia sp. (Connewarre) [live plants]	2	2
Tecticornia sp. (Connewarre) [dead plants]	10	10
Triglochin striata		1
Bare ground (%)	10	10
Plant litter (%)	5	5
Algal mat (%)		0.05

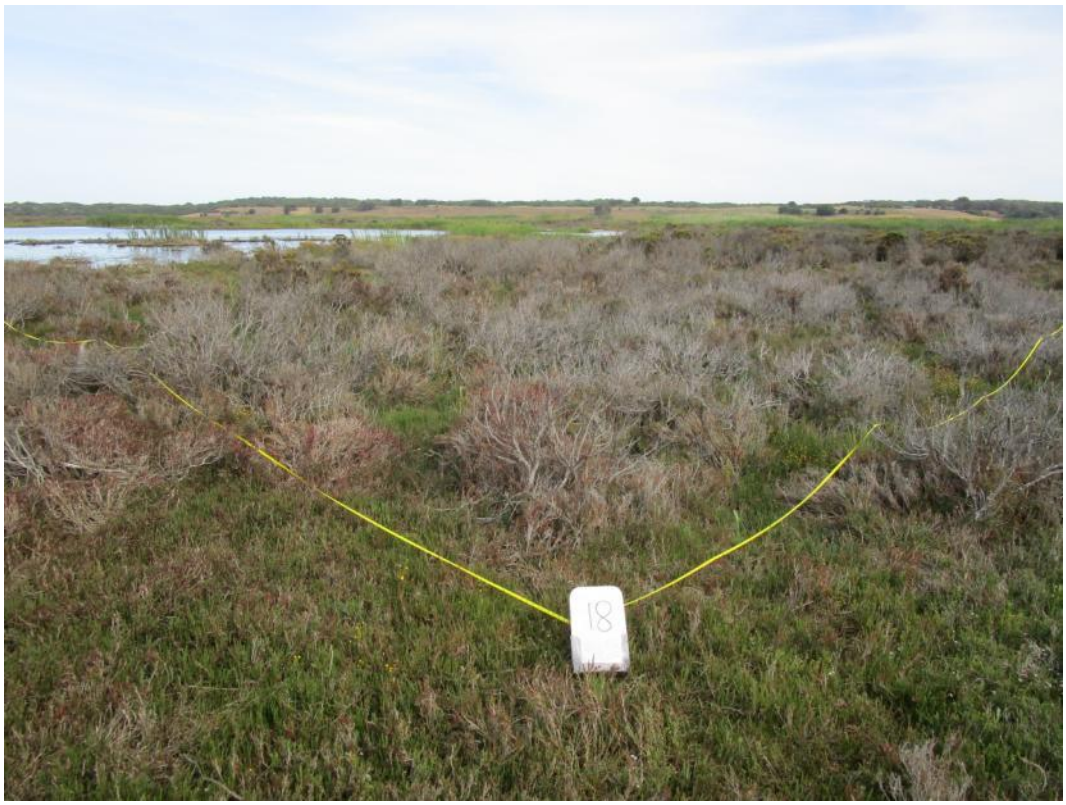
Additional species observed nearby: *Bolboschoenus caldwellii*, **Lolium rigidum* and *Puccinellia stricta* (2023); *Lilaeopsis polyantha*, **Plantago coronopus* and **Symphyotrichum subulatum* (2024).

NOTES:

2023: While the soil was damp, the site was effectively dry. No regeneration of *Tecticornia* spp. was evident.

2024: The soil was variously damp to saturated. No regeneration of *Tecticornia* spp. was evident.

Quadrat 18, 2023.



Quadrat 18, 2024.

QUADRAT NUMBER: 19

DATES: 10/11/23, 22/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269103/ 5756852 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION:

Vegetation modified by stormwater discharge, comprising prior saltmarsh now dominated by *Eleocharis acuta*, with colonisation by a patch of *Typha domingensis* (currently ca. 4% cover). A sparse component of dead *Tecticornia* spp. from an earlier dieback event was present. The small herb component was difficult to detect due to the dense sward of *E. acuta* and consequently has the potential to be underestimated. Algal crusts were not evident. The soil comprised silty black organic ooze over clay. Deep pugging was not obvious along kangaroo paths, as a consequence of the stability provided by the dense ground layer vegetation.

SPECIES AND COVERS:

	2023	2024
**Atriplex prostrata*	+	+
Bolboschoenus caldwellii	2	5
**Cotula coronopifolia*	2	1
Crassula helmsii	1	2
Eleocharis acuta	70	70
Epilobium billardierianum subsp. *billardierianum*	1	2
Epilobium hirtigerum	+	+
**Holcus lanatus*	1	1
Lilaeopsis polyantha	5	1
Lythrum hyssopifolia	1	1

Persicaria decipiens		+
**Polypogon monspeliensis*	1	1
**Rumex conglomeratus*	+	
**Rumex crispus*	1	1
**Rumex* spp. (juvenile plants)		1
Senecio pinnatifolius var. *lanceolatus*	2	1
**Sonchus oleraceus*	+	
**Symphyotrichum subulatum*	1	1
Tecticornia sp. (Connewarre) [live plants]	+	+
Tecticornia sp. (Connewarre) [dead plants]	5	5
Triglochin striata	2	1
Typha domingensis	2	5
Bare ground (%)	5	1
Plant litter (%)	2	5
Algal mat (%)		10

Additional species observed nearby: *Thyridia repens* (2023, 2024)

NOTES:

2023: The quadrat area was saturated to shallowly inundated (to <5 cm depth). No regeneration of *Tecticornia* spp. was evident.

2024: The soil was variously saturated to with very superficial inundation. No regeneration of *Tecticornia* spp. was evident.

Quadrat 19, 2023.

Quadrat 19, 2024.

QUADRAT NUMBER: 20

DATES: 11/11/23, 22/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269111/ 5756800 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION:

Vegetation modified by stormwater discharge, comprising prior saltmarsh now dominated by *Bolboschoenus caldwellii*. Part of the quadrat comprised a locally taller sward of *B. caldwellii* with small plants of *Typha domingensis*. The surface of the quadrat area was saturated. The soil consisted of black organic ooze over clay. Some local pugging was evident along kangaroo paths, but the relative impact was somewhat reduced by the organic component at the soil surface.

SPECIES AND COVERS:

	2023	2024
**Atriplex prostrata*	1	+
Bolboschoenus caldwellii	70	70
**Cotula coronopifolia*	5	5
Crassula helmsii	1	5
Eleocharis acuta	2	5
Epilobium billardierianum subsp. *billardierianum*		1
Epilobium hirtigerum	+	
**Holcus lanatus*		+
Isolepis cernua	1	1
Lilaeopsis polyantha	10	5
**Lolium rigidum*		+
Lythrum hyssopifolia		+

**Parapholis incurva*	+	
**Polypogon monspeliensis*	+	1
Puccinellia stricta	+	
**Rumex conglomeratus*	1	
**Rumex crispus*	1	2
**Rumex* spp. (juvenile plants)	1	1
Salicornia quinqueflora subsp. *quinqueflora*	1	+
Senecio pinnatifolius var. *lanceolatus*	2	+
**Symphyotrichum subulatum*	1	1
Tecticornia spp. [dead plants]	2	2
Triglochin striata		1
Typha domingensis	1	
Bare ground (%)	1	1
Plant litter (%)	20	5
Algal mat (%)	20	15

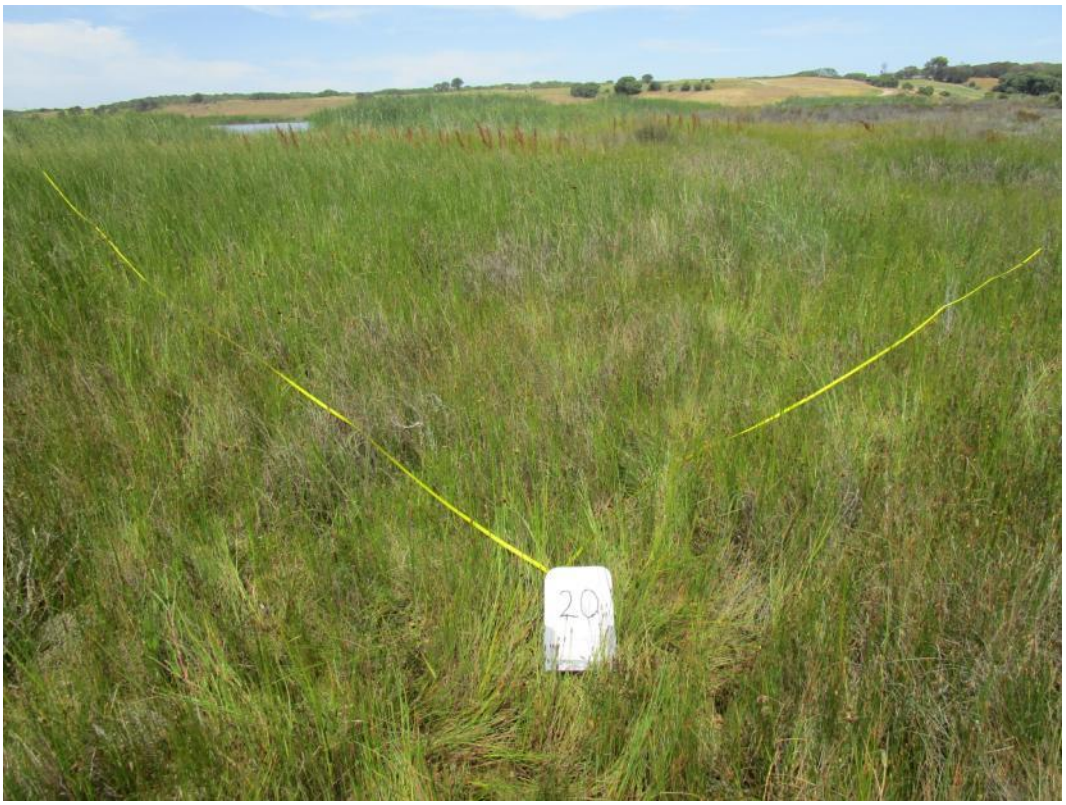
Additional species observed nearby: *Juncus kraussii* subsp. *australiensis* (isolated plant) (2023, 2024); *Epilobium hirtigerum* and *Typha domingensis* (2024)

NOTES:

2023: The surface of the quadrat area was saturated. Litter cover was rather ambiguous as to what proportion of dead plant matter remained attached. No regeneration of *Tecticornia* spp. was evident.

2024: The soil was variously very damp to saturated. Litter cover was rather ambiguous as to what proportion of dead plant matter remained attached. No regeneration of *Tecticornia* spp. was evident.

Quadrat 20, 2023.



Quadrat 20, 2024.

QUADRAT NUMBER: 21

DATES: 11/11/23, 22/11/24

RECORDER: D. Frood

GPS LOCATION OF MARKER POST (NW corner): 55H 0269082/ 5756833 (+/- 4 m)

QUADRAT SIZE: 10 m x 10 m

SITE DESCRIPTION:

Vegetation modified by stormwater discharge into former saltmarsh. Now dominated by *Eleocharis acuta* with *Senecio pinnatifolius*, with associated plants primarily comprising freshwater species. The quadrat is close to the apparent outlet of a pipe into the Karaaf, with a patch of *Typha* spp. and *Schoenoplectus tabernaemontani* present nearby. Algal crusts were evident in parts of the area. The soil consisted of black organic ooze over clay. Pugging from kangaroo tracks was not obvious.

SPECIES AND COVERS:

	2023	2024
**Atriplex prostrata*	1	1
Bolboschoenus caldwellii	1	1
**Cotula coronopifolia*	1	+
Crassula helmsii	1	2
Eleocharis acuta	60	65
Epilobium billardierianum subsp. *billardierianum*	2	2
Epilobium billardierianum subsp. *intermedium*	1	
Epilobium hirtigerum	5	10
**Holcus lanatus*	10	10
Lachnagrostis filiformis s.s.	+	
**Leontodon saxatilis* subsp. *saxatilis*		+

**Lolium rigidum*	+	
Lythrum hyssopifolia	1	1
Persicaria decipiens	+	+
**Polypogon monspeliensis*	1	+
**Rumex crispus*	1	1
**Rumex* spp. (juvenile plants)	1	1
Senecio pinnatifolius var. *lanceolatus*	25	15
**Sonchus asper* s.l.	1	
**Sonchus oleraceus*	1	
Bare ground (%)	2	1
Plant litter (%)	10	?
Algal mat (%)	10	2

Additional species observed nearby: *Schoenoplectus tabernaemontani*, *Typha* spp. (2023, 2024); **Festuca arundinacea* and *Gahnia filum* (2024)

NOTES:

2023: The quadrat area was waterlogged and effectively shallowly inundated (to <5 cm depth). Interpretation of the litter cover was somewhat ambiguous with high cover of dead *Eleocharis* culms. No regeneration of *Tecticornia* spp. was evident.

2024: Soil variously very damp to saturated. Interpretation of the litter cover was very ambiguous in relation to whether or not dead *Eleocharis acuta* culms were attached or otherwise. Estimated cover for the algal mat applied to the exposed (visible) portion only. No regeneration of *Tecticornia* spp. was evident.

Quadrat 21, 2023.

Quadrat 21, 2024.

APPENDIX 3. COMPARISON OF QUADRAT DATA FROM THE TWO YEARS

Note: Comments on site wetness or otherwise are relevant only to the time of sampling of the quadrats – in a number of cases, sites which were dry at the time of assessment showed indications of prior shallow inundation events since the previous assessment.

GROUP 1

Quadrat 1:

Prior *Tecticornia arbuscula* shrubland adjacent to Mullet Creek channel. The site was wetter than in 2023 due to closure of the estuary, with algal mat, but otherwise with no significant changes observed. No regeneration of *T. arbuscula* was observed.

Quadrat 2:

Relatively intact *Tecticornia arbuscula* shrubland. The site was dry both years. With a couple of extra drier saltmarsh species observed at incidental levels, but no significant changes observed within relatively intact vegetation. No regeneration of *T. arbuscula* was observed.

Quadrat 3

Dominated by *Suaeda australis*, with substantially impacted component of *Tecticornia* spp. (mainly *T*. sp. (Connewarre) and network of shallow ponds. The site was much wetter than 2023 (when dry), with algal mat probably obscuring a proportion of the *Salicornia quinqueflora* ground cover. No significant changes noted apart from the presence of some young plants of *Tecticornia* spp., presumed to be suckers.

Quadrat 4

Relatively intact *Tecticornia* sp. (Connewarre) open shrubland. The site was dry both years. No significant changes were noted apart from the presence of some young *Tecticornia* sp., presumed to be suckers.

Quadrat 5

Open shrubland of *Tecticornia* spp., with medium level of mortality and high cover of *Salicornia quinqueflora*, with small bare gaps in mosaic. The quadrat area was dry both years, but with residual small ponds present nearby in 2023. No significant changes were noted. No regeneration of *Tecticornia* spp. was observed.

Quadrat 6

Open shrubland of *Tecticornia* spp. with medium level of mortality. The site was dry both years. A range of annuals detected in 2023 were not evident, but otherwise no significant floristic changes were noted. Progressive regeneration of *Tecticornia* spp. was occurring, presumed to be by suckers.

Quadrat 7

Shrubland of *Tecticornia* spp. (mostly *T. arbuscula*) with medium level of mortality. The site was superficially wetter in 2024 than in 2023, with some shallow ponding. With notable recovery from previous dieback event, including substantial regeneration of *T. arbuscula*, presumably from suckers, and an apparent increase in cover of several other saltmarsh species (*Salicornia quinqueflora*, *Suaeda australis* and *Frankenia pauciflora*).

Quadrat 8

Highly intact and dense shrub layer of *Tecticornia* spp., mostly *T.* sp. (Connewarre). The site was dry both years. Some differences in expression of annual species between the years were observed, notably with **Melilotus indica* prevalent in 2024, while others such as *Apium annum* were not apparent in 2024, and apparently some

recruitment of *Disphyma crassifolium*, but otherwise the vegetation data were very similar. No regeneration of *Tecticornia* spp. was observed amidst the nearly intact canopy.

Quadrat 9

With moderately dense canopy of *Tecticornia arbuscula* with considerable mortality. The site was dry both years. No significant changes were noted, with ongoing recovery continuing from regeneration of *T.* arbuscula, presumed to be from suckers.

Quadrat 10

Shrubland of *Tecticornia arbuscula* with relatively low recent mortality and also evidence of historical dieback events. The site was dry both years, but an algal mat was present in 2024, comprising a coarser green alga, tentatively identified as a species of *Chaetomorpha*, rather than a finer filamentous species. No significant floristic changes were noted, apart from a reduced presence of the annual grass **Polypogon monspeliensis* and ongoing canopy recovery from regeneration of *T. arbuscula*, including some young seedlings.

Quadrat 11

Relatively open shrub canopy of *Tecticornia* sp. (Connewarre) with high level of mortality and a high cover of *Salicornia quinqueflora*. The site was considerably wetter in 2024, being inundated and with an algal mat present. Apart from the presence of the aquatic *Althenia bilocularis* in open patches in 2024, no significant floristic changes were noted. No regeneration of *Tecticornia* spp. was observed.

Quadrat 12

Low lying site, with a high cover of bare ground in 2023 and previously with a sparse component of *Tecticornia* spp. The site was dry both years, but had been inundated prior to the 2024 sampling. Regeneration of *Salicornia quinqueflora* noted in 2023 had established a substantial increase in cover, but otherwise no significant floristic

changes were noted. No regeneration of *Tecticornia* spp. was observed

GROUP 2

Quadrat 13

Prior *Tecticornia* spp. shrubland, with the majority of individuals dead and a ground layer dominated by *Salicornia quinqueflora*. The site was much wetter in 2024 than in 2023, with a range of floristic differences reflecting the wetter conditions evident. Notably, *Apium annuum* was not detected in 2024, *Lilaeopsis polyantha* was conspicuous in 2024 but not evident in 2023, and *Triglochin striata* had a higher cover in 2024. While still at low cover, *Bolboschoenus caldwellii* also had increased in abundance by 2024. No regeneration of *Tecticornia* spp. was observed.

Quadrat 14

Prior *Tecticornia* spp. shrubland, with the majority of individuals dead and with a moderately high cover of *Salicornia quinqueflora*. The site was wetter in 2024 than in 2023, being shallowly inundated with a high cover of algal mat. Some notable differences between the years were evident. *Bolboschoenus caldwellii* had a much increased cover in 2024. *Triglochin striata* also a higher cover in 2024, while the covers provided by **Cotula coronopifolia* and *Salicornia quinqueflora* were lower in 2024. *Lilaeopsis polyantha* was conspicuous in 2024, but not evident in 2023. No regeneration of *Tecticornia* spp. was observed.

Quadrat 16

Prior *Tecticornia* spp. shrubland, with nearly all individuals dead and a moderately high cover of *Salicornia quinqueflora.* The site was wetter in 2024 than in 2023. *Bolboschoenus caldwellii* had a much increased cover by 2024. While still a minor component of the vegetation in the quadrat, *Typha* spp. had also increased in cover in 2024. *Lilaeopsis polyantha* was conspicuous in 2024, but not evident in 2023. The cover provided by **Cotula coronopifolia* was lower in 2024. No regeneration of *Tecticornia* spp. was observed.

Quadrat 18

Prior *Tecticornia* spp. shrubland, with a high proportion of individuals dead and a very high cover of *Salicornia quinqueflora.* The site was a little wetter in 2024 than in 2023. There were some other differences between the years in species detected, including *Puccinellia stricta* and *Triglochin striata* being recorded in 2024 but not 2023, *Spergularia marina* observed in 2023 but not 2024, and an apparent decrease in the minor presence of *Disphyma crassifolium*. No regeneration of *Tecticornia* spp. was observed.

GROUP 3

Quadrat 15

In 2023 the site comprised a largely bare mudflat with scattered dead *Tecticornia* species and patchy Brackish Wetland species, surrounded by patches of *Typha* spp. The site was wetter in 2024 than in 2023, and *Typha* patches in the vicinity of the site had expanded substantially over the preceding year. In 2024, the mud flat was largely vegetated, with a high cover of **Cotula coronopifolia* and with very little bare ground present. Whilst the quadrat peg was not located, these differences in the vegetation would not be explained by any likely differences in the precise location of the sampled area. No regeneration of *Tecticornia* spp. was observed, and the dead stems of these present had decayed substantially over the previous year.

Quadrat 17

The quadrat was located on a mudflat between two ponds and included a portion of shallow fringing pond. The main vegetation comprised a dwarf herbland of Brackish Wetland species. A sparse component of dead *Tecticornia* spp. from an earlier dieback event was also present. The site was much wetter in 2024 than in 2023, with much of the quadrat area inundated. There were a number of mostly relatively minor differences between the two years, including increases in *Bolboschoenus caldwellii* and *Typha* spp., and decreases in *Salicornia quinqueflora* and *Triglochin striata*, in 2024. *Apium annuum* was conspicuous in 2023 but not detected in 2024. No regeneration of *Tecticornia* spp. was observed, and the dead stems of these

present had decayed substantially over the previous year.

Quadrat 20

The site supports modified vegetation, with the prior saltmarsh dominated by *Bolboschoenus caldwellii*. Part of the quadrat comprised a locally taller sward of *B. caldwellii* with small plants of *Typha domingensis*. The site appears to have been of relatively similar wetness in both years (more or less saturated). The cover *of B. caldwellii* remained similar in both years. There were some mostly relatively minor differences between the two years, including increases in cover of *Eleocharis acuta*, *Crassula helmsii*, **Rumex crispus* and *Triglochin striata*, with decreases in *Lilaeopsis polyantha* and *Senecio pinnatifolius* in 2024. While established patches of *Typha* spp. are prevalent nearby, the young clone previously recorded in the quadrat appears to have failed to perpetuate. No regeneration of *Tecticornia* spp. was observed.

GROUP 4

Quadrat 19

Vegetation modified by stormwater discharge into former saltmarsh, dominated by *Eleocharis acuta*, with colonisation by a patch of *Typha domingensis* (with ca. 4% cover in 2023). A sparse component of dead *Tecticornia* spp. from an earlier dieback event was present, as well as an incidental living plant. The site appears to have been of similar wetness in both years (saturated to very shallowly inundated). The cover *of E. acuta* remained similar in both years. There were some mostly relatively minor differences between the two years, including increases in cover of *Bolboschoenus caldwellii*, *Crassula helmsii*, *Epilobium billardierianum* subsp. *billardierianum* and *Typha domingensis*, with decreases in *Lilaeopsis polyantha*, *Senecio pinnatifolius*, *Triglochin striata* and **Cotula coronopifolia* in 2024. No regeneration of *Tecticornia* spp. was observed.

Quadrat 21

Vegetation modified by stormwater discharge into former saltmarsh, now dominated

by *Eleocharis acuta* with *Senecio pinnatifolius*, with associated plants primarily comprising freshwater species. The site was slightly drier in 2024 than in 2023 (saturated versus shallowly inundated). The cover *of E. acuta* was relatively similar in both years. There were mostly relatively minor differences between the two years, including increases in cover of *Crassula helmsii*, *Epilobium hirtigerum*, and decreases in *Senecio pinnatifolius* and **Sonchus* spp. in 2024. No regeneration of *Tecticornia* spp. was observed.