Eyre Peninsula distributions of some under collected samphires: Report on an expedition

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Report on an expedition

Prepared for Eyre Peninsula Landscape Board

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BACKGROUND

In 2018 a small booklet, Samphires of the Eyre Peninsula, was produced by the Eyre Peninsula Natural Resource Management Board. While photographs were being collected for that booklet, its author noted there was little distribution data for several of the species, some species had not been assessed for threats during the earlier regional species conservation prioritisation process (Gillam & Urban 2009) due to lack of data, and some taxonomic challenges meant some widely present species on the Eyre Peninsula had not been recorded in the past, or may have been identified as other species or subspecies.

In 2020 the Natural Resource Management Board funded an expedition by Delta Environmental Consulting to visit the Eyre Peninsula so that more data could be gathered, and a better understanding of the distribution and habitat preferences of these species developed, to inform any future conservation assessments.

The expedition was delayed by the onset of Covid-19, taking place in May and early June, rather than in March. Many samphires are more difficult to identify in the winter months as they may have shed their reproductive parts. Despite this, 65 vouchers were collected for submission to the Herbarium, and a further 52 separate "observations" recorded, for a total of 117 datapoints across the Eyre Peninsula. In addition to the collection work, at coastal locations in the northeast, south and upper west Delta joined Natural Resource Management Board staff members to look at local coastal temperate saltmarshes (as defined by the EPBC Act) where conservation and restoration work was being progressed.

Figure 1 - Voucher and observation points, May-June 2020 expedition (Map: Naturemaps)

On return to Adelaide all vouchers were processed and submitted to the Herbarium, the Herbarium datasheets filled in, and the DEW BioSurvey datasheets filled in and submitted, prior to starting work on the analysis of the species' distributions.

A range of publicly available data were used for the analyses, in addition to the data collected during the expedition. Records in the Atlas of Living Australia and observations in iNaturalist were examined, and habitat and geographic layers and data from NatureMaps, SARIG and the Bureau of Meteorology were incorporated where helpful.

In some cases, where species distributions in the Atlas of Living Australia showed "patterns" in the species' ranges, the Maxent (ALA 2020) species distribution modelling package was run, in order to develop a prediction about where the various species could be found on the Eyre Peninsula. Maxent may be run using a vast number of variables, with the main constraint being the speed of one's internet connection. A more rapid approach looks at climate factors only, and for many species the Bioclim 1960 "best five" preselected climatic variables, and a spatial resolution of 0.1°, will produce a reasonably clear picture. That approach was chosen to develop range predictions based on climate, for the species in this report.

Maxent prediction maps are colour coded to reflect the probability the species of interest could occur in an area. Blue = 0 (extremely unlikely to occur) while Red = 1 (almost certain to occur). White squares show those records used in the training set for the model, while purple squares are the records used to test the model.

The Bioclim climate parameters used in Maxent are discussed in a separate section at the end of this report. The variables used are graphed against the full range of values that occur in the Australian climate range, and the species compared.

Other environmental parameters that control species' distributions, such as soil types, hydrology and vegetation associations, were evaluated in an *ad hoc* manner. That information has been presented where it provides useful insight.

THE "SCLEROSTEGIA" TYPES

Amongst the genus *Tecticornia*, there are four species on the Eyre Peninsula where the flower clusters only contain one bisexual flower in each triad (group of three) with the outer flowers being male. They all have fruits that are buried to a certain extent, in the flesh of the fruiting spike. These four, *Tecticornia arbuscula, Tecticornia moniliformis, Tecticornia tenuis* and *Tecticornia disarticulata*, were previously classed as a separate genus, *Sclerostegia*. While one of them, *Tecticornia arbuscula*, is common right around the coast of the Eyre Peninsula in the intertidal zone, the others are recorded less frequently. This section of the report looks at the recorded occurrence of the remaining three "*Sclerostegia*" type samphires across the Eyre Peninsula.

TECTICORNIA MONILIFORMIS

Historically, *Tecticornia moniliformis* (Ruby, or Vase glasswort) was not recorded on the Eyre Peninsula, being misidentified as *Tecticornia arbuscula* (Shrubby samphire), which has a number of similarities in the flowering stage. Both have a very visible style with divided stigma on top that sticks out from the central female flower in each triad on either side of the flower spike. The differences are visible once fruits form – *Tecticornia moniliformis* fruits are corky little strings of pearls, while *Tecticornia arbuscula* fruits shrivel right back into the leathery flesh of the stem.

Sadly, the soft fruits of the Ruby glasswort fall from the plant easily, and once specimens are dried vouchers at the Herbarium there may not be sufficient determining features remaining to separate the species. The Herbarium vouchers for *Tecticornia arbuscula* are being reviewed opportunistically to extract any *Tecticornia moniliformis*, whenever someone with skills in this genus visits. However, it is also possible that few *T moniliformis* were ever collected – where the two species occur in close proximity collectors may have collected *Tecticornia arbuscula* preferentially, assuming the *T moniliformis* were stunted specimens of the former. The 2020 expedition collected *Tecticornia moniliformis* to identify its distribution, habitat preferences, and increase the number of vouchers of this species in the Adelaide Herbarium.

The Atlas of Living Australia distribution map for Ruby glasswort contains several South Australian records, reflecting a concerted effort made by Western Australian botanist Kelly Shepherd to redetermine Adelaide Herbarium vouchers and the recent collecting efforts of Ron Taylor. The ALA distribution map reveals the species occurs both inland and coastally, in the southern parts of Australia, in the areas where Koppen climate classes are Temperate or Grassland, warm to hot, with dry summers or persistently dry. Only two records of the species occur outside these Koppen climate classes. They are in East Gippsland near Orbost and are not vouchered specimens, rather they are human observations. Without a voucher these observations cannot be confirmed. These two records account for 1.2% of ALA's records of the species. Although included in the Maxent (ALA 2020) training set for modelling this species' distribution, the resultant model clearly suggests the East Gippsland records occur well outside the occurrence range for the species.

Figure 2 - Atlas of Living Australia records for *T moniliformis*

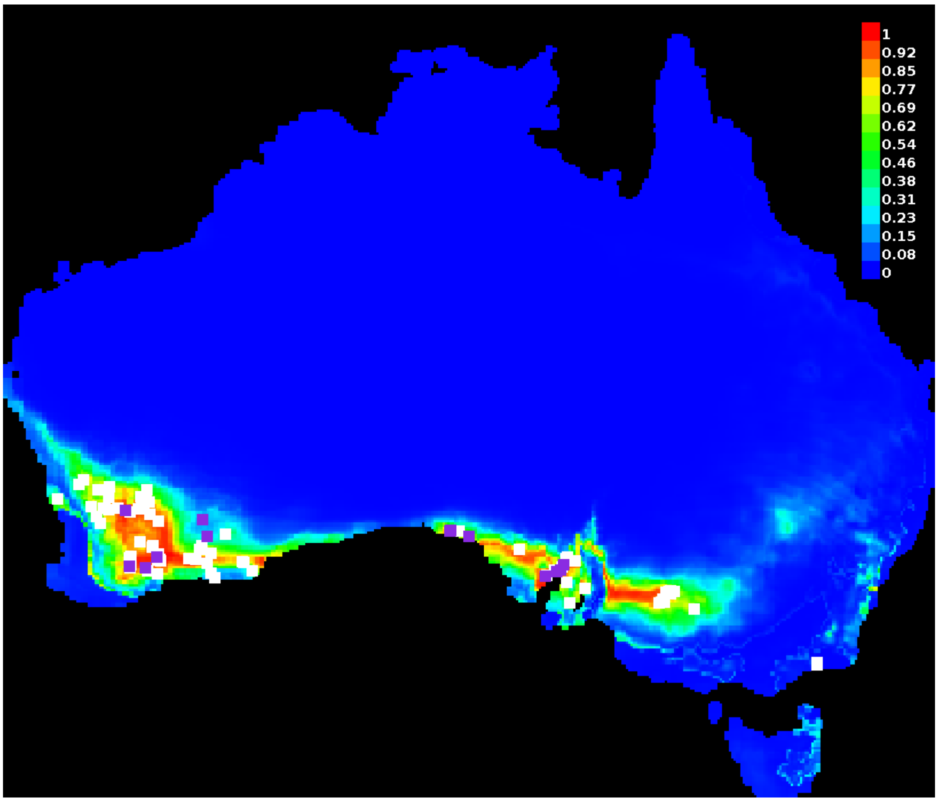


Figure 3 - Maxent predicted range of occurrence for *T moniliformis* based on Bioclim 1960 "best five" (Atlas of Living Australia)

Climate data for the two East Gippsland records have been removed from the following discussion of the climatic preferences of Ruby samphire.

The Maxent model suggests Australia-wide *Tecticornia moniliformis* will be found where rainfall in the driest quarter of the year is between 31-74mm. The difference between the wet and dry seasons is likely to be between 18-65mm. Regional soil moisture index in the wettest quarter ranges from 0.32-0.99, where 1 is saturated. Solar radiation during the warmest quarter is between 23.5-27.1 MJ/m2/day and plants occurred where radiation seasonality was 33-41 on the dimensionless scale for this parameter. The soil moisture index and radiation seasonality for the wettest quarter were the most predictive parameters.

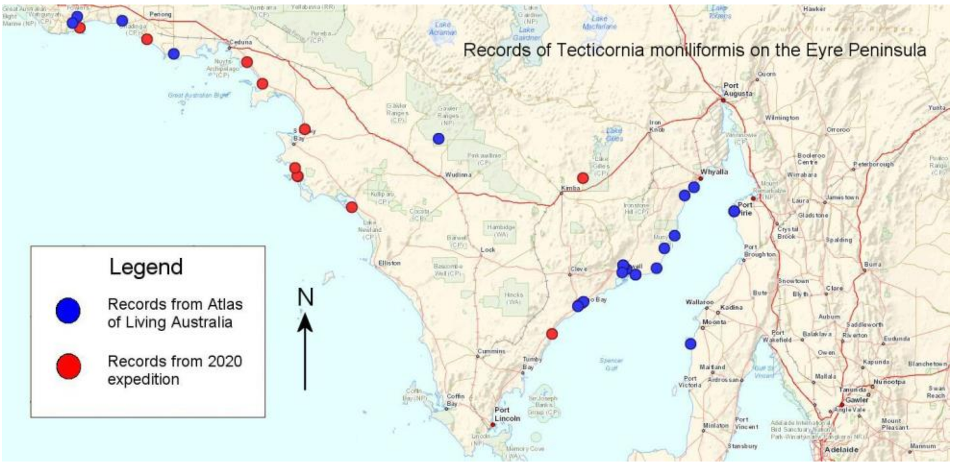


Figure 4 - ALA and 2020 expedition records for *T moniliformis* on the Eyre Peninsula (Map: Naturemaps)

Figure 5 - Estimated range for *T moniliformis* in the EP Landscape Region, based on Maxent (Map: Naturemaps)

The newly collected specimens fit well inside the predicted range for Ruby glasswort on the Eyre Peninsula, occurring in an area north of (less than) the 400mm annual rainfall isohyet, both coastally and inland. Examination of the ALA and 2020 expedition records against the SA Vegetation associations in Naturemaps (DEW 2020) reveals Ruby glasswort occurs in quite a range of vegetation associations – from samphire associations and coastal shrublands near the coast, to mallee and acacia lands inland. In nearly every case for the specimens collected in 2020, the plants occurred on sandy soils, usually in the ecotone between a chenopod association in a sump, lake, depression or flat, and a shrubland growing on the higher sandy land adjacent. Ruby glasswort was commonly associated with other samphires that do not tolerate high salinities, especially *Tecticornia pruinosa*.

These habitat preferences are quite different to those of *Tecticornia arbuscula*, the Shrubby samphire. Shrubby samphire is generally confined to coastal areas, tending to occur either in the intertidal zone or on well drained shelly substrates above the tides. It occurs around the coastline of mainland Australia from Sydney to Fowlers Bay, then along the southern coast of Western Australia, west of Israelite Bay. The species also occurs around the coast of Tasmania. While there is some overlap of the two species' distributions in areas with less than 400mm rain, areas wetter than this host only the Shrubby samphire. In colder, wetter areas it is found associated with the swamp tea tree, *Melaleuca halmaturorum*, and *Juncus krausii*, the sea rush, while in warmer climes it can be found immediately behind the mangroves (*Avicennia marina*).

TECTICORNIA TENUIS

The Slender glasswort, *Tecticornia tenuis* is widely distributed across inland Australia in the warm/hot grasslands and desert Koppen climate classes.

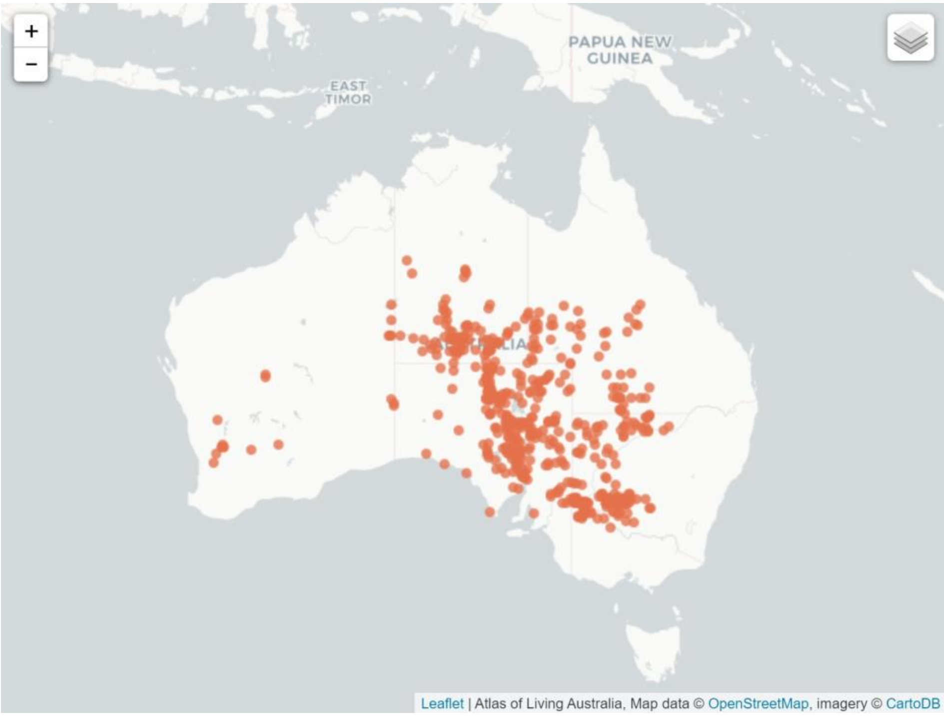


Figure 6 - Atlas of Living Australia records for *T moniliformis*

Of the 1076 records in ALA there seem to be very few outliers. In Western Australia the plants are much less common than in the other states, but the samples appear to be reliable. The two southernmost SA specimens may be suspect – both occur outside the climate classifications common to the other records. The Coffin Bay record was an observation, with no voucher, and the Adelaide voucher was at Osborne in the port area. There are *no Tecticornia tenuis* in that location now.

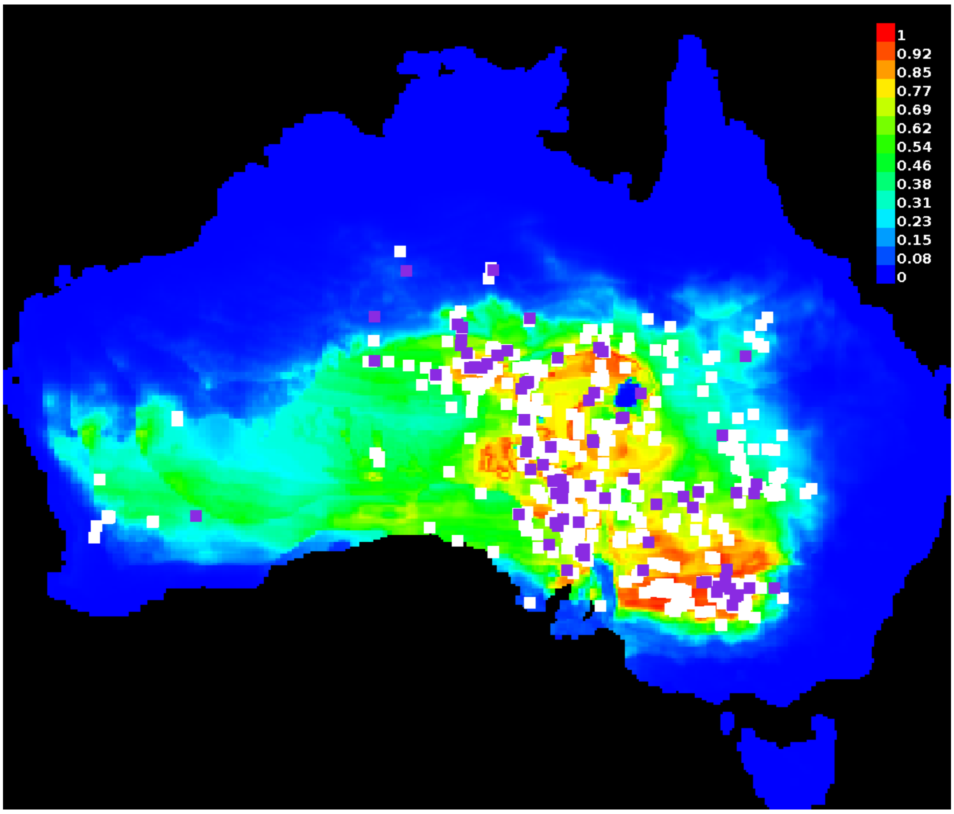


Figure 7 - Maxent predicted range of occurrence for *T tenuis* based on Bioclim 1960 "best five" (Atlas of Living Australia)

The Maxent model found *Tecticornia tenuis* widely tolerant of a range of climate variables, in the warm/hot, and dry end of the climate spectrum. Rainfall in the driest quarter of the year could be anywhere between 8-90mm. The difference between the wet and dry seasons varied from negligible to extreme, at 15-120mm. Regional soil moisture index in the wettest quarter ranged from 0.09-0.69, where 1 is saturated. Solar radiation during the warmest quarter was between 25.3-28.3 MJ/m2/day. Radiation seasonality varied widely across the species range (15-41).

Within the Eyre Peninsula, the northern end of Spencer Gulf appears to have the climate best suited to the Slender glasswort. Soil factors may also play an important role in the distribution of this species. Wilson (1980) noted that Slender glasswort grew in areas where underlying clay was present. This preference is definitely noticeable in collections made in 2020 in the upper Spencer Gulf – red loam in creek lines (Caroona Road), loams along road edges (Blanche Harbor Road), and at its closest approach to the sea “where the shelly sand changes to red sandy loam, an extensive area of *Atriplex vesicaria* and *Tecticornia tenuis*”.

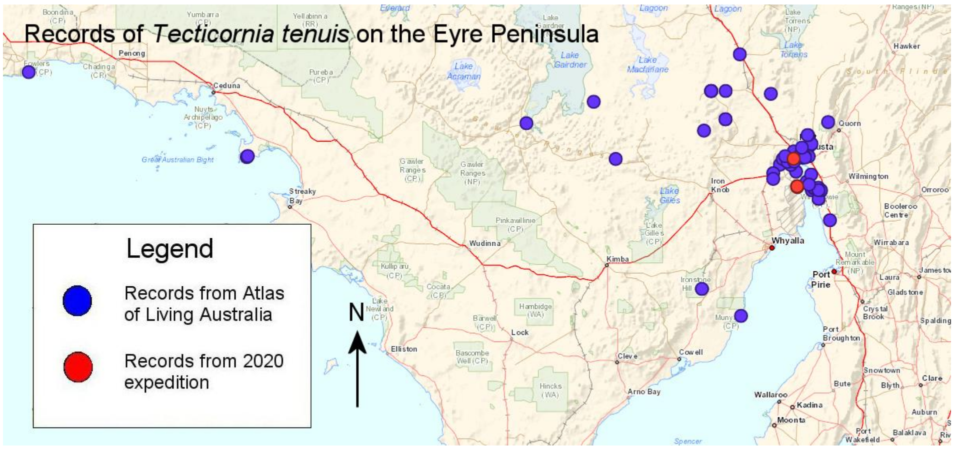


Figure 8 - ALA and 2020 expedition records for *T tenuis* on the Eyre Peninsula (Map: Naturemaps)

While small numbers of records on the Eyre Peninsula are associated with Acacia and mallee shrublands and woodlands, the species does not appear to be common in the EP Landscape Region, and so no predicted range has been provided here. The majority of records close to the region are clustered in the bluebush and saltbush plains (chenopod shrublands) of the northern Gulf.

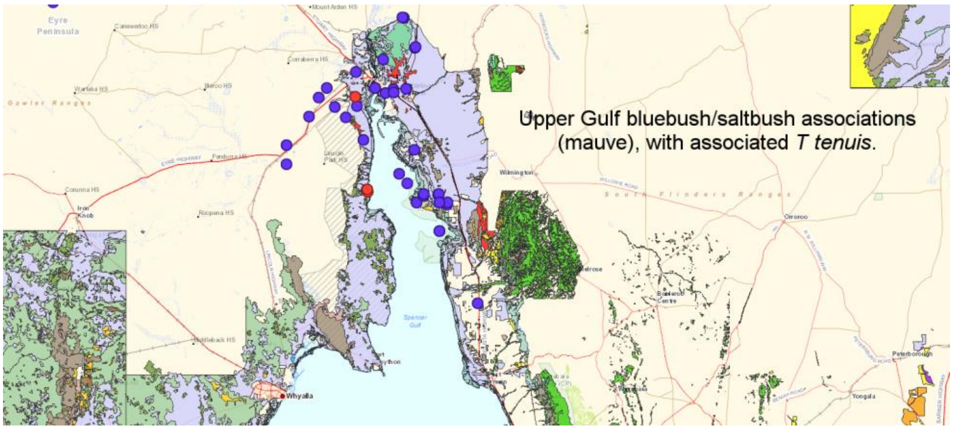


Figure 9 - *T tenuis* distribution in chenopod shrublands in neighbouring Landscape Regions

TECTICORNIA DISARTICULATA

Tecticornia disarticulata, the Plains samphire, has a relatively tidy-looking subtropical distribution in the Atlas of Living Australia. There are a few southerly outliers – a specimen recorded in the Great Southern Ocean, one on Boucaut Island in the Sir Joseph Banks Group, a record of a “few plants” near Wentworth in the Murraylands, and one in Adelaide. Clearly the oceanic specimen has some sort of problem with its location data. The specimen recorded in Adelaide is interesting – it was found in 1934 by Connie Eardley, Curator of the then Waite Herbarium. She recorded the plant on the side of the Port River not far from Osborne. The specimen was determined as *T disarticulata* as recently as 2008. Specimens sourced from ports are always suspect – it is amazing what arrives on shipping. The plant does not seem to have established a population at this location, not having been recorded since.

The four outliers comprise less than 1% of the 560 records in the Atlas of Living Australia, so Maxent (ALA 2020) was run without removing any records, to develop a predicted extent for the species. However, when discussing the climate parameters for comparison with other species, the four southernmost records have not been included.

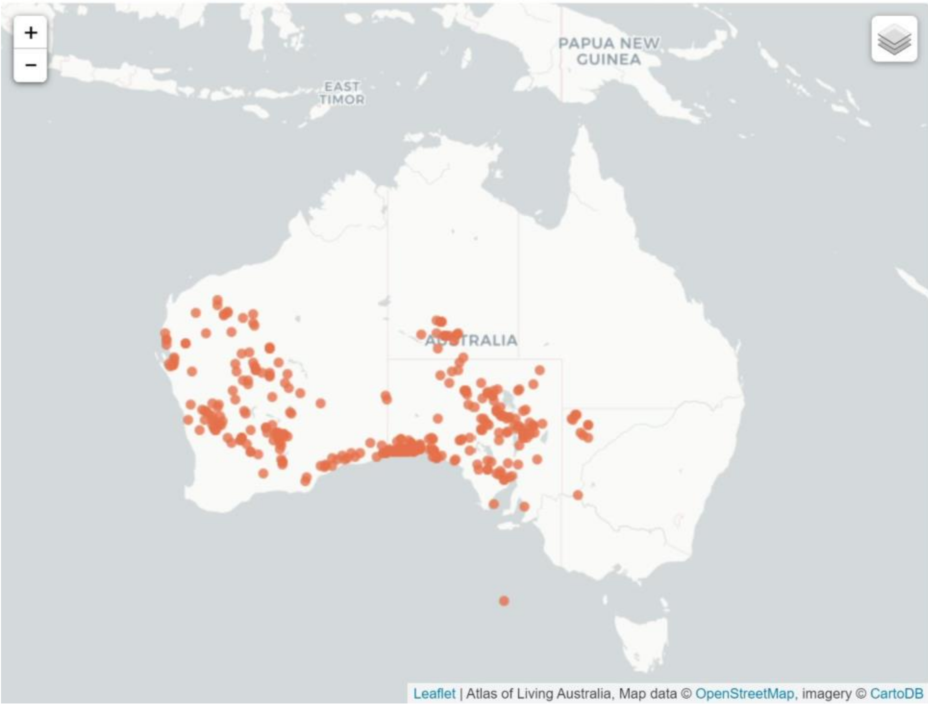


Figure 10 - Atlas of Living Australia records for *T disarticulata*

Maxent predicts this species will be found where rainfall in the driest quarter of the year is between 5-64mm. The difference between the wet and dry seasons in the area this plant occurs is between 13-99mm. Regional soil moisture index in the wettest quarter ranges from 0.09-0.58, where 1 is saturated. Solar radiation during the warmest quarter is between 25.5-28.3 MJ/m2/day and plants occurred where radiation seasonality was between 21-37 on the dimensionless scale for this parameter.

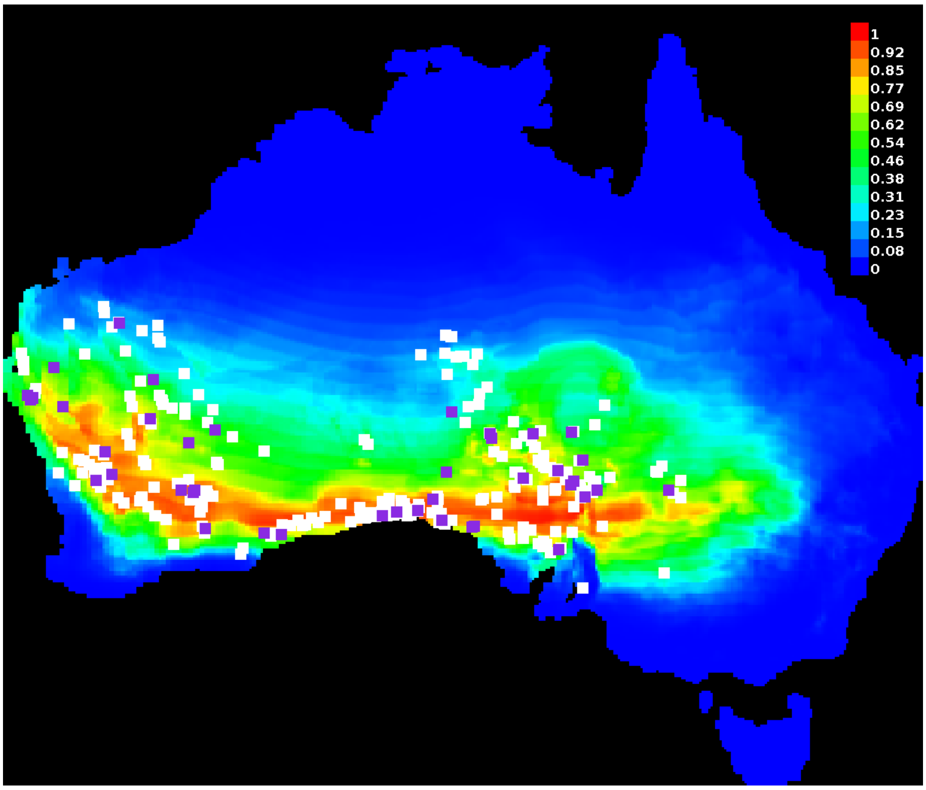


Figure 11 - Maxent predicted range of occurrence for *T disarticulata* based on Bioclim 1960 "best five" (Atlas of Living Australia)

It would seem likely from Maxent's prediction, that the Plains samphire is at the southern edge of its range where it occurs on the Eyre Peninsula. Within the EP Landscape Region the species is found north of (less than) the 300mm annual rainfall isohyet, being found more commonly in the South Australian Arid Lands Landscape Region.

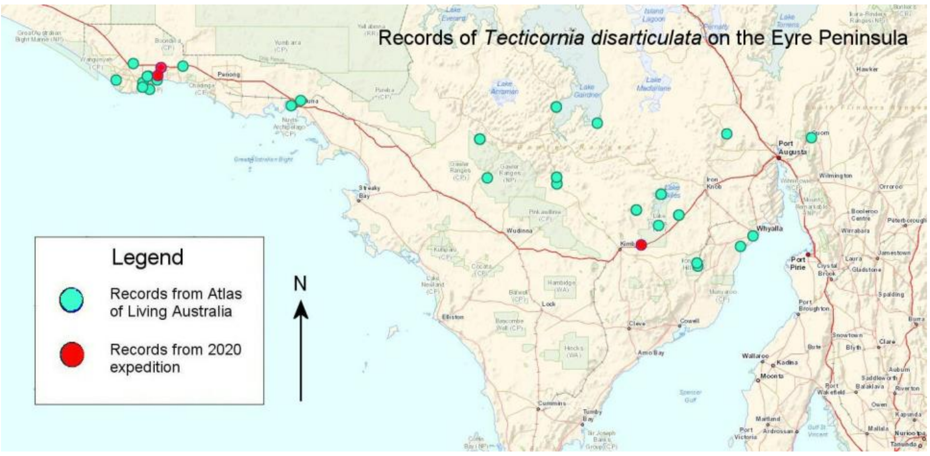


Figure 12 - ALA and 2020 expedition records for *T disarticulata* on the Eyre Peninsula (Map: Naturemaps)

Figure 13 - Estimated range for *T disarticulata* in the EP Landscape Region, based on Maxent and the 300mm rainfall isohyet (Map: Naturemaps)

The distribution of the Plains samphire across Australia is generally inland – it approaches the coast quite closely on the Nullarbor, but this is an environment where the limestone plains reach the coast at a cliff-line. On the northeast coast of the Eyre Peninsula and in the far west near Fowlers Bay where the plant is found on coastal plains, the land is well above the reach of any tidal inundation, with an elevation of at least 6m AHD. Datson (2005) reports that Plains samphire is found on dry, stony plains, away from wetlands, and has the lowest tolerance for salinity of any samphire. Wilson (1980) reported the species was also found on clay pans inland.

Where it has been collected in the Eyre Peninsula, Plains samphire has been found in chenopod shrublands in association with bluebush (*Maireana* spp.), and in mallee and Acacia woodlands and shrublands, where it has been found growing with bluebushes (*Maireana* spp.) and saltbushes (*Atriplex* spp.).

For populations of plants that occur at the limits of their range, relatively small perturbations in conditions can affect them significantly, in either positive or negative ways. Based on climate change predictions, it may be that *Tecticornia disarticulata* will be able to move south and may be recorded in a larger part of the Peninsula in the future.

THE "WHITE SEED" SAMPHIRES

There are two samphires on the Eyre Peninsula that have unusually large, white to fawn seeds that are ornamented with frills of various types. In most other ways the two species look very different, and they occur in distinct habitats, associated with separate vegetation associations. Unfortunately, the common name "whiteseed samphire" and a belief that "sea beans" were restricted to Western Australia led to numbers of vouchers at the Adelaide herbarium being historically misidentified. Considerable effort has been put in to separating and redetermining the vouchers, by Western Australian botanist Kelly Shepherd. Currently the "superceded" (incorrect) records are still displayed with each species in the Atlas of Living Australia, although tagged as such. This challenges the Maxent model – there is no easy way to exclude the superceded records. Attempting to run the model for White-seed samphire using uploaded data (after downloading the records and removing the superceded records) brought the model to a grinding halt. The number of irregular specimens was lower for Sea beans, so the model was run with all records, including the irregular ones.

TECTICORNIA PTERYGOSPERMA

The White-seed or Winged-seed samphire has a wide distribution, mostly inland, or at least well away from the risk of tidal inundation, in a band across southern Australia. The uncorrected records from ALA muddy the distribution somewhat. The more southerly records on the Eyre and Yorke Peninsulas, and the record in the South-East, have all been redetermined as *Tecticornia lepidosperma*.

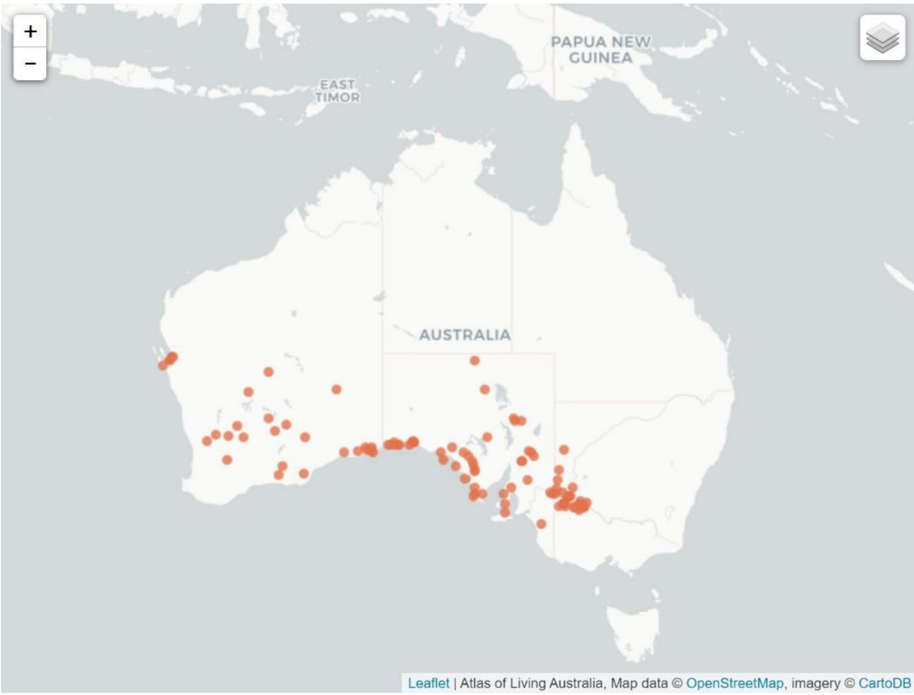


Figure 14 - Atlas of Living Australia records for *T pterygosperma* – uncorrected

So where, exactly, is *Tecticornia pterygosperma* found on the Eyre Peninsula? The Eyre Peninsula (and some area slightly north of the Landscape Region) records from the Atlas of Living Australia were corrected by having any "superceded" records removed along with any human observations that could not be confirmed via photographs or other means. The remaining eight records (which included one or possibly two that are actually in the neighbouring Landscape Region) and the twelve new records collected during the 2020 expedition reveal where the species is found on the Eyre Peninsula.

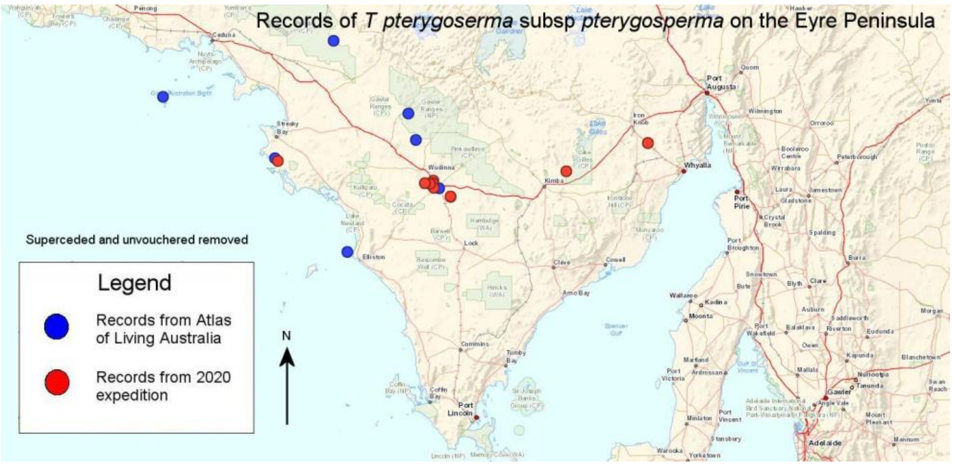


Figure 15 – Corrected ALA and 2020 expedition records for T pterygosperma on the Eyre Peninsula (Map: Naturemaps)

Climate obviously has an impact on the distribution of the White-seed samphire. The populations of the plant all occur in areas north of (less than) the 400mm rainfall isohyet. Yet that annual rainfall does not seem to be the only controlling factor, as there is a considerable area in the "less than 400mm" zone with no records at all of *Tecticornia pterygosperma* (Figure 16).

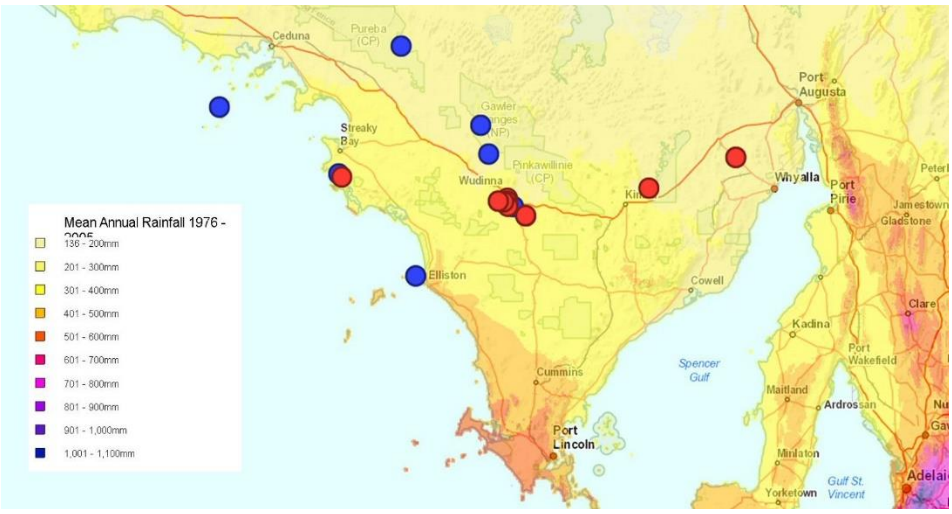


Figure 16 - Distribution of *T pterygosperma* against annual rainfall

The “best 5” Bioclim layers can be accessed in the Atlas of Living Australia separately to the Maxent model, so these climate layers were reviewed individually to see what they may reveal about White-seed samphire’s distribution across Australia. Populations have been recorded in areas where rainfall in the driest quarter of the year is between 22-75mm. The seasonal difference between wet and dry seasons varies between 19-95mm. Regional soil moisture index in the wettest quarter ranges from 0.09-0.78, where 1 is saturated. Solar radiation during the warmest quarter is between 24.4-28 MJ/m2/day and plants occurred where radiation seasonality was 26-41 on the dimensionless scale for this parameter.

The subspecies that occurs on the Eyre Peninsula (subsp *pterygosperma*) is described in Wilson (1980) as occurring on the margins of salt lakes. Where it occurs near the coast, it is usually in association with a coastal playa lake or wetland depression system, for example the Calpatanna wetland system and Seagull Lake.

Datson (2002) notes it can also be found on gypseous islands on salt lakes. Kopi ridges (gypsum-rich dunes) in the Kappacoola wetland area near Kyancutta host the species, and in these locations the plants often become huge (Coleman 2018). Soil mapping for the Eyre Peninsula (Naturemaps) revealed that records of the species occurred on calcareous loams, gypseous calcareous loams, calcareous loam over red clay, siliceous sand occurring adjacent saline soils or gypseous loams, carbonate sands and shallow calcareous loam on calcrete. All of this points to White-seed samphire being something of gypsophile, and definitely fond of calcium.

The distribution for this species, Australia-wide, is much broader than the Palaeovalley-preferring *Tecticornia calyptrata*, which is discussed separately in this paper. But the two species definitely overlap – wherever *Tecticornia calyptrata* has been found on the Eyre Peninsula, White-seed samphire is there too. This suggests that within the appropriate climate zones, *Tecticornia pterygosperma* may be found widely near salt lakes that are expressions of palaeovalleys. The SA palaeodrainage map (Hou *et al* 2012) shows that the Kyancutta and Sceale Bay-Streaky Bay records of Whiteseed samphire may be associated with the Yaninee Palaeovalley and the occurrences north of Wudinna may be associated with the Narlaby Palaeovalley, while the Lake Gilles records and Iron Knob-Whyalla records may be associated with unnamed palaeodrainages within the Pirie Basin of the Gawler Craton. These unnamed palaeodrainage lines were detected (and mapped) with night-time thermal imagery (Hou *et al* 2012).

The fringing vegetation for salt lakes in the drier northern half of the Eyre Peninsula is distinctly different from the fringing vegetation of wetter, more southerly saline wetlands on the Peninsula. White-seed samphire was found where upper canopies include dryland tea tree or western myall. In lower growing chenopod associations, White-seed samphire was found variously with *Tecticornia pruinosa, Tecticornia pergranulata* and occasionally *Tecticornia indica* subsp *bidens* and *Tecticornia calyptrata*. Towards the eastern end of its Eyre Peninsula range, White-seed samphire was found in dwarf chenopod shrublands dominated by *Atriplex vesicaria* with *Maireana* spp.

TECTICORNIA LEPIDOSPERMA

The second samphire with fancy white seeds on the Eyre Peninsula is *Tecticornia lepidosperma*, the Sea Beans. There are 306 records of this species across Australia in the Atlas of Living Australia, in temperate areas. The Eyre Peninsula boasts 17 of those records. Sadly, five of those records are faulty and two need further investigation – this is about 40% of the Eyre Peninsula records. Three northerly records have been superceded and redetermined as *T pterygosperma*. One offshore island specimen turns out to have really been found near Cummins, while the Port Augusta observation was a human observation with no voucher so is unverifiable, and the two Kimba specimens are from 1934 and the voucher details need examining to see if the location is correct or is an approximation, as was common before GPS or even detailed topographic mapping became easily available.

Figure 17 - Atlas of Living Australia records for T lepidosperma

Despite the known Eyre Peninsula irregular records accounting for more than 2% of the Australian records, the distribution of the species in ALA is clearly delineated. The classic triangular spread inland from western facing coastlines suggests that the predominant westerly rain-bearing winds that shape our southern climates are likely to have a lot to do with the distribution of the species.

The impact of the irregular records can be seen in the output of the Maxent model in the Eyre Peninsula region, where the Kimba and Port Augusta records probably have pulled the mid-range probability range somewhat to the east of where it truly lies.

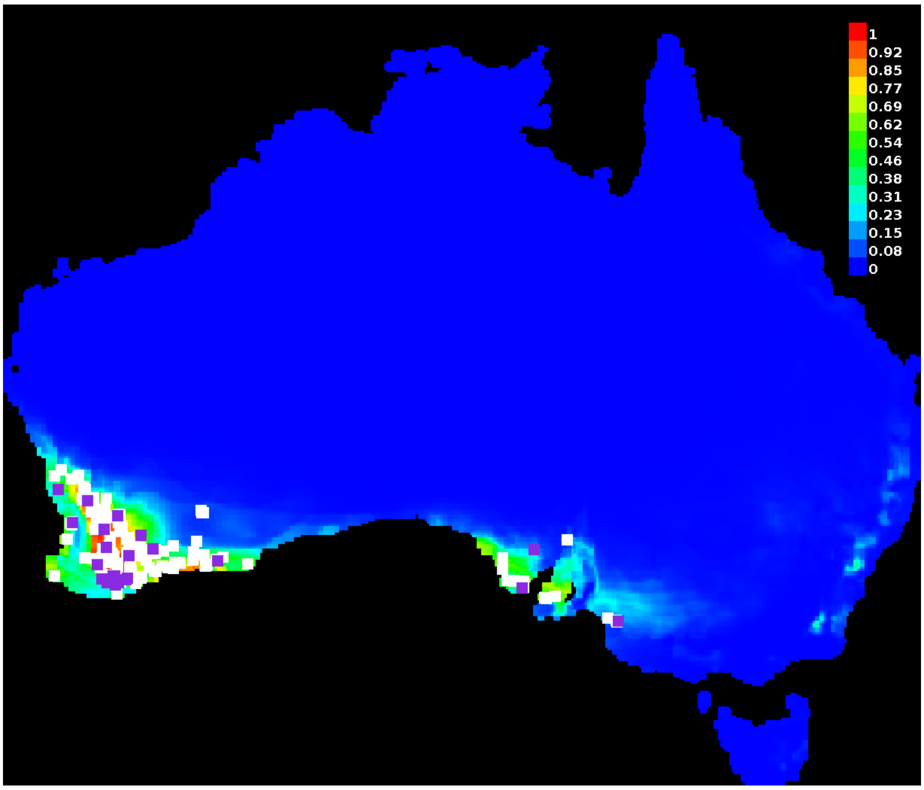


Figure 18 - Maxent predicted range of occurrence for T lepidosperma based on Bioclim 1960 "best five" (Atlas of Living Australia)

Maxent predicts that Australia-wide, Sea beans will be found where rainfall in the driest quarter of the year is between 30-90mm. Most records of the species on the Eyre Peninsula occur where the driest quarter receives about 45mm rain. The difference between the wet and dry seasons in the areas this plant occurs is between 21-85mm. Regional soil moisture index in the wettest quarter ranges from 0.34-1, where 1 is saturated. Solar radiation during the warmest quarter falls between 25.3-26.7 MJ/m2/day and plants occurred where radiation seasonality was 33-44 on the dimensionless scale for this parameter.

On the Eyre Peninsula, once the irregular records were removed, and the new records from the 2020 expedition added, the distribution of Sea beans is clearly restricted to the southern part of the Peninsula. The diagonal distribution pattern neatly occurs south of (more than) the 400mm rainfall isohyet.

Sea beans is associated with lower salinity wetlands, including near-coastal (estuarine) wetlands, inland winter-wet depressions in catchments that contain salt scalds (eg the Salt Creek and Glengyle Creek catchments east of Marble Range), and in roadside drains in saline areas where the road acts as a rainwater catchment (along the Bratten Way between Cummins and Lake Malata).

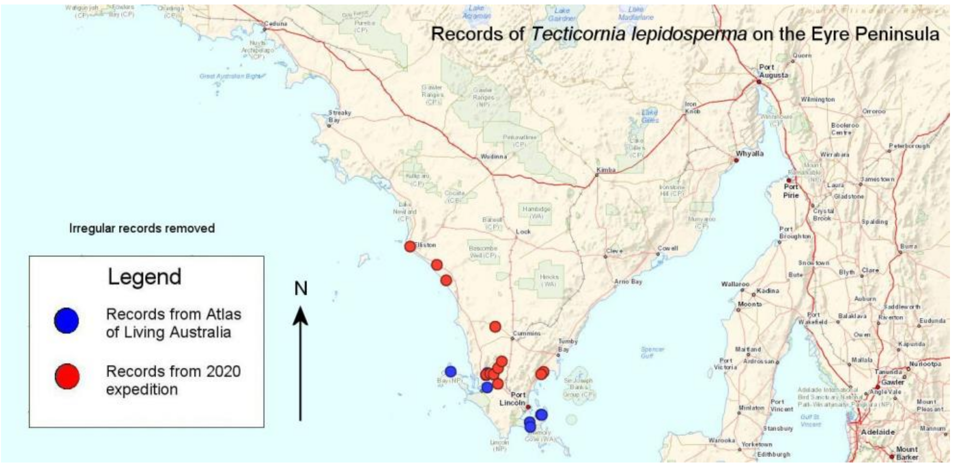


Figure 19 - Corrected ALA and 2020 expedition records for *T lepidosperma* on the Eyre Peninsula (Map: Naturemaps)

Figure 20 - Estimated range for *T lepidosperma* in the EP Landscape Region, based on Maxent and the 400mm rainfall isohyet (Map: Naturemaps)

On the Eyre Peninsula *Tecticornia lepidosperma* is strongly associated with *Melaleuca halmaturorum*, the swamp paperbark. In every case, the 2020 expedition records of Sea beans were found growing with paperbarks.

Other samphire species commonly associated with Sea beans include the Thick headed glasswort, *Sarcocornia blackiana*, the Black seed samphire *Tecticornia pergranulata*, the Brown headed samphire *Tecticornia indica* subsp *bidens*. The Bracelet samphire *Tecticornia syncarpa*, Bearded glasswort *Sarcocornia quinqueflora* and the Grey samphire *Tecticornia halocnemoides* were recorded at some locations. Sedges were also commonly found in the margins of these wetlands, particularly *Gahnia* spp.

A MYSTERY – THE GULF GREY SAMPHIRE

Tecticornia halocnemoides subsp *longispicata* is, according to its type description (Wilson 1980), a very short subshrub, only 30cm tall, glossy green or red, with flower spikes up to a remarkable 8cm long, distributed in inland areas of Australia from the tropics to southern Australia in “somewhat saline” conditions. The Atlas of Living Australia distribution for the species gave the first indication that there could be a mystery to uncover here, with numbers of intertidal South Australian records.

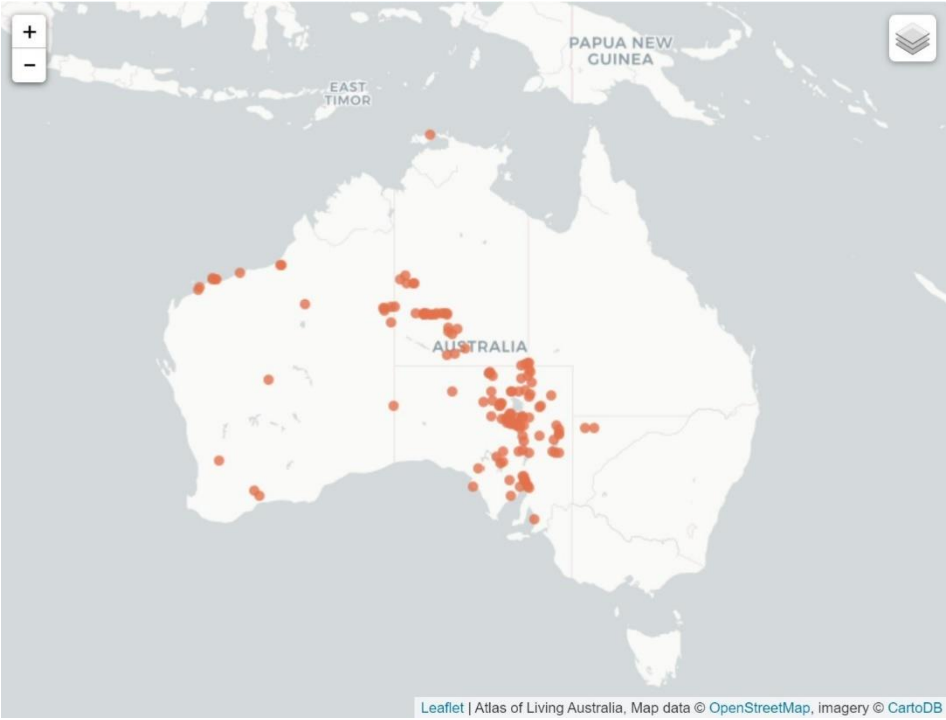


Figure 21 - Atlas of Living Australia records for *T halocnemoides longispicata*

Site visits to the locations of those records revealed a plant from the *Tecticornia halocnemoides* group that happily “keyed out” to subspecies *longispicata*, using the limited characters of the dichotomous key. However, when compared to the type description of the subspecies there were obvious differences. These plants were definitely coastal, occurring in intertidal, very saline conditions. In some cases they were found in hypersaline conditions behind tidal creeks in areas of high evaporation. The plants were not short – far from it. Heights of 1-1.4m were reasonably common and most plants exceeded 0.75m. Yes, the fruiting spikes were long, but the colour of the plants varied from bright apple green in the growing season to a yellowish green in winter.

A review of earlier taxonomic work on samphires (Wilson 1980) revealed that these unusual plants were known at that time. Wilson wrote about specimens of plants found in the vicinity of Port Pirie that “somewhat resembled” *T halocnemoides longispicata* and could possibly be included in the subspecies. But he chose not to. The differences in the dried specimens and the habitat they were found in was enough to cause him to set them aside. If he had seen the living plants in all their splendour and size, it is possible he may have determined them as a separate subspecies.

Recognising this, the plant known as the Gulf grey samphire is described in this report as *Tecticornia halocnemoides* subsp aff *longispicata*. The use of "aff" in a species name means "with an affinity to" or "like". It is a placeholder used to allow us to give a name to the plant while we await the eventual taxonomic determination of its relationship to other members of the species *Tecticornia halocnemoides*. Eventually the Gulf grey samphire may be determined to be a separate subspecies, or genetic information may determine it truly does belong with the type subspecies, connected to the rest of the subspecies by some ancient central Australian palaeoriverine system, with all the differences explained by environmental factors. Like many mysteries, it may be some time before it is solved, as it would depend on genetic analysis.

The common name acknowledges that the plants belong to the Grey samphire group (a reference to the woody grey stems of the *T halocnemoides* shrubs, not their variously coloured vegetative articles), and gives a nod to this specific mystery group's known distribution around the northern end of Spencer Gulf.

So where have Gulf grey samphires been recorded? For this exercise, inland records in the Atlas of Living Australia databases (almost entirely north of the Eyre Peninsula Landscape Region) were considered to belong to the "type" subspecies, rather than the Gulf grey subspecies, and were removed from consideration. The coastal specimens that remained, as well as vouchers and observations collected in the 2020 expedition, and observations collected during 2018-19, provide an indication of where the Gulf grey samphire occurs. Generally speaking, the species seems to be found in the northerly parts of the Gulf, right up to Yorkey's Crossing north of Port Augusta. An unusual occurrence further south at Cowell is intriguing.

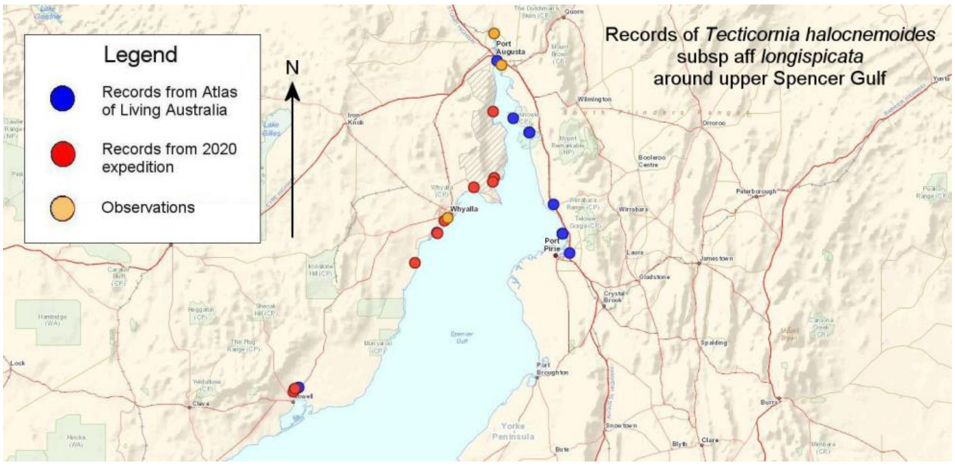
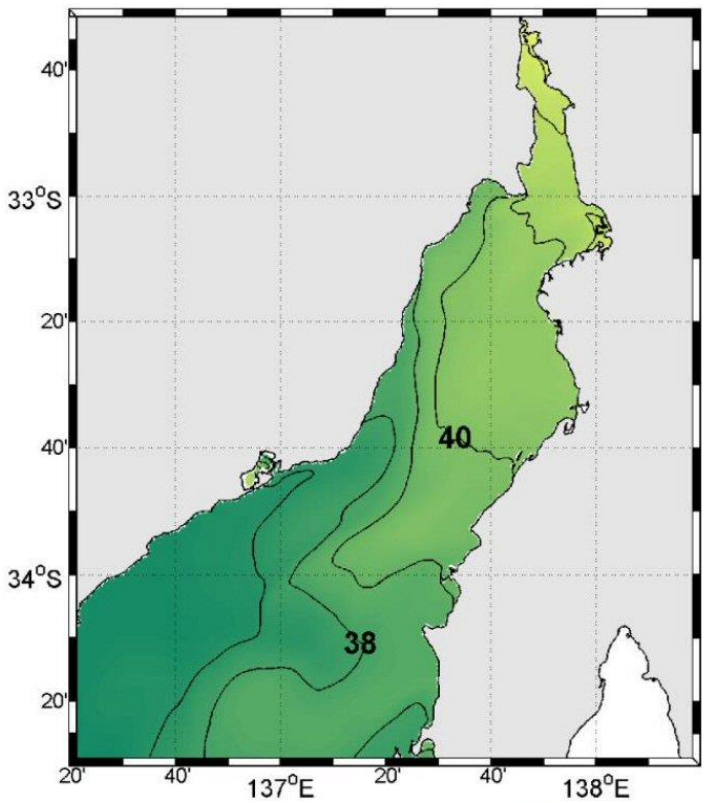


Figure 22 – ALA and 2020 expedition records, and 2018-19 observations for *T halocnemoides* subsp aff *longispicata* around upper Spencer Gulf (Map: Naturemaps)

Some of the observations of this species note that it can occur in tidal creeks just behind the mangroves, where *Tecticornia arbuscula*, the Shrubby samphire, is more usually found. Indeed, in some State vegetation mapping near Port Augusta the areas where Gulf grey samphire occur have been mapped as *Tecticornia arbuscula* – not surprising given the two are amongst the tallest samphires and both can be bright green. A close examination of the samphires at Port Augusta found that the Shrubby samphires only seemed to occur adjacent to mangroves if the mangroves were directly adjacent to the sea. In the small mangrove-lined tidal creeks that penetrate across the extensive intertidal flats, the Gulf grey samphire took the place of the Shrubby samphire, growing right down next to the mangroves.

Work at Port Pirie (Coleman & Cook 2007) established that the small estuaries of tidal creeks in the upper Gulf have an inverse salinity gradient, unlike estuarine creeks in wetter climes. The salinity of these creeks' headwaters is higher than the salinity at their mouths to the sea. This is a result of the high evaporation rate in the northern Gulf, combined with low rates of land-sourced runoff.

It has been suspected by some researchers (Vishnu Prahalad *pers com*) that Shrubby samphire does not tolerate hypersalinity particularly well, and their distribution in Port Augusta seems to support that. The corollary is that the Gulf grey samphire seems able to exploit that niche, suggesting it has a high tolerance to hypersalinity. As the plants are found in the intertidal and immediate supratidal, looking at Gulf waters' salinity seemed worthwhile.



Depth-averaged salinity in ROMS on the 18th June 2011.

Figure 23 - Salinity of Gulf waters (Middleton *et al* 2013)

A map of the salinity of Gulf waters (Middleton *et al* 2013) (Figure 23) reveals the Gulf itself to be an inverse estuary, with salinities at the northern end of the gulf being considerably higher than the 35g/L found in the waters of the Southern Ocean. The most interesting feature of Figure 23 is the small "appendix" at Cowell, where the stranded estuary of Poodra Creek is shown as having hypersaline conditions even though the offshore waters are only slightly more saline than open ocean waters. While many extensive estuarine areas in low rainfall areas are naturally hypersaline, the Cowell estuary may be more markedly hypersaline than most in this regard, a result of the estuary's effective "stranding" by the highway.

Other than the isolated population in the inverse estuary at Cowell, the Gulf grey samphire seems to be mostly found on the coast north of Cowleds Landing on the Eyre Peninsula. Gulf water salinities tend to be above 39g/L where the Gulf grey samphire occurs on the western shores of Spencer Gulf. The range of distribution of the Gulf grey samphire has not been specifically investigated on the eastern side of the Gulf. If the population range is controlled by salinity, it is possible the area south from Port Davis to Moonta may support Gulf grey samphire that has not been recorded.

The "best 5" Bioclim layers in the Atlas of Living Australia were reviewed individually to whether they may reveal anything more about Gulf grey samphire's distribution around the top end of Spencer Gulf. Plants have been recorded in areas where rainfall in the driest quarter of the year is between 46-50mm. The seasonal difference between wet and dry seasons is between 22-35mm. Regional soil moisture index in the wettest quarter ranges from 0.319-0.52, but this parameter probably matters little to a species that relies on at least occasional tidal inundation. Solar radiation during the warmest quarter falls between 26.4-26.8 MJ/m2/day and plants occurred where radiation seasonality was 36-37 on the dimensionless scale for this parameter.

As well as being frequently found near the mangrove *Avicennia marina*, the Gulf grey samphire is often recorded along with *Sarcocornia quinqueflora* and *Tecticornia halocnemoides halocnemoides*. The two *Tecticornia halocnemoides* subspecies are relatively easily separated in the field – the Grey samphire being smaller, dark green and dullish in summer, red in winter, while the Gulf grey is taller, shiny bright green in summer and yellowish green in winter.

Where sandy dunes or shingle ridges are close to the intertidal, *Tecticornia arbuscula* can sometimes be found near stands of Gulf grey samphire, along with other "higher and drier" saltmarsh species like *Tecticornia pruinosa*, *Atriplex* spp and *Maireana* spp.

HIDING IN PLAIN SIGHT – TECTICORNIA SYNCARPA

It was noted in the *Samphires of the Eyre Peninsula* (Coleman 2018) that *Tecticornia syncarpa*, the Bracelet or Fused samphire, had not been evaluated in the regional conservation assessments (Gillam & Urban 2009), presumably because there was doubt that the species occurred on the Peninsula. Even as recently as August 2020, Atlas of Living Australia records for the Eyre Peninsula were restricted to two records in the Lincoln National Park.

It seems apparent this species has been overlooked in the past. It may have been mistaken for one of the other robust samphire species, such as *Tecticornia pergranulata*, *Tecticornia pruinosa* or *Tecticornia indica bidens*.

Figure 24 - Atlas of Living Australia records for *T syncarpa*

Maxent predicts the Bracelet samphire will be found where rainfall in the driest quarter of the year varies between 14-74mm. The difference between the wet and dry seasons is between 24-90mm. Regional soil moisture index in the wettest quarter ranges from 0.23-1, where 1 is saturated. Solar radiation during the warmest quarter is between 24.3-27.1 MJ/m2/day. Radiation seasonality was 32-46 on the dimensionless scale for this parameter.

While not easy to see on the Maxent diagram for Australia, where the squares marking the two Eyre Peninsula samples obscure an area of warm colours, the model predicts the species should be found in southern Eyre Peninsula, southern Yorke Peninsula, the Fleurieu and South-East.

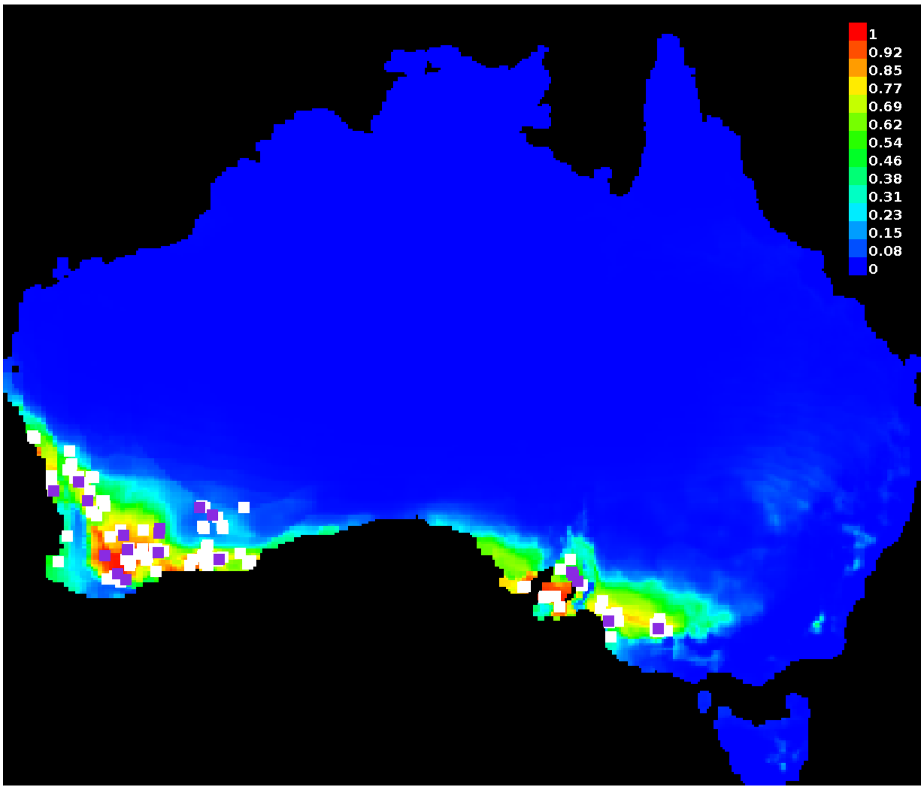


Figure 25 - Maxent predicted range of occurrence for *T syncarpa* based on Bioclim 1960 "best five" (Atlas of Living Australia)

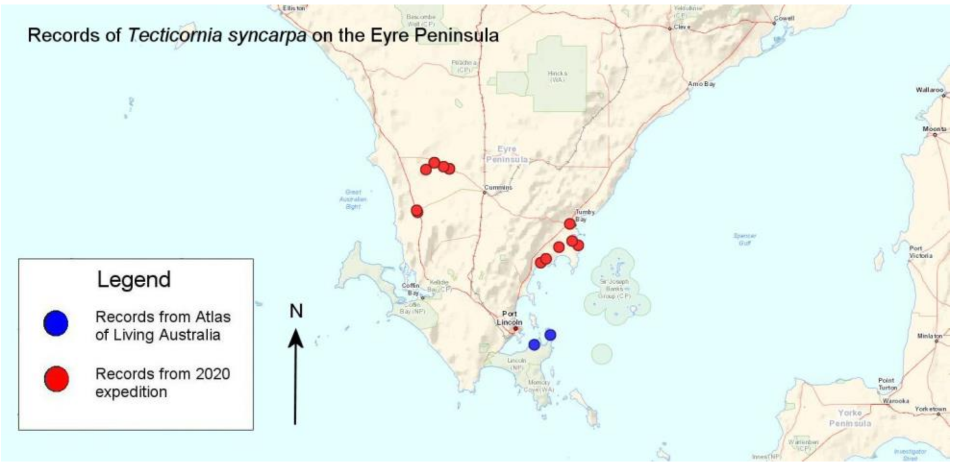


Figure 26 - ALA and 2020 expedition records for *T lepidosperma* on the Eyre Peninsula (Map: Naturemaps)

Records on the Eyre Peninsula are all in the south, mostly where there is more than 400mm rain annually and there are large wetland complexes like Lake Malata and Lake Greenly. That said, there are several occurrences in the east, in areas of between 350-400mm rain, where there are reasonably sized catchments supplying the estuarine habitats the plants occur within, and where the evaporation rate may be very slightly lower than the more northerly records. To an extent, lower evaporation offsets lower rainfall.

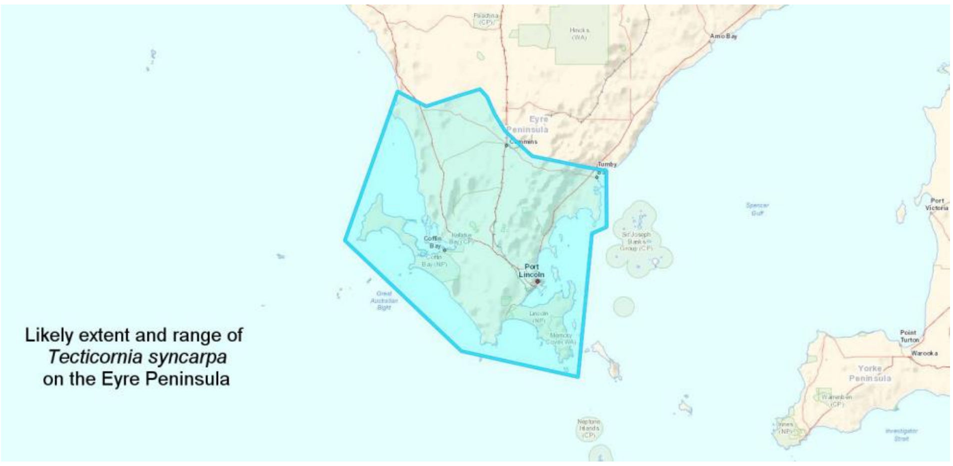


Figure 27 - Estimation of the range of *T syncarpa* in the EP Landscape Region, based on Maxent (ALA 2020), rainfall and the location of major wetland complexes (Map: Naturemaps)

The habitats Bracelet samphire are found within include the fringing vegetation on the margins of salt lakes and saline clay pans with varying salinity, the edges of coastal sabkhas on estuaries near Tumby Bay and Louth Bay, and in one case a population was found in a coastal depression behind dunes. Most of the soils were clay rich or loamy, with the exception of the population in the swale of the dunes, where the immediate surface was sandy.

In lower salinity habitats, Bracelet samphire has been found associated with the swamp paperbark *Melaleuca halmaturorum*, sedges including *Gahnia* spp, and Thick headed glasswort *Sarcocornia blackiana*. In slightly more saline situations the samphires *Tecticornia pergranulata, Tecticornia lepidosperma,* and *Tecticornia indica bidens* often co-occur with Bracelet samphire. Where *Tecticornia syncarpa* grows upslope from very saline lakes, *Tecticornia halocnemoides halocnemoides* and *Tecticornia flabelliformis* have been recorded within a few meters of the Bracelet samphires.

SAMPHIRES OF VERY SPECIFIC HABITATS

TECTICORNIA CALYPTRATA

The Capped samphire, *Tecticornia calyptrata* has only relatively recently been recognised on the Eyre Peninsula, with other Australian records occurring mostly inland in tropical and subtropical arid regions.

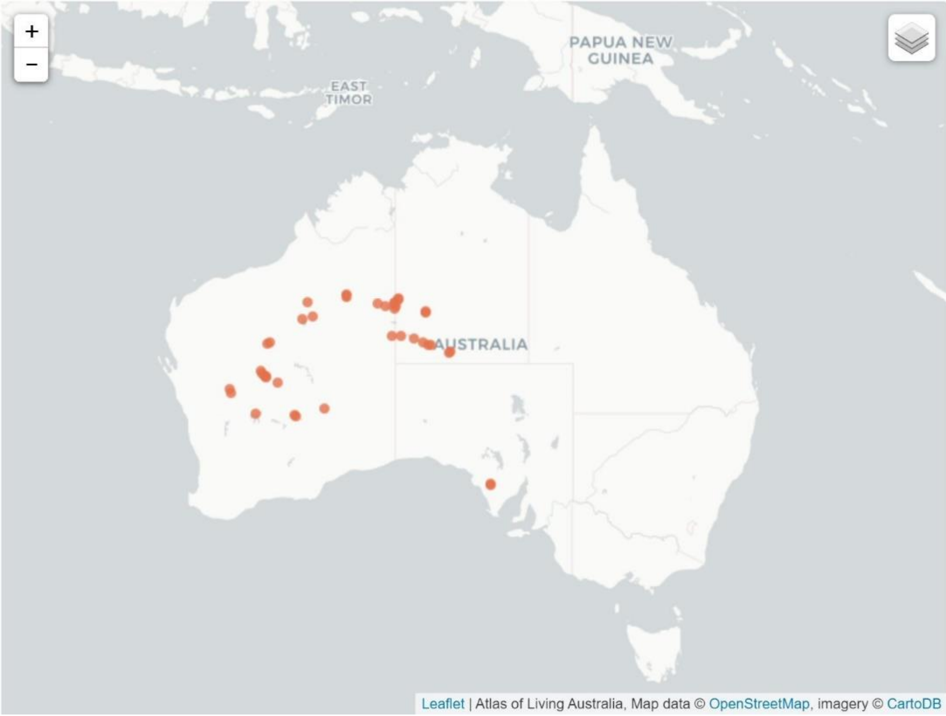


Figure 28 - Atlas of Living Australia records for *T calyptrata*

The species occurs on inland seasonal/intermittent saline lakes and inland seasonal saline marshes. These landscape features are classed as B8 and B12 of the wetland inventory classification (Seaman 2002). The species is a palustrine species – occurring in swathes across vegetated salt swamps and more marginally on unvegetated salt lakes. In the NT the species is recorded on the margins of gypseous salt lakes and in WA it is recorded as growing across slightly saline sump lands and claypans (Wilson 1980). On the Eyre Peninsula the salt lakes and saline swamps where the Capped Samphire has been recorded form parts of the Pinthaput Suite and the Samphire Flat Suite in Semeniuk's 2007 survey of Eyre Peninsula wetlands. These specific suites of salt lakes and saline swamps occur in the Kyancutta association of the Eyre Mallee (EYB05) on the Eyre Block of IBRA ver 7 (DAWE 2012).

The regional landscape is called the Tuckey Dune field and is characterised as extensive sandy dunes & kopi ridges. Interdune corridors of clay, silt & very fine sand also contain some silcrete and calcrete. There are evaporite deposits of gypsum and common salt in the numerous salt lakes.

The current expedition found the species in several locations around the Kappacoola (Kyancutta) saline swamp and at Lake Warramboo. All records on the Eyre Peninsula, so far, have occurred in areas overlying the Yaninee palaeochannel.

Figure 29 - ALA and 2020 expedition records for *T calyptrata* on the Eyre Peninsula (Map: Naturemaps)

In the area surrounding the lakes, the surface soils are alkaline, highly calcareous with some boron toxicity (DEW 2020). However, the sump lands and saline lakes have different conditions. The soils in the saline lakes comprise muds composed of gypsum and terrestrial clay, sand composed of quartz, gypsum, and intraclasts of carbonate mud (Semeniuk 2007). The lakes are significantly recharged by acidic groundwater from the palaeochannel, which has a pH around 3 and is enriched with lithium, having a Li/Cl ration in between 50-90 times that of seawater (Mernagh 2013). The groundwater is also enriched for boron and potassium (Mernagh 2013).

A careful review of the Atlas of Living Australia records for the species, against the palaeodrainage map of WA, SA and NT (Bell *et al* 2012) reveals the salt lakes that host the plants in WA and NT occur along continentally-draining (as distinct from seaward-draining) palaeovalleys in the arid zone. In the Northern Territory these include the Wilkinkarra, Lake Lewis and Katiti (Lake Amadeus) palaeovalleys. In Western Australia the plant has been recorded in the Percival, Disappointment, Carnegie, Carey, Raeside and Rebecca palaeovalleys.

The chemistry of brines in these subsurface drainage features depends not only on the underlying parent geology. The subsurface palaeotopography will be important. Palaeovalleys that drain to the sea are much less likely to concentrate salts and other minerals. Climate will have played a role in the concentration or dilution of brines as well, with evaporation, radiation and rainfall deficits important.

The Maxent species distribution modelling package (ALA 2020) in the Atlas of Living Australia was run, in order to develop a prediction about where *Tecticornia calyptrata* might be found on the Eyre Peninsula. Maxent predicts this species will be found where rainfall in the driest quarter of the year, averages 9-38mm. The difference between the wet and dry seasons is between 40-100mm. Regional soil moisture index in the wettest quarter ranges from 0.1-0.5, where 1 is saturated. Solar radiation during the warmest quarter is between 26.6-28 MJ/m2/day. Radiation seasonality was 19-37 on the dimensionless scale for this parameter.

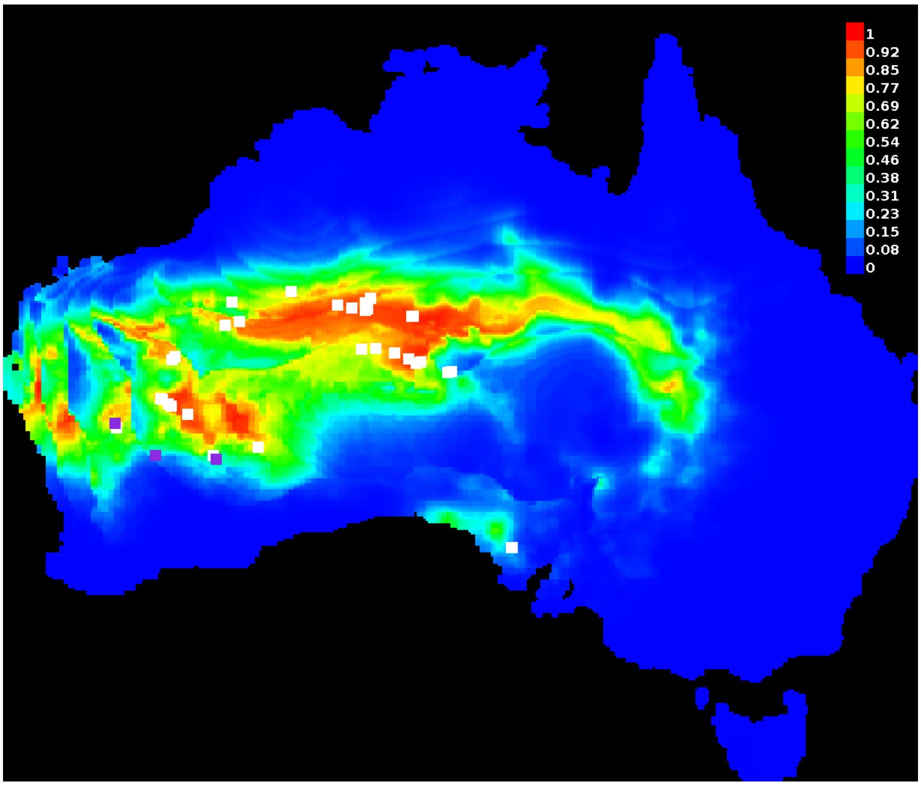


Figure 30 - Maxent predicted range of occurrence for *T calyptrata* based on Bioclim 1960 "best five" (Atlas of Living Australia)

Based on the small area predicted in Maxent, and the location of the Yaninee Palaeovalley (SARIG 2020, Hou *et al* 2012), it is quite likely that *Tecticornia calyptrata* may have a fairly restricted range within the Eyre Peninsula Landscape Board boundary. There is a possibility that the species has a wider distribution than Maxent has predicted, given the lack of collection in South Australia thus far. It seems most likely the species occurs between Minnipa and Koongawa, south of the Eyre Highway, and north of a line between Cocata and Kopi. It is less likely, but possible, that it occurs in the area of small salt lakes around Agars Lake, north of the highway. If the species is found to occur there, then it may also occur in some of the salt lake areas of the Gawler Ranges which overlay the Narlaby Palaeovalley, and in the Gawler Craton further north, although the bioclimatic factors used by Maxent (based on current collections) would seem to rule this out.

Capped samphire occurs with a narrow range of other samphire species. Datson (2002) records it growing with the Bluish or Waxy samphire (*Tecticornia pruinosa*) and with the Grey samphire, *Tecticornia halocnemoides*. On the Eyre Peninsula it has been recorded downslope of *Tecticornia pruinosa* and *Tecticornia pterygosperma* (Whiteseed, or Winged seed, samphire).

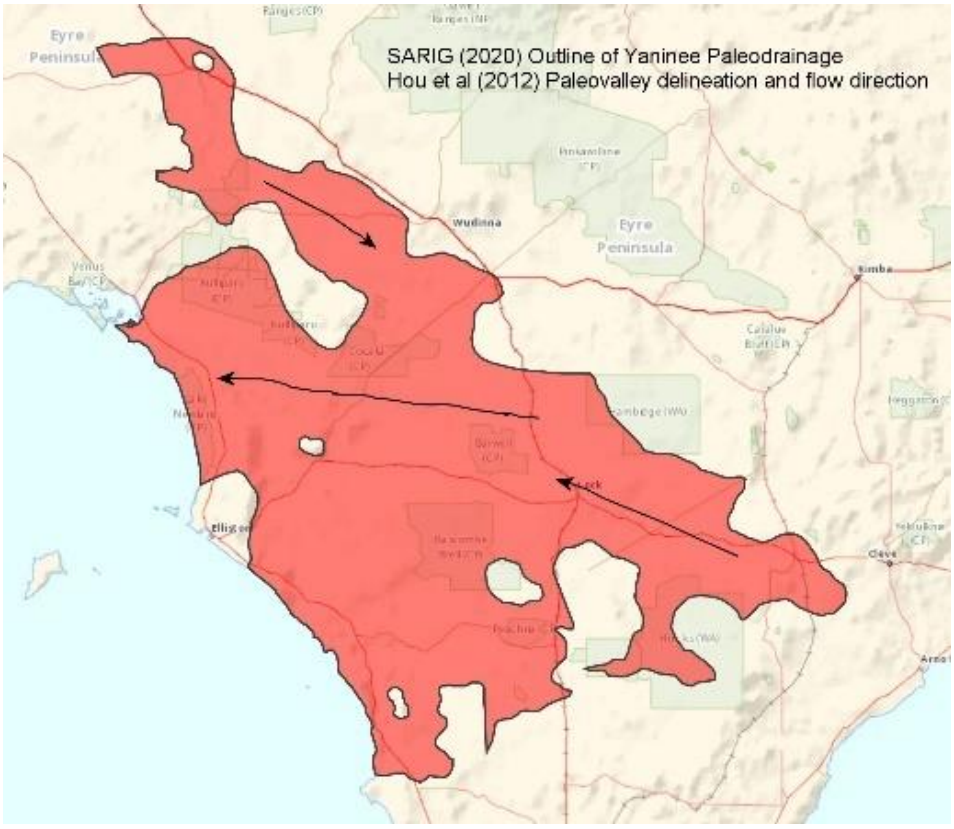


Figure 31 - Yaninee Palaeodrainage (Map: SARIG)

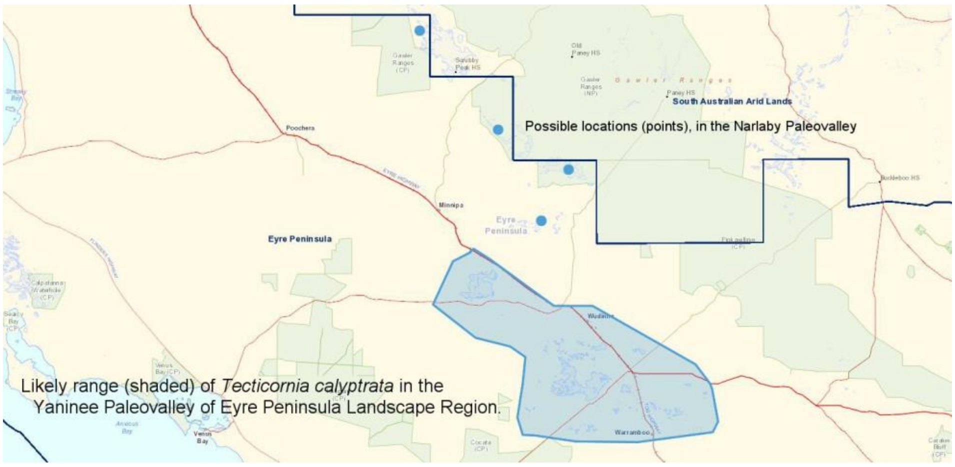


Figure 32 - Estimated range for *T calyptrata* in the EP Landscape Region, based on Maxent (ALA 2020) and occurrence of palaeodrainage (Hou *et al* 2012) (Map: Naturemaps)

TECTICORNIA LYLEI

The Wiry or Casuarina samphire, *Tecticornia lylei*, has been collected sporadically since Helms first collected it near Lake Lefroy in 1894. There are a mere 121 records for the species in the Atlas of Living Australia, distributed in warm temperate climate zones.

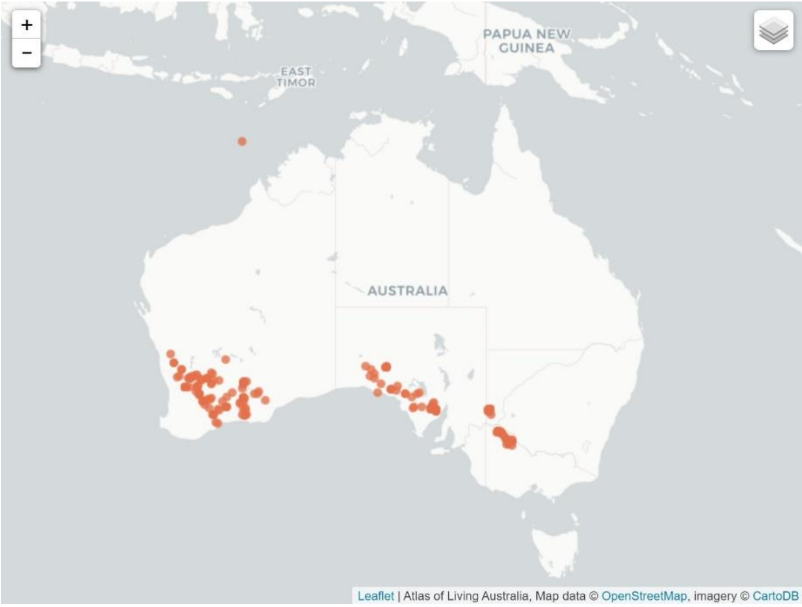


Figure 33 - Atlas of Living Australia records for *T lylei*

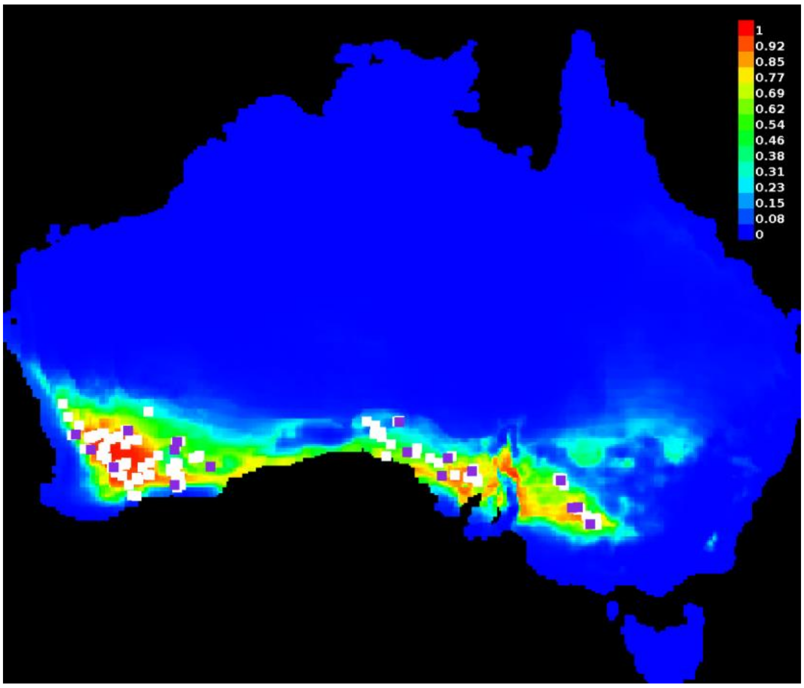


Figure 34 - Maxent predicted range of occurrence for *T lylei* based on Bioclim 1960 “best five” (Atlas of Living Australia)

Maxent predicts this species will be found where rainfall in the driest quarter of the year averages 29-75mm. The difference between the wet and dry seasons is between 20-72mm. Regional soil moisture index in the wettest quarter ranges from 0.12-0.81, where 1 is saturated. Solar radiation during the warmest quarter is between 23.9-27.3 MJ/m2/day. Radiation seasonality was between 31-41 on the dimensionless scale for this parameter.

While there is a clear climate pattern to the species records in the Atlas of Living Australia, the species is not distributed anywhere near as widely as the model predicts, (ALA 2020). For example, the area from Port Augusta to Adelaide is coloured as "highly predictive". While the climate of that area may be favourable, something else clearly isn't.

Where voucher specimens have habitat descriptions, this can provide useful insight into distribution patterns. All the records on the Atlas of Living Australia and at the Adelaide Herbarium were reviewed for such information. The species is palustrine (occurring in the marginal vegetation of large unvegetated salt lakes) and possibly lacustrine as well, as it is often found as monocultures on the actual lake floor of small episodic salt lakes and clay pans. The presence of gypseous material and saline clay-loam soils was commonly reported. There are very occasional records of the species occurring near springs in sandhills with other samphire species. These are similar soil preferences to *T calyptrata*, but Australia-wide the Casuarina samphire has a more southerly distribution, climate wise, than the Capped samphire.

Datson (2002, 2005) found that *Tecticornia lylei* was found on salt lakes where soil pH was 6-6.5. Salt lakes with acidic soil conditions are usually found as expressions of palaeovalleys, buried landscape features which frequently carry acidic brines. A review of the distribution of the salt lakes where Casuarina samphire has been reported, Australia-wide, reveals that Western Australian populations occur in the Lefroy, Cowan, Camm, Deborah, Moore-Monger, Mortlock and Yarra Yarra palaeovalleys (Bell *et al* 2012). In South Australia the species is found in the Wilkinson, Wolda, Tolmer, Acraman, Yaninee, Narlaby, and the unnamed Corrobinnie palaeovalleys, as well as the unnamed palaeodrainages within the Pirie Basin of the Gawler Craton (Hou *et al* 2012).

Extensive mapping of palaeovalleys in NSW and Victoria is not readily available. Instead, information on pH for salt lakes hosting Casuarina samphire in these eastern States was investigated.

In Victoria, populations of Casuarina samphire are found at Lake Tyrrell, Hattah Lakes and the Towan Plains flora and fauna reserve. While the *Ecological Character Description for Hattah-Kulkyne Lakes Ramsar Site* (Butcher & Hale 2011) describes a mega palaeolake (part of the Riverine Plain of the ancient Murray River) that the current lakes overlie, there is no information on groundwater quality. Lake Tyrrell, on the other hand, is well known as a saline lake fed by acid springs, which has partitioned metals in its sediments (Fegan *et al* 1992, Mernagh *et al* 2014). The pH of Lake Tyrrell's groundwater springs varies from 2.6-4, and the Li/Cl ratio of the sediments is up to 50x that of seawater (Mernagh *et al* 2014).

In NSW, Casuarina samphires are found at Scotia Sanctuary and Nanya Arid Zone Research Station on salt lakes that are expressions of the Scotia Discharge Complex, a palaeodrainage system. Measurements of brines in the palaeochannels underlying these lake complexes have shown the brines to be acidic saline with pH commonly between 5 and 5.9 (Ferguson *et al* 1995). Other landscape features adjacent the saline lakes include gypseous dunes, hosting the gypsophile daisy, *Kippistia suaedifolia*.

With the insights gleaned from looking at the wider distribution of this species in Australia, the narrowness of the species distribution on the Eyre Peninsula more widely, and the Eyre Peninsula Landscape Region in particular, can be better understood.

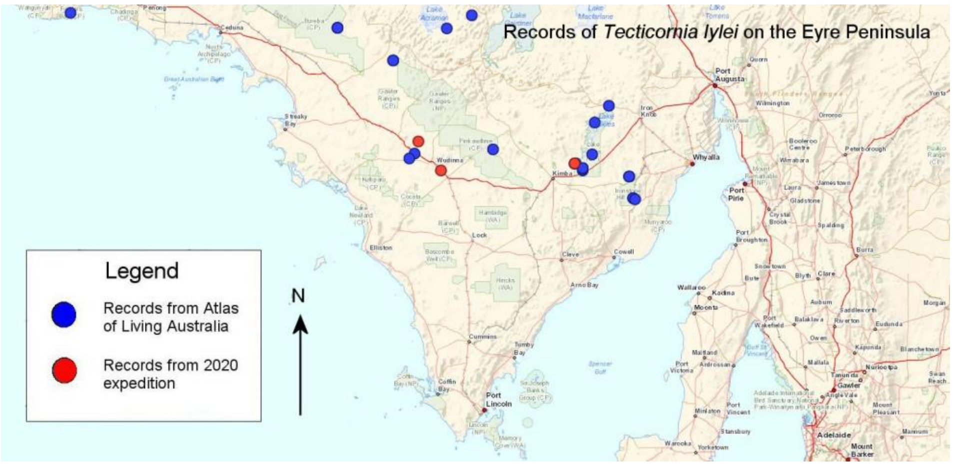


Figure 35 - ALA and 2020 expedition records for *T lylei* on the Eyre Peninsula (Map: Naturemaps)

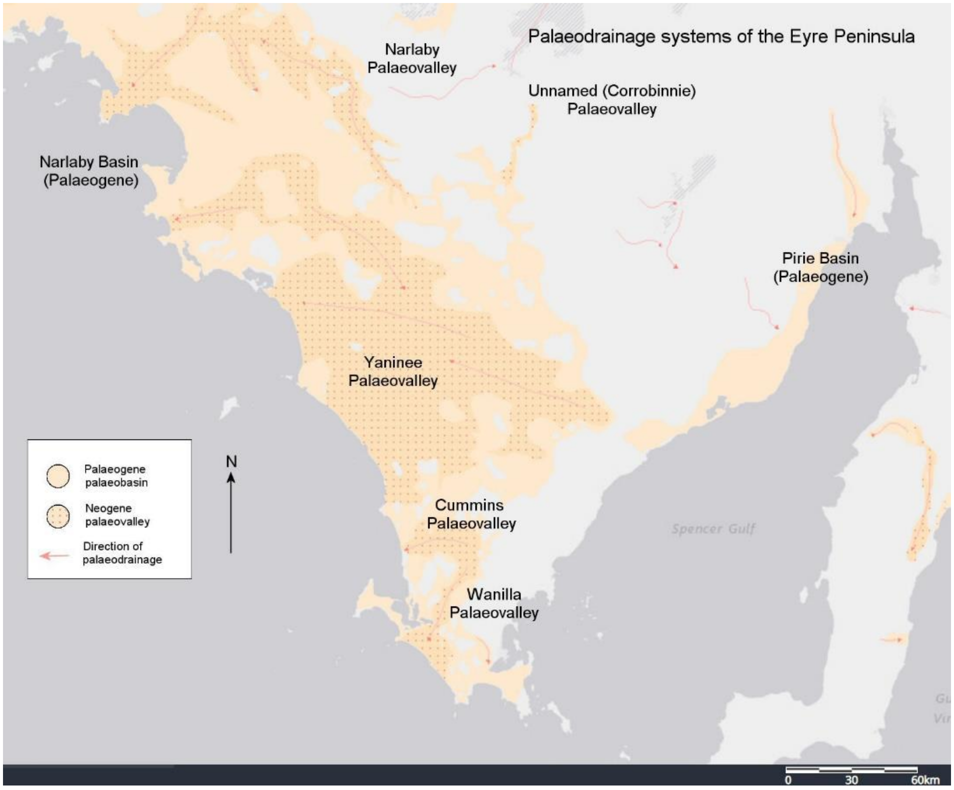


Figure 36 - Palaeodrainage of the Eyre Peninsula

In the western part of the EP Landscape Region *Tecticornia lylei* occurs north of the 300mm rain isohyet. However, the distribution does not simply follow the rainfall isohyet as it dips south on the eastern side of the Peninsula. Only a very few, specific areas in the “less than 300mm” rainfall zone on the eastern side of the Peninsula seem to support Casuarina samphire. Within the appropriate climate regime, *Tecticornia lylei* seems to be only found near salt lakes that are expressions of palaeovalleys, and these have a very limited presence on the eastern side of the Peninsula.

The SA palaeodrainage map (Hou *et al* 2012) suggests that records of Casuarina samphire on the Eyre Peninsula, west of Kimba, may be associated with the northern extent of the Yaninee Palaeovalley, the Narlaby Palaeovalley and an unnamed palaeovalley on Neogene sediments near Corrobinnie, within the Palaeogene Narlaby Basin.

East of Kimba, at Lake Gilles and in the Ironstone Hills area, the distribution of *Tecticornia lylei* may be associated with smaller unnamed palaeodrainages that occur within the Palaeogene Pirie Basin. These drain southward towards the coast between Whyalla and Cowell (Hou *et al* 2012).

Casuarina samphire often occurs as monospecific stands on the margins of unvegetated salt lakes, or even out on the lake pan of otherwise unvegetated lakes and saline clay pans. Upslope habitats range from other *Tecticornia* species (low down on the slope) through *Allocasuarina verticillata* (Lake Yaninee), *Melaleuca halmaturorum* (Lakes Yaninee and Wannamana) and *Melaleuca uncinata* (lakes on Scholz Road, east of Minnippa), up to mallee and acacia woodlands on the well-drained higher slopes (Lake Gilles).

Within the Eyre Peninsula Landscape Region, *Tecticornia lylei* has an extremely restricted range – the species seems to be generally found on, or immediately edging, unvegetated salt lakes that are expressions of palaeodrainage systems, in areas with less than 300mm of rain annually.

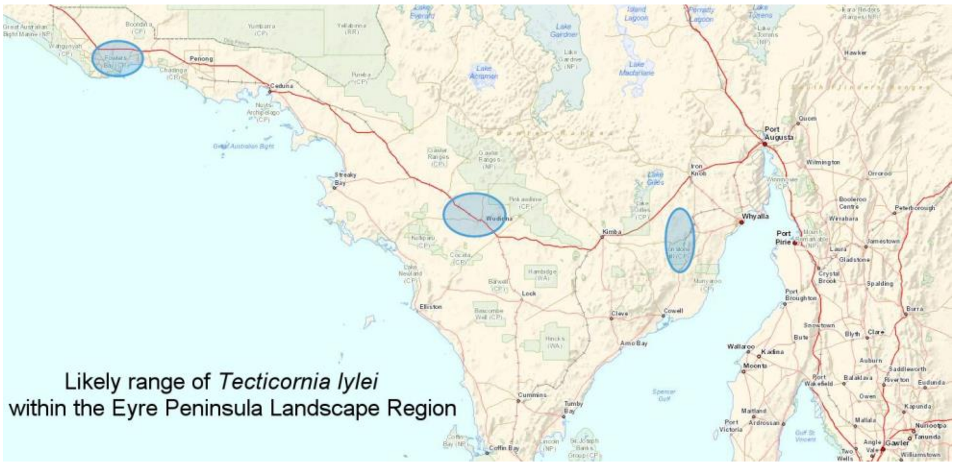


Figure 37 - Estimation of the range of *T lylei* in the EP Landscape Region, based on Maxent (ALA 2020), rainfall and the location of palaeodrainage features (Map: Naturemaps)

TECTICORNIA FLABELLIFORMIS

The Commonwealth Vulnerable samphire Tecticornia flabelliformis (the Fan or Bead samphire), is found on near-coastal sabkhas and inland salt lakes in southern Australia.

Figure 38 - Atlas of Living Australia records for *T flabelliformis*

An interesting aspect of the Australia-wide distribution of the Fan samphire is that while in Western Australia and in Victoria the species is found inland, in South Australia the majority of the occurrences are near-coastal. Some of those occurrences (West Coast) are in near-coastal ephemeral playa lakes, where the soil surface has an elevation of about mean sea level and the lakes are protected from tidal inundation by sand dune barriers but marine influence is common through marine springs and grounwater. Along the arid Gulf coasts of South Australia the Fan samphires can be found on sabkhas, which are near-coastal supratidal flats associated with tidal creek drainage systems. In many ways, near-coastal sabkhas have more in common with salt lakes than they do with intertidal habitats, as without daily tidal sorting their sediments are finer than most saltmarsh soils.

Studies by Coleman and Cook (2009) found *T. flabelliformis* growing along Gulf St Vincent occurred preferentially on clay-rich soils (31-37% clay) in very moist conditions with a relatively high pH (around 8). This may explain fan samphires' preference for argillaceous sabkha surfaces rather than the intertidal saltmarsh soils that often comprise organic peats, shelly sands or sandy clays. As well, Fan samphires were nearly always found above a "fragipan" or hardened sub surface layer. A likely mechanism for the formation of the hardened pans is evaporation. Saline groundwaters, whether in near-coastal sabkhas or inland salt lakes, are rich in sulfate (and possibly carbonate) as well as chlorides. Evaporative processes at the soil surface cause concentration of the ions in the ground and if sulfate or carbonate concentrations reach relative saturation, crystallisation of salts such as flos ferri (calcium carbonate) and gypsum (calcium sulfate) may occur in the sub-soil, creating the fragipans (Flood & Walbran, 1986).

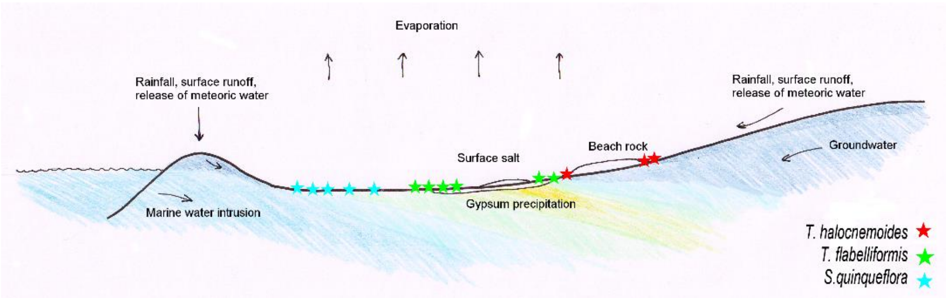


Figure 39 - Conceptual model of hydrology and samphire species distribution on a sabkha

The conceptual model in Figure 39 shows the interaction of the various water sources and the resultant distribution of three different samphire species on sabkhas or salt lakes.

Waters underlying the sabkhas near the sea are a mixture of marine intrusion, rainfall, runoff from the dunes and slowly released “meteoric” water (rainwater stored in the freshwater lens of the dune, and discharged very slowly over time). In the areas nearest the sea the Bearded glasswort *Sarcocornia quinqueflora* can be found.

Evaporation from the sabkha surface concentrates the underlying brine – the further away from the sea, the higher the salinity of the underlying brines. Flos ferri (a carbonate deposit) and gypsum can both precipitate out of solution as they become concentrated. This precipitated material cements the soil particles together as a “fragipan” maybe 25-50cm below the soil surface. The soils above this are saturated with hypersaline brine. *Tecticornia flabelliformis* grows above these fragipans.

Where the evaporation is extreme, eventually sodium chloride will start to precipitate out on the surface of the sabkha or salt lake, and no plants grow in those areas. On a sabkha the surface salt forms towards the landward side of the sabkha, while in a salt lake the surface salt is usually located centrally.

At the very landward edge of the sabkha (or right around an inland salt lake) the hypersaline groundwater is diluted by rainfall runoff, leading to marginal patches of the Vulnerable Fan samphire. The gently rising surface near the sabkha edge is usually slightly drier than the main pan, and *Tecticornia halocnemoides* (Grey samphire) can establish. Where land sourced groundwater, high in carbonates, seeps into the edge of the sabkha, “beach rock” deposits are common and *Tecticornia halocnemoides* frequently grows on these.

These soil and chemistry habitat preferences and combined with climate preferences to determine the species range. Maxent predicts this species will be found where rainfall in the driest quarter of the year averages 38-58mm. The difference between the wet and dry seasons is between 21-61mm. Regional soil moisture index in the wettest quarter ranges from 0.31-0.52, where 1 is saturated. Solar radiation during the warmest quarter is between 26.4-26.8 MJ/m2/day. Radiation seasonality was between 36-37.

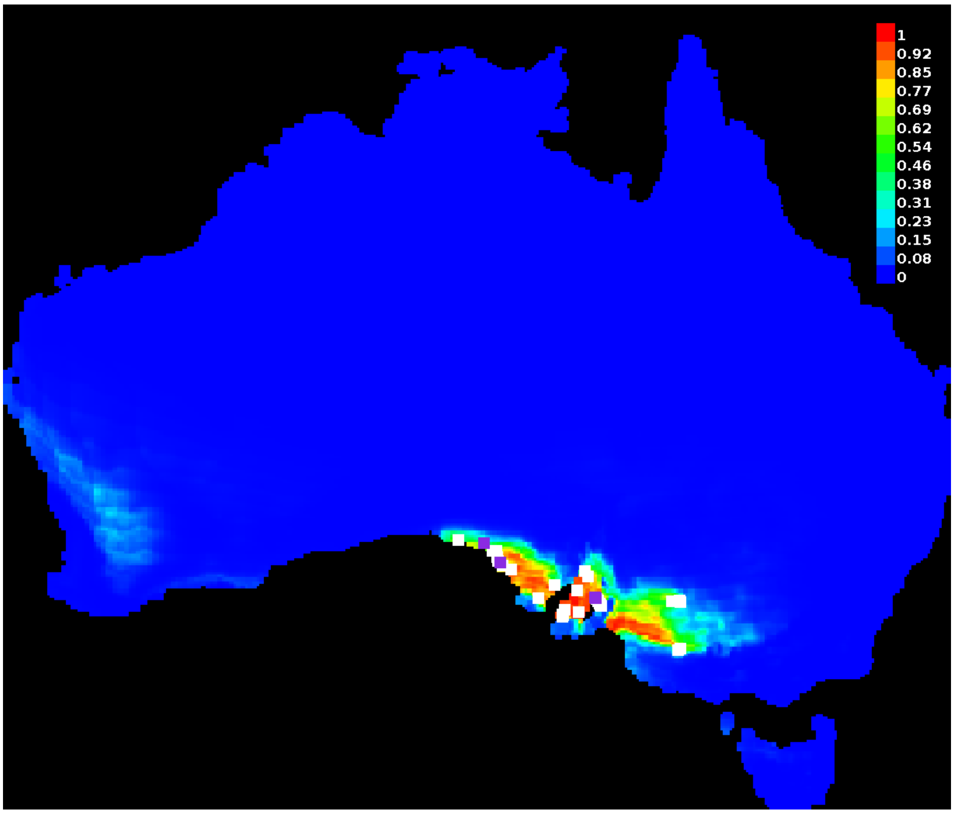


Figure 40 - Maxent predicted range of occurrence for *T flabelliformis* based on Bioclim 1960 "best five" (Atlas of Living Australia)

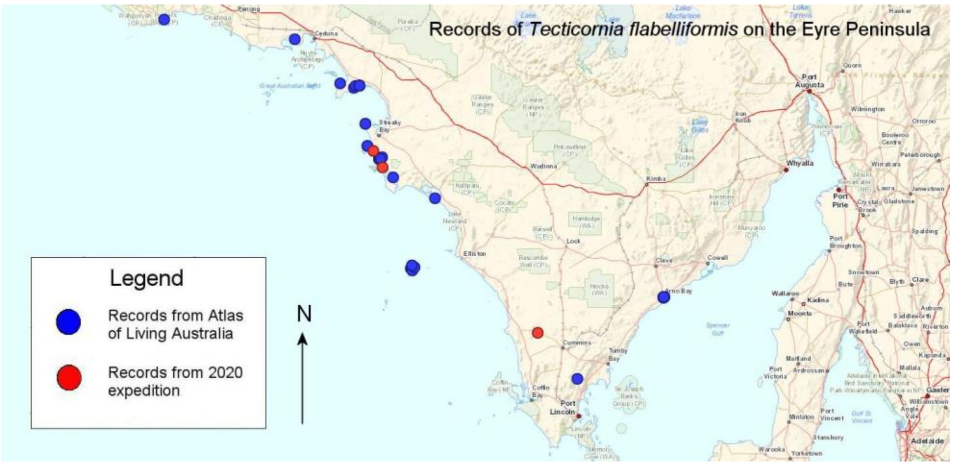


Figure 41 - ALA and 2020 expedition records for *T flabelliformis* on the Eyre Peninsula (Map: Naturemaps)

On the Eyre Peninsula the Fan samphire is found in a number of very specific habitats scattered widely throughout the 250-450mm rainfall band.

On the higher energy west coast the species is found on coastal playa lakes.

On the low energy east coast and protected west coast embayments like Venus Bay, Fan samphires are found on extensive supratidal sabkhas adjacent to estuaries.

Inland the species can be found on a number of salt lakes where the soil pH is in the alkaline end of the scale (mostly on the Cummins Palaeovalley within the Lake Malata complex). So far, on the Eyre Peninsula the plant has not been recorded in acid saline lakes. Where the species occurs in conjunction with palaeovalleys and drainages that have been recorded as producing acidic brines (eg Yaninee and Narlaby), it occurs in near-coastal playa lakes with some marine influence. Seawater contains high levels of carbonate and bicarbonate, which buffers pH levels in the saturated soils.

This specificity seems to be reflected in the distribution of the species, Australia-wide. Where Fan samphire occurs on palaeodrainages that are saline acidic, it does not co-occur with the acid-loving Casuarina samphire. Although the two species can occur relatively close together, they inhabit slightly different niches.

Fan samphire has not been recorded in either the Scotia Discharge Complex In NSW or the very acidic Lake Tyrrell in Victoria. The two species **do** occur in the Hattah Lakes-Kulkyne complex of wetlands, but the Fan samphire occurs in the west of that complex, edging smaller lakes or on vegetated kopi (gypsum) depressions, while Casuarina samphire occurs in the east, on the larger lakes. In Western Australia the analysis is complicated by the “generalisation” of the records for Fan samphire – as a threatened species its exact location is not released. However, within the two wetland complexes known to host both Casuarina and Fan samphires (the Lake Lefroy and Lake Baladjie systems), the Fan samphires seem to occupy small basins separated from the main lake basins, while the Casuarina samphires are associated with the main lakes. The small separated lakes occupied by Fan samphire appear, on satellite imagery, to have very differently coloured floors to the adjacent lakes and may be somewhat “upslope” of the main lakes. This could mean their soil and water chemistry is controlled by the local landforms they occur within, such as kopi deposits, rather than by the expression of palaeovalley brines.

SPECULATION ABOUT TECTICORNIA INDICA SUBSPECIES

Tecticornia indica, the Brown headed samphire, is an interesting species that has several subspecies across Australia. The species has adaptations that enable it to live in tropical climates, and the majority of its subspecies occur in northern Australia. The subspecies with the southernmost distribution is *Tecticornia indica* subsp *bidens*.

Wilson (1980) wrote of *T indica bidens* "This species is a subtropical plant and is relatively common in the southern portion of Australia south of 26° latitude. It occasionally occurs in association with subsp *leiostachya* in more northern localities…" In WA and NT subspecies *T indica leiostachya* is recorded southward from the tropical to the northernmost parts of the subtropical zones. In SA and Victoria the records of *Tecticornia indica leiostachya* occur much further south than would be expected for a tropical species. The question arises, is the species identified as *Tecticornia indica leiostachya* in the southernmost parts of Australia really that?

Identification of plant species usually takes place through the use of dichotomous keys. These use a series of "either-or" questions to separate out the species. Such keys are commonly known as "artificial" keys. They only work if the plants you are looking at are included in the key. They only work if the features used to separate the species out are true across the entire range of the species. The feature used to separate out *T indica bidens* from *T indica leiostachya* in most keys is the lowest bracts of the flowering or barely ripe fruiting spike. The lowest bract in typical southern *T indica bidens* is larger than the upper bracts, while specimens of *T indica leiostachya* have a lowest bract that is smaller or the same size as upper bracts. But it is known this feature becomes less obvious in fully ripe dried fruit spikes and it is possible that this feature can vary across the range of each subspecies. Datson (2002) has described, in the north-eastern Goldfields, a "slim form" of *T indica bidens* where the lower bract is not noticeably larger than the upper bracts.

Another way to check a plant's identity is to compare it, feature by feature, with descriptions of the species. This can be done with a table, such as this one based on descriptions in Wilson (1980) and Datson (2002):

Feature	***T indica leiostachya***	***T indica bidens***	***T indica bidens "slim form"***
Form	Decumbent to erect sub-shrub	Robust shrub	Sprawling open shrub
Height	About 40cm	Up to 2m	Less than 1m
Vegetative articles	Thick, cylindrical to obovoid, to 10mm long, only slightly lobed, ciliolate	Thick, obovoid, deeply lobed, keeled apices, sometimes ciliolate	Keeled apices, barely ciliolate
Fruiting spikes	5-40mm long, bracts overlap each other, lowest article smaller than or equal to ones above	Bracts overlap each other, lowest article **at first** larger than and more deeply lobed than the ones above	Bracts overlap each other, lowest article **barely (or not)** larger than, and **not more deeply lobed** than the ones above
Fruiting spike on drying	Remains **fawn**, leathery to corky	**Brown to grey** with age, often with black spots. Corky.	**Grey** with black spots
Dried individual fruits	Outer perianth soft and spongy, inner pericarp hard and horn-like	Outer perianth soft and spongy, inner pericarp hard and horn-like	

Table 1 - Features of *T indica bidens* and *T indica leiostachya*

The author has spent some time looking for subspecies *leiostachya* on the Eyre Peninsula. The only time a plant was found that recalled those the author was familiar with from the Pilbara region of NW Australia, was a single specimen near the Arid Lands Botanic Garden at Port Augusta. The specimen was a small shrub about 30cm tall, the vegetative articles were markedly ciliolate, the dried fruits stayed fawn, and the hard pericarp around the seeds was surrounded by spongy material.

Figure 42 - T indica leiostachya

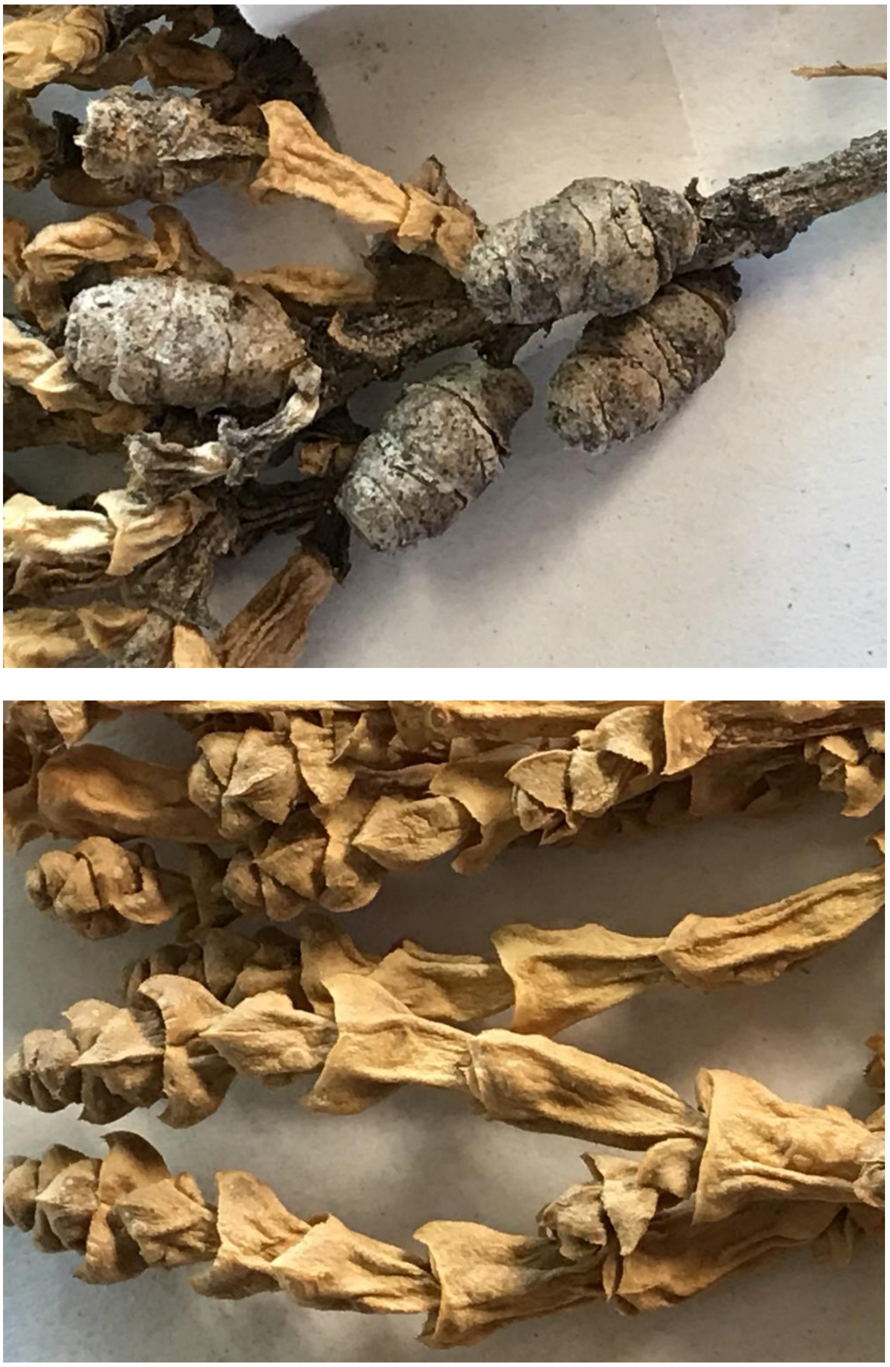


Figure 43 - *T indica bidens*

Figure 43 shows the grey fruits and deeply lobed vegetative articles of *T indica bidens*, more commonly found on the Eyre Peninsula. Datson's "slim form" may be present on the Eyre Peninsula, possibly amongst those plants identified as subsp *leiostachya*. With T indica bidens known for its "plasticity" of form (Wilson 1980), determination is not always cut and dried.

BIOCLIM COMPARISONS

Booth *et al* (2014) described the development of early species distribution modelling (SDM), researched and developed by CSIRO. BioClim was the modelling package that resulted from CSIRO's work to determine climatic variables across the entire continent of Australia, even where weather stations were very widely spaced. As well as the weather variables, the Bioclim model included a digital elevation model to assist in the interpolation of weather data. The variables developed were freely shared with later SDM packages, including the Atlas of Living Australia's Maxent model. Modern packages include the capacity to model a species likely distribution against other variables such as soils, geology, topography and vegetation associations, but for this report BioClim's "best five" variables were used, in order to gain a quick understanding of the likely ranges for each species.

The five BioClim variables used to model likely ranges for the species in this report were:

1) Precipitation, driest quarter average total (mm)
2) Precipitation seasonality (difference between wet & dry season) (mm)
3) Soil moisture index, highest quarter (a dimensionless value from 0-1, where 1 is "saturated")
4) Solar radiation seasonality (a dimensionless value)
5) Solar radiation, daily average in the warmest quarter (MJ/m^2/day)

Australia is a large country, with a varied climate. The range of values that may be expressed across Australia are presented in these graphs to give a sense of scale, as well as delineating the specific preferences of each species. The figures for *T halocnemoides* subsp aff *longispicata* have a much narrower range than the others, being only representative of a tiny area at the top f the Gulf, whereas the other species have Australia-wide distributions. So the figures for Gulf grey samphire should be considered cautiously.

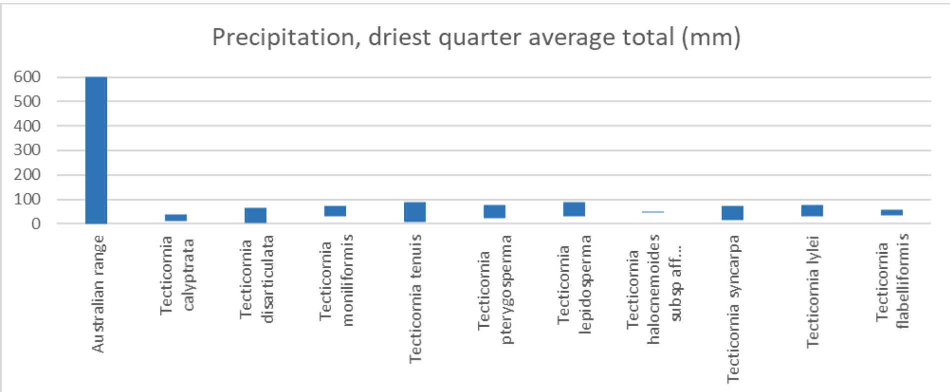


Figure 44 - Bio17, measuring precipitation in the driest quarter of the year

All the samphire species investigated in this report occur in places where the driest quarter of the year is markedly dry. Within that narrow range of dryness, some like the summer a bit wetter – *T lepidosperma* for example. Others like *T tenuis* seem to tolerate quite a range of relative dryness, while *T calyptrata* occurs where the dry season is seriously dry.

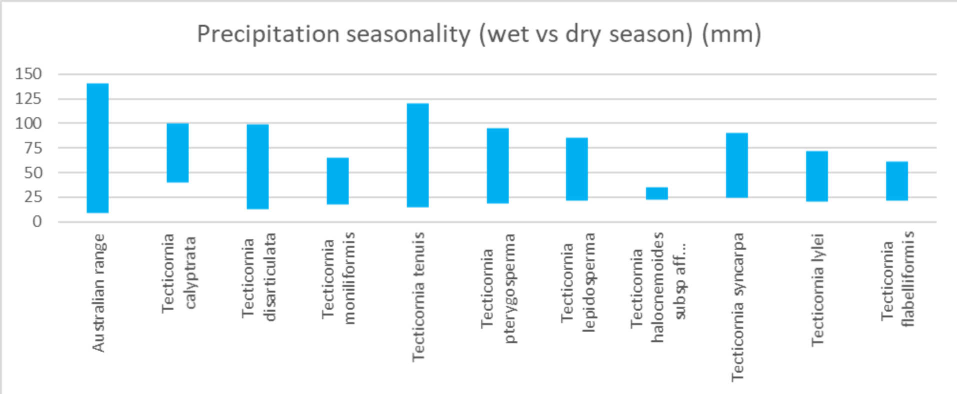


Figure 45 - Bio15, measuring seasonal difference in precipitation

Seasonality in rainfall varied considerably in the areas these samphires occurred, across Australia. Once again, *T tenuis* seems to be quite unfussy, tolerating living where seasonal variation can be minor, or extreme. The "upper range" of seasonality was lowest for *T flabelliformis* and *T moniliformis*, and highest for *T tenuis and T disarticulata*.

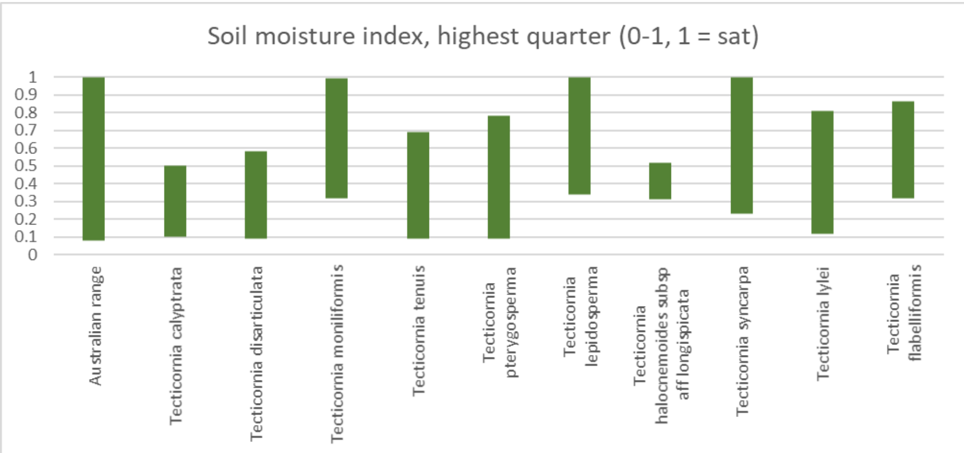


Figure 46 - Bio32, measuring how saturated the soil gets in the wettest quarter

Several species are found where regional wet season soil moisture is negligible (*T calpytrata, T disarticulata, T tenuis, T pterygosperma* & *T lylei*). Most of these are found in depressions where water gathers, so their apparent disdain of wet soil may not be relevant. The one that can truly be found in extremely dry conditions is *T disarticulata*, the Plains samphire, that occurs away from any water bodies, yet still is recorded from some areas with next to no soil moisture in the wettest time of the year. The species that are restricted to the south of the Eyre Peninsula (*T lepidosperma and T syncarpa*) both occur in some areas where regional soils may be saturated in the wet season, as does the more widely distributed *T moniliformis*.

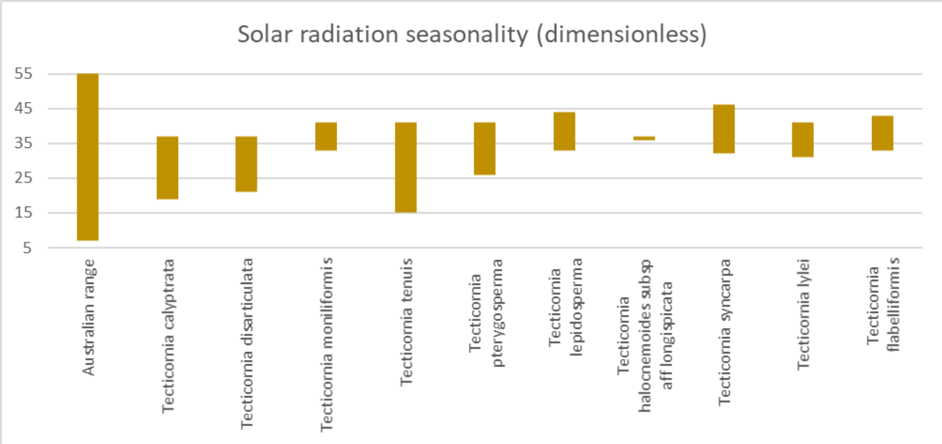


Figure 47 - Bio23, seasonal difference in solar radiation

None of the samphires examined here are absolutely temperate – if the modelling had included *Sarcocornia quinqueflora* subsp t*asmanica* and *Tecticornia arbuscula*, which both occur in Tasmania, one would expect to see remarkably high radiation seasonality for those species. At the other extreme, with tropically restricted species like *Tecticornia australasica*, the seasonality would be minimal. Once again, the very wide distribution of *T tenuis* across inland Australia sees it tolerating the widest range of radiation seasonality.

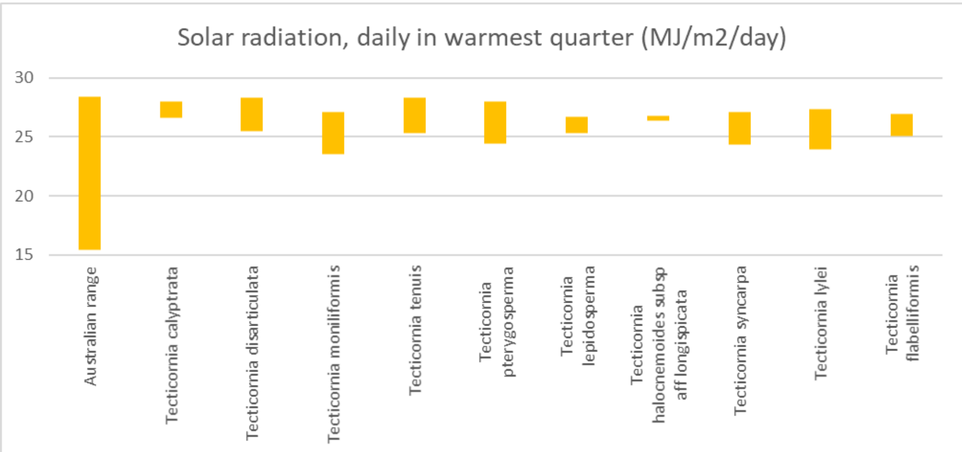


Figure 48 - Bio26, measuring the daily radiation in the warmest quarter

All the samphires investigated here occur in areas where summer solar radiation can be very high.

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APPENDICES

Detailed citation for Atlas of Living Australia records used in this report:

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