Coast and Marine Branch

Department for Environment and Water (DEW), South Australia

Technical Report 2019/01

Observations concerning a monitored saltmarsh at Pt Pirie, Spencer Gulf, South Australia.

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Introduction

During the period 1993 to 2002 eighteen profiles were surveyed within saltmarsh habitats across SA by the Coastal Management Branch (CMB) of the state Environment Department. Over the same period the CMB in partnership with the Geographic Analysis and Research Unit of the Department of Housing and Urban Development was involved in a state-wide saltmarsh and mangrove habitat mapping programme. Initially it was planned to map the plant communities using an airborne scanner. After considerable testing was undertaken in partnership with the SA Remote Sensing Centre, a Daedalus scanner was flown along the SA coast to capture the saltmarsh and mangrove communities. However due to equipment failure during scanning and then financial constraints the mapping was undertaken at a broader habitat level using existing colour aerial photography. To provide more detailed information at a plant community level, which was absent from the broader habitat mapping, 18 profiles were surveyed. These were surveyed across saltmarsh habitats from the landward to the seaward edge on Kangaroo Island, in both Gulfs and along the west coast of Eyre Peninsula.

In 1991 the SA government endorsed a policy on sea level rise (slr) developed by an expert committee. The policy forecasted a possible 0.3 m sea level rise by 2050 and 1 m by 2100. Both slr scenarios would impact mangroves and saltmarshes. To enable future resurvey to measure change the CMB surveyed saltmarsh profiles to a high level of horizontal and vertical spatial accuracy using technical expertise and precision survey equipment associated with the beach profiling programme.

Figure 1. A 2017 aerial view of profile 430001 adjacent Port Pirie. 1994 quadrat locations shown. (Source: DEW).

The Port Pirie profile (430001) shown in Figure 1 was first surveyed on November 14-15 1994. The profile extended seaward 3112 metres (m) from a flood protection levee to the mangroves. The profile was specifically undertaken to assess potential slr impacts on the mangrove and saltmarsh communities in Spencer Gulf. It formed part of a Spencer Gulf Vulnerability Study undertaken for the Federal Department of Environment, Sport and Territories (DEST) by the Mawson Graduate Centre for Environmental Studies, Adelaide University (Harvey et al 1995). The study brief provided by DEST proscribed two slr scenarios 0.18 m slr by 2030 and 0.44 m slr by 2070. These were based on the 1990 Intergovernmental Panel on Climate Change (IPCC) Report. These heights were used to adjust the existing profile to show translocation of the plant communities. The results (Fotheringham 1995) predicted an expansion of mangroves and tidal saltmarshes and loss of supratidal communities that were unable to retreat due to the levee.

A repeat survey of the Pt Pirie profile was undertaken on November 20th 2018 to detect change. Both surveys reached the mangrove zone but the 2018 profile did not extend beyond 3074 m due to wet ground conditions. In 1994, photographs and detailed vegetation descriptions were recorded at 16 quadrat sites along the profile. All of these sites were revisited and photographed in 2018 apart from site 16 in the mangroves and six of the sites were resurveyed.

This report compares the information collected from both surveys.

Methods

Surveying the profile line.

In 1994, a Leica Total Survey Station (TSS) shown in Figure 2 was used to survey the profile line. A permanent survey mark (PSM) was established at the start of the profile. This was connected to other existing survey marks that were part of the State Survey Network so that precise height and position could be determined. This also ensured the line could be re-established even if the PSM was destroyed.

The actual survey of the line using the TSS instrument involved two survey officers; one on the TSS instrument and the other with a prism mounted survey pole walking the profile.

Figure 2. 1994 photo of Leica TSS at Port Pirie.

The officer on the TSS instrument kept the profile team on line and recorded height and position measurements as they went. Communication was by UHF radio. The TSS was moved regularly along the profile to maintain high accuracy. Galvanized iron pipes (GIPS) marked these instrument change positions. Any changes in overstory, plant species, topography or landform were recorded on the instrument using the radio to relay the information. Standard survey feature codes were used to identify landforms such as creeks, tracks, fences, pans or rock surfaces.

In November 2018, a Leica Real-Time Kinematic (RTK) Global Navigation Satellite System (GNSS) was used to undertake the survey. A base station was set on Port Pirie West. A roving unit located with the plant observer was used to record heights and co-ordinates including topographic features such as creeks and tracks along the length of the profile.

Due to a possible disturbance of one of the original 1994 Base Marks (DPR 6431/1981), a static survey was conducted to establish the integrity of the profile line survey marks and the surrounding survey marks in the area. The data collected confirmed a small discrepancy in DPR 6431/1981 so a more stable PSM 6431/1497 was chosen.

The 1994 survey data, showed that a Ground to Grid correction needed to be applied to the survey (to take into account curvature of the earth). All survey marks and quadrat sites were corrected from ground distance system to ellipsoid coordinate system (Grid distance). A differential level run was also carried out to confirm the vertical integrity of the survey. The traverse included the following marks; PSM 6431/1497 (Base Station - Nov 2018), PSM 6431/1498, DPR 6431/1981 (Quadrat 1), Peg 2 (Quadrat 2), GIP 3 (Quadrat 3), Peg 4 (Quadrat 4), Peg 5 (Quadrat 5), DPR 6431/1982 (Quadrat 6), DPR 6431/1547. The total distance of the traverse was approximately 1607m with a misclosure (sum of errors) of 0.022 m.

Processed AUSPOS GPS results from the static observations and the reduced level run showed a misclosure in heights of -0.111 m compared to the Land Services published height values. This height correction was applied to the 2018 survey.

In comparison to the 1994 survey, 2018 data could be captured much faster. In 1994, every point required radio communication to get line, measure and communicate codes. In contrast, in 2018 each point could be collected in seconds, a bit longer when topographic feature codes had to be entered. For this reason, the 1994 profile survey captured 302 elevation points, whereas the 2018 survey captured 658 providing greater detail. In both surveys, height was recorded as metres (m) Australian Height Datum (AHD).

Vegetation recording

In both surveys the vegetation recorder was kept on line by the survey team. The plant recorder observed and recorded the plants along the profile. Visual estimates of species cover abundance was not recorded in 1994 as the methodology was still being developed. However it was recorded in later profiles and was recorded in the 2018 survey.

There were some differences in recording methods between the two surveys. In 1994 code numbers representing plant species were used. The radio was used to communicate these codes to the surveyor on the TSS who recorded the information electronically. This was a slow process and only overstory species were recorded. A string of plant codes indicated a change in vegetation.

The field data was processed using an in-house programme called BeachPro. Output was a spreadsheet with distance, elevation and associated plant codes in separate columns. The codes were automatically converted into the plant species names.

In 2018 the plant recorder was also able to record location in the field and therefore a field sheet was used to record the vegetation information. This enabled more detailed information to be recorded and also reduced the chances of errors when codes were used. All species observed were recorded and vegetation changes noted. Species cover abundance and lifeform were also recorded using the descriptive codes shown in Table 1. The vegetation information was transferred from the field sheet to an excel spreadsheet with the associated distance and elevation records.

After the data from both surveys had been compared, the profile was revisited on May 15 2019 to verify some of the differences that were identified between the two surveys. This proved to be a very useful exercise because it not only gave greater confidence in the results but it also identified different soil and surface conditions along the profile. These differences had not been obvious during the original profile surveys because they were both undertaken in dry conditions. This is in direct contrast to the most recent visit which was undertaken after the site had experienced heavy rain in the previous week. This resulted in the soil and surface conditions varying greatly from waterlogged and slushy, to well drained and firm. These varying conditions, no doubt have an effect on plant species distribution.

Quadrats

In 1994 the vegetation was described and photographed at the 16 locations shown in Figure 1. Nearly all of these locations were instrument change points. The vegetation was opportunistically surveyed during the time available while the instrument was being relocated. These surveys did not conform to Standard Biological Survey of SA (BSSA) methodology. Vegetation structure, life form and species cover abundance was recorded in a notebook. Unfortunately there is no record of quadrat size. At several sites it appears only the overstory species were recorded.

In 2018, based on the 1994 distribution of the plant communities six of the 16 sites were selected for resurvey. BSSA methodology was used. This methodology is outlined by Heard and Channon (1997).

With the exception of quadrat 1 (90 x 10), quadrats were 30 x 30 metres. Plant species, vegetation association, life form, height, cover abundance and life stage information were recorded within each quadrat using the descriptive codes shown in Table 1.

(AD) Vegetation association code		**(LS) Life stages**	
O	Overstory	V	Vegetative
E	Emergent	R	Regenerating
U	Understory	D	Dead/Dormant
(LF) Life form/Height class (modified Muirs Table)		B	Budding
S	Shrubs greater than 2 m	F	Flowering
SA	Shrubs 1.5 – 2 m	I	Immature fruits
SB	Shrubs 1 -1.5 m	M	Mature fruits
SC	Shrubs 0.5 – 1 m	X	Recently shed
SD	Shrubs 0.0 – 0.5 m	S	Seedling
P	Mat plants		
GT	Grass > 0.5 m		
GL	Grass M < 0.5 m		
J	Herbaceous species		
(CA) Cover Abundance Scale (adapted Braun-Blanquet)			
N	Not many, 1 – 10 individuals		
T	Sparsely or very sparsely present (less than 5% cover)		
1	Plentiful, but of small cover (less than 5%)		
2	Any number of individuals covering 5-25%		
3	Any number of individuals covering 25-50%		
4	Any number of individuals covering 50-75%		
5	Covering more than 75%.		

Table 1. Descriptive codes used for recording vegetation information (BSSA methodology).

At five of the sites a tape measure was also used to measure species cover abundance. This was oriented north – south, 15 metres either side of the quadrat centre point. Plant species presence/absence was recorded at 0.6 m intervals resulting in 50 sample points. A similar measurement was undertaken east – west resulting in a total of 100 sample points within the quadrat. Ten overstory heights were also recorded.

Vegetation classes as prescribed for BSSA quadrats were based on three criteria: over-story species, life form (after Muir) and canopy cover (after Specht).

In 1994 the plant identification was field only. Plants were not verified at the Herbarium. In 2018 all of the species recorded were collected and verified at the Herbarium. These have been submitted for incorporation into the collection of the State Herbarium of South Australia.

Tecticornia pergranulata recorded in the 1994 survey is considered incorrect. It was recorded in the 2018 field survey several times but when checked at the Herbarium was *Tecticornia halocnemoides ssp. halocnemoides*. *Tecticornia halocnemoides ssp. longispicata* is also present along the profile. This wasn't picked up in the 1994 survey. Unfortunately the 2018 field survey was well advanced before the difference was determined and this survey also did not separate the two subspecies. *Tecticornia moniliformis* was recorded at quadrat 2 in 2018. This species until very recently was only known in WA.

Photography

In 1994 photographs using colour film were taken at the 16 vegetation sites. The 1994 photos appear to be taken with a 50 mm lens but details were not recorded. In 2018 apart from site 16 in the mangrove zone which was not visited all of the sites were again photographed using a digital camera with a 50mm lens setting. Unfortunately a photo of quadrat 3 was not taken.

Results

Plant Species Distribution

Figure 3 plots the distribution of fifteen of the sixteen plant species recorded in the 2018 profile survey. *Tecticornia monoliformis* was not included on the plot as it was only recorded at quadrat 2. Figure 4 shows the 1994 and 2018 distribution of the ten species that were recorded in the 1994. Only overstory species were recorded in 1994.

Information about the observed range, elevation, and extent of each species recorded along the profile is presented in Tables 2 and 3.

Certain species only occurred at high elevations and others only at low elevations. Others occupied a wide range of elevations in the middle between the two extremes. In both Tables, species are classed into low (L), mid (M) and high (H) saltmarsh based on the elevation of where they occurred. Although the overall profile sloped seawards, tidal creeks and ridges enabled low and high saltmarsh species to occur at various locations along the profile extending their range.

Species	Class	1994	2018
		Observed Range Distance (Metres) and Elevation (Metres AHD)	Observed Range Distance (Metres) and Elevation (Metres AHD)
Atriplex paludosa	H	1367 (1.37) – 2482 (1.34)	1360 (1.39) – 2128 (1.29)
Atriplex vesicaria	H	9.45 (2.37) – 637 (1.61)	11.34 (2.53) – 349.17 (2.18)
Avicennia marina	L	2943 (0.8) – 3112 (0.45)	2943 (0.79) – 3074 (0.62)
Disphyma crassifolium	M	-	11.34 (2.53) – 2076 (0.8)
Frankenia pauciflora	H	-	11.34 (2.53) – 2128 (1.29)
Frankenia sessilis	M	-	1221 (1.63) – 2819 (0.97)
Hemichroa pentandra	M	-	1360 (1.39) – 2819 (0.97)
Maireana oppositifolia	M	9.45 (2.37) – 2859 (0.84)	11.34 (2.53) – 2819 (0.97)
Nitraria billardierei		2466 (1.39)	Not found
Sarcocornia quinqueflora	L	2918 (0.76) – 3071 (0.56)	2880 (0.8) – 3062 (0.62)
Sarcocornia blackiana	M	-	2029 (1.53) – 2814 (1.0)
Suaeda australis	L	2945 (0.79) – 3071 (0.61)	2943 (0.79) – 3062 (0.62)
Tecticornia halocnemoides	M	211.86 (2.05) – 2918 (0.76)	30.71 (2.52) – 2913 (0.75)
Tecticornia moniliformis	M		Quadrat 2 453 (1.89)
Tecticornia arbuscula	L	2689 (0.91) – 3074 (0.62)	2819 (0.97) – 3074 (0.62)
Tecticornia indica	M	9.45 (2.37) – 2803 (1.19)	11.34 (2.53) – 2819 (0.9)
Wilsonia humilis	M	-	1360 (1.39) – 3019 (0.58)

Table 2. Recorded plant species show elevation and extent along the profile for 1994 and 2018.

Species	Class	1994		2018		% Difference
		Total Extent Along profile (Metres)	Total Extent %	Total Extent Along profile (Metres)	Total Extent %	
Atriplex paludosa	H	312	10	353	11	1
Atriplex vesicaria	H	103	3	98	3	0
Avicennia marina	L	47	2	47	2	0
Disphyma crassifolium	M			1056	34	
Frankenia pauciflora	H			512	17	
Frankenia sessilis	M			995	32	
Hemichroa pentandra	M			1130	37	
Maireana oppositifolia	M	599	19	908	30	11
Nitraria billardierei	H	1	0			
Sarcocornia quinqueflora	L	164	5	257	8	3
Sarcocornia blackiana	M			406	13	
Suaeda australis	L	126	4	119	4	0
Tecticornia halocnemoides	M	2562	83	2841	92	9
Tecticornia arbuscula	L	385	13	256	8	-5
Tecticornia indica	M	1700	55	2794	91	36
Wilsonia humilis	M			951	31	

Table 3. Plant species records along the profile in 1994 and 2018. Total extent in metre and as a percentage is shown. Where 1994 records exist % difference is shown.

Vegetation Classes and Distribution

Eight vegetation classes are defined and have been mapped along the profile for 1994 and 2018. These are shown in Figure 5. Overstory cover abundance for the 2018 survey is also shown. This was not recorded in 1994. Four classes are shown:

Dense = 70 -100% cover,

Mid-dense = 30 – 70%,

Sparse = 10 – 30%,

Very sparse = < 10%.

Table 4 shows extent in 1994 and 2018.

Vegetation class	1994 Extent (Metres)	% of profile	2018 Extent (Metres)	% of profile
Tecticornia indica - Atriplex vesicaria	86.62	3	102.2	3
Tecticornia indica	220.92	7	285.27	9
Tecticornia indica - Atriplex paludosa	351.29	11	244.78	8
Tecticornia indica - Tecticornia halocnemoides	1416.63	46	1476.54	48
Tecticornia halocnemoides	578.07	19	682.17	22
Tecticornia halocnemoides - Tecticornia arbuscula	231	8	93.52	3
Tecticornia arbuscula	134	4	148.69	5
Avicennia marina	27.48	1	26.08	1
Total		99		100

Table 4. Observed extent of vegetation classes recorded along the profile for the comparison years.

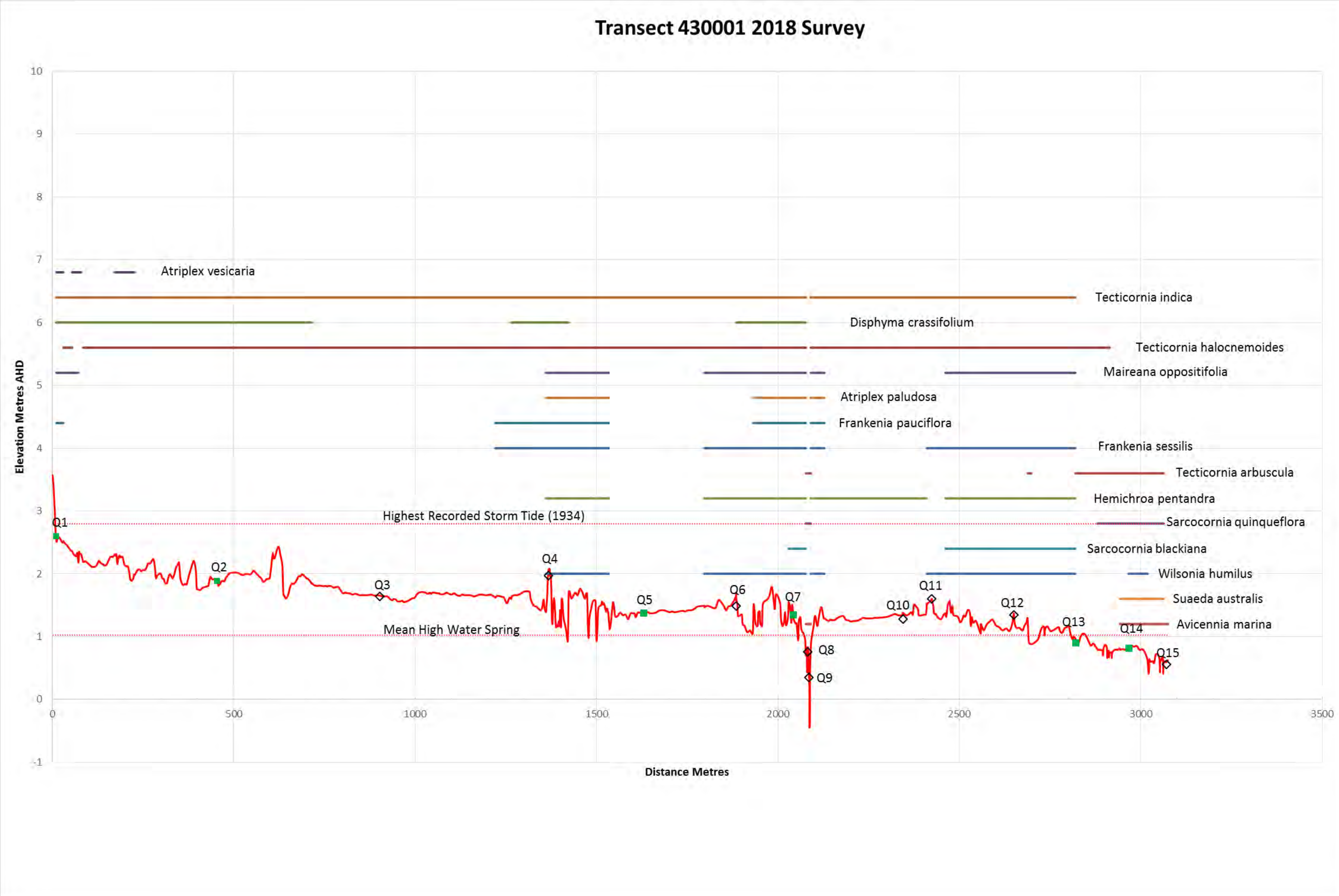

Figure 3. Profile 430001 elevation and plant species distribution, November 2018.

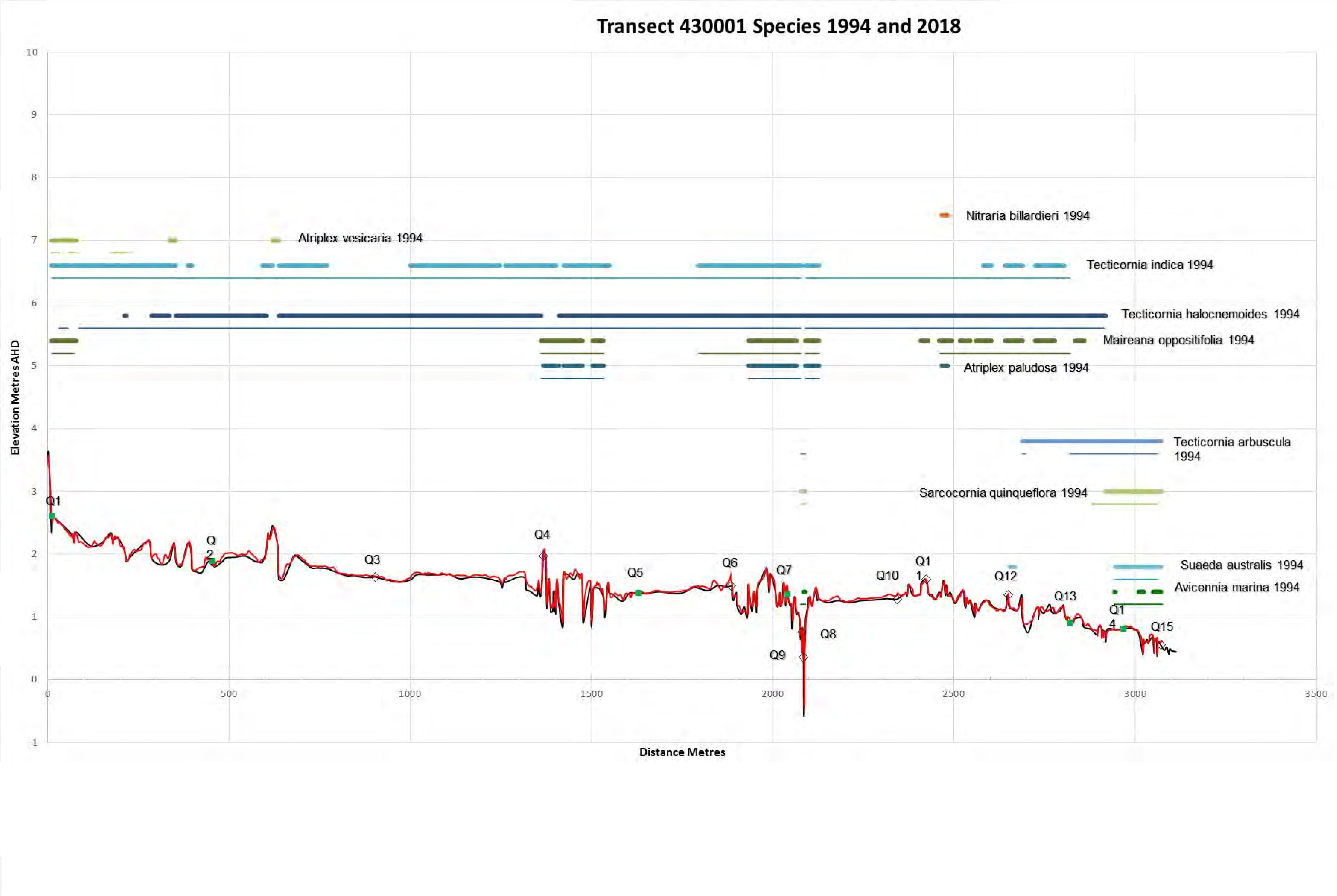

Figure 4. Profile 430001 elevation and overstory species distribution 1994 (thick line) and 2018 (thin line).

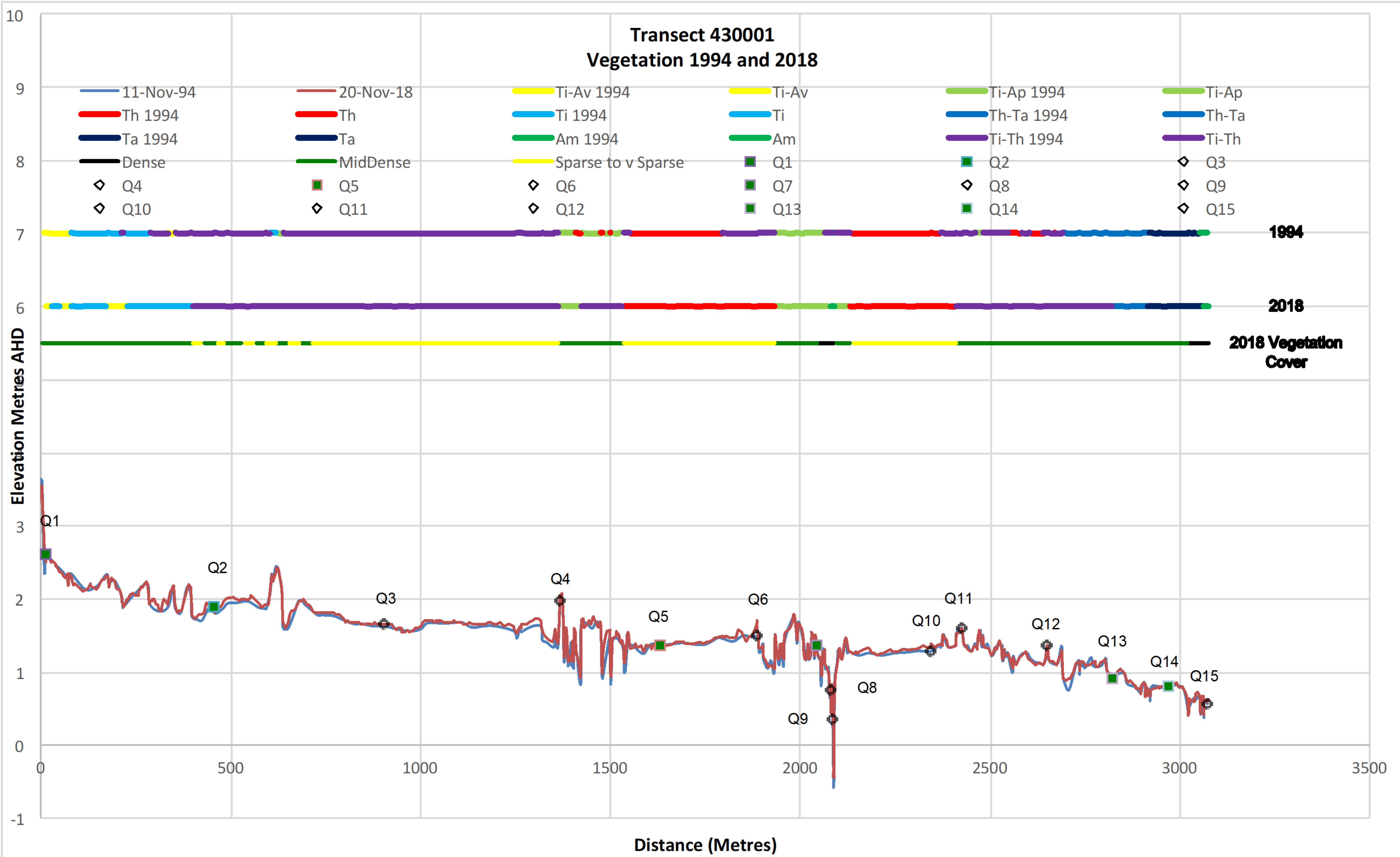

Figure 5. Profile 430001 elevation and distribution of vegetation classes in 1994 and 2018.

Discussion

Sea level change

Frequency of seawater flooding is a major factor determining the distribution of plant species within saltmarshes. Whereas lower parts of the saltmarsh are regularly flooded by astronomical tides on a daily, weekly or monthly basis, the higher parts are only flooded by weather-assisted tides or storm events at intervals ranging from months to years. Some saltmarsh species are quite tolerant of a wide range of flooding frequency, others are restricted to a narrow range.

Site drainage is also an important factor in where different saltmarsh species occur. Some saltmarsh species are tolerant of waterlogged soil conditions that can persist during the winter months. Other species although tolerant of occasional seawater flooding require well drained soils.

Since 1994, sea level would have risen approximately 7 - 8 cm assuming an average sea level rise over much of this period of approximately 3.2 mm a year (IPCC 2014). However, an investigation undertaken by Harvey et. al. (1999) actually recorded land uplift occurring at Port Pirie which was identified to offset the global sea level rise predictions. The investigation included coring, surveying of the land and the dating of sediment facies at Port Pirie. It also included the examination of 64 years of tide gauge records from 1930 to 1994 that showed an average fall of 0.02 mm year. Based on all of these factors, it was estimated by Harvey et al that there was a long-term rate of sea level fall of 0.33 mm/year at Port Pirie.

More recent examination of the tide gauge data (annual mean sea level) from 1940 to 2017 shown in Figure 6 supports this falling sea level trend until about 1997. Since then the record shows a sea level rise. An average rise of 72 mm a year between 1997 and 2000 cannot be correct. Using only the last 15 years of data, from 2002 until 2017, the average sea level rise has been determined to be 3.5 mm a year which approximately accords with the global average.

Mean High Water Spring (MHWS) tide height at Port Pirie shown in Figure 3 is approximately 1 m AHD. Most of the profile exceeds this height and the vegetation is therefore above the reach of astronomical tides. However, approximately 200 m of the profile is subject to regular tides and the entire length of the profile is below the height reached by extreme storm tides. Figure 3 shows the level reached by the 1934 storm tide at Port Pirie. This record storm tide caused major flooding of the town and several deaths. In 2018 strandlines from several storm tides were present near the start of the profile at the levy.

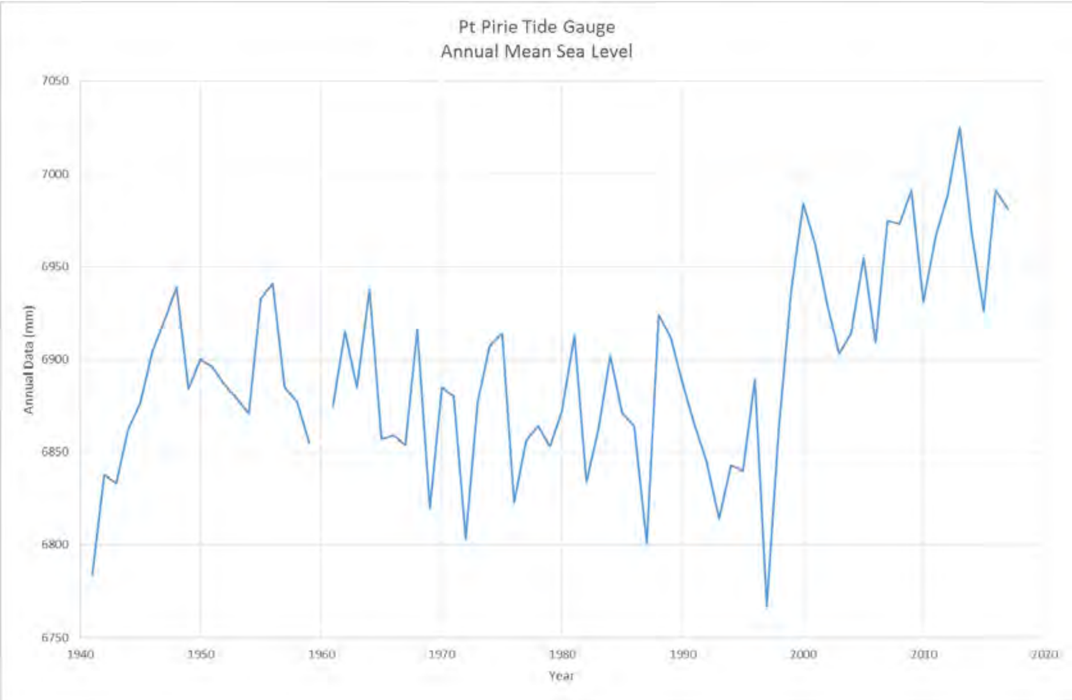

Figure 6. Graph shows annual mean seal level (mm) at Port Pirie 1940 to 2017 (National Tidal Centre Bureau of Meteorology).

Plant species

The 2018 status of the ten species recorded in the 1994 survey and shown in Figure 4 are discussed below.

Atriplex vesicaria. This a high marsh species that only occupies elevated sites rarely flooded by storm tides. In 1994 it occupied an elevated strip alongside the levee and was also found on several ridge tops to approximately 620 m along the profile. Total extent has slightly increased since 1994 but the plant is no longer present on the more seaward ridge tops. It's most seaward position is now 349 m.

This plant is palatable to livestock, rabbits and kangaroos and will have benefited from rabbit control measures since 1994. It may have been less visible in 1994 due to suppression by rabbits. The Millennium drought (van Dijk, 2013) occurred between 1996 and 2009 and this may have caused loss of vegetation on the ridge tops. Increasing exposure to seawater flooding due to sea level rise is another possible cause of loss on the ridgetops.

Tecticornia indica. This species occupies a broad range across both high and mid marsh habitats. In 2018 it occupied a similar range to 1994. In 1994 it was only recorded if it formed an overstory species whereas, in 2018 it was recorded if it was present on the profile. This explains the gaps in the 1994 distribution. Its cover abundance varied considerably along the profile. On well-drained higher sites, it formed a mid-dense overstory but on low poorly drained sites it was only very sparsely present and did not contribute to the overstory.

Maireana oppositifolia. This mid marsh species mainly occupies sites with good drainage such as ridges. Its association with ridges can be seen in Figure 4. In 2018 it occupied a similar range to 1994 although the seaward position based on the records has receded 50 metres. The landward position has not changed.

Tecticornia halocnemoides. Two subspecies of this mid marsh species were recorded in 2018, both were likely present in 1994 but were not identified. *T. halocnemoides ssp. halocnemoides* in the field had a red colouration whereas *T. halocnemoides ssp. longispicata* was taller and had yellow green colouration. By the time it was realized that two subspecies were present, it was too late to map their distribution. Both were often found together and occupied pans and poorly drained sites. Whereas *T. halocnemoides ssp. halocnemoides* tended to predominate on the middle pans, *T. halocnemoides ssp. longispicata* occurred further seaward forming a very distinct shrubland community behind the low marsh communities. The seaward range is similar to 1994 but in 2018 it was recorded approximately 180 m further landward possibly because it wasn't an overstory species and therefore not recorded in the 1994 survey.

Atriplex paludosa. This high marsh species occupied elevated ridges in the middle of the profile. Three sites were recorded in 1994. In 2018 the species was absent from the most seaward ridge. *Nitraria billardierei* was also recorded on this same ridge in 1994 and was also absent in 2018. The Millennium drought or increased flooding by tides are both possible causes of this loss.

Nitraria billardierei. This high marsh species normally found at the back of saltmarshes or on ridge tops was recorded at one ridge top location in 1994 but was not recorded in 2018. As mentioned previously *Atriplex paludosa* recorded at the same location also was not present in 2018. This was rechecked and confirmed in May 2019.

Tecticornia arbuscula. This low marsh species was found along the larger tidal creeks. Its main habitat was along a 125 m wide intertidal zone adjacent the mangrove edge. *T. arbuscula* in 1994 was first recorded with *T. halocnemoides (ssp. longispicata)* at a tidal creek at 2688 m. It was also recorded at 2722 m, and 2793 m. *T. arbuscula* was not recorded at the creek in 2018 but was found in the May 2019 visit. It was not observed again until 2820 m at quadrat 13. This gap was rechecked in May 2018. This disparity is puzzling, as *T. arbuscula* would be expected to increase landwards with rising sea levels.

Sarcocornia quinqueflora. This low marsh species, similar to *T. arbuscula* was recorded where regular tidal flooding occurred. It was recorded along several tidal creeks but its main habitat was a 50 m zone adjacent the mangrove edge. In 2018 it was observed 20 m further landward than the 1994 position.

Suaeda australis. This low marsh species was found adjacent the mangrove edge. Its range in 2018 was very similar to that observed in 1994.

Avicennia marina. The landward position of the mangrove zone has shown little change in position since 1994 and juvenile mangroves were not evident. However, photos show that mangrove trees have increased in height and density.

Vegetation classes

The eight vegetation classes shown in Figure 5 are discussed.

1. *Tecticornia indica - Atriplex vesicaria* low shrubland.

Atriplex vesicaria grew along the base of a flood protection levee at the start of the profile and was also sparsely present on several ridge tops further seaward. During the site visit in May 2019 the ground was dry despite significant rainfall the previous week. Quadrat 1 was located in the community near the levee and is shown in Figure 7. Photos from both surveys are shown.

Figure 7. Quadrat 1 at 11m (2.6 m AHD) showing Tecticornia indica - Atriplex vesicaria low shrubland in 1994 and 2018.Vegetaion growing on smelter slag is visible in the 2018 photo

Data from quadrat 1 is shown in Table 5.

Quadrat 1 Plant Species Recorded	**1994**				**2018**			
2.6 m AHD	**AD**	**LF**	**CA**	**LS**	**AD**	**LF**	**CA**	**LS**
Atriplex vesicaria ssp. sphaerocarpa	O	SD	3	S	O	SC	3	M
Tecticornia indica var. leiostachya	O	SD	3	V	U	SD	2	M
Tecticornia halocnemoides ssp. halocnemoides					O	SC	2	M
Maireana oppositifolia	O	SD	2	S				
Dissocarpus biflorus var. biflorus	U	SD	T	S	U	SD	T	F
Osteocarpum salsuginosum					U	SD	T	V
Disphyma crassifolium	U	P	3	F/S	U	P	T	M
Avena barbata (grass)*	U	GT	T	S				
Senecio glossanthus (herb)	U	J	T	D				
Medicago spp. (herb)*	U	J	T	S				
Frankenia pauciflora var. fruticulosa					U	SD	T	F
Parapholis incurve (grass)*					U	GL	T	De
Total species	9				8			
Average shrub height	No data				(10 samples) 0.564			

Table 5. Quadrat 1 species list. AD = Vegetation Association Description, LF = Life Form, CA= Cover Abundance, LS = Life Stage (for sub codes see Table 1).

Both surveys were undertaken in November but herbs and grasses recorded in the 1994 survey were absent in 2018 due to dry conditions. *Maireana oppositifolia* was not recorded within the quadrat in 2018 but was sparsely present in the surrounding vegetation. *Tecticornia halocnemoides ssp. halocnemoides* was sparsely present in 2018 but not recorded in 1994. *Frankenia pauciflora* was also very sparsely present in 2018 but not recorded in 1994. Species diversity is considered high compared to most of the other quadrats.

Since 1994 the total extent of this community has increased from 86 to 102 m. It currently represents 3.3% of the profile vegetation.

2. Tecticornia indica **low shrubland to low open shrubland association.**
A general view of this low shrubland vegetation dominated by *T. indica* can be seen in the background of Figure 7. This community occupied elevated supratidal habitat mostly within 500 metres of the levee bank. During the site visit in May 2019 the site was dry. Canopy cover varied from mid-dense to sparse. *Tecticornia halocnemoides* was recorded at trace levels. In 1994 the community occupied 220 m. In 2018 the community was mapped further seaward increasing its extent to 285 metres. It currently represents 9% of the profile vegetation.

There are no quadrats or comparison photographs of this association. The mat plant *Disphyma crassifolium* currently forms a sparse to very sparse understory.

3. *Tecticornia indica – Tecticornia halocnemoides* low shrubland to low open shrubland complex.
This extensive, very patchy community occurs on habitat in the middle of the profile. Currently it represents 48% of the profile vegetation. During the site visit in May 2019 the inland parts of this habitat was dry but further seaward the ground was saturated and slushy, due to rain the previous week. There is considerable variation in the relative representation of *T. halocnemoides* and *T. indica*. Overall canopy cover varied from mid-dense to very sparse.

Due to its extent five of the 1994 quadrats are located within this community. Comparative views of the various quadrats are shown in Figures 8 to 12. Both human disturbance and natural change is evident. Quadrat 2 shown in Figure 8 has been disturbed by a track. Slag deposited on nearby saltmarshes since 1994 can be seen in the background. Quadrat 6 shown in Figure 10 appears to have lost vegetation cover since 1994. In 1994 it was classed as *Tecticornia indica – T. halocnemoides* low shrubland but due to the reduced presence of *T. indica* is now classed as a *T. halocnemoides* low open shrubland. At quadrat 11 shown in Figure 11, the *Frankenia sessilis* understory visually present in 1994 and is absent in 2018.

Figure 8. Quadrat 2 at 454 m (1.89 m AHD) showing Tecticornia indica - T. halocnemoides low shrubland. Track disturbance and slag infill can be seen in the 2018 photo.

No 1994 photo record of quadrat 3

Figure 9. Quadrat 3 at 902 m (1.64 m AHD) showing Tecticornia indica – T. halocnemoides low shrubland.

Figure 10. Quadrat 6 at 1884 m (1.28 m AHD) showing vegetation cover loss.

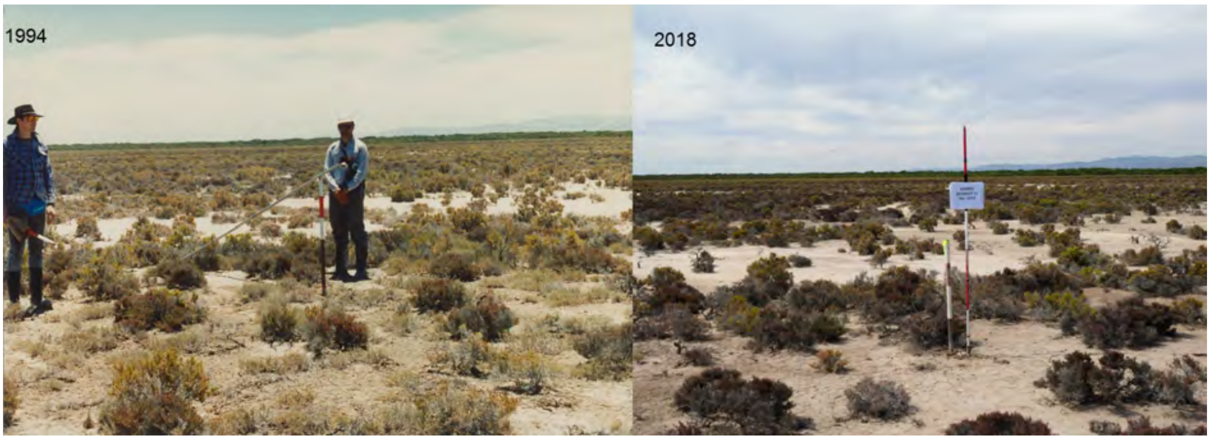

Figure 11. Quadrat 11 located on a rise at 2423 m (1.6 m AHD) showing Tecticornia indica – T. halocnemoides low shrubland. The Frankenia sessilis understory present in the 1994 photo is absent in 2018.

Figure 12. Quadrat 12 on a low rise at 2650 m (1.35 m AHD) showing Tecticornia indica – T. halocnemoides low shrubland. Yellow-green T. halocnemoides ssp. longispicata is evident in both photos.

Quadrat 2 (see Figure 8) was resurveyed and the information is shown in Table 6.

Quadrat 2 Plant Species Recorded	**1994**				**2018**				
1.89 m AHD	**AD**	**LF**	**CA**	**LS**	**AD**	**LF**	**CA**	**LS**	**CA%**
Tecticornia indica var. leiostachya	O	SD	T	S	O	SD	2	V	1
Tecticornia halocnemoides ssp. halocnemoides	O	SD	2	S	O	SD	3	V	16
Tecticornia moniliformis					O	SD	T	V	
Tecticornia pergranulata	O	SD	2	S					
Disphyma crassifolium	U	P	T	S	U	P	T	V	1
Frankenia sessilis	U	SD	1	F					
*Parapholis incurve**	U	GL	N	D					
Species recorded	6				4				
Average shrub height	No data				(10 samples) 0.43				

Table 6. Quadrat 2 species list.

This site was well elevated at 1.89 m AHD. *Tecticornia moniliformis* recorded at quadrat 2 in 2018 was until recently not known to occur in SA. Recent familiarization with this plant helped distinguish it from the other *Tecticornia's*. *Tecticornia pergranulata* was recorded at this quadrat in 1994 but is considered a misidentification and was most likely *T. halocnemoides ssp halocnemoides.*

This complex was 1416 m in extent in 1994 and 1476 m in 2018. It occupies a wide elevation range between the high and low marsh communities. Both subspecies of *T. halocnemoides* occur. *T. halocnemoides ssp. longispicata* had minor representation at higher elevations but became predominant at the seaward end. It formed a distinct mid dense shrub community behind the low marsh vegetation near the mangrove edge.

4. *Tecticornia indica – Atriplex paludosa* low shrubland association

This mid dense community occupies several locations where low ridges provide well drained elevated habitat. During the May 2019 fieldtrip ground conditions on these elevated sites were dry. *T. indica* is the predominant overstory species, with *A. paludosa* sparsely present. A number of mid marsh understory species form a mid-dense understory.

Two 1994 quadrat sites are located in this association. Figure 13 and 14 show comparative views of quadrats 4 and 7 in 1994 and 2018.

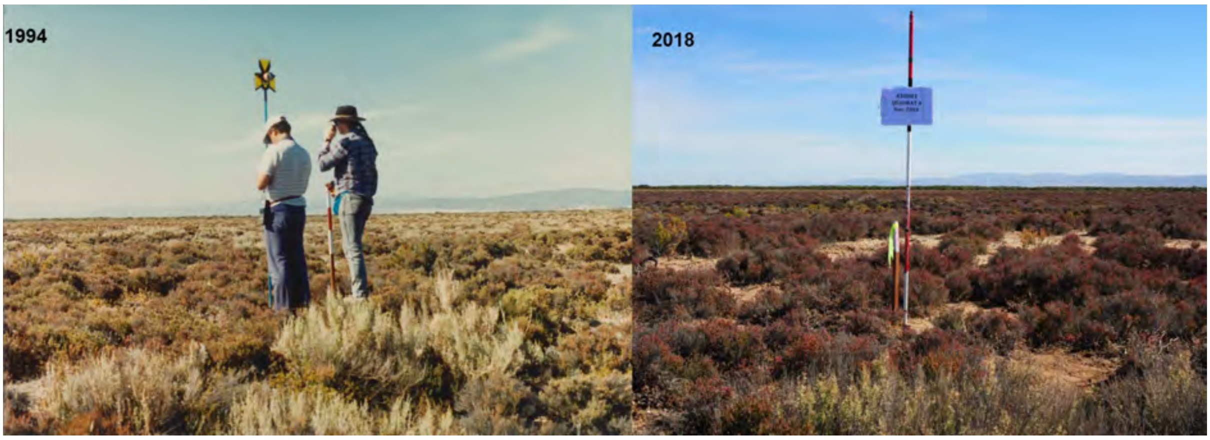

Figure 13. Quadrat 4 at 1367 m (1.97 m AHD) on a ridge showing the Tecticornia indica-Atriplex paludosa low shrubland. A. paludosa seen in the foreground of the 1994 photo is less evident in 2018.

Figure 14. Quadrat 7 on a low rise at 2042 m (1.35 m AHD) showing Tecticornia indica - Atriplex paludosa low shrubland.

Quadrat 7 was resurveyed and the information is shown in Table 7.

Quadrat 7 Plant Species Recorded	**1994**				**2018**				
1.35 m AHD	**AD**	**LF**	**CA**	**LS**	**AD**	**LF**	**CA**	**LS**	**CA%**
Tecticornia indica var. leiostachya	O	SD	3		O	SD	4	V	23
Tecticornia halocnemoides ssp. halocnemoides	O	SD	2		U	SD	T	V	8
Tecticornia halocnemoides ssp. aff. longispicata					O	SC	2	V	
Maireana oppositifolia	O	SD	2		U	SD	T	V	5
Atriplex paludosa ssp. cordata	O	SD	2		E	SD	2	F	4
Frankenia sessilis	U	SD	2		U	SD	T	VF	1
Frankenia pauciflora var. fruticulosa	U	SD	2		U	SD	T	VF	1
Sarcocornia quinqueflora					U	SD	T	V	
Sarcocornia blackiana	U	SD	T		U	SD	T	I	
Tecticornia arbuscula					U	SD	T	V	
Hemichroa pentandra	U	P	2		U	P	2	V	1
Wilsonia humilis	U	P	2		U	P	3	V	41
Species recorded	9				12				
Average shrub height	No data				(10 samples) 0.645				

Table 7. Quadrat 7 species list.

Quadrat 7 is on a ridge adjacent a tidal creek. Three additional species were recorded in 2018. Possibly due to differences in quadrat size. *T. arbuscula* and *S. quinqueflora* are intertidal species found along the adjacent creek. Although not recorded in 1994 the yellow-green *Tecticornia halocnemoides ssp. aff. longispicata* can be seen in the 1994 photograph.

A. paludosa was recorded in 1994 on a ridge at 2466 m. It is no longer present at this location. The photos seem to show a decrease the cover abundance of this species since 1994. This association was 351 m in extent in 1994 and 244 m in extent in 2018. Currently it represents 8% of the profile vegetation.

5. *Tecticornia halocnemoides* low open shrubland association.

T. halocnemoides formed a sparse to very sparse vegetation cover on pans subject to ponding and waterlogging. Generally the understory was sparse or not present. During the site visit in May 2019 some standing water was observed in this habitat as shown in Figure 15.

Figure 15. Standing water and saturated ground conditions between quadrat 5 and 6 in May 2019.

Quadrat 5 at 1630 m shown in Figure 16 and quadrat 10 at 2344 m shown in Figure 17 are located within this community. In addition quadrat 6 (Figure 10) is now also classed in this habitat due to an apparent loss of *T. indica* since 1994. Photos of these quadrats show a loss of vegetation cover.

Figure 16. Quadrat 5 at 1630 m (1.37 m AHD) showing Tecticornia halocnemoides low shrubland.

Figure 17. Quadrat 10 at 2344 m (1.28 m AHD) showing Tecticornia halocnemoides low open shrubland. Loss of vegetation cover since 1994 is evident.

Quadrat 5 was resurveyed and the data is shown in Table 8.

Quadrat 5 Plant Species Recorded	**1994**				**2018**				
1.37 m AHD	**AD**	**LF**	**CA**	**LS**	**AD**	**LF**	**CA**	**LS**	**CA%**
Tecticornia halocnemoides ssp. longispicata					O	SD	T	V	1
Tecticornia halocnemoides ssp. halocnemoides	O	SD	2	V	O	SD	T	V	
Tecticornia spp.					O	SD	T	V	
Species recorded	1				3				
Average shrub height	No data				(10 samples) 0.305				

Table 8. Quadrat 5 species list.

The community currently occupies 682 m representing 22% of the profile. This is an increase from 1994 where it was 578 m in extent and represented 19% of the profile. However cover density appears to be decreasing.

6. *Tecticornia halocnemoides – Tecticornia arbuscula* low shrubland association.

The presence of the low marsh species *T. arbuscula* indicates regular seawater flooding. The site appeared well drained during the May 2019 field visit.

Both subspecies of *T. halocnemoides* were recorded. However *T. halocnemoides ssp halocnemoides* is only very sparsely present. *T. halocnemoides ssp.*

longispicata is much more abundant. Cover abundance of between 15 and 50% was recorded, decreasing in a seaward direction. In contrast *T. arbuscula* recorded an increase in cover abundance in a seaward direction from approximately 15 % to the 25 to 50% range.

Quadrat 13 at 2821 m shown in Figure 18 was resurveyed in 2018. The data is shown in Table 9. It appears that in 1994 only overstory species were recorded. Diversity was high in the 2018 survey, 9 were species recorded including both low and mid marsh species.

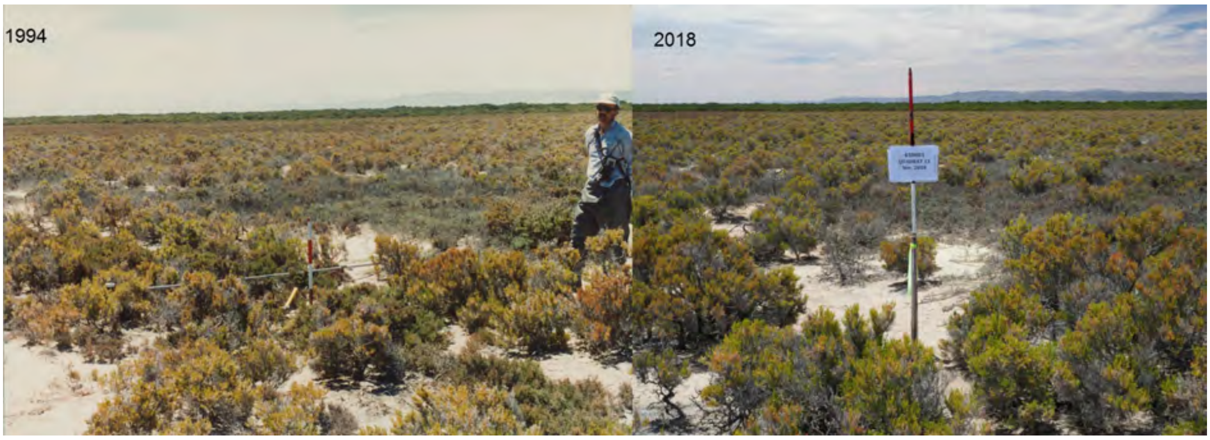

Figure 18. Quadrat 13 at 2821 m (0.9 m AHD) showing Tecticornia halocnemoides ssp. longispicata - T arbuscula low shrubland.

Quadrat 13 Plant Species Recorded	1994				2018				
0.9 m AHD	**AD**	**LF**	**CA**	**LS**	**AD**	**LF**	**CA**	**LS**	**CA%**
Tecticornia indica var. leiostachya					U	SD	N	V	
Tecticornia halocnemoides ssp. halocnemoides					U	SD	N	V	2
Tecticornia halocnemoides ssp. longispicata	O	SD	5		O	SC	3	V	21
Maireana oppositifolia					U	SD	N	V	3
Frankenia sessilis					U	SD	1	V	2
Sarcocornia quinqueflora					U	SD	1	V	
Sarcocornia blackiana					U	SD	N	V	
Tecticornia arbuscula	U	SD	3		U	SD	2	V	2
Wilsonia humilis					U	P	3	V	23
Species recorded	2				9				
Average shrub height	No data				(10 samples) 0.546				

Table 9. Quadrat 13 species list.

The1994 survey records *T. arbuscula* as present with *T. halocnemoides* from 2688 m whereas the 2018 survey does not record this species it until 2820 m. This is a significant disparity between surveys that is puzzling, as *T. arbuscula* would be expected to record a landward shift with rising sea levels.

7. *Tecticornia arbuscula* low shrubland association.

The low marsh species *Sarcocornia quinqueflora* is the main understory species with *Suaeda australis* sparsely present. The matplant *Wilsonia humilis* regarded as a mid-marsh species is also found. The mangrove *Avicennia marina* is present as an emergent.

Quadrats 8 and 14 are located in this community and are shown in Figures 19 and 20. Quadrat 14 was resurveyed and the data from both surveys are shown in Table 10.

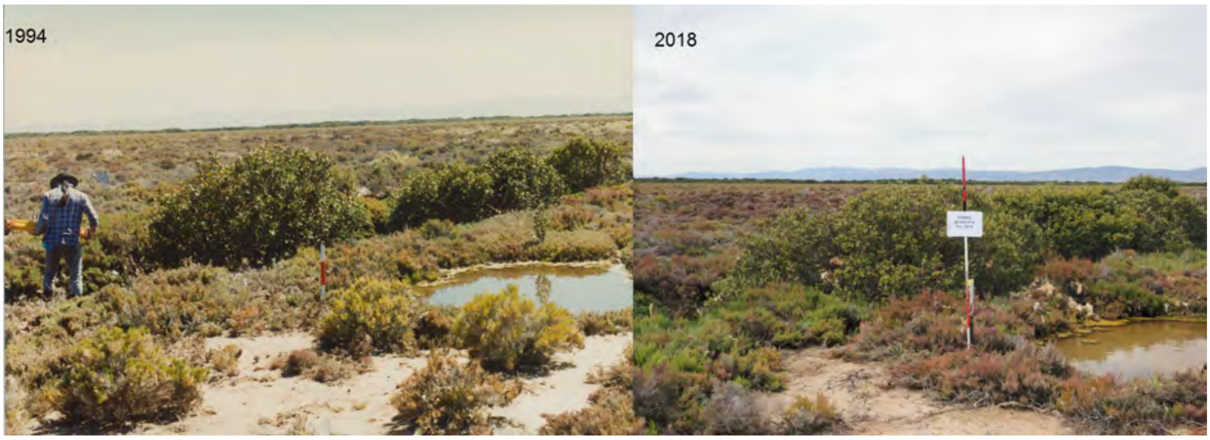

Figure 19. Quadrat 8 near a tidal creek at 2081 m (0.76m AHD). Tecticornia halocnemoides ssp. aff. longispicata is more evident in the 1994 photo. The mangroves are taller and denser in 2018.

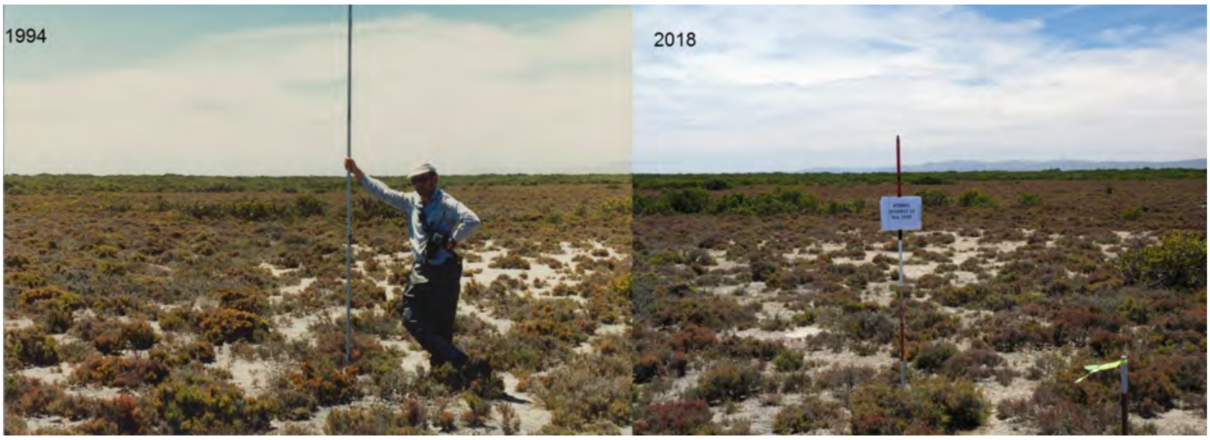

Figure 20. Quadrat 14 at 2967 m (0.81 m AHD) showing Tecticornia arbuscula low shrubland complex.

Quadrat 14 Plant Species Recorded	**1994**				**2018**				
0.81 m AHD	**AD**	**LF**	**CA**	**LS**	**AD**	**LF**	**CA**	**LS**	**CA%**
Sarcocornia quinqueflora	U	SD	3		U	SD	2	V	7
Suaeda australis	U	SD	2		U	SD	N	V	
Tecticornia arbuscula	O	SD	3		O	SD	3	V	42
Wilsonia humilis					U	P	2	V	4
Avicennia marina var resiniferous					E	SC	N	V	
Species recorded	3				5				
Average shrub height	No data				(10 samples) 0.27				

Table 10. Quadrat 14 species list.

The matplant *Wilsonia humilis* although not recorded at the quadrat site, can be seen in the 1994 photo. A mangrove emergent also not recorded in 1994 can be seen in the 1994 photograph.

The community was 134 m in extent in 1994 representing 4% of the profile. In 2018 it was recorded as 148 m in extent representing 5% of the profile vegetation.

8. *Avicennia marina* shrubland to tall shrubland association.
The profile ended at the mangrove zone. The mangrove plants were mature and no seedlings were observed.

Figure 21. Quadrat 15 at 3071 m (0.56 m AHD) in the mangrove zone.

T. arbuscula and *S. quinqueflora* formed the understory.

In 1994 the edge of mangrove zone was identified at 3052 m whereas in 2018 it was recorded as 3062 m. This difference is not significant as the mangrove zone has a fuzzy edge due to mangrove outliers.

Conclusion

The Port Pirie saltmarsh profile was one of the first profiles surveyed as part of the broader sate-wide project to map the distribution of mangrove and saltmarsh habitats in South Australia and had limitations compared with more recent surveys. During the original survey in 1994, only overstory plants were recorded, cover abundance wasn't recorded, quadrats did not conform to BSSA methodology and plants IDs were not checked by the Herbarium. Comparing vegetation classes for 1994 and 2018 was problematic as a result of these inconsistencies. Therefore, reliably detecting small shifts in vegetation boundaries is difficult. Despite the tide gauge indicating an average 3.5 mm annual sea level rise, the intertidal communities appear to occupy the same zone as in 1994. The mangroves which should be a good indicator of sea level rise seem to also occupy the same zone. Mangrove seedlings along the inland edge were not evident, but may be attributed to land uplift (Harvey et al 1999) that has been reported at Pt Pirie mentioned earlier in this report which would offset global sea level rise. The apparent loss of *Tecticornia arbuscula* is also puzzling.

Nevertheless changes to the profile vegetation is evident from this limited data. The photographs have been particularly valuable in identifying change. Some of the changes are the result of human disturbance, particularly in the inland part of the profile near the township. Since 1994, slag heaps from the smelter are now a visible feature on the photographs.

Most of the change along the profile however appears to be natural in origin. The greatest apparent change is occurring to the *Tecticornia indica-T. halocnemoides* and *T. halocnemoides* plant complexes. These two supratidal communities represent 70% of the profile, mainly occupying the pans in the mid part of the profile. Since 1994 vegetation cover appears to have decreased in these pan environments. The loss of the understory is also evident. *T. indica* appears to be preferentially impacted but *T. halocnemoides* has also been affected. The cause of the change is not apparent and requires further investigation. Key areas of investigation should include environmental parameters such as hydrology, soil environments and changes in climatic conditions.

Some changes were observed in the ridge vegetation. *Nitraria billardierei* observed on a ridge in 1994 was no longer present in 2018. The cover abundance of *Atriplex paludosa* appears to have decreased. Both *Atriplex paludosa* and *A vesicaria* are also now absent from several ridges where they were previously recorded in 1994. This loss could be due to an increased exposure to seawater flooding. However, it could also be caused by the Millennium drought. The Millennium drought may have been associated with predicted climate change. Drier and hotter conditions are predicted in the future.

The 2018 survey did not record *T arbuscula* at several sites near the intertidal zone where it was recorded in 1994. However the data (3 records) is not considered sufficient to be definitive about whether actual loss has occurred here.

Key findings

- The Port Pirie saltmarshes have very likely experienced a 6 to 8 cm rise in sea level since 1994.
- Significant change since 1994 is evident, mainly affecting vegetation in the pans occupying the mid part of the profile. Ridge vegetation also shows some change with loss of *Atriplex spp*. and *Nitraria spp*. which were both previously recorded in 1994.
- Although a rise in sea level is a possible cause of change, other climatic factors such as reduced rainfall and increased temperature averages could also be contributing causes.

Methodological learnings

Comparison of the two surveys was limited due to information gaps in the 1994 survey. Key issues identified included:

1. Plants were field identified only.
2. Only overstory species were recorded during the 1994 profile survey.
3. Cover abundance was not recorded except at quadrat sites.
4. Quadrats did not conform to BSSA methodology.

These information gaps were addressed in later profile surveys, however this resulted in challenges when the data was compared. Nevertheless, the 2018 survey will provide a lot more information for a future resurvey and comparison.

Recommendations

The profiles provide good opportunities for additional research. Research organizations should be encouraged to use the saltmarsh profiles to undertake research on environmental parameters such as hydrology, soil environments, and climatic conditions to better understand the causes of change currently being observed along the profiles.

The photographs were very useful. Archival storage and/or high resolution scanning of the original photographs is recommended.

To date two historic saltmarsh profiles have been resurveyed - the Port Pirie Saltmarsh Survey, subject of this investigation, along with the re-survey of the Sandy Point Saltmarsh Profile (Fotheringham et al, 2018). Both have shown change. Continued resurvey of other historic saltmarsh profiles is recommended.

References

Fotheringham D.G. (1995) *Possible impact of two sea level rise scenarios on salt marsh communities at Port Pirie, South Australia.* Technical Report 95/1 Coastal Management Section. Department of Environment and Natural Resources.

Fotheringham D.G., Quinn J. and Virag A. (2018) *Observations concerning possible sea level rise effects on a monitored saltmarsh near Sandy Point, Gulf St Vincent, South Australia.* Technical Report 2018/01 Coastal Management Branch, Department for Environment and Water.

Harvey N, Clouston B, Carvalho P (1995) *Coastal Vulnerability Study, Northern Spencer Gulf, SA.* A report prepared by the Mawson Graduate Centre for Environmental Studies SA for the Department of the Environment, Sport and Territories.

Harvey N, Barnett E.J, Bourman R., Belperio A.P. (1999) *Holocene Sea-Level Change at Port Pirie, South Australia: A Contribution to Global Sea- Level Rise Estimates from Tide Gauges*. Journal of Coastal Research 15 (3) pp 607 - 615

Heard L and Channon B 1997 *Guide to a native vegetation survey using the Biological Survey of South Australia methodology* Department of Housing and Urban Development.

IPCC, 2014. Climate Change 2014: Synthesis Report. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L. A. Meyer (eds)]. IPCC, Geneva, Switzerland, 151 pp.

Van Dijk A.H, Beck E, Crosbie R.S, de Jeu R.A.M, Lui Y.Y, Podger G.M, Timbal B and Viney N.R (2013). *The Millenium Drought in southeast Australia (2001-2009): Natural and human causes and implications for water resources, ecosystems, economy, and society.* Water Resources Research 49:1040-1057.