

Benthic Macroinvertebrate survey 2017-2018 – brief summary report

Coorong and Murray Mouth Icon Site

**Report for the
Department of Environment, Water and Natural Resources
and the Murray-Darling Basin Authority**

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1. Introduction

The Lower Lakes, Coorong and Murray Mouth is listed as a Ramsar wetland, protected as a National Park and partially as a Marine Park in the Encounter Bay region. Over the past decade there have been extreme environmental changes with the Millennial Drought and subsequent flood events (Wainwright and Christie 2008, Paton et al. 2009, Kingsford et al. 2011; Dittmann et al. 2015) (Figure 1). Typical of estuaries elsewhere in the world (Nebra et al. 2016), salinity is an important factor explaining macroinvertebrate distributions in the Murray Mouth and Coorong due to a strong salinity gradient (Dittmann et al. 2015; Hemraj et al 2017; Hossain et al. 2017).

Several years of continuous flow with moderate to high flow volumes have led to a recovery from drought conditions in the estuarine Murray Mouth and North Lagoon, but there were little signs of improvement in the South Lagoon (Dittmann & Baring 2016; Dittmann et al. 2016). Continued monitoring will identify further changes and whether the objectives and targets set by the Murray – Darling Basin Authority’s (MDBA) Living Murray Condition Monitoring Program are met.

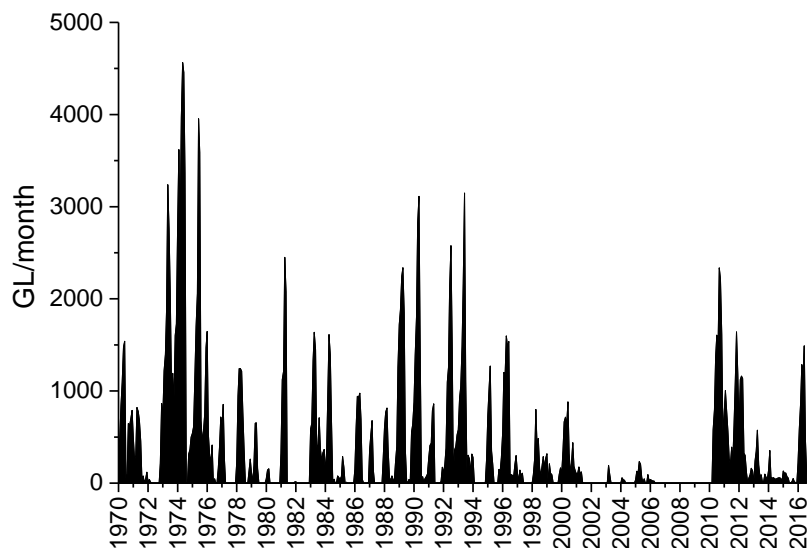


Figure 1: Monthly flow through the barrages from the Lower Lakes into the Murray Mouth and Coorong from 1970-2016. Based on modelled monthly barrage outflow data from the MDBA. Note, macroinvertebrate and mudflat monitoring has been undertaken from 2004 onwards.

The assessment of macroinvertebrates, sediment grain size, organic matter and microphytobenthic biomass, together with water quality measurements at the study sites, will inform on the habitat value of mudflats in the Murray Mouth and Coorong. These parameters are linked to the following objectives of the Condition Monitoring Plan (Revised) 2017 The Living Murray - Lower Lakes, Coorong and Murray Mouth Icon Site (DEWNR 2017):

- a) Maintain or improve mudflat invertebrate communities that are of high condition relative to southern Australian estuarine ecosystems (formerly objective I-1 – Maintain or improve invertebrate populations in mudflats)
- b) Maintain or improve habitable sediment conditions in mudflats (formerly M-2 – Maintain sediment size range in mudflats, and M-3 – Maintain organic content for mudflats).

Data from this monitoring are also informing the objective

- c) Support aquatic habitat by establishing and maintaining variable salinity regimes in the Murray Mouth Estuary, North Lagoon and South Lagoon (formerly objective W-1).

Based on the analyses, the following targets for macroinvertebrates and mudflats were assessed:

1. *Macroinvertebrate species richness increases throughout the Murray Mouth and Coorong.*
2. *Macroinvertebrate occurrence extends along the Coorong into the South Lagoon.*
3. *The area of occupation for typical estuarine and marine macroinvertebrate species exceeds 60% of the sites sampled.*
4. *Macroinvertebrate abundance is maintained at, or increases above, reference levels.*
5. *Macroinvertebrate biomass is maintained at, or increases above, reference levels.*
6. *Macroinvertebrate communities are similar to those occurring under intermediate continuous flows.*
7. *Habitable sediments are occurring along the Coorong into the South Lagoon.*
8. *Sediments are maintained as fine to medium sands and are mostly moderately well sorted.*
9. *Sediment organic matter is maintained.*
10. *Sediments provide microphytobenthic food for the benthic food web.*

In this brief summary report, findings from the December 2017 monitoring of macroinvertebrates and mudflat condition are presented with data from previous years (2004 onwards) for reference condition and Indices of Relative Change as proposed in the Condition Monitoring Plan for The Living Murray – Lower Lakes, Coorong and Murray Mouth Icon Site (Dittmann 2017).

3. Materials and Methods

3.1 Sampling sites and dates

Macroinvertebrate monitoring occurred at the same eleven sites used in previous monitoring and identified in the TLM Condition Monitoring Plan for the Lower Lakes, Coorong and Murray Mouth Icon Site (Maunsell 2009, DEWNR 2017). The sites cover the region from the Goolwa Barrage to the southern end of the Coorong, with five sites located in the Murray Mouth area, and three sites each in the North and South Lagoon of the Coorong (Figure 2, Table 1). An ecological distinction occurs in the southern North Lagoon (between Noonameena (site 7) and Parnka Point (site 8), and therefore the region is defined by the North and South Coorong (Dittmann 2017).

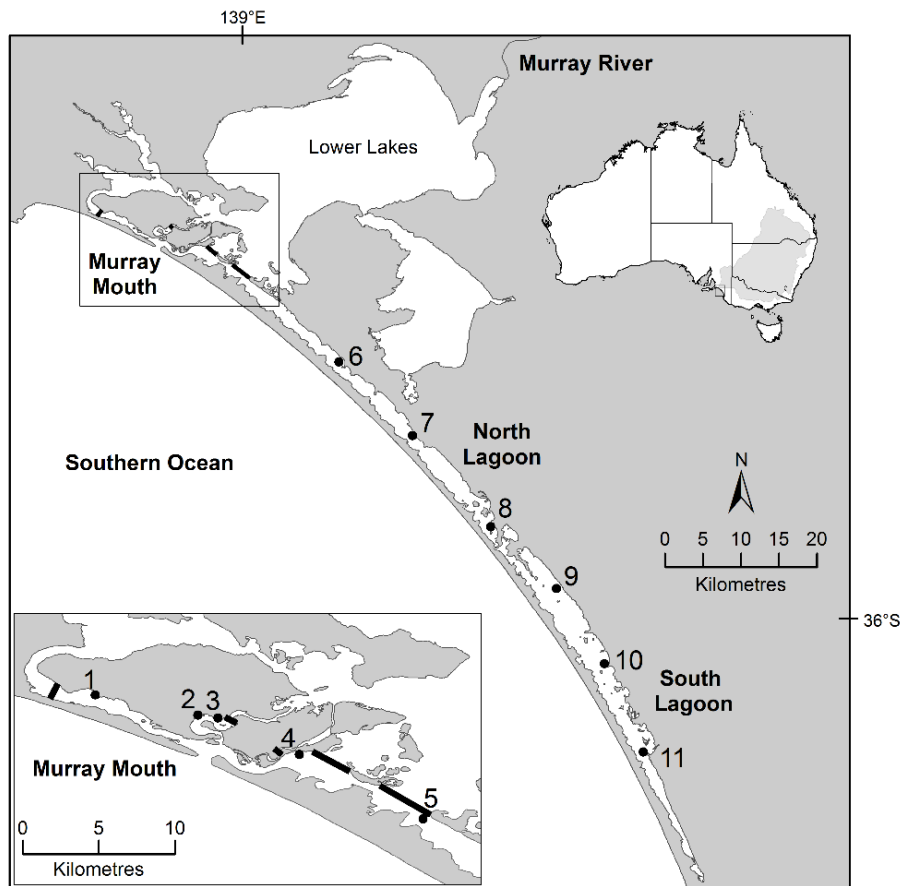


Figure 2: Location of study area and sampling sites for macroinvertebrate monitoring in the Murray Mouth and Coorong. See Table 1 for the site names.

The 2017 survey was conducted in early summer (December) and all mudflats were accessible by shore (Table 1). Sediment at the Parnka Point site was again smothered by extensive dense filamentous green algal mats as seen earlier in 2017 during mudflat surveys. Several species of shorebirds were noted, particularly at sites in the North Coorong, and waterbirds as well as terns were also present. Samples were taken at several distances from the shore to the water's edge and into knee deep water, covering approximately between 10 to 200 m from shore. At Villa de Yumpa, the

sediment surface was slimy and slippery, similar to conditions observed in previous surveys during 2016/17.

Table 1: Sampling sites and dates for macroinvertebrate monitoring in December 2017. See Appendix 1 for coordinates and daytime of sampling.

Region	Site		Sampling dates
	Code	Name	Spring
North Coorong	1	Monument Road	6/12/17
	2	Hunters Creek	6/12/17
	3	Mundoo Channel	4/12/17
	4	Ewe Island	4/12/17
	5	Pelican Point	6/12/17
	6	Mulbin Yerrok	5/12/17
	7	Noonameena	5/12/17
South Coorong	8	Parnka Point	5/12/17
	9	Villa de Yumpa	5/12/17
	10	Jack Point	4/12/17
	11	Loop Road	4/12/17

3.2 Environmental parameters

Sediment characteristics and water quality were measured in the field during the December 2017 survey. Assessing these environmental parameters informs the evaluation for the condition monitoring objectives M-2 and M-3 (maintaining sediment size ranges and organic matter content) and W-1 (assessing estuarine conditions) (DEWNR 2017).

Water Quality

Various water quality characteristics were obtained; temperature, dissolved oxygen (DO) concentration and saturation, salinity (ppt) and pH, at all of the sites during sampling in December 2017. Three replicate measurements for each parameter were taken at each site and in each survey. For long term comparability and measurements in extreme hypersaline waters, salinity was measured with a refractometer from the water column and additionally from the residual pore water of the core sampling. Salinity data presented in this report are all based on the refractometer readings.

Further environmental measurements were recorded with a hand-held Hannah HI98194 Multiparameter Meter that was used to measure; temperature, DO concentration and saturation, pH, conductivity, salinity and total dissolved solids (TDS) at all sites. For the pH of sediment, pH indicator strips were used (Acilit 0-14).

Sediment analyses

In December 2017, sediment samples were obtained from each site for the analysis of grain size, organic matter content and chlorophyll-*a* (as a proxy for microphytobenthic biomass). To account for spatial variation, three replicate samples of each sediment parameter were taken per site and survey, and analysed separately. All sediment samples were stored in a portable freezer (-4°C) in the field and frozen (-20°C) upon return to the laboratory until further analysis.

For sediment organic matter, samples were extracted using a cut off 10 mL syringe (surface area 1.8 cm²). To obtain a bulk parameter of organic matter as % dry weight (d.w.), sediment samples were dried to constant weight using an Ohaus MB45 Moisture Balance. Sediment samples were homogeneously distributed onto aluminium trays and dried using a standard drying protocol (controlling the temperature profile at 80 °C). The profile burn was automatically completed after all moisture content was dried and remained stabilised for 30 seconds of drying time. Samples were then burnt in a muffle furnace at 450 °C for 5 hrs.

For sediment grain size, samples were taken using a cut-off 60 mL syringe (surface area 6.6 cm²). Grain size was determined by laser diffraction using a particle size analyser (Malvern Mastersizer 2000). After frozen samples were thawed, the fraction >1 mm was sieved off manually to avoid blockage in the machine. To correct for this procedure, the weight of this fraction and of the remaining sediment were determined and normalised in the data set. Median and quartiles as well as percentages of various particle sizes were obtained from the Mastersizer output. Sediment sorting was calculated using the formula $S_o = (P_{25}/P_{75})^{1/2}$ from plotting cumulative curves in a percent finer direction (Bale & Kenny 2005).

For chlorophyll-*a*, sediment surface was sampled with a 5 mL vial inserted 1 cm into the sediment. Subsequently, 5 mL of methanol was added to extract the chlorophyll, and the vial was vigorously shaken before being wrapped in aluminium foil (Seuront and Leterme 2006). Samples were later analysed with a fluorometer (Turner 450). After the initial reading for total chlorophyll, drops of 0.1 M HCl were added to the samples to correct for phaeophorbides.

3.3 Macrofauna

During the December 2017 survey, all mudflats were exposed and accessible from shore. Samples for macroinvertebrates were taken using handheld PVC corers (83.32 cm² surface area) with ten replicate samples haphazardly taken per site which were then sieved through 500 µm mesh size in the field.

Where possible, samples were sorted live within a few days of collection, but due to the very high abundances encountered at some sites, many samples had to be preserved in 70% ethanol until further processing. After sorting, specimens were identified to the lowest possible taxonomic level and the numbers of individuals of each species were counted. Amphipods and chironomid larvae were not differentiated to species, as shorebirds are unlikely to be selective towards particular species of these taxa as prey. While identification was to the lowest taxonomic unit possible and reasonable for the objectives of the monitoring, the terminology 'species' or 'taxa' is used throughout the report. All

polychaete specimens with a complete anterior region (prostomium) were included in abundance counts, but polychaete fragments were included with the complete specimens for biomass determination. The larval and pupae stages of insects were recorded, while all adult winged life stages were excluded as they are highly motile and not part of the benthic macrofauna. All macroinvertebrates were further preserved in 70 % ethanol until biomass determination.

Biomass was analysed for all macroinvertebrates per replicate sample and not differentiated per phyla. Each sample was dried to constant weight (d.w.) using an Ohaus MB45 Moisture Balance. Specimens were homogeneously distributed onto aluminium trays and dried using a standard drying protocol (controlling the temperature profile at 80 °C). The profile burn was automatically completed after all moisture content was dried and remained stabilised for 30 seconds of drying time. Samples were then placed in a muffle furnace at 450 °C for 5 hours. Samples were removed from the furnace and cooled in a desiccator before final weighing. The weight after burning was subtracted from the dry weight to obtain the biomass measurement as grams of ash free dry weight (g AFDW).

3.4 Data Analysis

The analysis follows procedures used in previous monitoring reports (e.g. Dittmann et al. 2014, Dittmann & Baring 2016), and also adopts approaches outlined in the TLM refinement process for macroinvertebrates and mudflat. Both regional groupings (Table 1) are used, with the old regional grouping mostly useful for environmental data and long term comparisons. For long-term comparisons, data from previous monitoring since 2004 were included, yet no TLM spring/early summer monitoring occurred in 2014. In this transition report between current and future condition monitoring, the reference conditions, such as for the Index of Relative Change, were taken from the refinement process, based on years from 2004-2013 (Dittmann 2017).

Diversity data are reported as species richness (number of species S), and several indices, Shannon-Wiener diversity (H') using \log_e , Margalef's Index (d) for species richness and Pielou's Index (J') for equitability. For comparison over time, a tolerance range is included for species numbers based on the TLM refinement on data from 2004-2013.

An Index of Occurrence was calculated as the number of sites where a species was found across all sites sampled in the survey. Converted to percent, this index equates to the Constancy Index, used here with a finer breakdown for the index classifications following Rabaoui et al. (2009). Both measures are depicted for long term changes since 2004.

Due to the large spread in some environmental conditions and macroinvertebrate abundances in the samples within and between sites, data were mostly treated as non-parametric and are displayed as box and whisker plots, showing the median, the 25th and 75th percentiles, and outliers (1.5 IQR = interquartile range).

For long-term comparisons of macroinvertebrate abundances and communities, rare species were excluded. The six species of Hydrobiidae (small gastropod snails of ~2-4 mm size) were combined to family level for long-term comparisons of communities, as they were not differentiated in all years.

Prior to multivariate community analyses, macroinvertebrate data were log-transformed ($\log(x+1)$), and a dummy value of 1 added to the Bray-Curtis similarity, because of the large number of 0 values. Community configurations are displayed as nMDS plots with trajectories for the North and South Coorong, with overlays of significantly different clusters as identified by SIMPROF tests.

4. Results – Murray Mouth and Coorong

4.1 Mudflat habitats in the Murray Mouth and Coorong

4.1.1 Water quality

4.1.1.1 Salinity

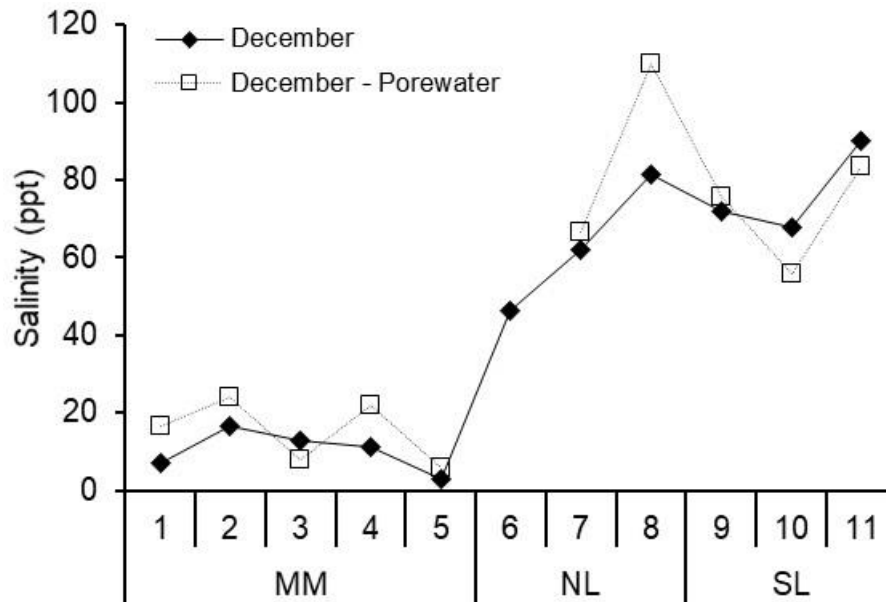


Figure 3: Salinity (average of three measurements per site taken with a refractometer) in the water overlying the mudflats at the 11 sampling sites in the Murray Mouth (MM), North (NL) and South (SL) Lagoon of the Coorong during the spring survey in December 2017 (black symbols) Salinity was also measured in pore water at most of the sites.

4.1.1.2 Dissolved oxygen

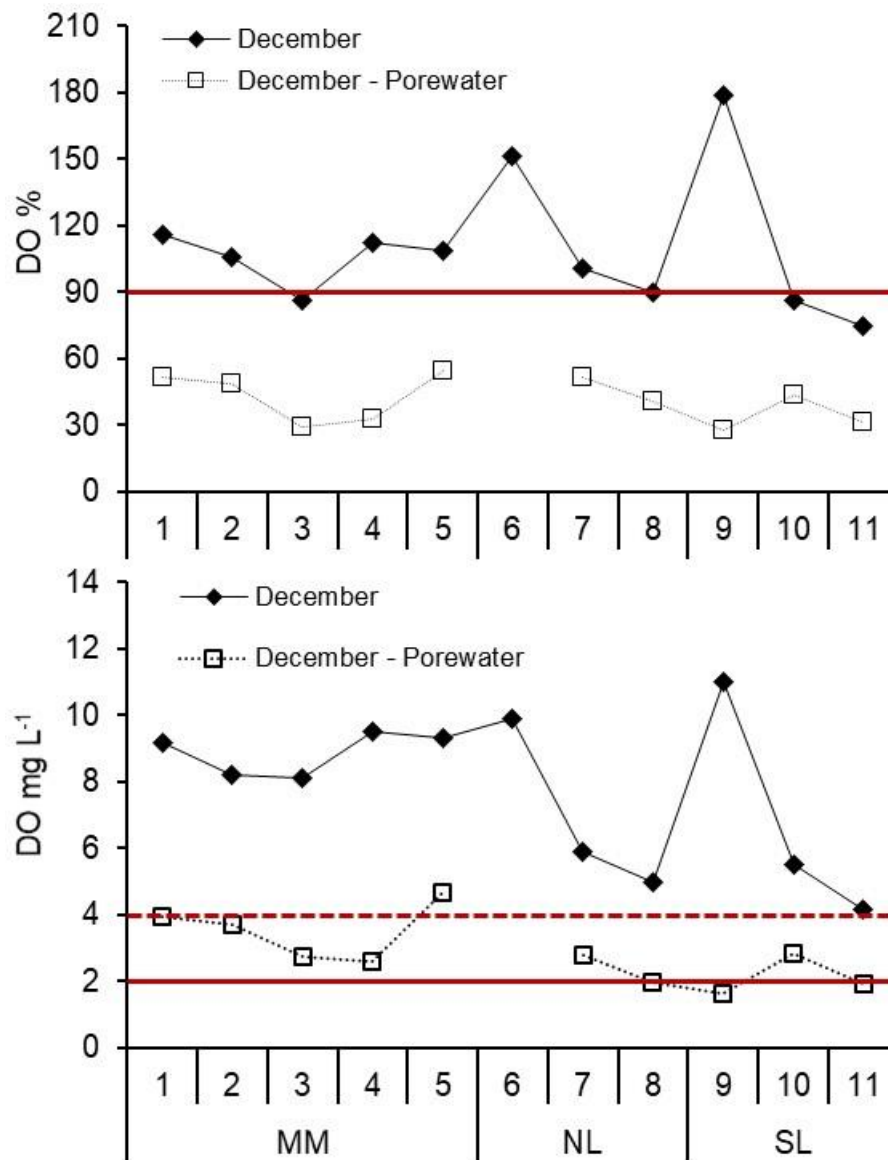


Figure 4: Dissolved oxygen (DO) at the study sites over the two surveys in December 2017. DO was measured in the water above the mudflats and also in pore water from the sediment. a) DO saturation, red line indicates the 90% trigger value of the ANZECC Guidelines; b) DO concentration, the dotted red line indicates low DO (<4 mg/L), and the solid red line demarcates hypoxic concentrations (<2 mg/L).

4.1.2 Sediment characteristics

4.1.2.1 Grain size composition

Table 2: Sediment characteristics (median grain size, sorting coefficient S_o and organic matter content in percent dry weight) from the survey carried out in spring (December 2017) at the eleven sites in the Murray Mouth and Coorong. Values are averages from three replicate samples per site.

Region	Site	Organic Matter (% DW)	Grain size (μm)	Grain size description	Sorting S_o	Sorting description
December 2017						
North Coorong	1	2.15	174	Fine sand	0.78	moderately well sorted
	2	1.86	167	Fine sand	0.80	moderately well sorted
	3	1.77	165	Fine sand	0.70	moderately sorted
	4	1.44	166	Fine sand	0.79	moderately well sorted
	5	1.10	297	Medium sand	0.66	moderately sorted
	6	1.90	183	Fine sand	0.77	moderately sorted
	7	0.90	205	Fine sand	0.76	moderately sorted
South Coorong	8	3.09	224	Fine sand	0.74	moderately sorted
	9	16.97	69	Very fine sand	0.34	extremely poorly sorted
	10	1.90	240	Fine sand	0.68	moderately sorted
	11	2.71	230	Fine sand	0.73	moderately sorted

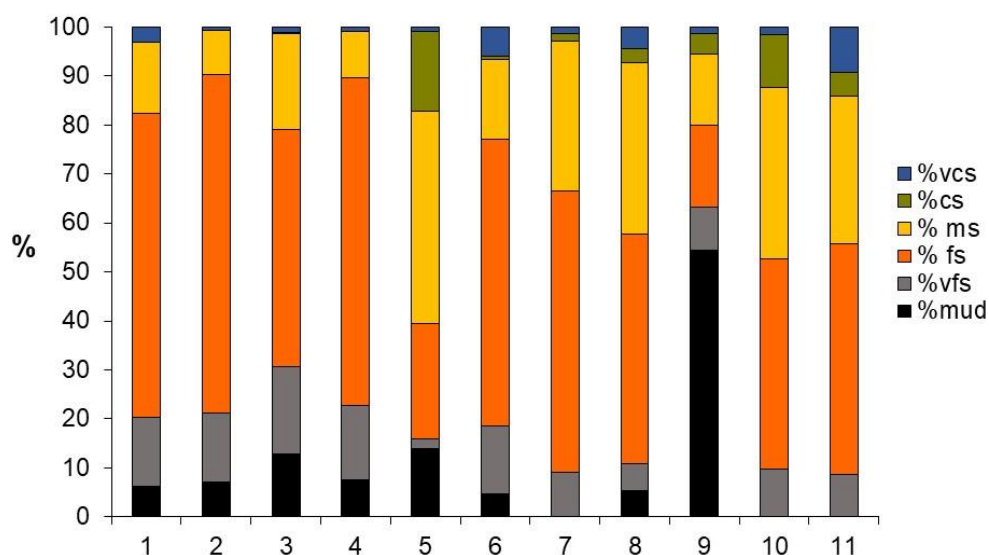


Figure 5: Grain size composition of sediments at the study sites in the Murray Mouth, North and South Lagoon of the Coorong over the survey in spring (December 2017). The grain size fractions are: %mud <63 μm , %vfs (very fine sand) 63-125 μm , %fs (fine sand) 125-250 μm , %ms (medium sand) 250-500 μm , %cs (coarse sand) 500-1000 μm , %vc (very coarse) >1000 μm .

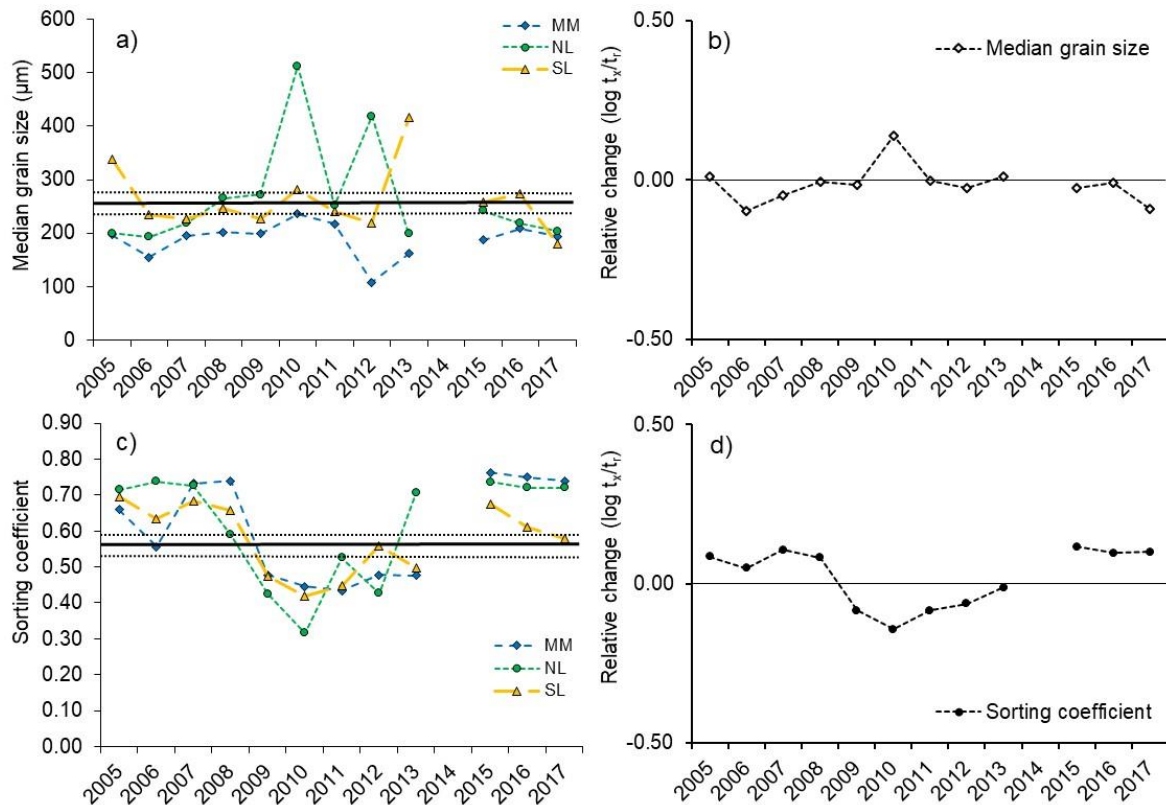


Figure 6: Long term changes in median grain size (a, b) and sorting coefficient (c, d) in mudflats over the monitoring years since 2005 (no TLM monitoring in 2014). Average of a) median grain sizes and b) sorting coefficient for the Murray Mouth (MM), North (NL) and South Lagoon (SL) of the Coorong. The horizontal black and dotted lines indicate a reference, based on the monitoring years from 2005-2013, with 90 % confidence intervals. Index of Relative Change for the c) median grain size and d) sorting coefficient for all monitoring sites (irrespective of region). Index values are plotted as a ratio of observed values (averages per year t_x) to reference data (t_r) obtained from the monitoring 2005-2013. The black line at 0 marks where observed values equal the reference values.

4.1.2.2 Sediment organic matter and chlorophyll-a

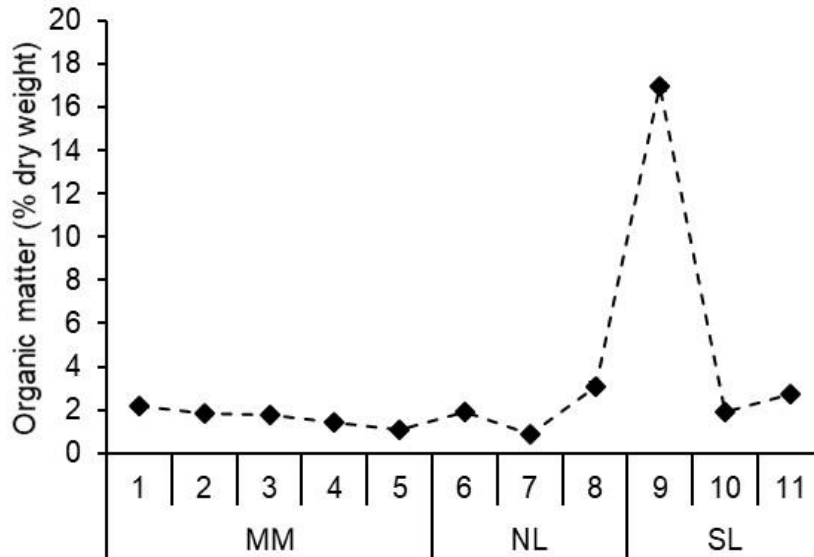


Figure 6: a) Sediment organic matter content at the study sites in spring (December 2017).

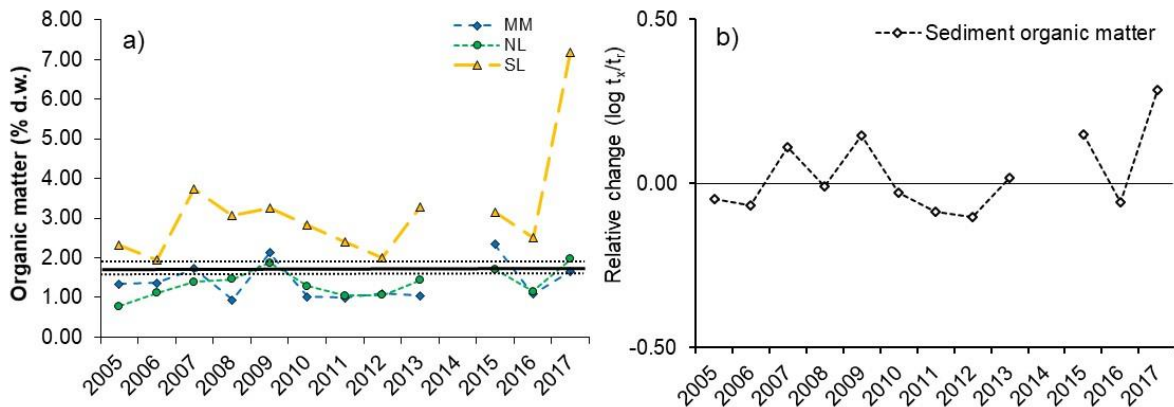


Figure 7: Long term changes in sediment organic matter since 2005 (no TLM monitoring in 2014). a) average of organic matter across the study sites in each of the regions Murray Mouth (MM), North (NL) and South Lagoon (SL) of the Coorong. The horizontal black and dotted lines indicate a reference, based on the monitoring years from 2004-2013, with 90 % confidence intervals. b) Index of Relative Change for sediment organic matter for all monitoring sites (irrespective of region). Index values are plotted as a ratio of observed values (averages per year t_x) to reference data (t_r) obtained from the monitoring 2005-2013. The black line at 0 marks where observed values equal the reference values.

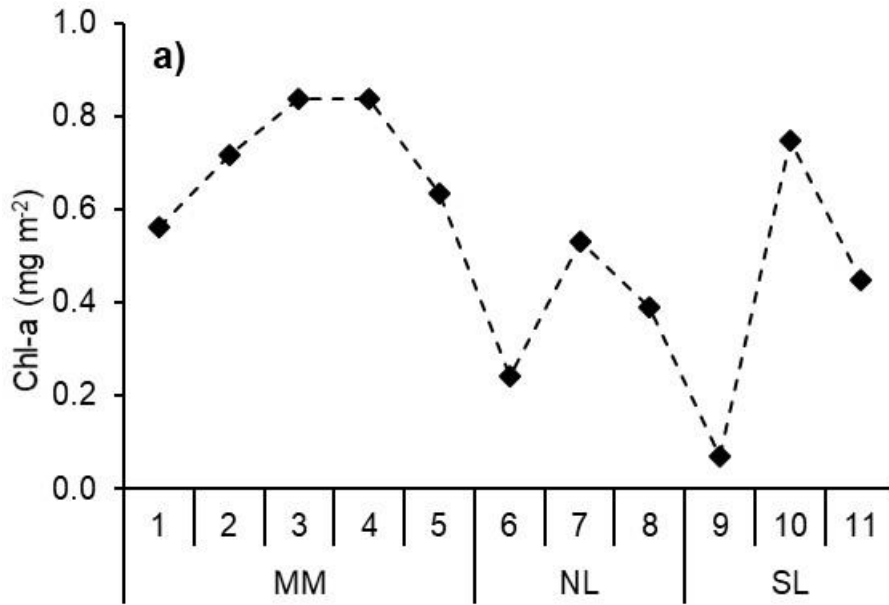


Figure 8: a) Sediment chlorophyll-a content at the study sites over the two surveys in spring (December 2017).

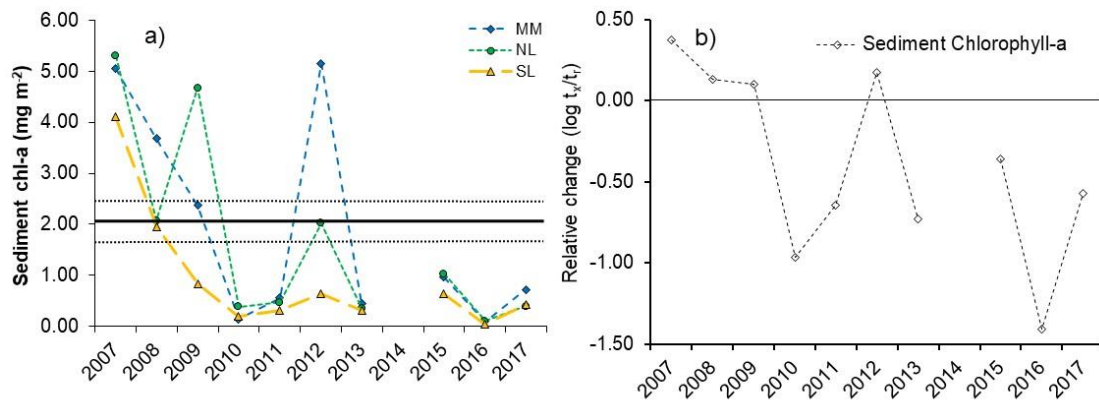


Figure 9: Long term changes in sediment chlorophyll-a content measured since 2007 (no TLM monitoring in 2014). a) average of chlorophyll-a across the study sites in each of the regions Murray Mouth (MM), North (NL) and South Lagoon (SL) of the Coorong. The horizontal black and dotted lines indicate a reference, based on the monitoring years from 2004-2013, with 90 % confidence intervals. b) Index of Relative Change for chlorophyll-a for all monitoring sites (irrespective of region). Index values are plotted as a ratio of observed values (averages per year t_x) to reference data (t_r) obtained from the monitoring 2005-2013. The black line at 0 marks where observed values equal the reference values.

4.2 Macroinvertebrate populations

4.2.1 Macroinvertebrate species richness, diversity and distribution

Table 3: Species list of macroinvertebrates recorded at the study sites through sampling (√) and field observations (#) during the December 2017 monitoring. The total number of taxa per site based on samples and observations is also given, as well as the number of taxa for the two main regions. The number of taxa is also indicated per site and region. Sampling sites were: Site 1 = Monument Road; 2 = Hunters Creek; Site 3 = Mundoo Channel; Site 4 = Ewe Island; Site 5 = Pelican Point; Site 6 = Mulbin Yerrok; Site 7 = Noonameena; Site 8 = Parnka Point; Site 9 = Villa dei Yumpa; Site 10 = Jack Point and Site 11 = Loop Road. See Figure 2 for site locations.

Phyla/Class/Order	Family/Genus/Species	North Coorong							South Coorong				
		1	2	3	4	5	6	7	8	9	10	11	
Annelida Polychaeta	<i>Capitella spp.</i>			✓			✓	✓	✓		✓		
	<i>Simplisetia aequisetis</i>	✓	✓	✓	✓	✓	✓	✓					
	<i>Nephtys australiensis</i>				#		✓						
	<i>Phyllodoce novaehollandiae</i>				#								
	<i>Boccardiella limnicola</i>	✓	✓	✓	✓	✓							
Crustacea Amphipoda	<i>Haloniscus searlei</i>	✓	✓	✓	✓	✓	✓	✓	✓	✓			
		Isopoda								✓	✓		✓
		Ostracoda								✓	✓	✓	✓
		Mysidacea	✓	✓		✓							
Mollusca	Bivalvia	<i>Arthritica helmsi</i>	✓	✓	✓	✓	✓	✓		✓	✓		
		<i>Soletellina alba</i>						✓					
	Gastropoda	Hydrobiidae sp. 2	✓	✓	✓	✓	✓	✓					
		Hydrobiidae sp. 4	✓	✓	✓	✓	✓	✓					
		Hydrobiidae sp. 5	✓	✓		✓	✓						
		Hydrobiidae sp. 6					✓						
		<i>Salinator fragilis</i>				✓		✓	✓				
Hexapoda Diptera	Chironomidae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Dolichopodidae	✓			✓			✓	✓				
	Ceratopogonidae							✓		✓	✓		
Total species number per site		10	9	8	13	9	10	6	7	4	4	4	
Species number per region		17							8				

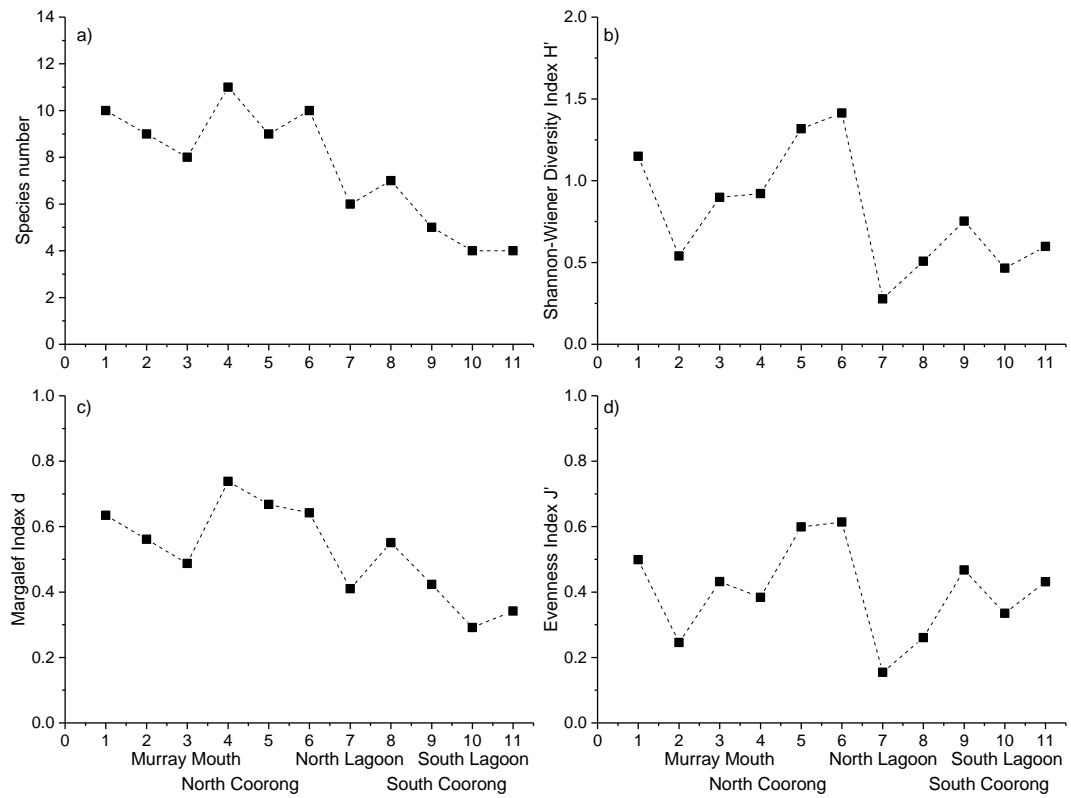


Figure 10: Diversity measure for macroinvertebrates from mudflats in the Murray Mouth, North and South Lagoon of the Coorong, showing a) the total number of species, b) Shannon-Wiener diversity H' , c) evenness J' and d) Margalef's index for dominance d . Sites 1 (Monument Road) – 7 (Noonameena) are located in the North Coorong, and sites 8 (Parnka Point) – 11 (Loop Road) in the South Coorong. See Figure 2 for site locations and Table 1 for the new regional groupings.

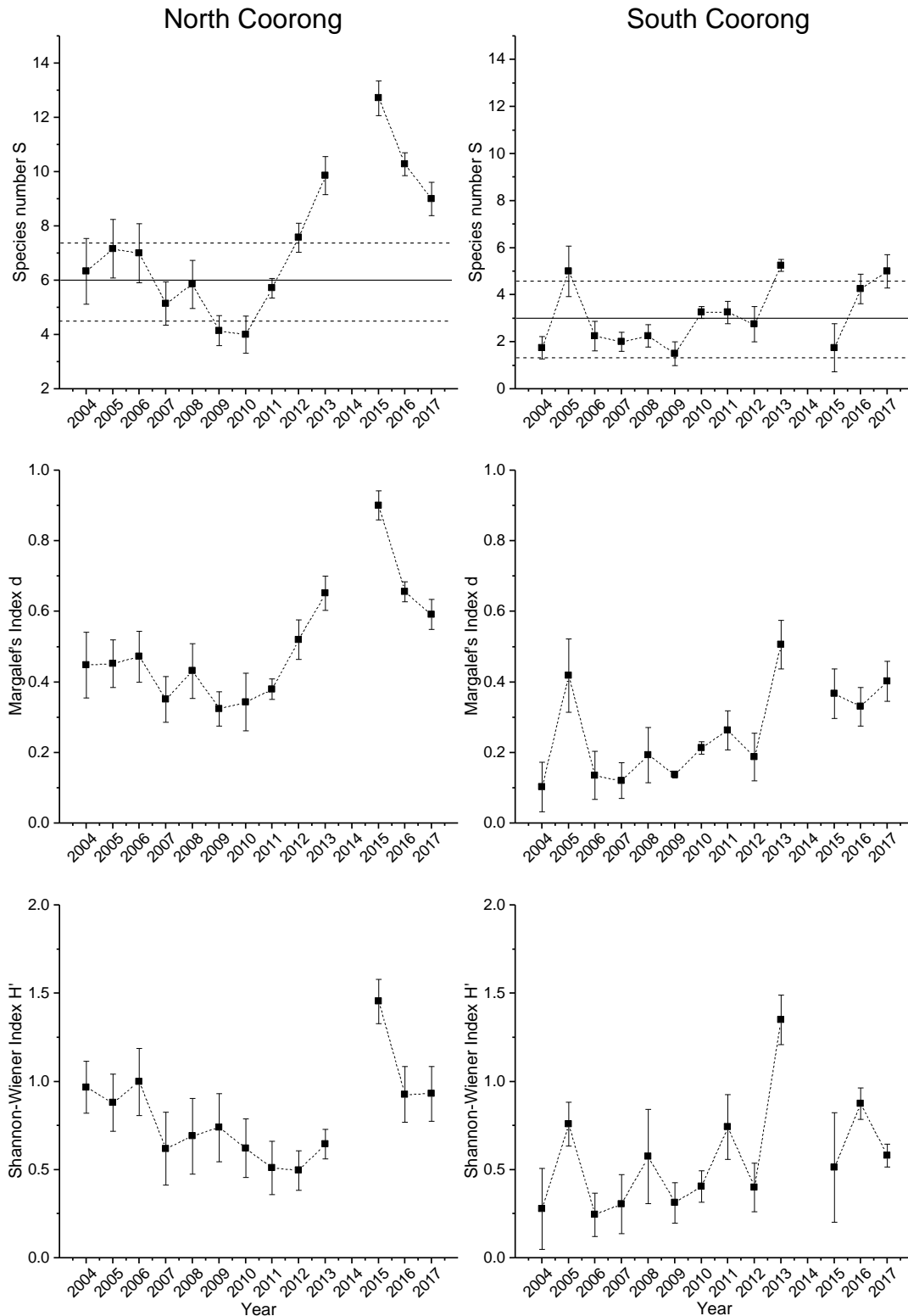


Figure 11: Changes in diversity measures over time for sites located in the North and South Coorong (7 and 4 sites respectively), over the monitoring years since 2004. The plots show the average index value for each year with standard error. No TLM survey was carried out in 2014. For species numbers, average (black line) and upper and lower tolerance ranges (dotted lines) are indicated based on the TLM refinement using data 2004-2013.

4.2.2 Macroinvertebrate occurrence and abundance

4.2.2.1 Macroinvertebrate occurrence and distribution ranges

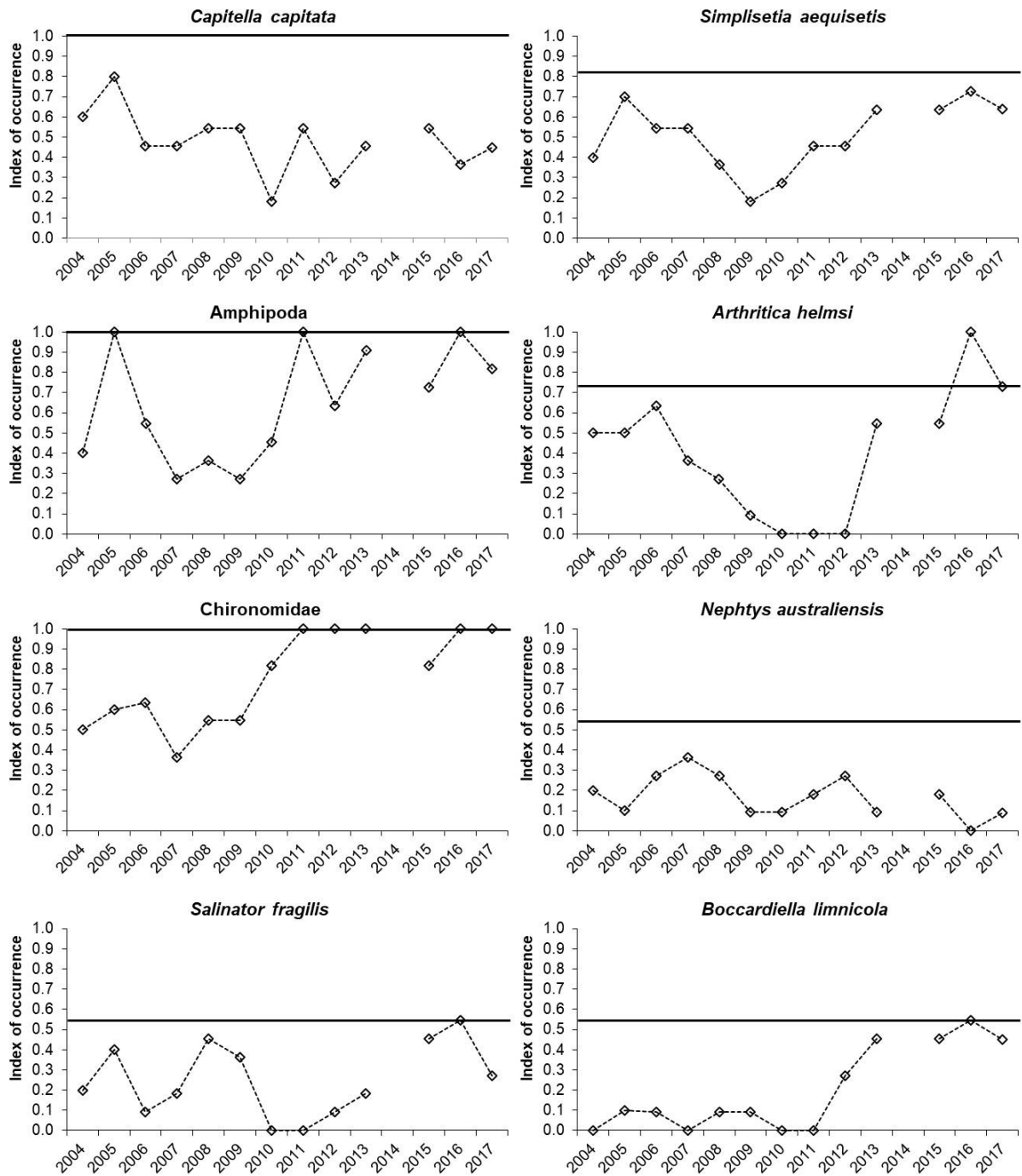


Figure 12: Index of Occurrence for the key macroinvertebrate species over the TLM monitoring years 2004 to 2017. No TLM sampling occurred in 2014. The Index shows the number of sites at which a species was found, out of all the sites sampled in that survey (e.g. the index is 1 if a species occurred at all 11 sites in a year, and 0.45 if found at 5 out of 11 sites), shown by the symbols and line for all regions. The solid black line indicates a reference for this index, based on the number of sites the species was found over the TLM surveys from 2004-2013, as per TLM refinement.

4.2.2.2 Macroinvertebrate abundances 2016/17 spring and autumn

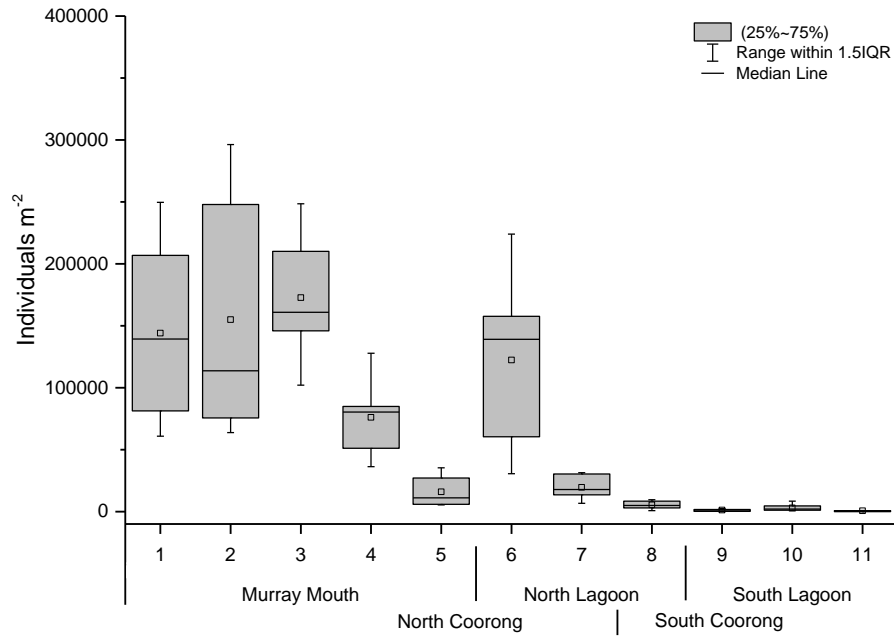


Figure 13: Box plots of individual densities for total macroinvertebrates at the study sites from the Murray Mouth and Coorong in the spring survey (December 2017) Box plots show the median, quartiles and minimum and maximum values. Note the break in the y-axis due to the outliers at Pelican Point (site 5). Regions are indicated with the old and new differentiation.

4.2.2.3 Long term changes in macroinvertebrate abundances

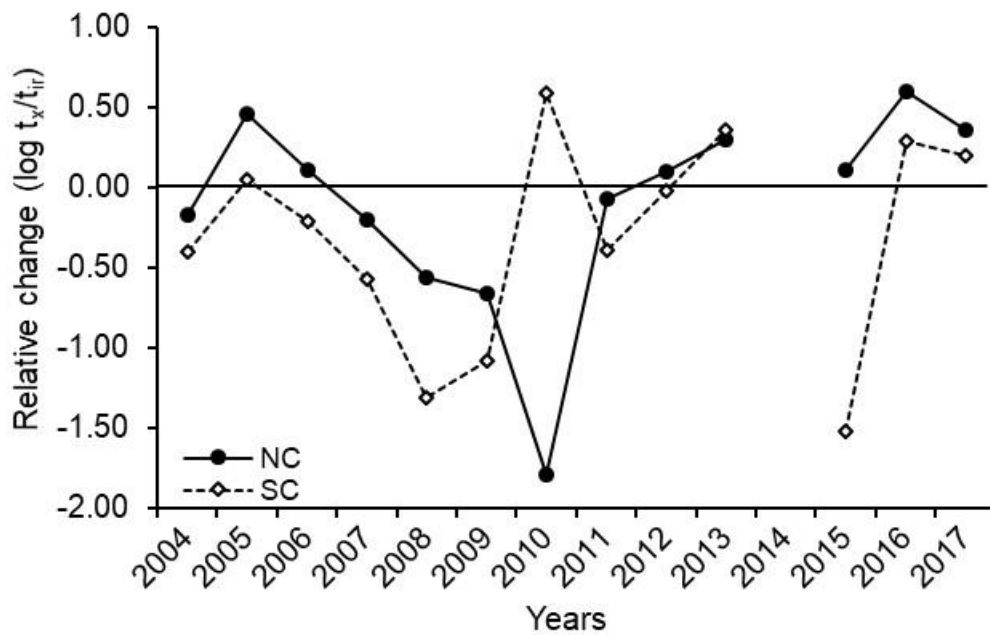


Figure 14: Index of Relative Change showing long-term changes in the abundance of macroinvertebrates (all species) for the North Coorong (NC, 7 sites) and South Coorong (SC, 4 sites). Index values plotted are a ratio of observed (t_x , any particular year) to reference data (t_r based on ten year monitoring 2004-2013), based on average values per region and year. The black line at 0 marks where observed values equal reference values.

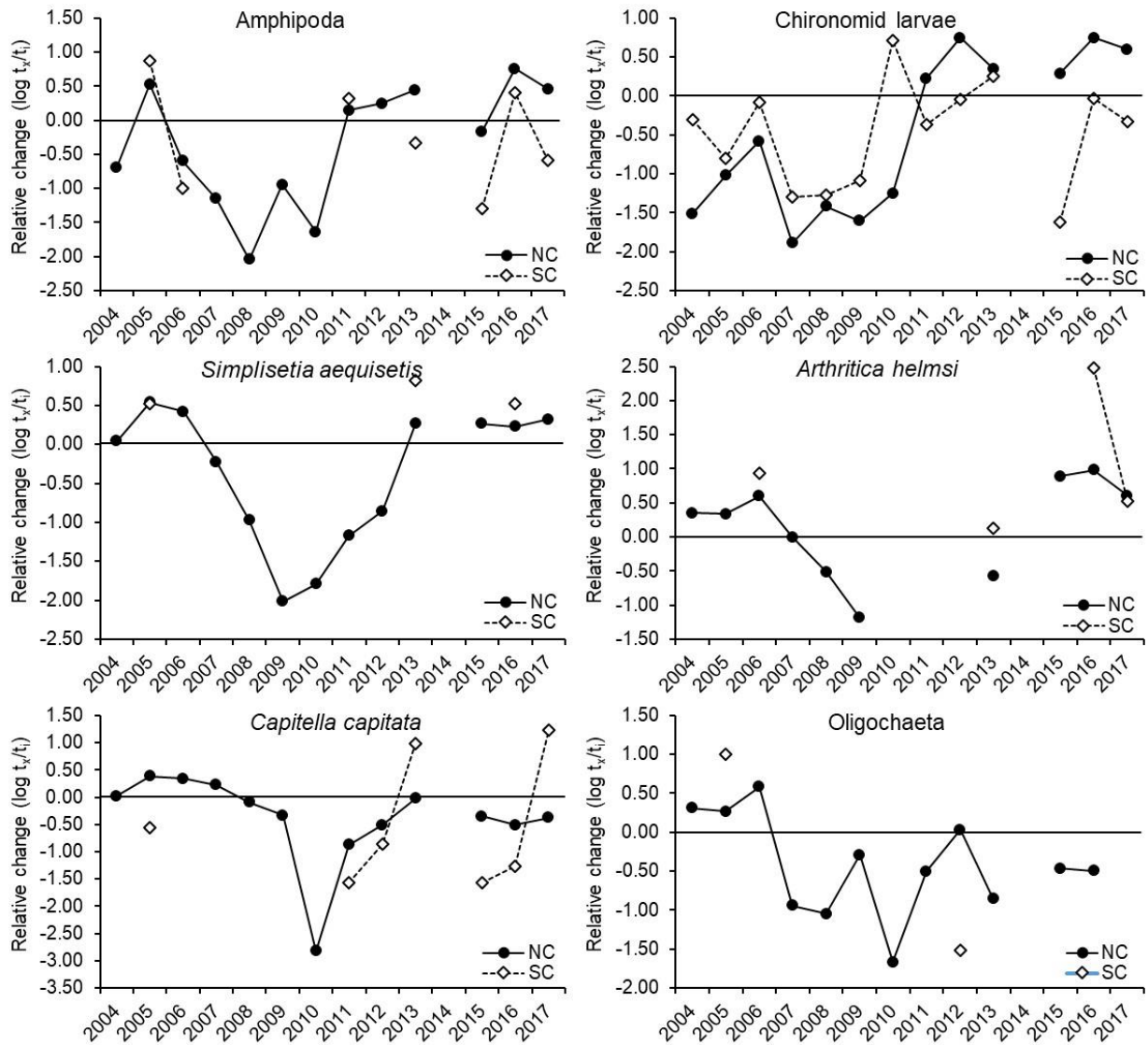


Figure 15: Index of Relative Change showing long-term changes in the abundance of several key macroinvertebrates species for the North Coorong (NC, 7 sites) and South Coorong (SC, 4 sites). Index values plotted are a ratio of observed (t_x , any particular year) to reference data (t_r based on ten year monitoring 2004-2013), based on average values per region and year. The black line at 0 marks where observed values equal reference values.

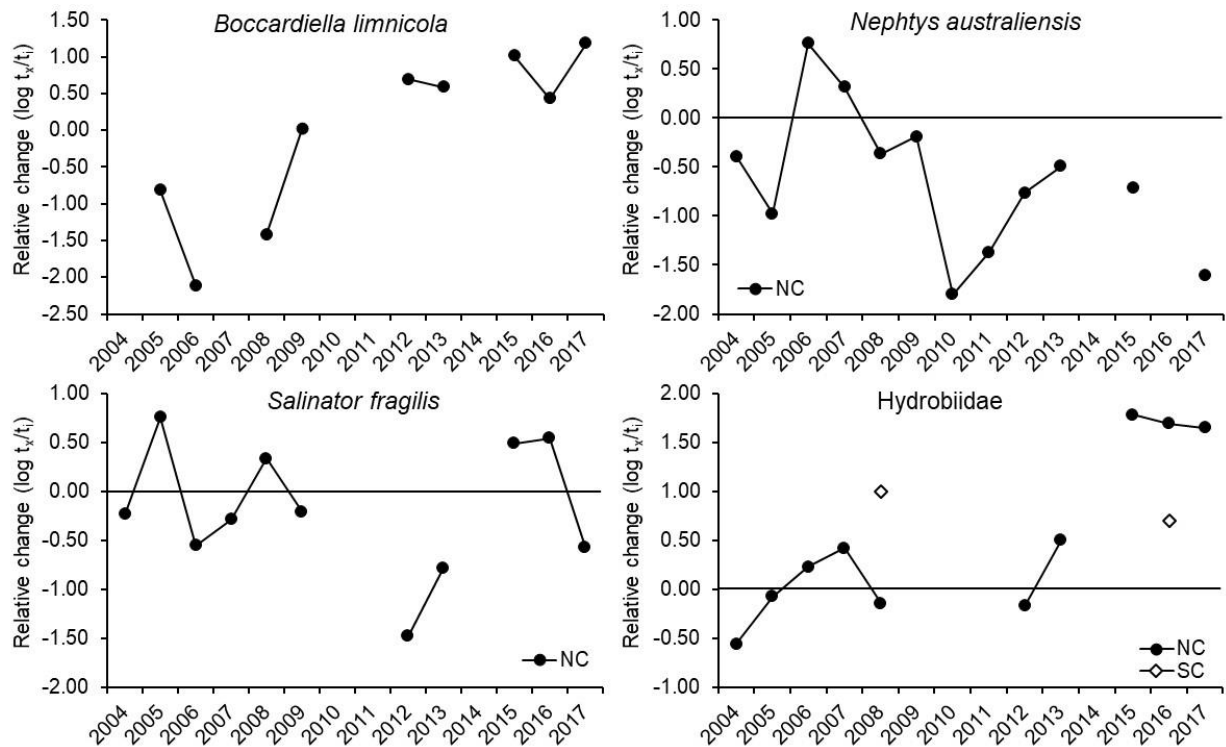


Figure 16: Index of Relative Change showing long-term changes in the abundance of further macroinvertebrates species occurring almost exclusively in the North Coorong (NC, 7 sites). Only hydrobiid snails were also found in the South Coorong (SC). Index values plotted are a ratio of observed (t_x , any particular year) to reference data (t_i , based on ten year monitoring 2004-2013), based on average values per region and year. The black line at 0 marks where observed values equal reference values.

4.2.3 Macroinvertebrate biomass

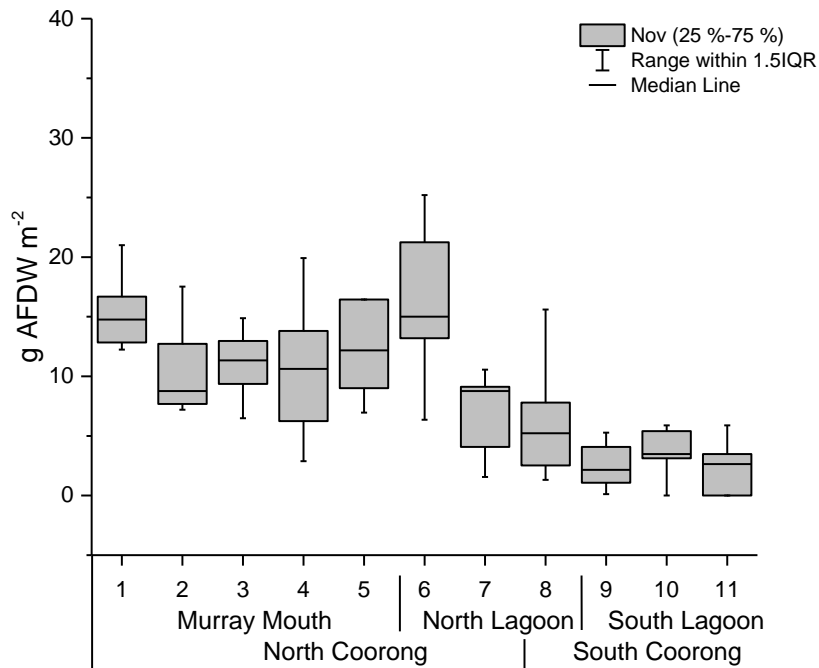


Figure 17: Box plots of total macroinvertebrate biomass at the study sites from the Murray Mouth and Coorong in the spring survey (December 2017). Regions are indicated with the old and new differentiation.

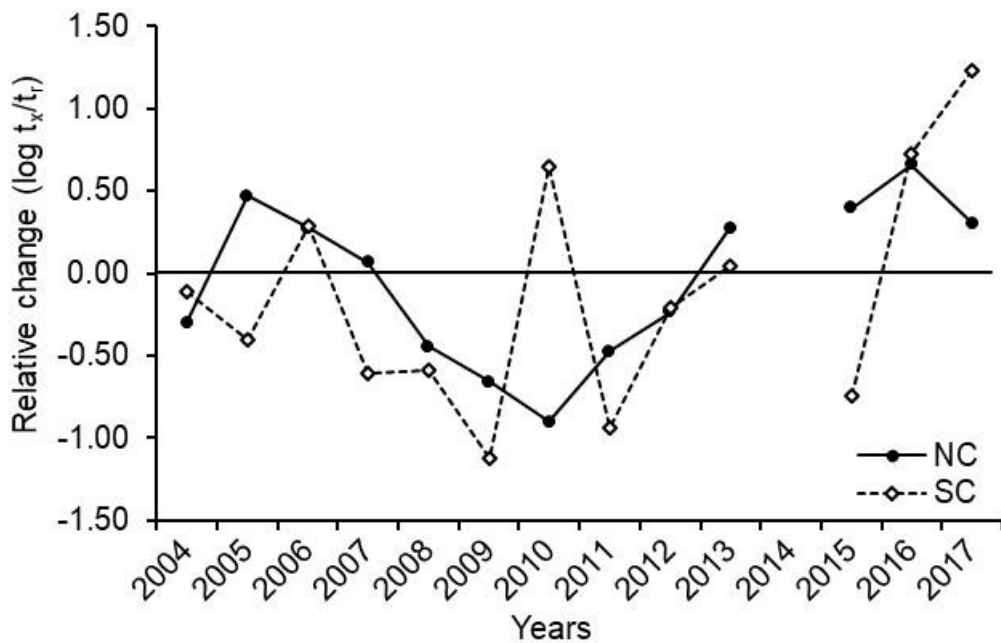
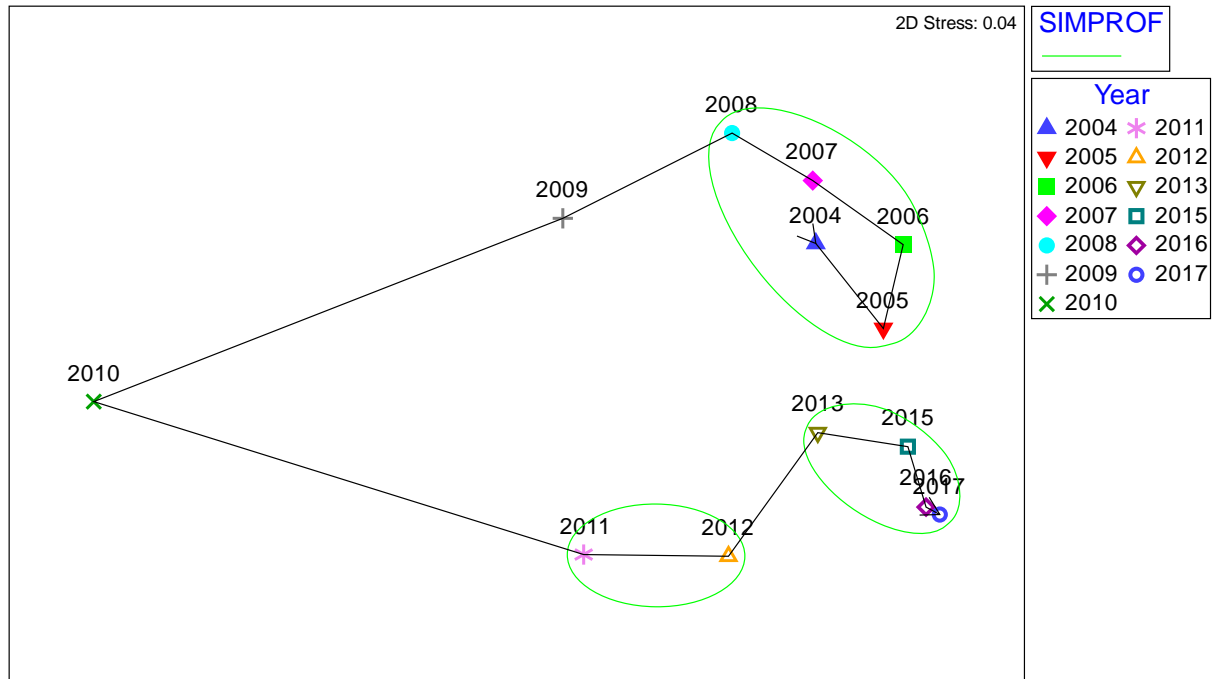


Figure 18: Index of Relative Change showing long-term changes in the biomass of macroinvertebrates for the North Coorong (NC, 7 sites) and South Coorong (SC, 4 sites). Index values plotted are a ratio of observed (t_x, any particular year) to reference data (t_r based on ten year monitoring 2004-2013), based on average values per region and year. No TLM monitoring occurred in 2014. The black line at 0 marks where observed values equal reference values.

4.2.4 Macroinvertebrate communities

a) North Coorong (sites 1-7)



b) South Coorong (sites 8 – 11)

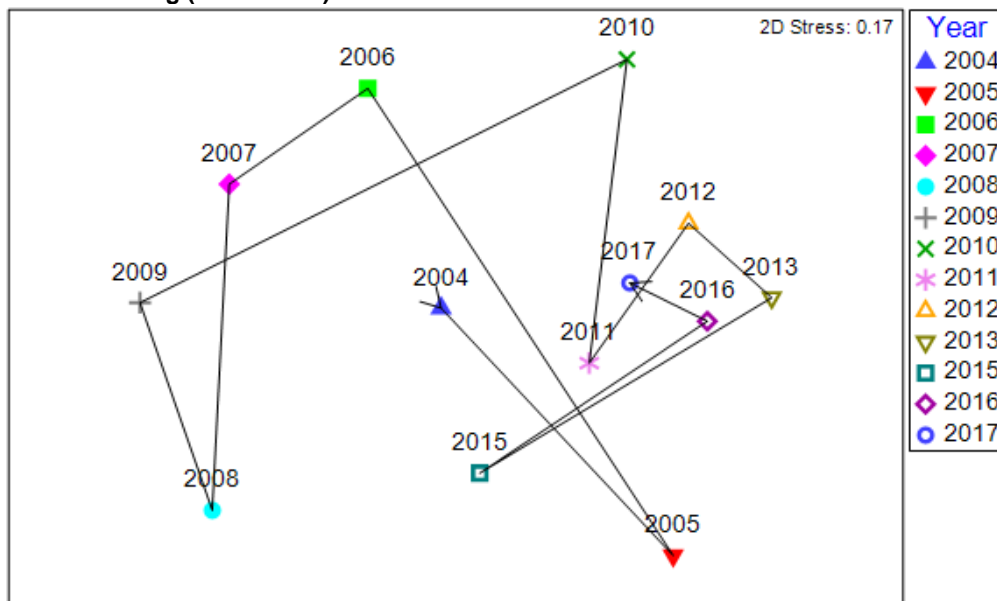


Figure 19: nMDS (non-metric multidimensional scaling) plots for macroinvertebrate communities in a) the North Coorong, and b) the South Coorong, based on averages per year and region. The green circles in a) show significantly different groupings based on SIMPROF tests. No significant groupings over the years were found with SIMPROF tests for the South Coorong. No TLM monitoring occurred in 2014.

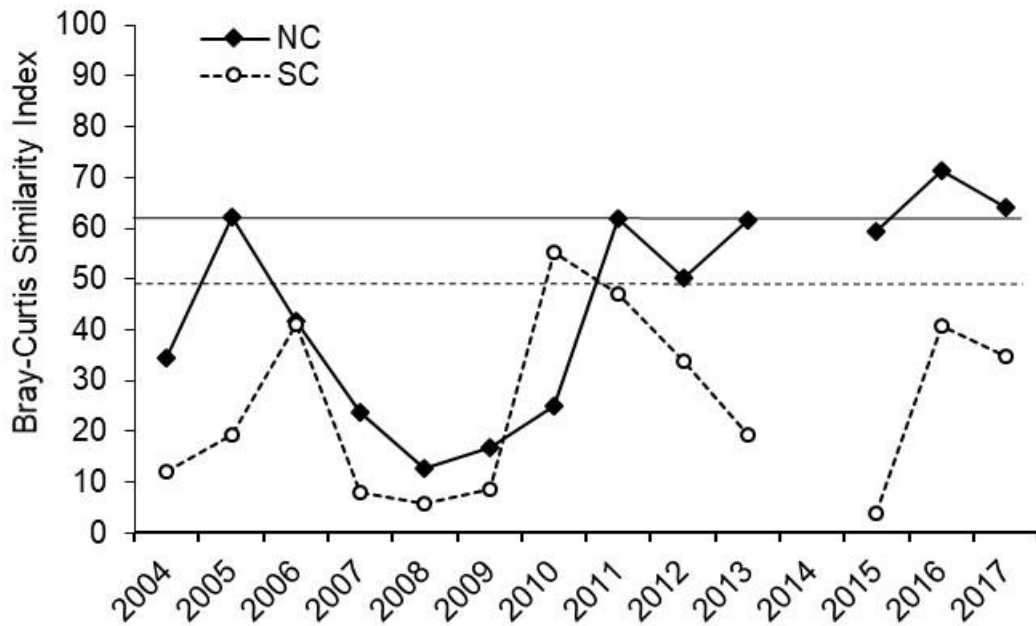


Figure 38: Average Bray-Curtis similarity index for similarity within macroinvertebrate communities in the North (NC, sites 1-7) and South (SC, sites 8-11) Coorong across each of the monitoring years. No TLM monitoring occurred in 2014. The horizontal lines indicate reference similarities for each region, taking selected years as reference (2005 and 2013 for the NC, 2006 and 2010 for SC). A higher index shows greater similarity between the sites in each region for the respective year.

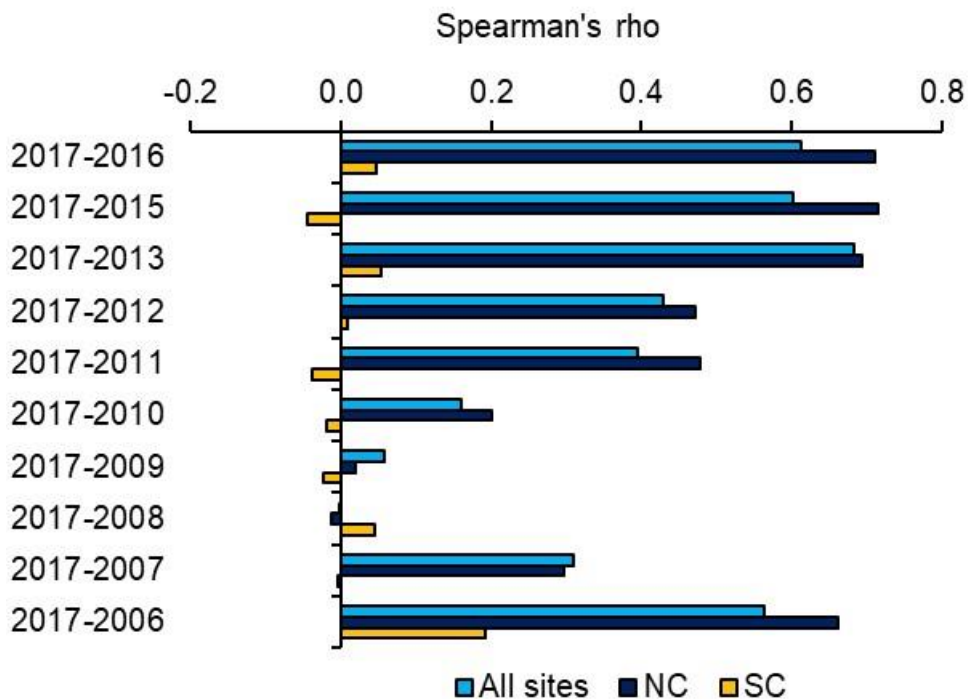


Figure 39: Spearman's Rank Correlation Coefficient rho (δ) comparing the similarity matrices of macroinvertebrate communities from spring 2017 to previous years. Comparisons are not made to 2004 and 2005 as one sampling site was missing in each of these years. The coefficient δ was calculated using data from all 11 sites (light blue), the North Coorong (NC, sites 1-7), and the South Coorong (SC, sites 8-11). Low values for δ indicate that communities in the two years are unrelated.

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6. References

- DEWNR (2017) Condition Monitoring Plan (Revised) 2017. The Living Murray – Lower Lakes, Coorong and Murray Mouth Icon Site. DEWNR Technical report 2016-17. Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide.
- Dittmann, S., (2017) Chapter 4.3 Invertebrates & 4.5 Mudflats In: *Condition Monitoring Plan (Revised). The Living Murray – Lower Lakes, Coorong and Murray Mouth Icon Site*. DEWNR Technical report 2016-17. Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide.
- Dittmann, S. & Baring, R. (2016) Benthic macroinvertebrate survey 2015-16: Coorong and Murray Mouth Icon Site. Report for the Department of Environment, Water and Natural Resources and the Murray-Darling Basin Authority.
- Dittmann, S., Baring, R. & Ramsdale, T. (2016) Macroinvertebrate monitoring, analysis and synthesis for Coorong and Murray Mouth locations, Final report and response on Key Monitoring Questions. Report for the Department of Environment, Water and Natural Resources, Adelaide. Flinders University of South Australia.
- Dittmann, S., Navong, N., Ramsdale, T. & McGuire, A. (2014) Benthic macroinvertebrate survey 2013-14: Lower Lakes, Coorong and Murray Mouth Icon Site. Report for the Department of Environment, Water and Natural Resources and the Murray-Darling Basin Authority. *Flinders University of South Australia*,
- Dittmann, S., Baring, R., Baggalley, S., Cantin, A., Earl, J., Gannon, R., Keuning, J., Mayo, A., Navong, N., Nelson, M., Noble, W. & Ramsdale, T. (2015) Drought and flood effects on macrobenthic communities in the estuary of Australia's largest river system. *Estuarine, Coastal and Shelf Science*, **165**, 36-51.
- Hemraj, D.A., Hossain, M.A., Ye, Q.F., Qin, J.G. & Leterme, S.C. (2017) Plankton bioindicators of environmental conditions in coastal lagoons. *Estuarine Coastal and Shelf Science*, **184**, 102-114.
- Hossain, M.A., Ye, Q., Leterme, S.C. & Qin, J.G. (2017) Spatial and temporal changes of three prey-fish assemblage structure in a hypersaline lagoon: the Coorong, South Australia. *Marine and Freshwater Research*, **68**, 282-292.
- Kingsford, R.T., Walker, K.F., Lester, R.E., Young, W.J., Fairweather, P.G., Sammut, J. & Geddes, M. (2011) A Ramsar wetland in crisis - the Coorong, Lower Lakes and Murray Mouth, Australia. *Marine and Freshwater Research*, **62**, 255-265.
- Maunsell (2009) Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Plan. In, p. 57 pp. South Australian Murray-Darling Basin Natural Resources Management Board, Adelaide.
- Nebra, A., Alcaraz, C., Caiola, N., Muñoz-Camarillo, G. & Ibáñez, C. (2016) Benthic macrofaunal dynamics and environmental stress across a salt wedge Mediterranean estuary. *Marine Environmental Research*, **117**, 21-31.
- Paton, D.C., Rogers, D.J., Hill, B.M., Bailey, C.P. & Ziembicki, M. (2009) Temporal changes to spatially stratified waterbird communities of the Coorong, South Australia: implications for the management of heterogenous wetlands. *Animal Conservation*, **12**, 408-417.
- Rabaoui, L., Tlig-Zouari, S., Cosentino, A. & Hassine, O.K.B. (2009) Associated fauna of the fan shell *Pinna nobilis* (Mollusca: Bivalvia) in the northern and eastern Tunisian coasts. *Scientia Marina*, **73**, 129-141.
- Seuront, L. and C. Leterme. 2006. Microscale patchiness in microphytobenthos distributions: evidence for a critical state. Pages 165-183 in J. C. Kronkamp, J. F. C. de Brouwer, G. F. Blanchard, R. M. Forster, and V. Creach, editors. *Functioning of Microphytobenthos in Estuaries*. The Academy of Arts and Sciences, Amsterdam/The University of Chicago Press, Chicago.
- Wainwright, P. & Christie, M. (2008) Wader surveys at the Coorong and S.E. coastal lakes, South Australia, February 2008. *The Stilt*, **54**, 31-47.

Appendix 1: Sampling sites and dates of the TLM macroinvertebrate and mudflat monitoring in December 2017. GPS coordinates, sampling dates and times of sampling are given for the survey in late spring/early summer. In transition to the revised TLM condition monitoring plan, the old and new regional terminologies and site numbers are given in the table.

Region		Site			2017/18			
Old	New	Old	New	Name	Southing	Easting	Sampling dates	Sampling time
Murray Mouth	North Coorong	1	1	Monument Road	35°31.522	138°49.750	6/12/17	1:15 pm
		HC	2	Hunters Creek	35°32.190	138°53.394	6/12/17	11:30 am
		4	3	Mundoo Channel	35°32.277	138°54.074	4/12/17	10:00 am
		6	4	Ewe Island	35°33.486	138°57.377	4/12/17	11:00 am
		20	5	Pelican Point	35°35.568	139°01.288	6/12/17	10:00 am
North Lagoon		22	6	Mulbin Yerrok	35°40.149	139°08.327	5/12/17	3:30 pm
		26	7	Noonameena	35°45.431	139°15.703	5/12/17	2:00 pm
South Lagoon	South Coorong	24	8	Parnka Point	35°53.841	139°24.022	5/12/17	11:40 am
		19	9	Villa de Yumpa	35°54.654	139°27.220	5/12/17	09:45 am
		16	10	Jack Point	36°01.914	139°34.135	4/12/17	4:50 pm
		14	11	Loop Road	36°10.205	139°39.093	4/12/17	3:45 pm