Macroinvertebrate monitoring, analysis and synthesis for Coorong and Murray Mouth locations

Progress report and preliminary response to "Condition of the RAMSAR site since listing"

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Interim Report

for the Department of Environment, Water and Natural Resources

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Contents

1. Background

This progress report addresses the key questions for the analysis and synthesis of macroinvertebrate data based on response monitoring in the Murray Mouth and Coorong from 2010 to 2015. In particular, this progress report includes a preliminary response to the final key question, “What is the Change in Ecological Character since listing (1985)”.

The information presented in this report is based on response monitoring undertaken since the restoration of flows in 2010, as well as comparisons to historical data for the system from monitoring since 2004 for The Living Murray” condition monitoring and studies by Geddes in the 1980s. In addition, information from similar systems in temperate Australia was considered for some questions as was biological information for key species known from the scientific literature.

2. Progress on Key Questions

The majority of the key questions outlined in Schedule 3 have been partially or completely addressed. Analyses of datasets are complete and responses to most key questions have either been drafted or are in the process of being drafted for the final report. A summary of our progress towards completing the responses to each key question is provided in Table 1. Further detail regarding content that has been prepared for each key question is provided below and in the appendices for this report. Throughout the following sections, references to figures and tables in the appendix precede with an A. Layout and font sizes of some of the figures and tables in the appendix will be improved for the final report.

Table 1. Summary table of work completed, work in progress and work yet to start for each key question

Key Questions	Components completed	Components in progress	Components still to start
Stocktake of Monitoring to Date	• Table of data collection periodicities over time • Percent contribution plots for 2010 – 2015 dataset. Includes comparisons for tidal position, years, regions, sites and low versus high taxonomic resolution. • Figures of total abundances, abundances of various taxonomic groups, and species richness, diversity indices and index of occurrence. • Explanation of patterns in the dataset. • DRAFT PREPARED	• Various descriptive scenarios of alternate monitoring design that include less spatial, temporal and taxonomic effort. (Near completion) • Overview with succinct recommendations.	NONE

Key Questions	Components completed	Components in progress	Components still to start
Recovery	• Articulate hypotheses regarding response outcomes. • Assess evidence to evaluate hypotheses. • Evaluate hypotheses based on available information using monitoring data and information from the literature. • 2015 Monitoring survey report. • DRAFT PREPARED	• Annotated table detailing data currently available and future data requirements to address hypotheses. (Near completion)	NONE
Annual trends	• Define regions over years using macroinvertebrate communities and salinity data (LinkTREE, SIMPROF) • Explore community change over time using MDS trajectory plots • Identify species accounting for differences in communities using SIMPER • Relationship of macroinvertebrate communities to plankton and water quality. • DRAFT PREPARED	• Food web function with comparisons of macroinvertebrate data and other levels of food web (e.g. zooplankton, fish, birds).	NONE
Functions – **Linkages to CPS**			• Comparison of macroinvertebrate abundances and biomass with the Paton Index of waterbird health • Review of data sets, reports and papers to evaluate energy transfer and food web flow on effects
Conceptual **Models**	• Detailed evaluation of species in the system, their environmental tolerances and species attributes • Comparison of historical and current communities • Species trends over time • Biological traits analysis	• Update of existing conceptual models (currently working on) • Evaluation of recruitment processes • Figure 18 South Lagoon integration	NONE

Key Questions	Components completed	Components in progress	Components still to start
	• DRAFT PREPARED		
Ecosystem condition		• Information required to answer these components comes from key questions that have already been completed (e.g. Annual Trends, Recovery) or that are nearing completion (e.g. Conceptual Models).	• Distribution of species categorised into response patterns • Analysis of changes in distributional ranges • Evaluation of potential indicator species • Evaluation of other possible management tools for assessing system health • Site description and ranking of health
Change in ecological character since listing (1985)	• Comparison of current and historical species distribution ranges • Comparisons of current and historical ecological character		• Detailed species temporal comparisons • Comparison to other Ramsar listed estuaries • Quantified statement of whether site still meets Ramsar criteria

2.1 Stocktake of Monitoring to Date

An annotated table covering data periodicities was prepared for the response monitoring program between 2010 and 2015 (Table A1). Patterns of change in both intertidal and subtidal benthic macroinvertebrate abundances, percent contributions and species diversity indices (number of species, S; and species diversity, H') were explored graphically and statistically (Figures A1 – A9). A four-factor nested PERMANOVA design (analysed using PRIMER + PERMANOVA version 7) was used to determine if there were significant differences in species abundances across time (years and months) and space (sampling regions and sites). Those investigations and analyses were explored to characterise and describe key patterns of the macrobenthos across time and space during the water release period, and a draft of this section has been completed. Key elements from that section are provided in Appendix A.1.

Scenarios on the effect of reducing sampling effort or taxonomic resolution were explored (Figure A10) and results are currently being prepared to discuss the findings of these investigations. Final recommendations for future design of monitoring studies in the Murray Mouth and Coorong Lagoons are also in preparation.

2.2 Recovery

Hypotheses regarding the response of macroinvertebrates to flow restoration have been developed for both communities and individual species. At present, six hypotheses have been explored as follows:

It is hypothesised that continued environmental freshwater flows over the barrages into the Murray Mouth and Coorong Lagoons will result in changes in benthic macroinvertebrate communities, more specifically, that continued flow over the barrages will lead to;

1. Increases in benthic macroinvertebrate diversity and abundances;
2. Extended distribution ranges of benthic macroinvertebrates, with occurrences reaching further into the South Lagoon; and
3. Changes in the macroinvertebrate community structure, increasingly dominated by species larger in size and dwelling deeper in the sediment.

The mechanisms driving the hypothesised changes in macroinvertebrate communities have not been formally tested with manipulative experiments, but can be theoretically discussed based on patterns seen in our data and general scientific knowledge of estuarine and lagoon ecosystems. This includes consideration of species-specific traits affecting the ability to recolonise mudflats at locations where they had previously been lost during the Millennium Drought. Generally, it is expected that species-specific responses of macroinvertebrates to continued flow may be determined by;

4. Life-history (e.g. dispersal potential, reproduction, larval development)
5. Habitat suitability affecting recolonization (e.g. water and sediment quality)
6. Species interactions (e.g. predation, competition, bioturbation)

Hypotheses 1 and 3 were tested using multivariate PERMANOVA analyses using the same statistical design that was used to identify differences in abundance, diversity and community structure for the first key question, Stocktake of Monitoring to Date. Patterns in macroinvertebrate total abundance, species number and community structure have also been investigated graphically using bar graphs and Multidimensional Scaling (MDS) plots as appropriate (Figures A11 - A14).

Hypotheses 2 has been explored using graphical comparisons of distribution ranges of 5 key species/taxa (*Simplisetia aequisetis*, *Capitella spp.*, Amphipoda, *Arthritica helmsi* and Diptera larvae) in both the intertidal and subtidal benthos throughout the system across the monitoring period (2010 – 2015)(Figures A15 - A19) and for all taxa across the system using the index of species occurrence (Figure A20).

Hypotheses 4 – 5 have been investigated for 13 key taxa/species in the system using information on life-history traits, habitat requirements and species interactions for these taxa known from the literature. An evaluation of available data for individual species or taxa revealed that there are large gaps in our understanding of their biology, which makes a detailed assessment on recovery of those taxa very difficult. An annotated table of the known biology of these species/taxa has been prepared (Table A2).

A monitoring event was completed in February 2015 to determine if distributional changes for some taxa were still 'playing out'. Eleven intertidal sites were selected throughout the system for this monitoring event. The findings of this single monitoring event have been presented in an interim report[1] and incorporated into the analysis of long-term monitoring data to assess the benthic macroinvertebrate response to water flows in the Murray Mouth and Coorong Lagoons (upcoming final report).

The data included in this section were evaluated with patterns observed in the system described over several pages of text, and a draft of this section has been completed. Key elements from this section are provided in Appendix A.2.

2.3 Annual Trends

LinkTREE(+SIMPROF) was used to investigate community relationships to salinity over the monitoring period (2010 – 2015) to define regions in the system based on biological assemblages and salinity rather than just geographical boundaries as done previously. This analysis revealed that there were changes in macroinvertebrate community structure both within years (seasonal changes) and across years as the system recovered from drought conditions in both the Murray Mouth and North Lagoon. However, south of Noonameena/Parnka Point, where conditions were consistently hyperhaline, there has been no change in overall community structure over the monitoring period (Figure A22, Table A3).

[1] Dittmann, S., Baring, R. & Ramsdale, T., 2015: Benthic Macroinvertebrate Response Monitoring in the Coorong and Murray Mouth, February 2015. Report for the Department of Environment, Water and Natural Resources, Adelaide.

MDS trajectory plots have been prepared for each region defined by the LinkTREE(+SIMPROF) analysis to investigate change in community structure over time (Figure A23). Those plots showed a clear pattern of change in community structure, especially in the Murray Mouth and Northern Coorong which could be related to changes in abundance of macroinvertebrate species over time as the system recovered.

The data included in these sub-sections were evaluated and the patterns described, and a draft text of this section has been completed. Key elements from this section are provided in Appendix A.3.

Work on two further subsections is yet to be started, as we are in the process of scheduling meetings with other service providers regarding the patterns and changes over time in other ecosystem components, specifically fish, and how changes observed for macroinvertebrates have been reflected by other levels in the food web.

2.4 Functions – Linkages to CPS

Work on this section is scheduled for late July and August 2015 and is yet to be started. It will be informed by Biological Trait Analysis done for conceptual models (see 2.5).

2.5 Conceptual Models

Species inhabiting the system were identified and their distribution throughout the system (Table A4), environmental tolerances (Table A5) and attributes (Table A6) have been detailed in a series of annotated tables and discussed. Historical communities were detailed for the Coorong in an annotated table and compared to current communities in the system (Table A7). Species trends over time were investigated using line graphs of average abundance for key species/taxa for each region across years (Figure A24).

Biological traits analysis was also completed on 17 species. Results from SIMPER analysis showed that the major contributing biological traits in the Murray Mouth diversified in every year through to 2015 (Table A8). Diversification in benthic reproductive strategies and the arrival of longer lived taxa started in the Murray Mouth during 2011/12 and 2012/13. During 2013/14 larger taxa, predatory feeding habits and deeper bioturbation started in the Murray Mouth. In 2015 biological traits such as filter feeding, benthic larvae and taxa with preference for euhaline (30-40 ppt) salinity conditions were more important in the Murray Mouth (Table A8, Figure A25).

In the North Lagoon the biological traits that changed from 2011/12 to 2012/13 were smaller taxa, pelagic planktonic larvae and preference for medium sized sand grain sizes (Table A8). There were no more changes to biological traits in subsequent years for the North Lagoon with mainly short lived, surficial sediment modification, and sediment surface and bentho-pelagic habits (Table 8, Figure A25). In 2010/11 and 2013/14 the biological traits in the North Lagoon were too inconsistent for reliable interpretation of the data (Table A8).

During 2010/11 and 2011/12 the South Lagoon had biological traits that mainly consisted of small-bodied, short lived, opportunistic, free living, pelagic or benthic larvae and only surficial sediment modification (Table A8). In 2010/11, and 2012 to 2015 the biological traits in the South Lagoon were too inconsistent for reliable interpretation of the data (Table A8).

The current (2015) biological functioning of the macrobenthos varies between the Murray Mouth and the North Lagoon (Figure A25). In the Murray Mouth, there is deep bioturbation, benthic-pelagic coupling is increasing and the food web is diversifying compared to earlier years. For the North Lagoon, there is only surficial bioturbation, benthic-pelagic coupoing is only beginning and the food web is rather simple in comparison to the Murray Mouth (Figure A25).

The data included in these sub-sections were evaluated with the patterns described, and a draft text of this section has been completed. Key elements from this section are provided in Appendix 4.

Work on three further subsections; recruitment patterns, abundance and distribution of species over time and our conceptual understanding of benthic communities in the system was scheduled for late July 2015 and is in progress.

2.6 Ecosystem Condition

Work on this section is scheduled for late July and August 2015 and is yet to be started, although much of the background information needed to address this key question has already been compiled in other sections of the report.

3. Preliminary response to Key Question "Change in Ecological Character since listing (1985)"

What are the quantitative or qualitative changes in benthic macroinvertebrates?

3.1 Macroinvertebrate communities at the time of listing (1981 – 1985) – species and distribution in the system

Information on macroinvertebrates around the time of listing is only available from studies by Mike Geddes. These studies focussed on the Coorong, and data of macroinvertebrates at the times of listing are not available for the Murray Mouth.

Community types were qualitatively described for the Coorong Lagoons during a period of drought and then flow over the barrages between 1981 and 1985 (Geddes & Butler 1984; Geddes 1987). These community types are summarised in Table 3.1 and A7 (see Conceptual Models; this report), and include; a freshwater community where estuarine polychaete worms and molluscs were either rare or absent; an estuarine community, when these species were present and even abundant in communities; a hypermarine community dominated by amphipods, *Capitella* sp. and larvae of salt-tolerant dipterans, and finally; a hypersaline community, where only isopods, ostracods and salt-tolerant dipteran larvae were present (Geddes & Butler 1984; Geddes 1987).

Only sites in the Coorong were sampled during the 1981 – 1985 monitoring period (Geddes & Butler 1984; Geddes 1987). In total, 14 sites were sampled by Geddes & Butler (1984) and Geddes (1987)

(Table 3.1) and some sites were the same or nearby to sites used in the current monitoring program. The following summary of the description of macroinvertebrate communities has been adapted from qualitative descriptions in Geddes (1987) for communities at the end of the 1981 – 1985 monitoring period (ending approximately around 1984 – 1985); at the time when the site received Ramsar listing:

Conditions in the Coorong Lagoons had freshened following freshwater releases over the barrages after a 16 month period of no water release between 1981 and 1983. Estuarine conditions were recorded from just south of Pelican Point to Dodd Point (north of Noonameena), with hyperhaline conditions dominating south of the area around Noonameena (Table 3.1). Communities in the northern part of the North Lagoon, approximately between Pelican Point and Dodd Point were dominated by polychaete worms, *Ficopomatus enigmaticus*, *Capitella capitata*, *Nephtys australiensis* and *Simplisetia aequisetis*. During the same period, when conditions became estuarine, *Boccardiella limnicola* and *Australonereis ehlersi* were present (Table 3.1). Amphipods, the bivalves *Arthritica helmsi* and *Spisula trigonella*, and hydrobid snails were abundant, with *Soletellina alba* and *Salinator fragilis* present in lower abundances (Table 3.1). Decapods and insect larvae were also commonly found in samples (Table 3.1). Around Robs Point (south of Noonameena) to The Needles just north of Parnka Point, most polychaetes dropped out of communities as conditions were marine to hyperhaline, with only *F. enigmaticus*, *C. capitata* and *S. aequisetis* remaining at times when salinities were lower (Table 3.1). The large bivalve, *S. alba* also dropped out of communities at this transition point (Table 3.1). When salinities at those Northern Coorong sites increased above 50 ppt, only *C. capitata*, salt-tolerant dipteran larvae, hydrobiid snails and *S. fragilis* remained (Table 3.1). South of (and including) Parnka Point, conditions were hyperhaline and only salt-tolerant species of isopods, ostracods and insect larvae were able to tolerate the high salinities present (Table 3.1).

3.2 Current macroinvertebrate communities: 2013/14 - 2015

During the most recent monitoring years, salinity conditions in the Murray Mouth region, including all sites between Monument Road and Pelican Point, have typically been oligohaline in early summer and risen to polyhaline conditions by late summer, but the region could generally be considered to be estuarine overall (Table 3.1). Macroinvertebrate communities in this region have been dominated by the polychaete worm *Simplisetia aequisetis*, chironomid larvae and amphipods, with *Arthritica helmsi* becoming more common in samples in the most recent monitoring events (see Annual Trends A.3; Table 3.1).

Table 3.1. Macroinvertebrate communities at sites throughout the Murray Mouth and Coorong at the time of Ramsar listing (1985; Geddes 1987) and currently (2013/14 – 2015 monitoring events). Colours indicate approximate salinity conditions at the site (green: estuarine; blue: estuarine – marine; orange: marine to hyperhaline; and red: hyperhaline to extreme hyperhaline) based on Whitefield *et al.* (2012). Salinity ranges for 1984-85 from Figure 1 in Geddes (1987). Salinity ranges for current conditions from LinkTREE analysis (see Figure A22; Appendix A.3; this report).

Time of Listing (1984 - 1985)		Polychaeta						Arthropoda					Mollusca				
Sites	Salinity Range (ppt)	*Ficopomatus enigmaticus*	*Capitella capitata*	*Nephtys australiensis*	*Boccardiella limnicola*	*Australonereis ehlersi*	*Simplisetia aequisetis*	Ampihpoda	Isopod	Ostracod	Decapoda	Insect Larvae (Diptera/Chironomidae)	*Arthritica helmsi*	*Spisula trigonella*	*Soletellina alba*	Hydrobiidae	*Salinator fragilis*
Monument Road	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hunters Creek	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mundoo Channel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ewe Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pelican Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pelican Point Gate	10 - 30	**P**	**P***	**P***	P	P	**P***	**P**	X	X	P	P	**P**	**P**	P	**P**	P
Mark Point	10 - 30	**P**	**P**	**P**	P	P	**P**	**P**	X	X	P	P	**P**	**P**	P	**P**	P
Mulbin-Yerrok	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Point	10 - 30	**P**	**P**	**P**	P	P	**P***	**P**	X	X	P	P	**P**	**P**	P	**P**	P
Dodd Point	10 - 30	**P**	**P**	**P**	P	P	**P**	**P**	X	X	P	P	**P**	**P**	P	**P**	P
Noonameena	20 - 40																
Robs Point	30 - 50	P	P**	X	X	X	P	P	X	X	P	P**	P	P	X	P**	P**
The Needles	30 - 50	P	P**	X	X	X	P	P	X	X	X	P**	P	P	X	P	P
Parnka Point (NL)	50+	X	X	X	X	X	X	X	P	P	X	P	X	X	X	X	X
Parnka Point (SL)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Villa dei Yumpa	50+	X	X	X	X	X	X	X	P	P	X	P	X	X	X	X	X
Stony Well Island	50+	X	X	X	X	X	X	X	P	P	X	P	X	X	X	X	X
Woods Well	50+	X	X	X	X	X	X	X	P	P	X	P	X	X	X	X	X
Jacks Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Policeman Point	50+	X	X	X	X	X	X	X	P	P	X	P	X	X	X	X	X
Loop Road	50+	X	X	X	X	X	X	X	P	P	X	P	X	X	X	X	X
Bul Bul Basin	50+	X	X	X	X	X	X	X	P	P	X	P	X	X	X	X	X

Current (2013/14 - 15)		Polychaeta						Arthropoda					Mollusca				
Sites	Salinity Range (ppt)	*Ficopomatus enigmaticus*	*Capitella capitata*	*Nephtys australiensis*	*Boccardiella limnicola*	*Australonereis ehlersi*	*Simplisetia aequisetis*	Ampihpoda	Isopod	Ostracod	Decapoda	Insect Larvae (Diptera/Chironomidae)	*Arthritica helmsi*	*Spisula trigonella*	*Soletellina alba*	Hydrobiidae	*Salinator fragilis*
Monument Road	0.6 - 35	R	X	X	**P**	X	**P**	**P**	X	X	X	**P**	P	X	X	**P**	P
Hunters Creek	3 - 30	X	R	R	**P**	X	**P**	**P**	X	X	X	**P**	**P**	R	X	P	P
Mundoo Channel	12 - 16.5	X	X	X	**P**	X	**P**	**P**	X	X	X	**P**	**P**	X	X	**P**	R
Ewe Island	3 - 40	X	P	P	P	R	**P**	**P**	X	X	X	**P**	**P**	R	P	P	R
Pelican Point	3 - 30	X	R	X	P	X	**P**	**P**	X	X	X	P	**P**	X	X	P	R
Pelican Point Gate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mark Point	9.5 - 40	X	R	X	X	X	R	P	X	X	X	P	P	X	P	X	X
Mulbin-Yerrok	16 - 50	X	**P**	X	X	X	**P**	**P**	X	X	X	P	**P**	X	X	X	X
Long Point	25 - 35	X	**P**	X	X	X	**P**	P	X	X	X	R	P	X	X	X	X
Dodd Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Noonameena	40 - 50+	X	**P**	X	X	R	R	P	X	X	X	P	X	X	X	X	X
Robs Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
The Needles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parnka Point (NL)	50+	X	P	X	X	X	X	X	R	P	X	**P**	X	X	X	X	X
Parnka Point (SL)	50+	X	X	X	X	X	X	R	X	P	X	P	X	X	X	X	X
Villa dei Yumpa	50+	X	X	X	X	X	X	R	X	R	X	P	R	X	X	X	X
Stony Well Island	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Woods Well	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jacks Point	50+	X	R	X	X	X	R	R	X	X	X	P	X	X	X	X	X
Policeman Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loop Road	50+	X	R	X	X	X	R	R	X	X	X	R	X	X	X	X	X
Bul Bul Basin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Key:

X	Absent	**P**	Abundant
R	Rare	**P***	Abundant when estuarine but absent when fresh
P	Present	P**	Present when salinity higher (> 50 ppt)

Arthritica helmsi abundances started to recover in 2013 from very low abundances in the Murray Mouth region during the Millennium Drought (Figure A1). *Capitella capitata* was mostly confined to the North Lagoon since flows resumed in 2010, yet occurred at Ewe Island in 2015, possibly because of macroalgal mats seen at the site (Table 3.2). Amphipods were more abundant at sites in the Murray Mouth when conditions were freshest (Table 3.2) at the start of summer. *Simplisetia aequisetis* generally increased in abundance as conditions became more polyhaline in the Murray Mouth, towards late summer (Table 3.2). Many interactions could have resulted in the pattern of declines in amphipods abundances and increases in *S. aequisetis* abundances over summer months. Abiotic interactions (e.g. salinity increase over summer months), in combination with biotic interactions (such as competition or predation), are influencing the abundance and structure of benthic communities.

Sites in the northern North Lagoon (hereafter Northern Coorong), between Mark Point and Long Point, act as a highly dynamic transition zone from estuarine conditions in the Murray Mouth to hyperhaline conditions in the South Lagoon (Table 3.1). Salinity conditions range from mesohaline to euhaline, and communities were numerically dominated by *Capitella capitata*, amphipods and, also *Arthritica helmsi* during very recent sampling occasions (Tables 3.1, 3.2). The polychaete, *Simplisetia aequisetis* was also common in samples (Table 3.1), but did not reach the same high abundances in the Northern Coorong as were observed in the Murray Mouth (Table 3.2). Abundances of these species over the summer months were highly variable and showed no clear pattern for increase or decrease (Table 3.2), and likely reflect a response to the highly dynamic salinity conditions observed in this region.

Sites in the southern North Lagoon and South Lagoon (hereafter Southern Coorong), south of (and including) Noonameena were consistently hyperhaline, and macroinvertebrate communities in this region were generally depauperate (Table 3.1). Only larvae and pupae of the salt-tolerant dipteran families Chironomidae and Ephydridae were consistently present across sampling occasions and sites (Table 3.2). Ostracods, isopods and amphipods were sometimes present in samples and on rare occasions individuals of *Simplisetia aequisetis*, *Arthritica helmsi* and even *Australonereis ehlersi* were found (Table 3.2). The polychaete *Capitella capitata* was consistently present in samples from Noonameena, but only rarely observed further south (Table 3.1, 3.2).

3.3 Have macroinvertebrate communities changed since listing, and if so, how?

Comparisons between the two monitoring periods (1985 and current 2013-2015 surveys) are difficult to draw because of the purely qualitative nature of the data available from the 1980's surveys (Geddes 1987). Overall, the taxa recorded in the system at the time of listing are generally still found in the Coorong and areas with similar salinity ranges are still represented by similar suites of species/taxa as were observed at the time of listing. Between the times of 1985 and 2013-2015, two taxa, the polychaete *Ficopomatus enigmaticus* and decapod crustaceans, appear to be less widely distributed throughout the system during the more recent monitoring (Table 3.1). Sampling methods used for the more recent monitoring in 2013-2015 did not target these invertebrates well. For example, *F. enigmaticus* build reefs which were not included when collecting mudflat core samples.

Yet, observations were made during field trips and presence of live tubeworms recorded qualitatively, showing their presence in the North Lagoon to Noonameena. Decapods (represented in the 1980's surveys by a single crab species) are highly mobile and not likely to be collected by coring into the muddy substrate. Yet we qualitatively recorded sightings of crabs during field work, and noted the presence of several species of decapod crabs, mostly in the Murray Mouth and northern North Lagoon.

Over time there appears to have been a shift in salinity conditions and macroinvertebrate distribution towards the Murray Mouth, with salinity conditions and fauna observed in the Northern Coorong at the time of listing now occurring in the Murray Mouth. Some of the large-bodied, deep burrowing species such as *Australonereis ehlersi*, *Nephtys australiensis* and *Spisula trigonella* are relatively rare in samples and only recorded at some sites, months or only in relatively low abundances (Table 3.1, 3.2). With only qualitative data available from the 1980's surveys, it is not known if the relative abundances of these species has declined, remained stable or even increased. However, recolonisation of the sediment by those large-bodied, deep burrowing species is likely to be the beginning of the last successional steps in the recovery of this system following disturbance during the prolonged period of no freshwater flows during the Millennium Drought. Therefore, the larger-bodied, deep burrowing species may not become common in communities unless conditions continue to remain estuarine in the Murray Mouth into the future.

Many species previously recorded in the Northern Coorong region were not observed or rare during the most recent monitoring, particularly polychaete worms such as *Nephtys australiensis*, *Boccardiella limnicola* and *Australonereis ehlersi*, gastropod species and the large, deep dwelling bivalve species *Spisula trigonella* and *Soletellina alba* (Table 3.1). This may simply reflect the current position of the highly dynamic boundary between the Murray Mouth and Northern Coorong regions, with some of those species previously absent from sites once salinities increased to marine and hypermarine levels (Table 3.1). Salinity conditions in the southern part of the North Lagoon at Noonameena are similar to those observed at Robs Point and The Needles in the past, but none of the mollusc species previously observed in this region have been recorded during recent monitoring (Table 3.1). Across the Northern Lagoon, most mollusc species recorded at the time of listing have not been recorded during recent monitoring, even though they can tolerate the higher salinities that are currently observed in the region (Table 3.1).

There has been no apparent shift in the boundary of the Southern Coorong hyperhaline region (Table 3.1). In the hyperhaline Southern Coorong region, species compositions are largely unchanged, with communities still dominated by salt-tolerant dipteran larvae, isopods and ostracods, with some amphipods also found during recent monitoring (Table 3.1). *Capitella capitata* were sometimes observed in the Southern Coorong, particularly during December at Parnka Point, but populations of this species do not appear to persist (Table 3.2).

Table 3.2. Detailed macroinvertebrate species abundances (numbers are average individuals/m^2 for each site/sampling occasion) at each site sampled and each sampling occasion for the monitoring period 2013/14 – 2015. Zero abundances are highlighted by dark hatching. Groups identify community types from the LinkTREE(+SIMPER) analysis (see Annual Trends; this report) with their associated salinity ranges also listed (Salinity (ppt)). Colours have been used to highlight the different groups and correspond to those used in Figure A22 (see Appendix A.3; this report).

Ave. Macroinvertebrate abundance (ind/m2)						Polychaeta							Arthropoda						Mollusca				
Region	Site	Year	Month	Group	Salinity (ppt)	*Ficopomatus enigmaticus*	*Capitella capitata*	*Nephtys australiensis*	*Boccordiella limincola*	*Australonereis ehlersi*	*Simplisetia aequisetis*	*Phylodoce novaehollandia*	Amphipoda	Isopoda	Ostrocoda	Decapoda	Chironomid (Larvae + pupae)	Ephydridae pupae	*Arthritica helmsi*	*Spisula trigonella*	*Soletellina alba*	Hydrobiidae	*Salinator fragilis*
MM	MR	2013/14	Dec	5	0.6 - 1	0	0	0	2172	0	7753		38286	0	0		2268	0	0	0	0	72	48
		2013/14	Feb	14	16 - 24	0	0	0	672	0	2340		276	0	0		1224	0	0	0	0	1272	72
		2013/14	Mar	13	30 - 35	12	0	0	156	0	2088		300	0	0		144	0	0	0	0	1068	60
		2015	Feb	16	15 - 16.5	0	0	0	2964	0	13226		20763	0	0		2364	0	1980	0	0	1128	24
	HC	2013/14	Dec	7	3 - 6	0	0	0	1584	0	5317		88970	0	0		3865	0	396	0	0	360	12
		2013/14	Feb	12	25 - 30	0	0	12	1464	0	4213		324	0	0		192	0	660	96	0	12	24
		2013/14	Mar	12	25 - 30	0	12	0	1032	0	4369		3709	0	0		540	0	4333	0	0	288	48
		2015	Feb	16	15 - 16.5	0	0	0	1284	0	7369		9974	0	0		852	0	15242	0	0	168	24
	MC	2013/14	Dec	15	12 - 15	0	0	0	1308	0	8953		54825	0	0		9650	0	252	0	0	552	0
		2015	Feb	16	15 - 16.5	0	0	0	3589	0	14354		51764	0	0		2424	0	46135	0	0	2304	120
	EI	2013/14	Dec	7	3 - 6	0	0	180	60	36	1956		103361	0	0		6937	0	216	0	96	192	0
		2013/14	Feb	13	30 - 35	0	36	48	108	12	5533		180	0	0		156	0	1224	0	60	120	24
		2013/14	Mar	10	35 - 40	0	156	0	12	0	4705		264	0	0		48	24	444	12	0	24	0
		2015	Feb	16	15 - 16.5	0	5893	0	276	36	16503		29081	0	0		360	0	36690	0	60	1668	36
	PP	2013/14	Dec	7	3 - 6	0	0	0	876	0	9962		44575	0	0		492	12	588	0	0	168	0
		2013/14	Feb	12	25 - 30	0	12	0	48	0	1668		24	0	0		24	12	804	0	0	12	12
		2013/14	Mar	12	25 - 30	0	0	0	48	0	2352		168	0	0		960	0	168	0	0	60	24
		2015	Feb	16	15 - 16.5	0	0	0	888	0	11066		1824	0	0		132	0	26752	0	0	396	0
NL	MP	2013/14	Dec	11	9.5 - 10.5	0	12	0	0	0	48		96	0	0		0	996	144	0	0	0	0
		2013/14	Feb	12	25 - 30	0	0	0	0	0	0		0	0	0		0	120	144	0	0	0	0
		2013/14	Mar	10	35 - 40	0	0	0	0	0	0		24	0	0		0	168	0	0	0	0	0
	MY	2013/14	Dec	14	16 - 24	0	44011	0	0	0	8413		115999	0	0		396	0	3325	0	60	0	0
		2015	Feb	2	40 - 50	0	29777	0	0	0	9866		7609	0	0		0	0	10706	0	0	0	0
	LP	2013/14	Dec	12	25 - 30	0	29849	0	0	0	5365		6529	0	0		12	0	396	0	0	0	0
		2013/14	Feb	13	30 - 35	0	35454	0	0	0	3949		120	0	0		0	0	564	0	0	0	0
		2013/14	Mar	13	30 - 35	0	7777	0	0	0	2016		216	0	0		0	0	48	0	0	0	0
	NM	2013/14	Dec	1	> 50	0	38634	0	0	156	0		228	0	0		1548	1236	0	0	0	0	0
		2013/14	Feb	1	> 50	0	132	0	0	0	0		0	0	0		0	384	0	0	0	0	0
		2013/14	Mar	2	40 - 50	0	1908	0	0	0	0		0	0	0		12	984	0	0	0	0	0
		2015	Feb	1	> 50	0	19575	0	0	0	672		0	0	0		108	0	0	0	0	0	0
	PaPN	2013/14	Dec	1	> 50	0	4153	0	0	0	0		0	12	1524		6841	0	0	0	0	0	0
		2015	Feb	1	> 50	0	0	0	0	0	0		0	0	0		780	0	0	0	0	0	0
SL	PaPS	2013/14	Dec	1	> 50	0	0	0	0	0	0		0	0	52484		432	12	0	0	0	0	0
		2013/14	Feb	1	> 50	0	0	0	0	0	0		0	0	16983		48	0	0	0	0	0	0
		2013/14	Mar	1	> 50	0	0	0	0	0	0		12	0	12338		72	48	0	0	0	0	0
	VdY	2013/14	Dec	1	> 50	0	0	0	0	0	0		24	0	192		240	300	24	0	0	0	0
		2013/14	Feb	1	> 50	0	0	0	0	0	0		0	0	0		72	0	0	0	0	0	0
		2013/14	Mar	1	> 50	0	0	0	0	0	0		0	0	0		12	0	0	0	0	0	0
		2015	Feb	1	> 50	0	0	0	0	0	0		0	0	0		36	0	0	0	0	0	0
	JP	2013/14	Dec	1	> 50	0	12	0	0	0	24		60	0	0		60	12	0	0	0	0	0
		2015	Feb	1	> 50	0	0	0	0	0	0		12	0	0		24	0	0	0	0	0	0
	LR	2013/14	Dec	1	> 50	0	12	0	0	0	0		24	0	0		24	0	0	0	0	0	0
		2015	Feb	1	> 50	0	0	0	0	0	12		0	0	0		0	0	0	0	0	0	0

Overall, it seems that many of the larger-bodied, deeper dwelling species of polychaetes and bivalves are still recovering with regard to both distributional ranges and population abundances in the system following the prolonged Millennium Drought of 2005 – 2010. Whether these species continue to recover and recolonise sites where they were previously distributed at the time of Ramsar listing will depend on future environmental conditions and freshwater flows into the system to maintain estuarine conditions.

3.4 Were these change(s) beyond the bounds of normal seasonal (within years) or inter-annual (between years) and/or exceeded specified limits of environmentally acceptable change?

The most notable change in the system since listing has been the reduction in occurrence and spatial distribution of large-bodied, deep dwelling species such as *Australonereis ehlersi*, *Nephtys australiensis*, *Soletellina alba* and *Spisula trigonella*, especially from the Northern Coorong. Without a detailed understanding of the nature of the Coorong prior to installation of barrages and flow regulations across the whole Murray-Darling system, or even quantitative data from the time of listing, it is difficult to say whether these changes are beyond the bounds of natural seasonal and inter-annual variation for these species. No historic data exist for seasonal patterns.

Unfortunately there is no quantitative or qualitative evidence indicating what macroinvertebrate communities were like prior to flow regulations in the Murray Mouth and Coorong Lagoons. Anecdotal evidence from the Ngarrindjeri people tells us that the system once received freshwater inputs from both the River Murray in the north and the South East in the south, and that salinity changed seasonally from freshwater to marine conditions as freshwater flows varied across the year (Phillips & Muller 2006). After the installation of flow regulators (barrages and weirs) into the Murray Darling system during the 1940s, salinities rose noticeably in the 1970s and the ecological condition of the system began to decline (Phillips & Muller 2006). Freshwater flows that previously flushed the system from Salt Creek in the South Lagoon ceased (Phillips & Muller 2006), and it is likely that salinity increases in the Southern Coorong led to a decline in macroinvertebrate communities as conditions became increasingly hyperhaline. Thus it is highly unlikely that the macroinvertebrate community currently observed in the Southern Coorong, or that which was observed at the time of Ramsar listing, is natural to the region. It is more likely that the community currently observed in the Murray Mouth and previously observed in the Northern Coorong in the 1980s once extended across the whole Murray Mouth and Coorong.

Early macroinvertebrate surveys were qualitative (Geddes & Butler 1984; Geddes 1987), and there is no information on the levels of natural variation in species or communities at the time of Ramsar listing. Anecdotal evidence suggests that the system had in fact been declining in health for 30 years prior to listing, and that declines observed since listing were the result of changes that had been occurring since flow regulation began (Phillips & Muller 2006). Since flow regulations began, the system has been subject to periods of no-flow (drought), small flows and some large flows over the barrages, with fewer periods of continuous flows of different durations. It is likely that macroinvertebrate communities have been responding to changing salinity conditions throughout the system over different temporal scales from long term (across the 75 years since flow regulations began), to decadal, inter-annual and also seasonal changes.

There are currently no specified limits of environmentally acceptable change for benthic macroinvertebrates in the system (Phillips & Muller 2006). However, given the importance of these species as a food source for many fish and bird species, as well as the roles many of the macroinvertebrates play in habitat stabilisation and ecosystem engineering, limits of acceptable environmental change for this group should be developed. Without a baseline, we will trial multivariate control charts (Anderson & Thompson 2004) to find trigger values for unacceptable change.

3.5 Were these changes adverse and, if so, were they human induced?

The reduced abundance and distribution of large-bodied, deep dwelling species from the system is an adverse change. These species are often long-lived and serve important roles in bio-irrigation of deep sediments by oxygenating deeper layers of the sediment.

These changes appear to be the result of flow regulation in the Murray Darling system and in the South East region over the last 75 years, and, more recently, the Millennium Drought between 2005 and 2010. Whilst periods of drought and flow were probably typical of this system even prior to flow regulations, climate change is a recognised human-induced phenomenon that is affecting rainfall patterns across Australia resulting in extremes. Data from the monitoring period 2010 – 2015 indicate that any reductions in flow have negative effects on macroinvertebrates in the Murray Mouth and Coorong, and consistent flows, even at lower volumes, are better than no flow at all.

Does the site still meet the Ramsar nomination criteria for which the site was listed?

This site was not listed on any criteria based on macroinvertebrate communities or species populations within the system *per se*, although macroinvertebrate communities are an important food source for many of the fish and migratory shorebird species that are listed under the nomination criteria. In response to this, we will be making further comparisons to other Ramsar listed estuaries in the final report (see Table 1).

A. Appendix

A.1 Stocktake of Monitoring to Date

Table A1: Surveys and sampling site periodicities for benthic macroinvertebrate communities from 2010-2015. Note abbreviated month names as D, December; J, January; J/F, January-February; F, February; M March; A/My, April-May; My, May; S, September; O, October; N/D, November-December, followed by abbreviated year sampled. TLM=The Living Murray program; WR=Water release monitoring

		2010-2011					2011-2012					2012-2013				2013-2014			2015
Region	**Site**	**D10**	**J11**	**F11**	**M11**	**A/My11**	**O11**	**D11**	**J/F12**	**M12**	**My12**	**S12**	**D12**	**F13**	**M13**	**N/D13**	**F14**	**M14**	**F15**
MM	Monument Rd	I,S	I	S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I	I	I
	1/2 Way Beach	I,S	I,S	x	I,S	I,S	x	x	x	x	x	x	x	x	x	x	x	x	x
	Sugars Beach	I,S	I,S	x	I,S	I,S	I,S	I,S	I,S	I,S	I,S	x	x	x	x	x	x	x	x
	Hunters Ck	I,S	I,S	x	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I	I	I
	Boundary Ck	I,S	x	I,S	I,S	I,S	x	x	x	x	x	x	x	x	x	x	x	x	x
	Mundoo Channel	I	x	x	x	x	x	I	x	x	x	x	I	x	x	I	x	x	I
	Ewe Is.	I,S	I	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I	I	I
	Pelican Point	x	I,S	I,S	I,S	I,S	I	I	I	I	I	I	I	I	I	I	I	I	I
	Tauwitcherie	I,S	x	I,S	I,S	I,S	I,S	x	x	x	x	I,S	x	I,S	I,S	I,S	x	x	x
NL	Mark Point	x	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I	I	x
	Mulbin-Yerrok	x	I	x	x	x	x	I	x	x	x	x	I	x	x	I	x	x	I
	Long Point	x	I	x	x	x	I,S	I,S	I,S	I,S	I,S	I,S,P	I,S	I,S	I,S,P	I,S,P	I	I	x
	Noonameena	x	I	x	x	x	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I,S	I	I	I
	Parnka Point North	x	I	x	x	x	x	I	x	I,S	x	I,S	I,S	I,S	I,S	I,S	I	I	I
SL	Parnka Point South	x	x	x	x	x	I,S	x	x	x	x	x	I	I,S	I,S	I	I	I	x
	Villa de Yumpa	x	I	x	x	x	I,S	I	x	I,S	x	I,S	I,S	I,S	I,S	I,S	I	I	I
	Jacks Point	x	I	x	x	x	x	I	x	x	x	x	I	x	x	I	x	x	I
	Loop Road	x	I	x	x	x	x	I	x	x	x	x	I	x	x	I	x	x	I

Key:

x	Site not sampled
(green)	TLM only sites/data
(orange)	TLM/WR overlap sites & dates
(white)	WR only sites

I = Intertidal
S = Subtidal
P = Peninsula

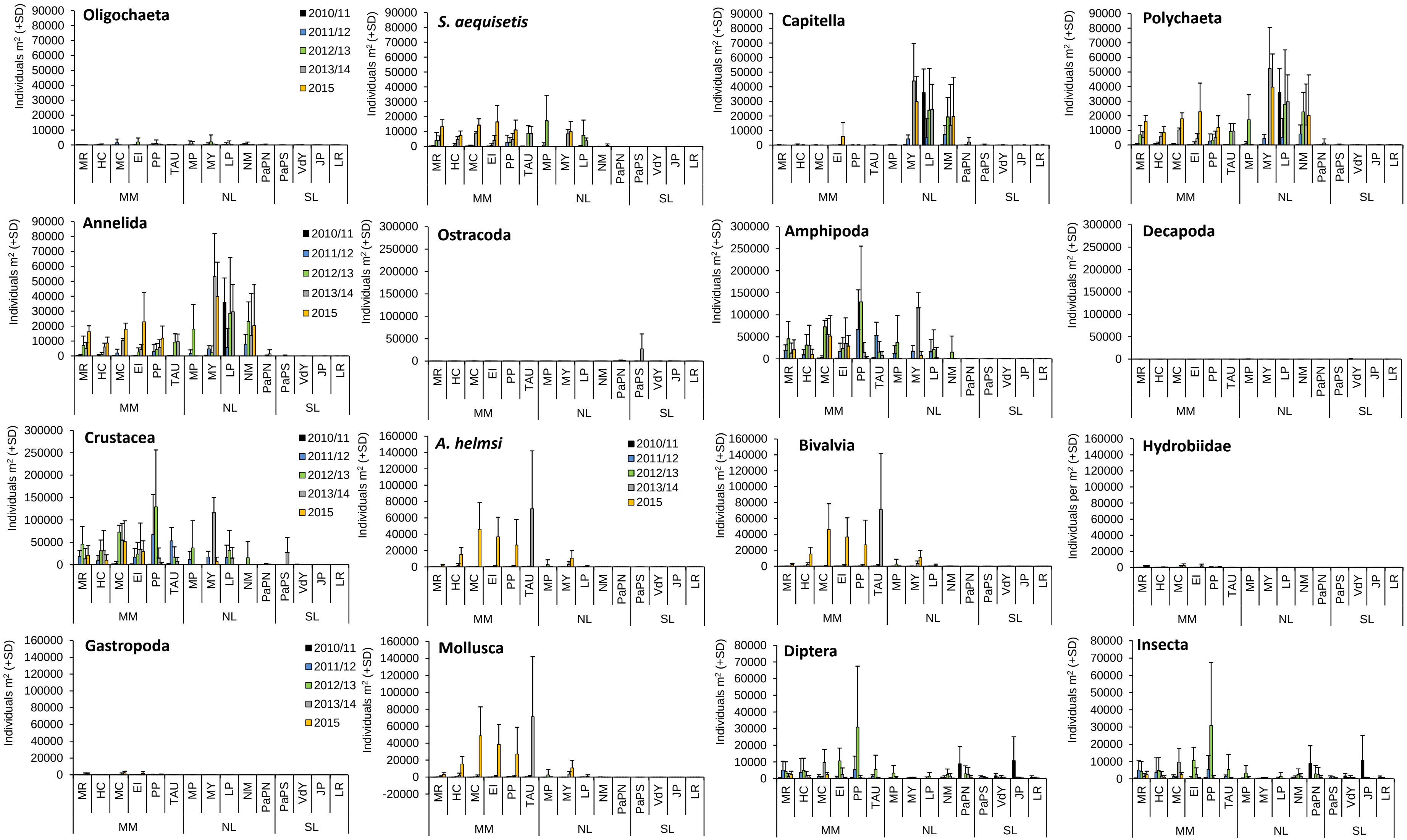


Figure A1: Abundances of key intertidal macrobenthic taxa sampled in the Murray Mouth and Coorong from 2010/11 to 2015. Note different y-axis scales.

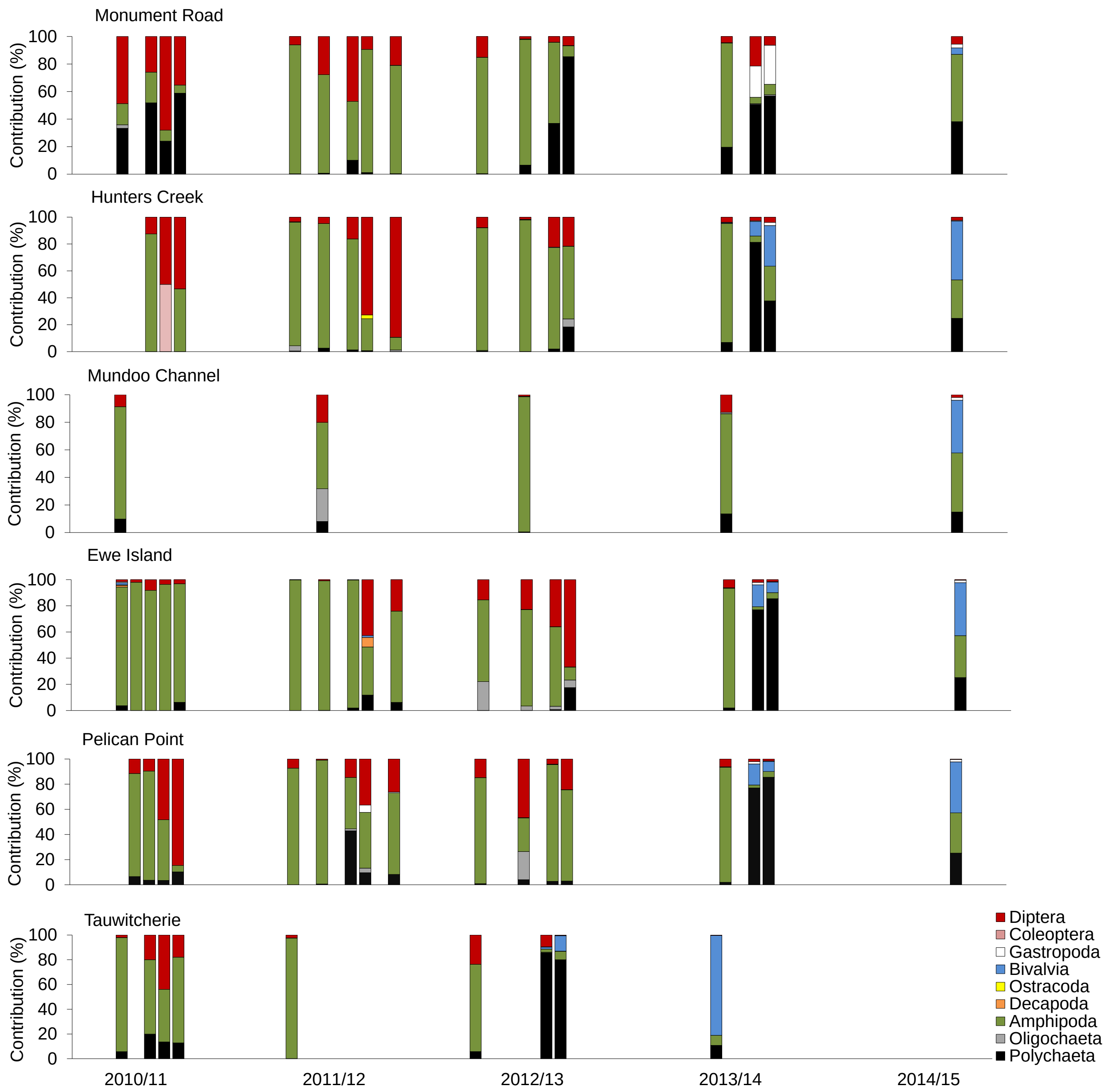


Figure A2: Percent contributions of benthic macroinvertebrates sampled at intertidal sites in the Murray Mouth during multiple seasons within years from 2010 to 2015

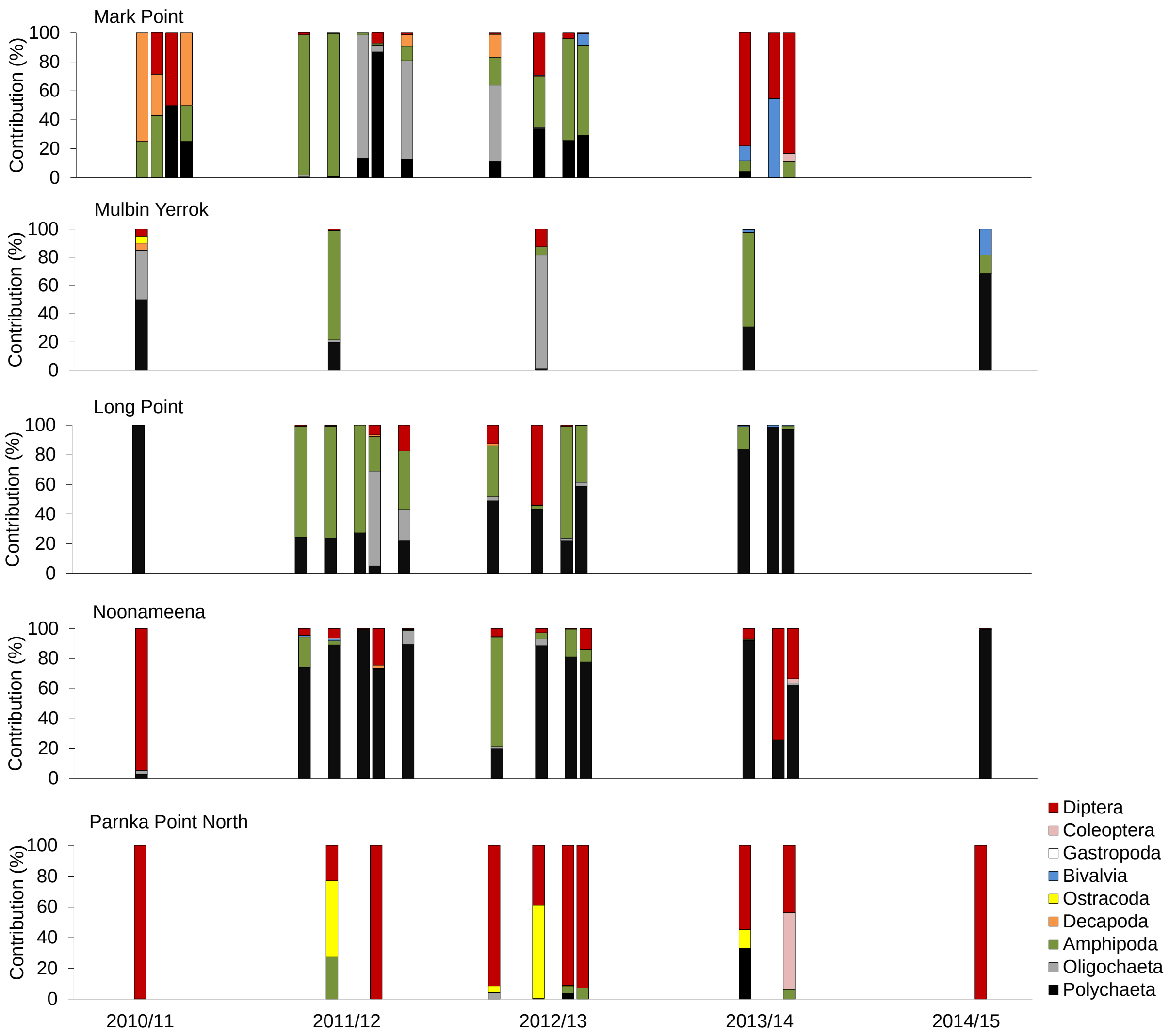


Figure A3: Percent contributions of benthic macroinvertebrates sampled at intertidal sites in the North Lagoon during multiple seasons within years from 2010 to 2015.

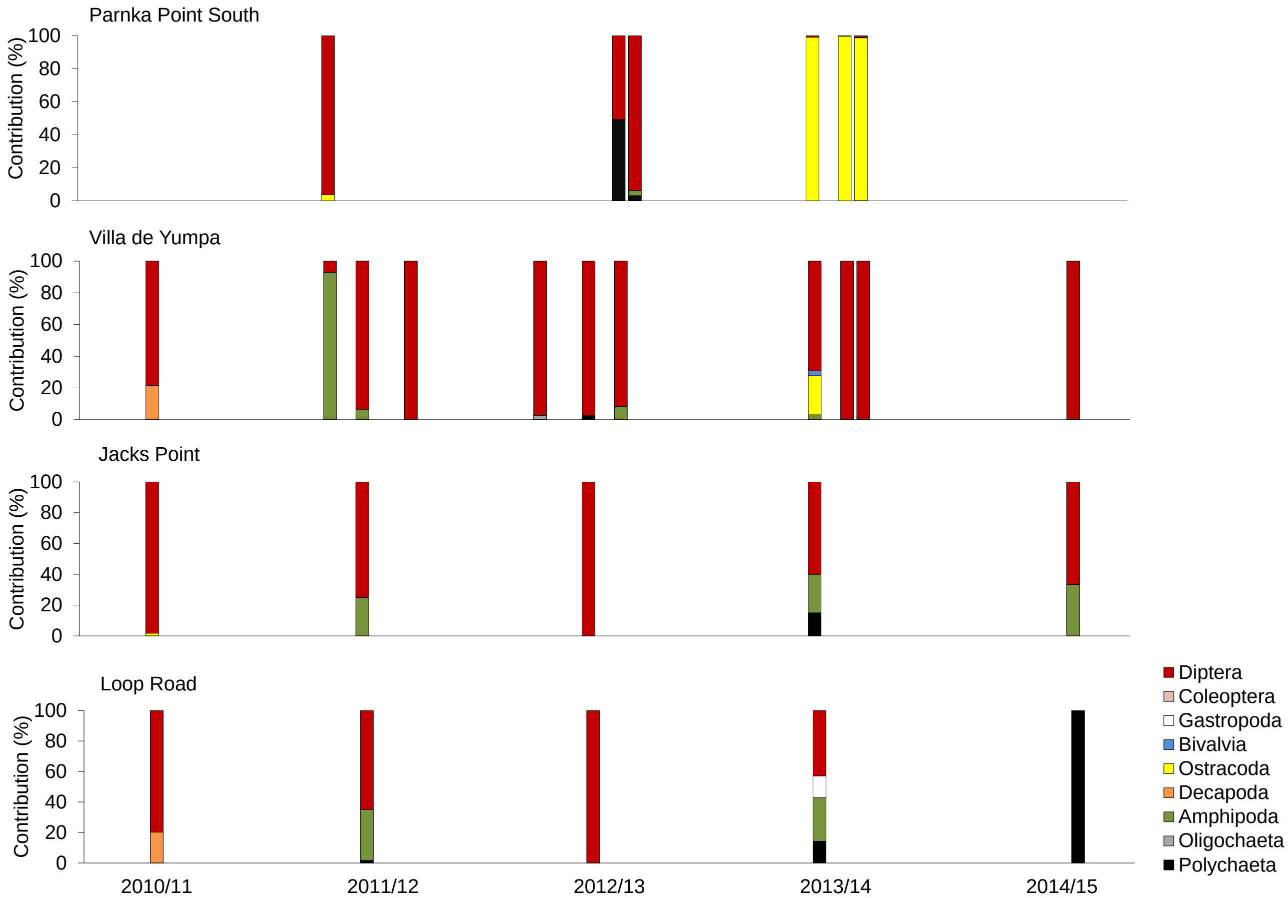


Figure A4: Percent contributions of benthic macroinvertebrates sampled at intertidal sites in the South Lagoon during multiple seasons within years from 2010 to 2015.

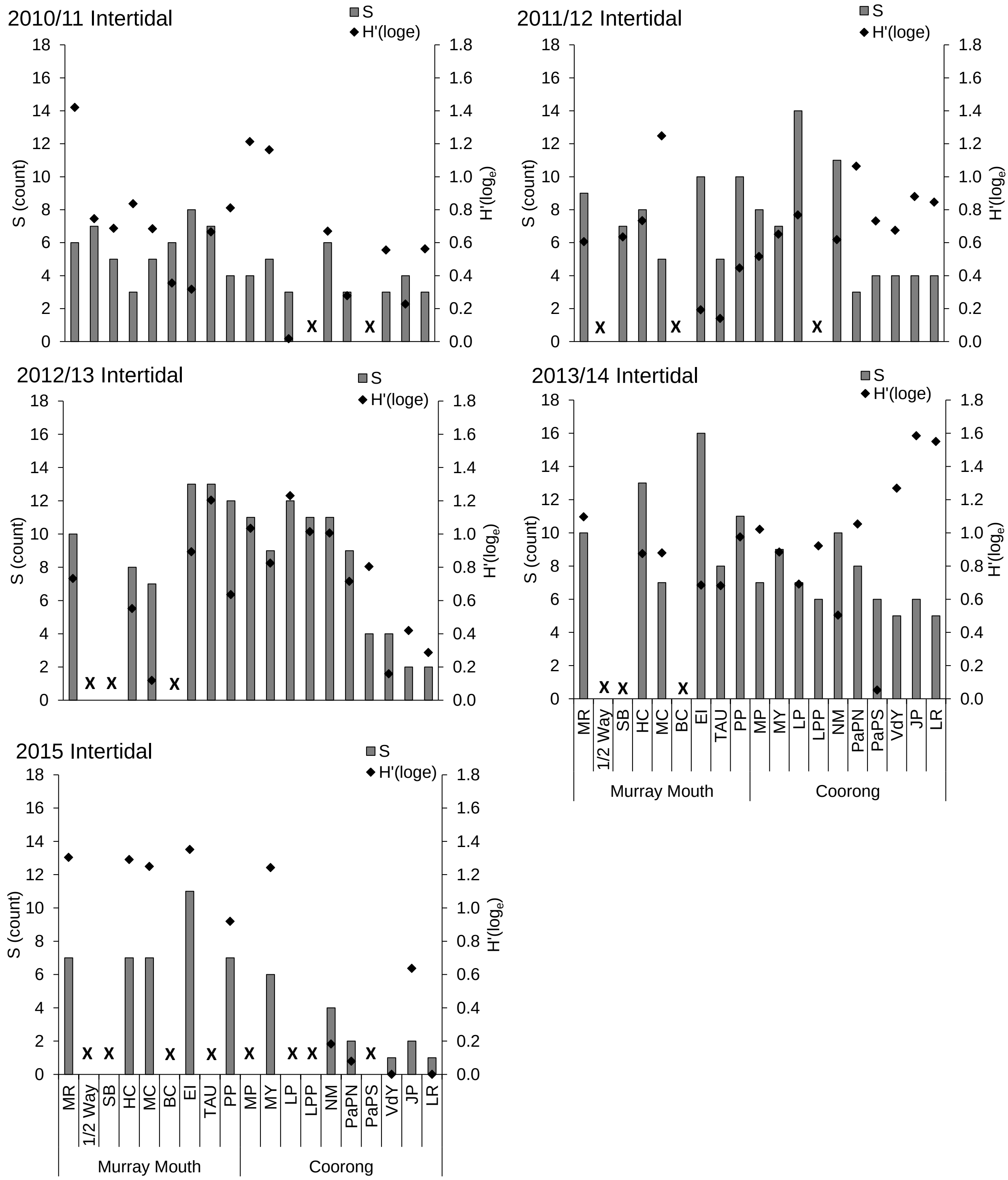


Figure A5: Species richness (S) and Shannon-Wiener diversity (H') of benthic macroinvertebrates sampled at intertidal sites in the Murray Mouth and Coorong across all years from 2010/11 to 2015.

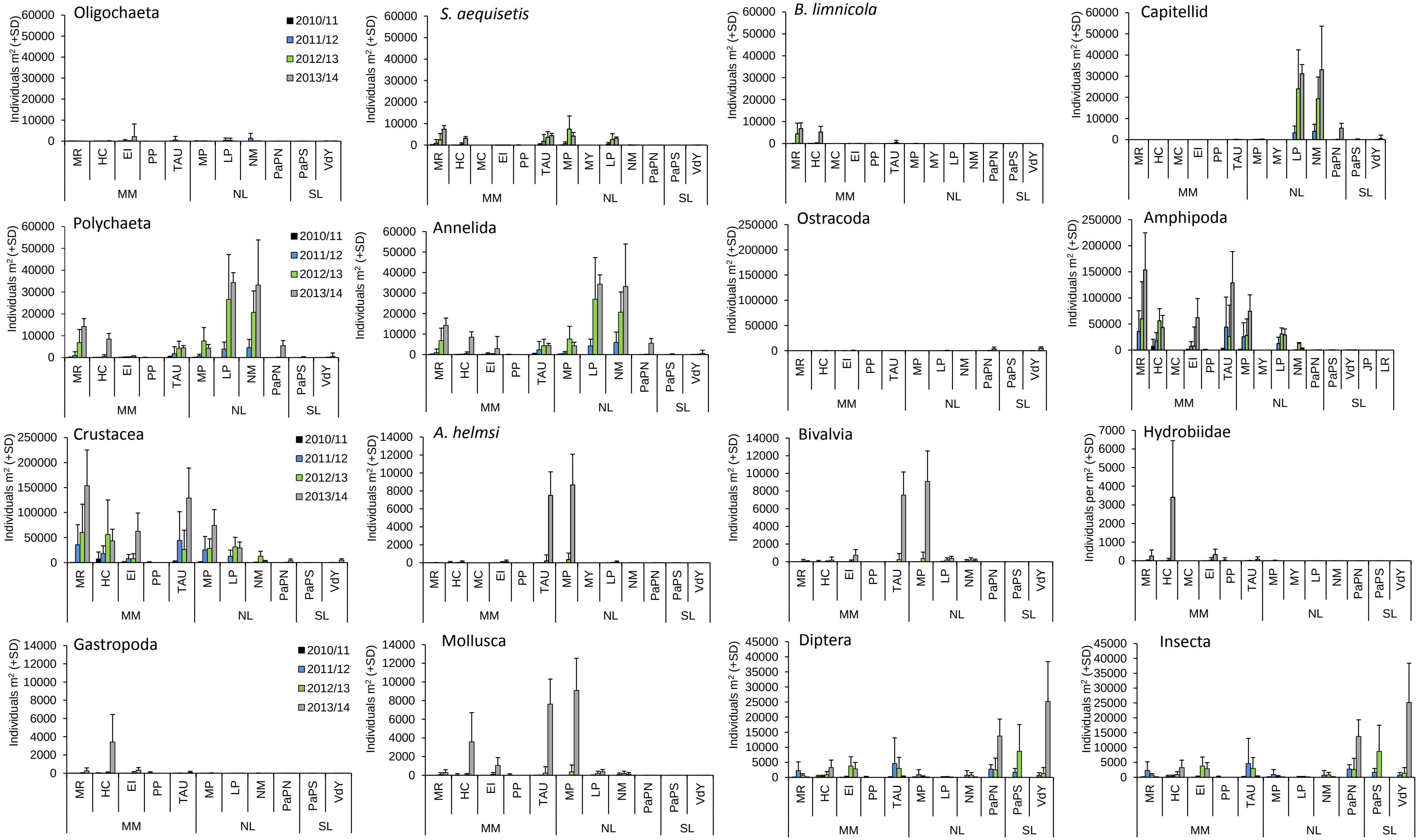


Figure A6: Abundances of key macrobenthic taxa sampled at subtidal sites in the Murray Mouth and Coorong from 2010/11 to 2015.

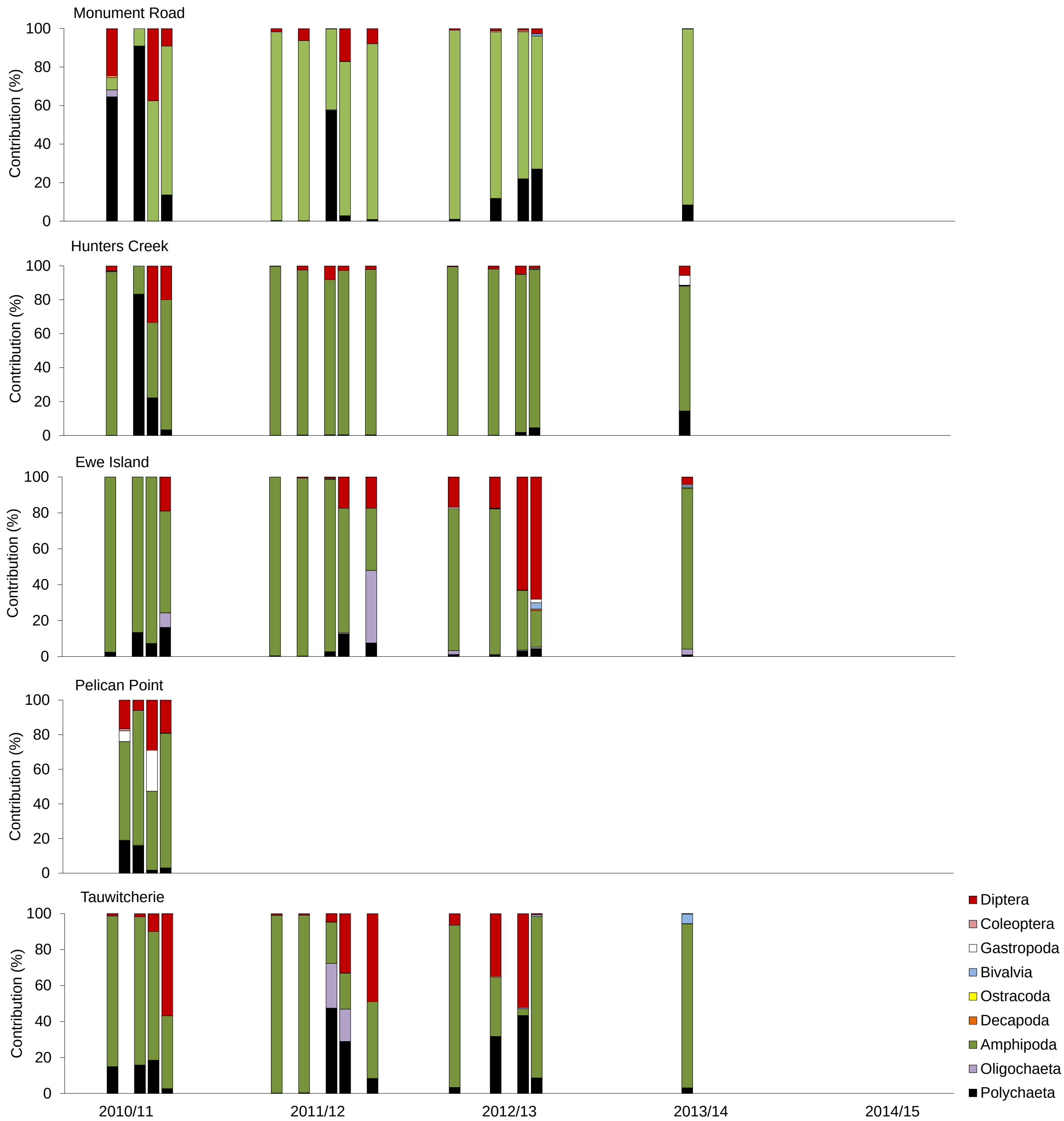


Figure A7: Percent contributions of benthic macroinvertebrates sampled at subtidal sites in the Murray Mouth during multiple seasons within years from 2010 to 2015.

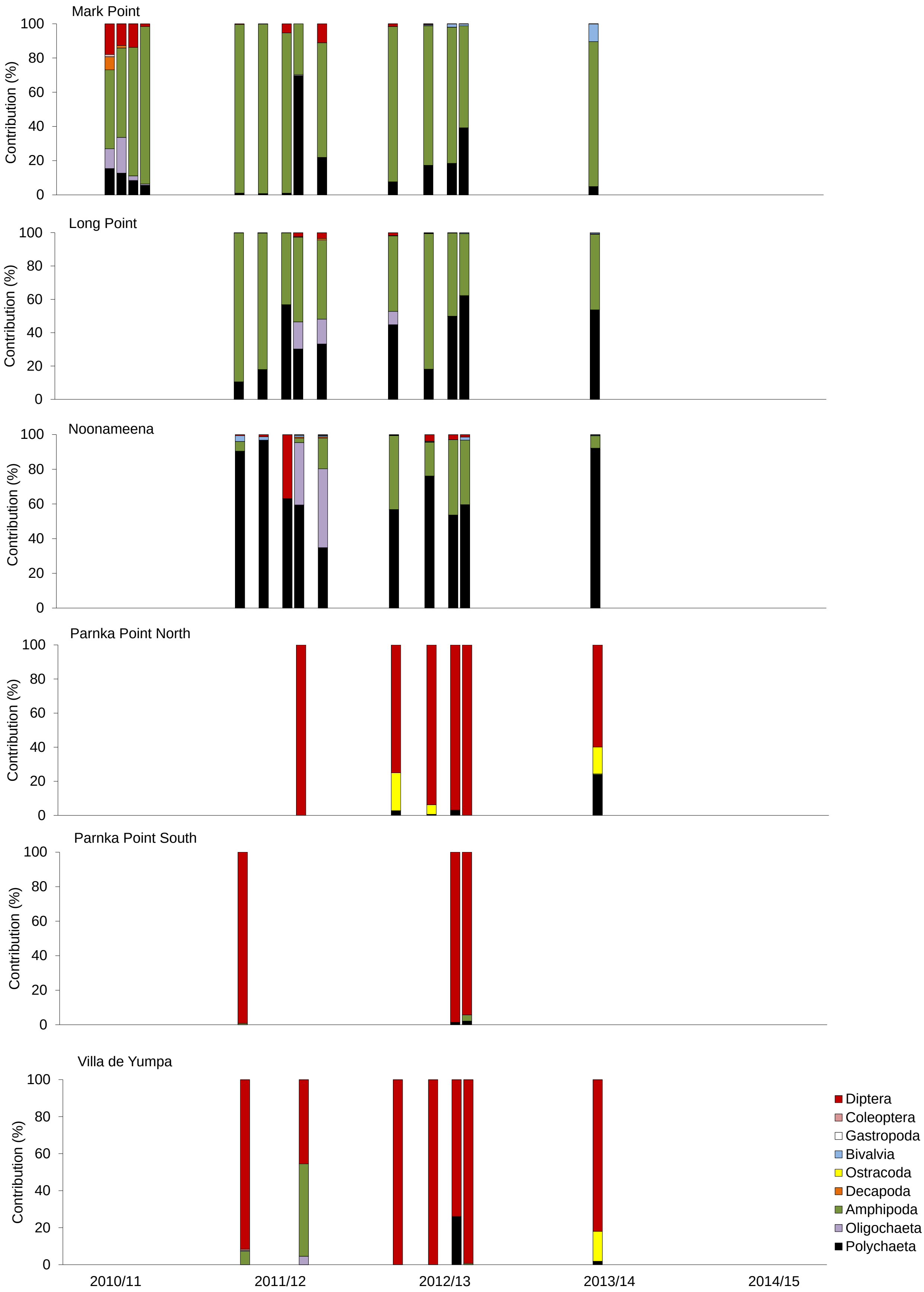


Figure A8: Percent contributions of benthic macroinvertebrates sampled at subtidal sites in the North and South Lagoon of the Coorong during multiple seasons within years from 2010 to 2015.

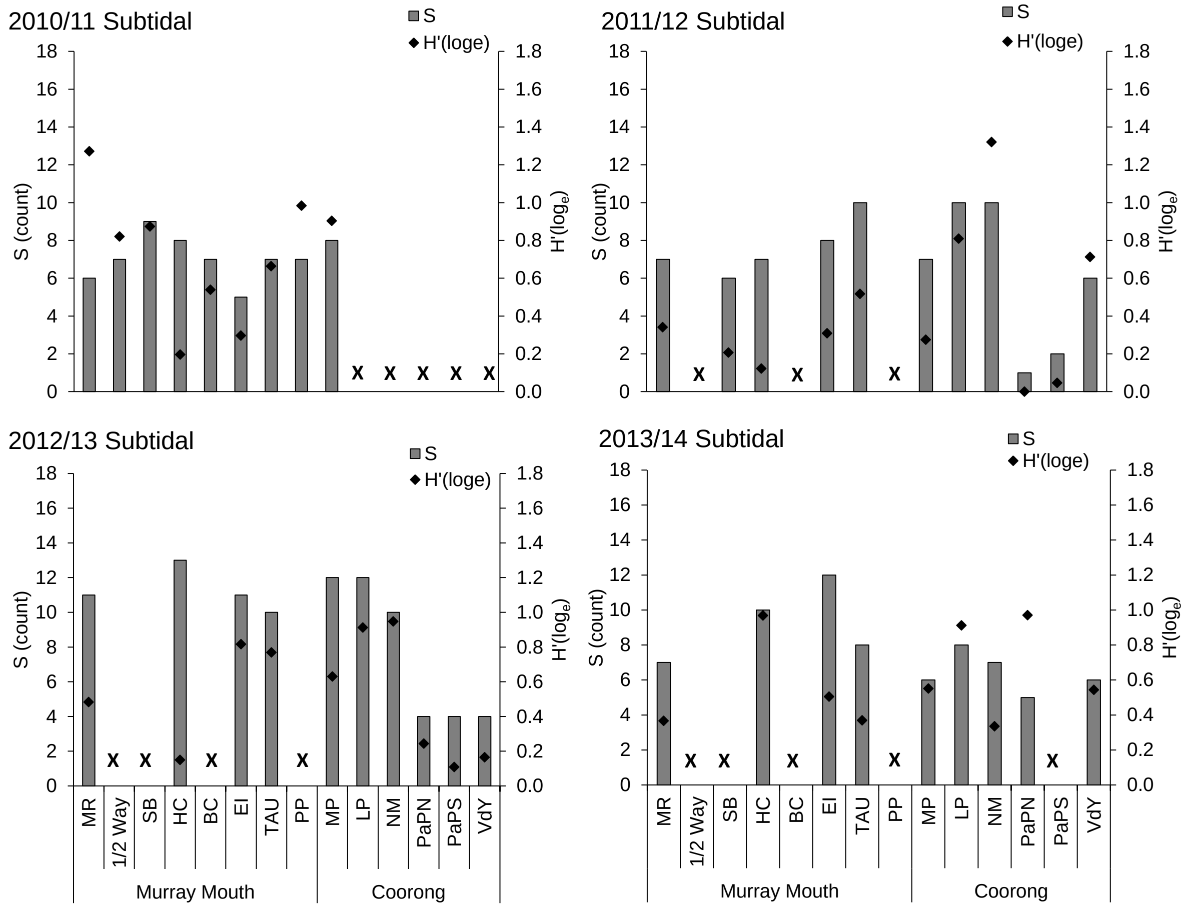


Figure A9: Species richness (S) and Shannon-Wiener diversity (H') of benthic macroinvertebrates sampled at subtidal sites in the Murray Mouth and Coorong across all years from 2010/11 to 2015.

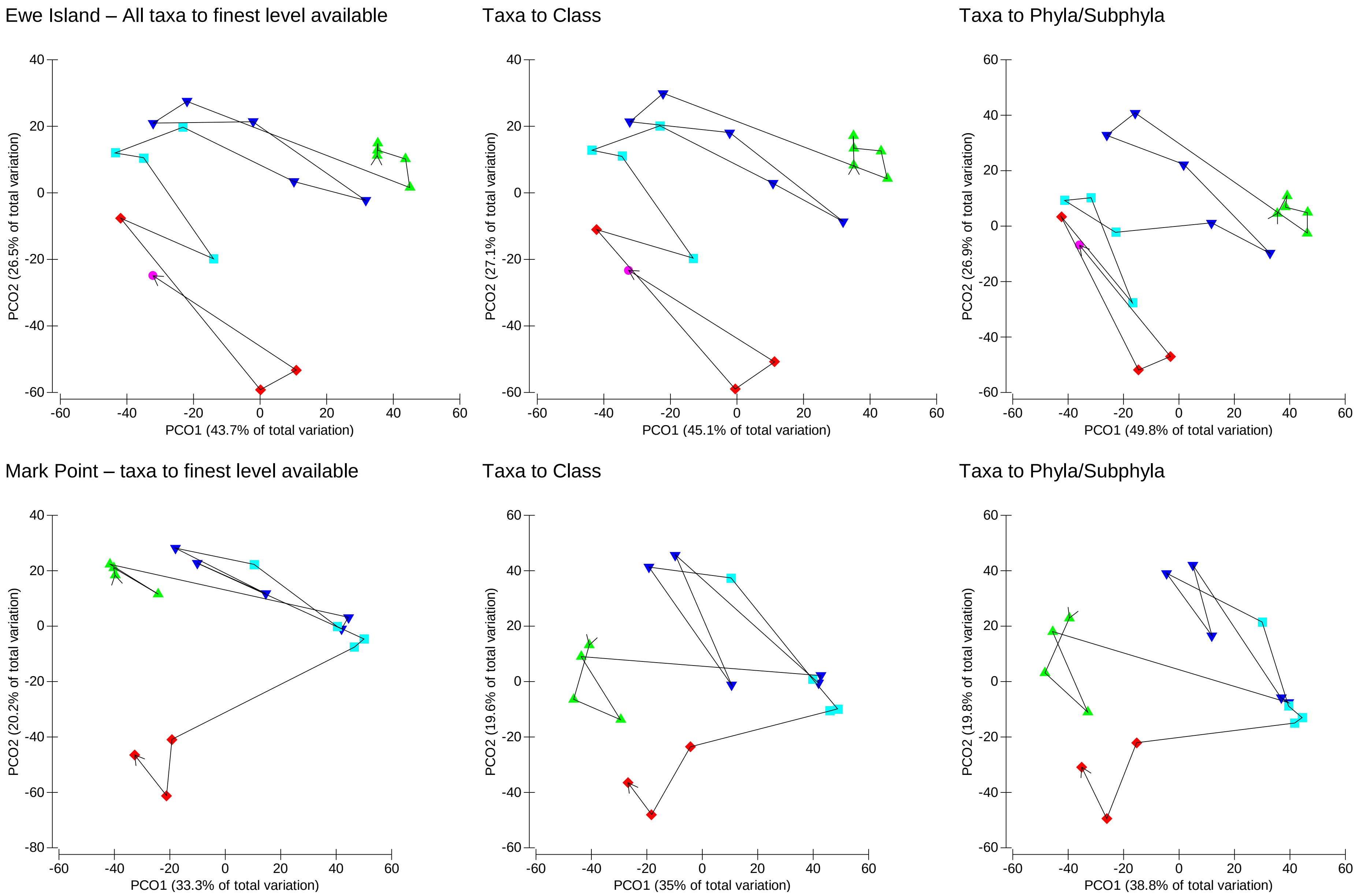


Figure A10: Reduced taxonomic distinction: effects on overall temporal trends observed at community level.

A.2 Recovery

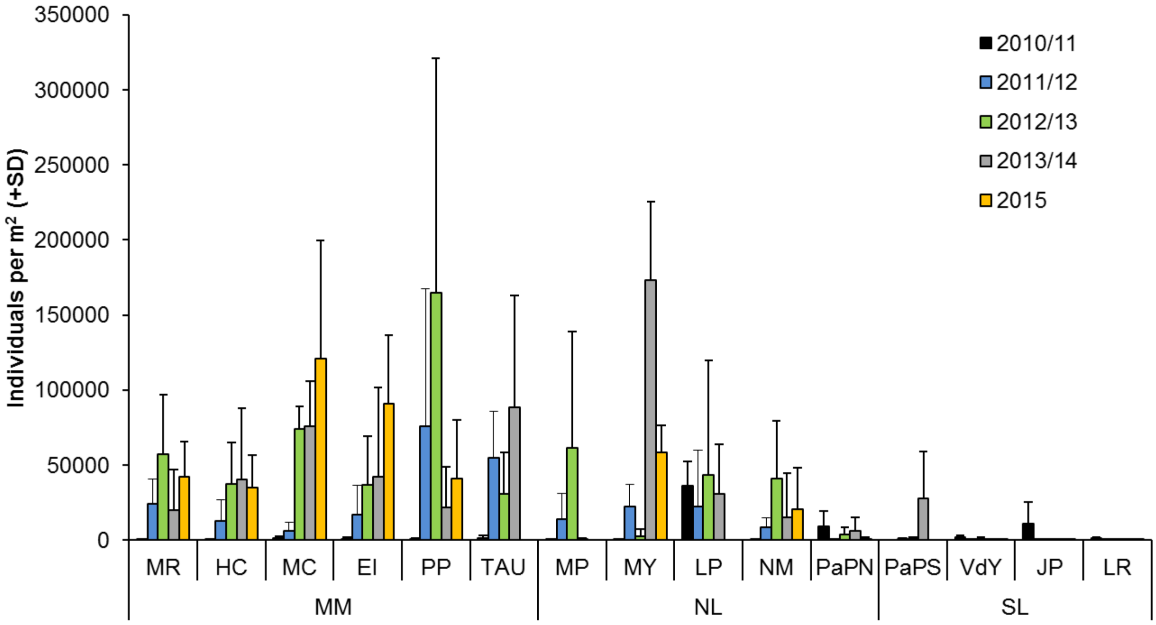


Figure A11. Total abundance (mean individuals per m² ± SD) of benthic macroinvertebrates at each sampling site in the Murray Mouth and Coorong Lagoons, since environmental flows recommenced in 2010/11 to the most recent sampling event (2015). Note that not all sites were sampled again in 2015.

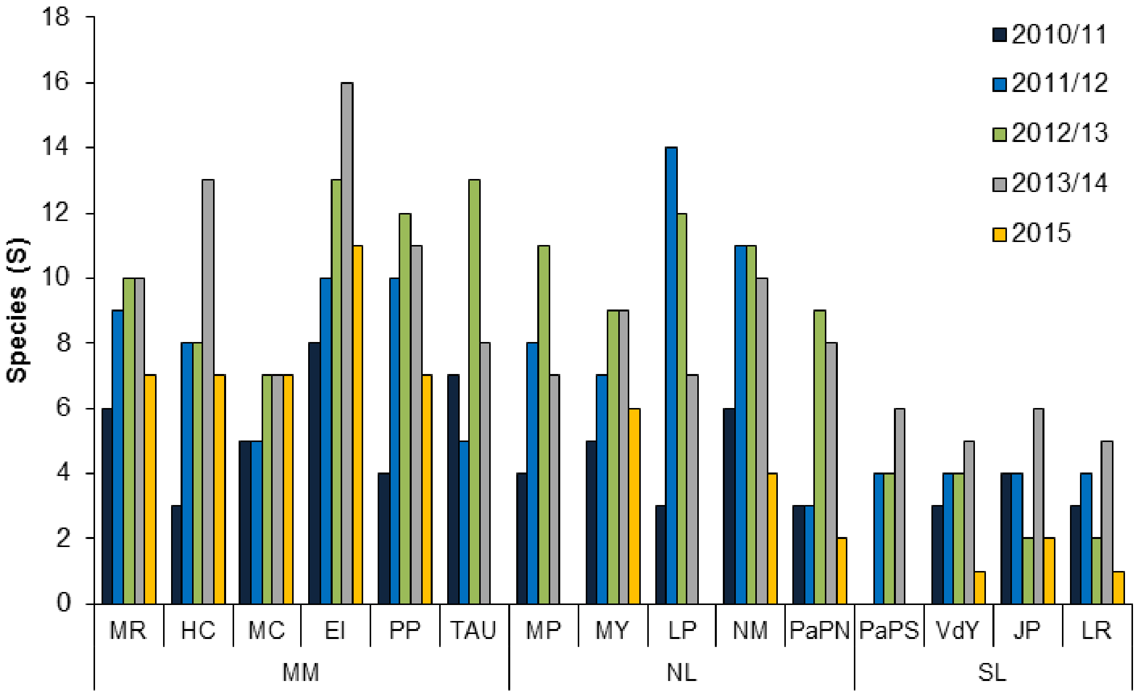


Figure A12. Total number of species (count per site) of benthic macroinvertebrates for each sampling site in the Murray Mouth and Coorong Lagoons, since environmental flows recommenced in 2010/11 to the most recent sampling event (2015). Note that not all sites were sampled again in 2015.

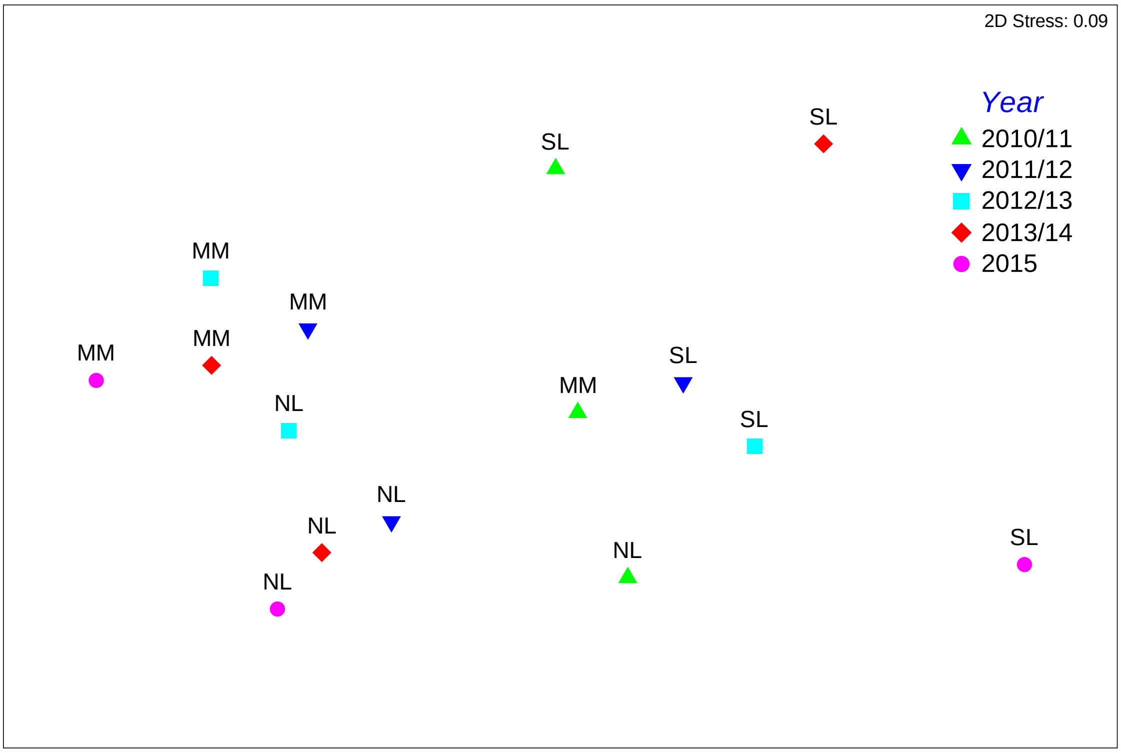


Figure A13. Multidimensional scaling plot (MDS) for benthic communities at intertidal sampling locations from 2010-2015. MM=sites in the Murray Mouth, NL= sites in the North Lagoon, SL= sites in the South Lagoon of the Coorong.

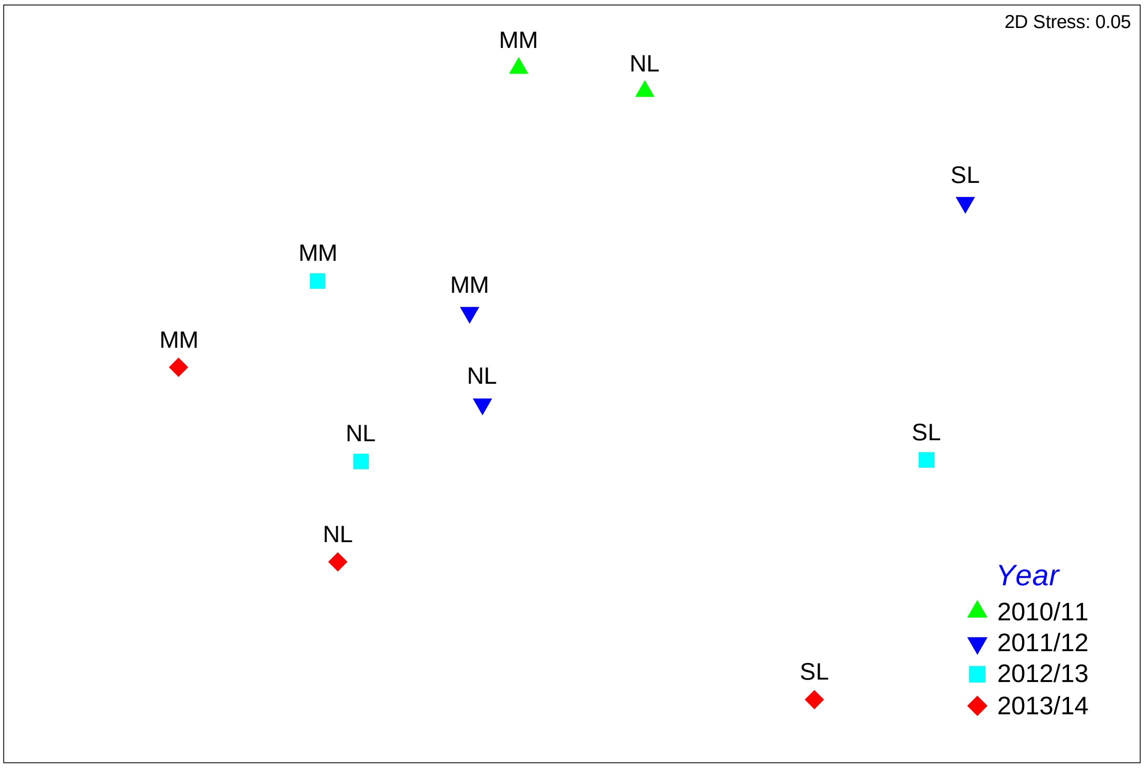


Figure A14. Multidimensional scaling plot (MDS) for benthic communities at subtidal sampling locations from 2010-2015. MM=sites in the Murray Mouth, NL= sites in the North Lagoon, SL= sites in the South Lagoon of the Coorong.

a) Intertidal

b) Subtidal

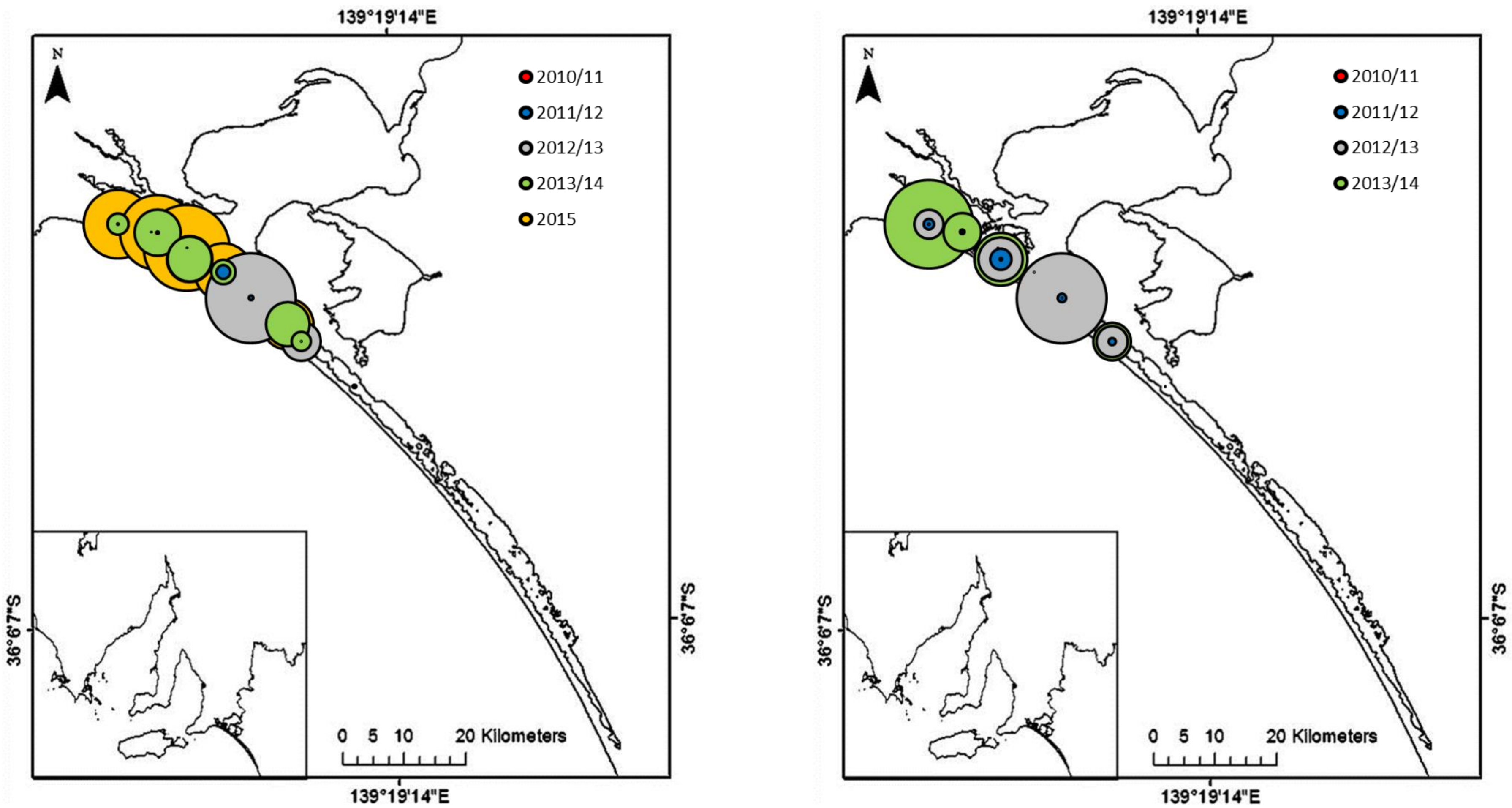
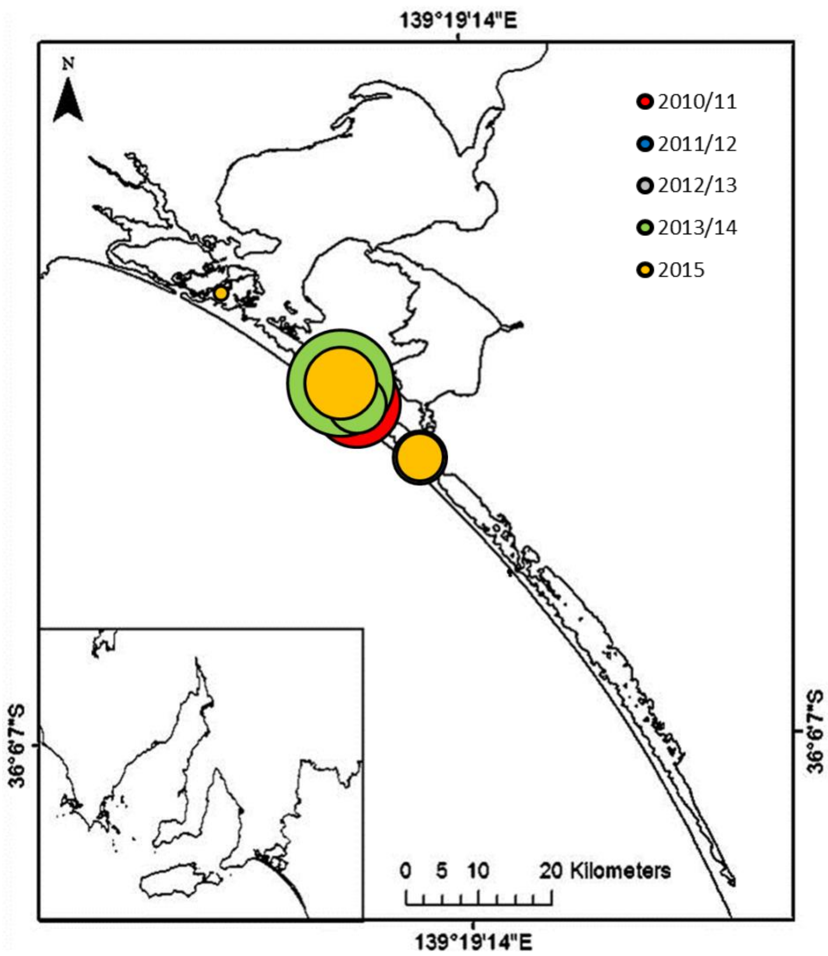


Figure A15. Distribution and relative abundance (averaged by year and site for each depth) of *Simplisetia aequisetis* in the a) intertidal, and b) subtidal sampling sites for each year since flows began in 2010. Bubbles are scaled to relative abundance (over the entire sampling period) and centred on each sampling site. Subtidal locations were not sampled in 2015.

a) Intertidal



b) Subtidal

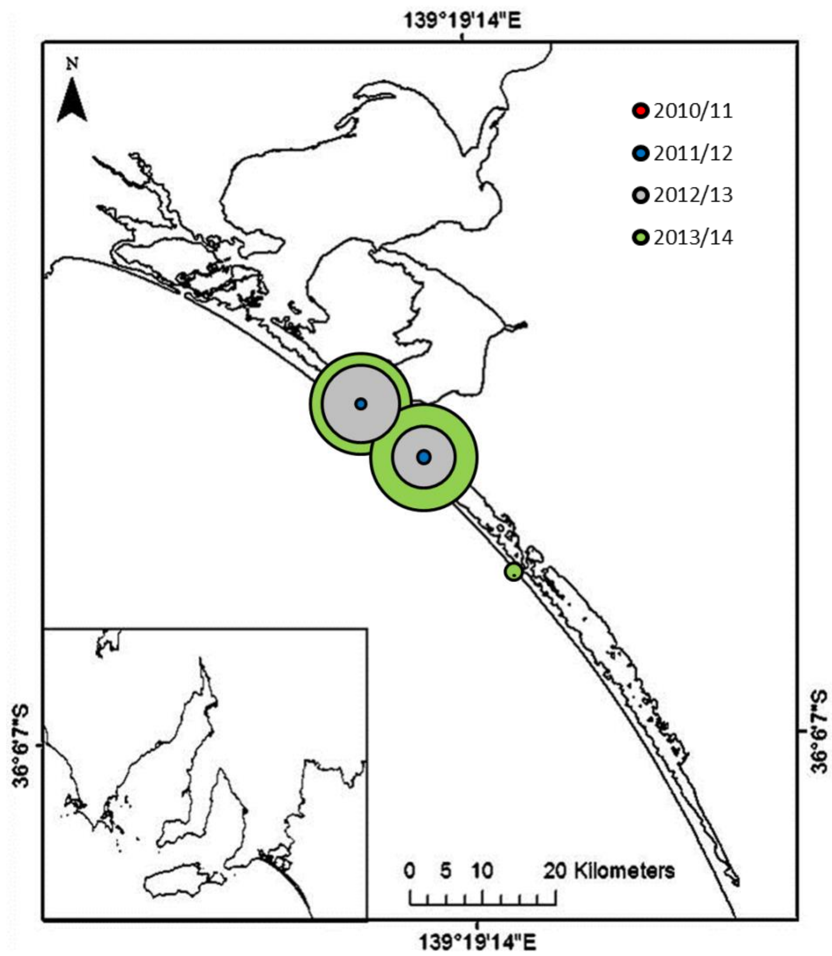
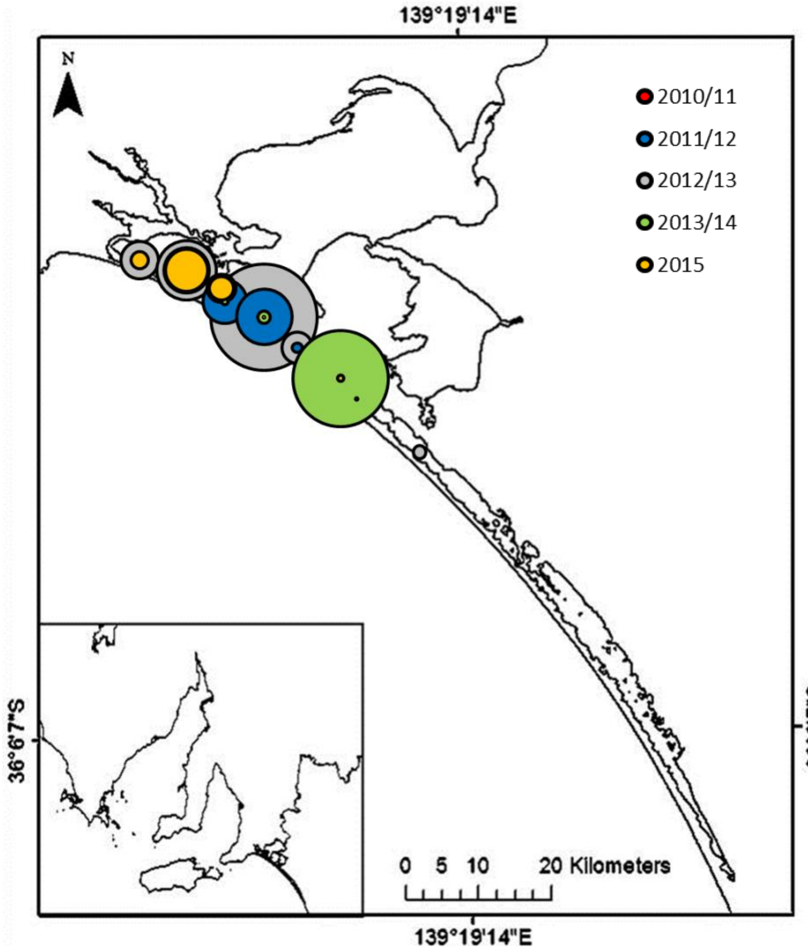


Figure A16. Distribution and relative abundance (averaged by year and site for each depth) of *Capitella sp.* in the a) intertidal, and b) subtidal sampling sites for each year since flows began in 2010. Bubbles are scaled to relative abundance (over the entire sampling period) and centred on each sampling site. Subtidal locations were not sampled in 2015.

a) Intertidal



b) Subtidal

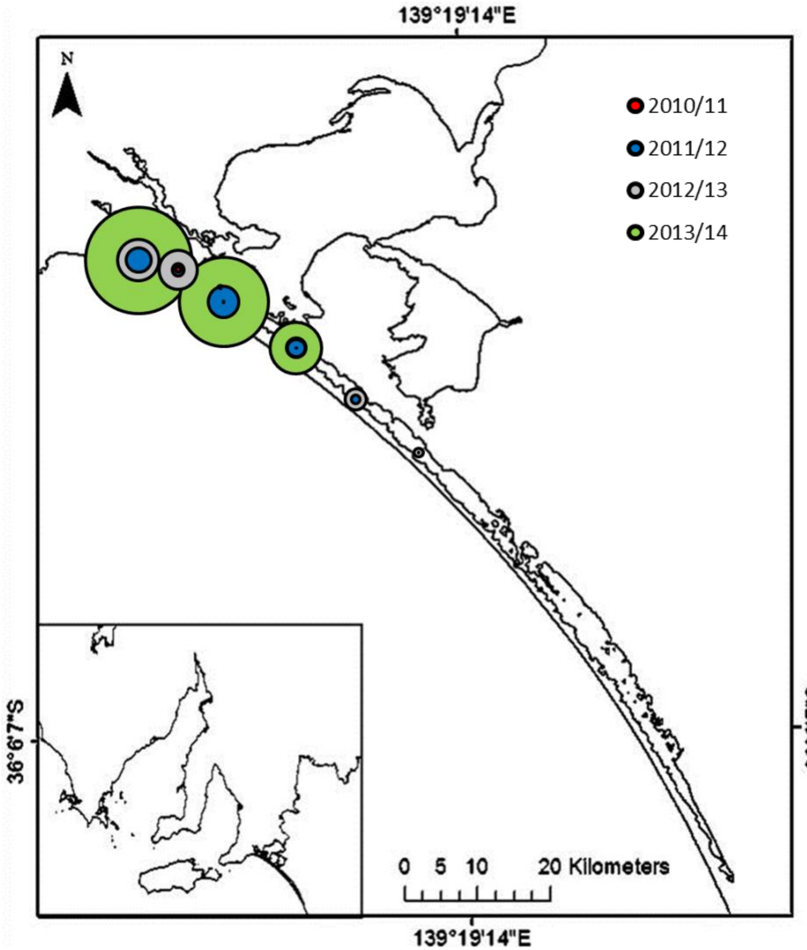


Figure A17. Distribution and relative abundance (averaged by year and site for each depth) of Amphipoda in the a) intertidal, and b) subtidal sampling sites for each year since flows began in 2010. Bubbles are scaled to relative abundance (over the entire sampling period) and centred on each sampling site. Subtidal locations were not sampled in 2015.

a) Intertidal

b) Subtidal

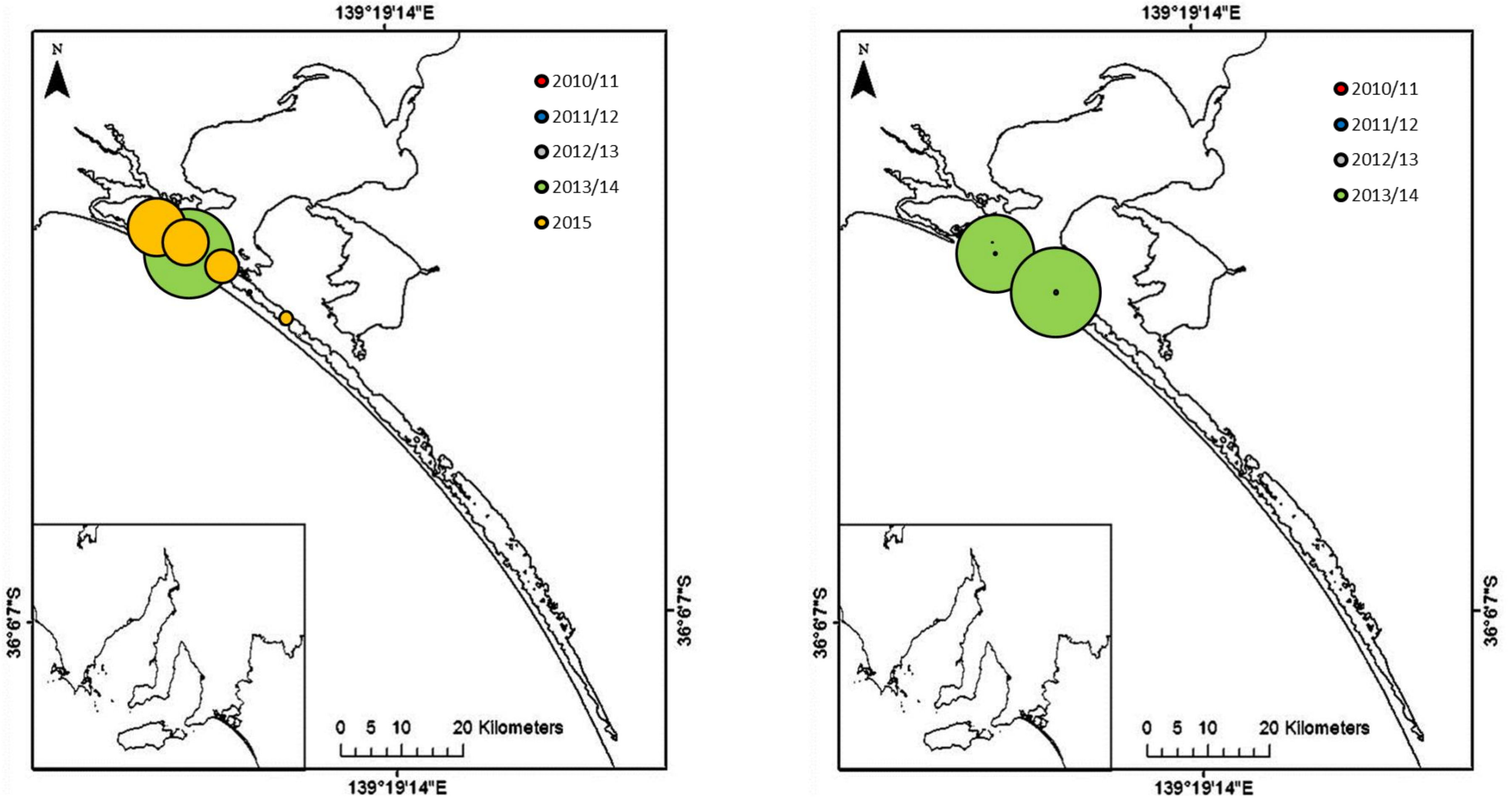
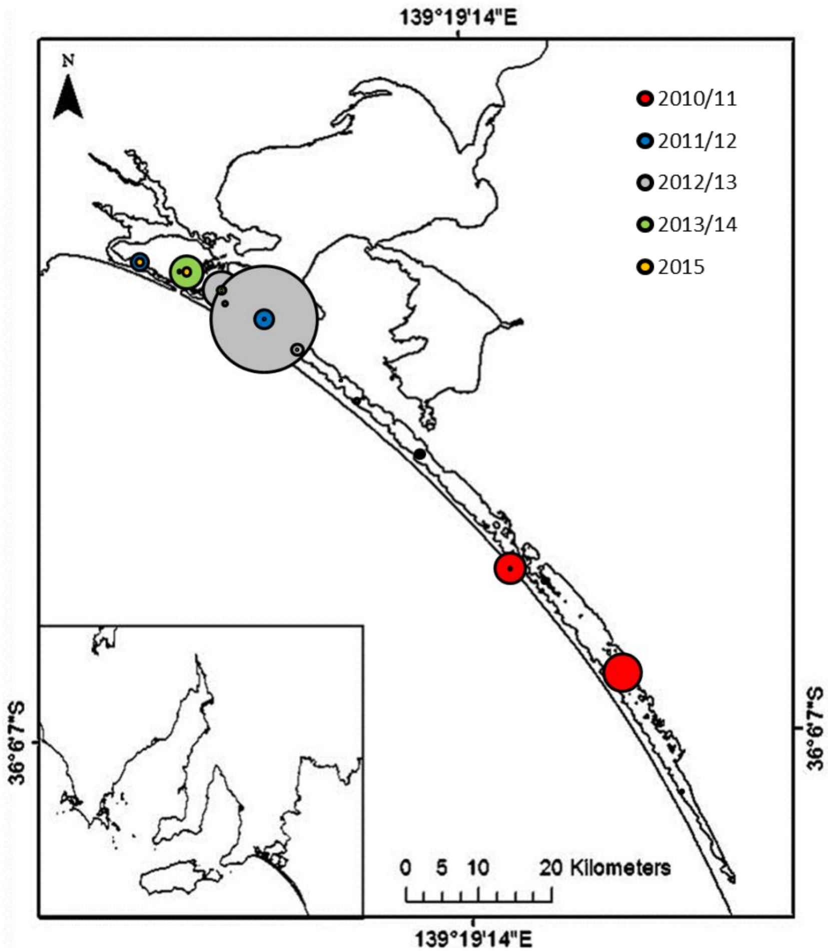


Figure A18. Distribution and relative abundance (averaged by year and site for each depth) of *Arthritica helmsi* in the a) intertidal, and b) subtidal sampling sites for each year since flows began in 2010. Bubbles are scaled to relative abundance (over the entire sampling period) and centred on each sampling site. Subtidal locations were not sampled in 2015.

a) Intertidal



b) Subtidal

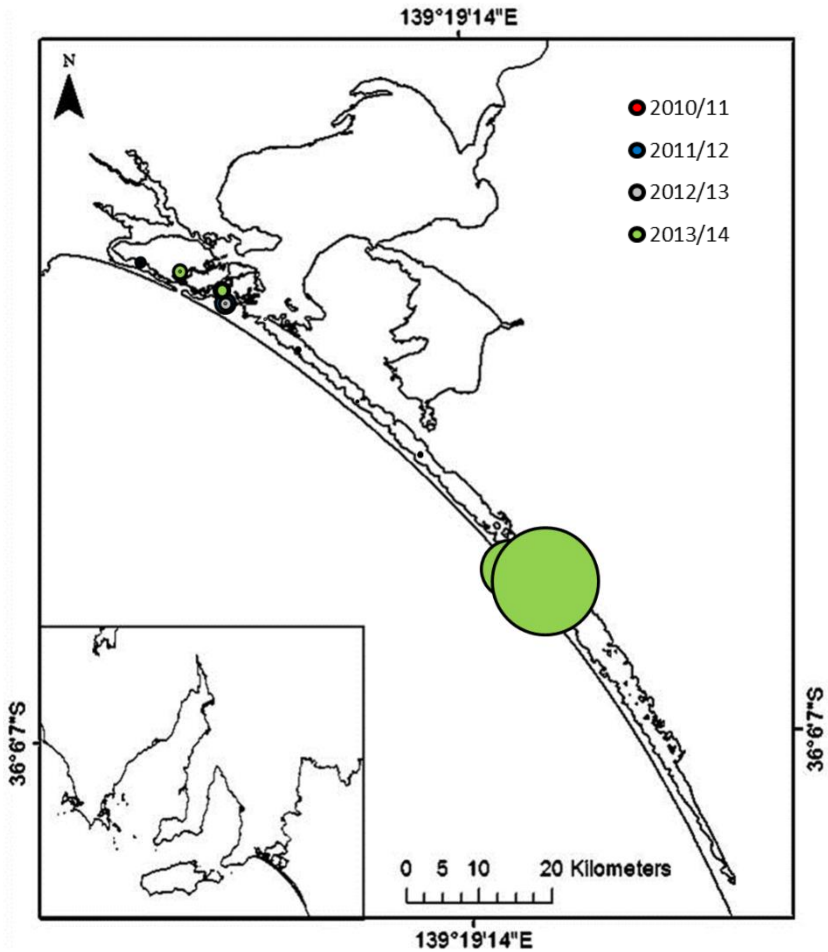
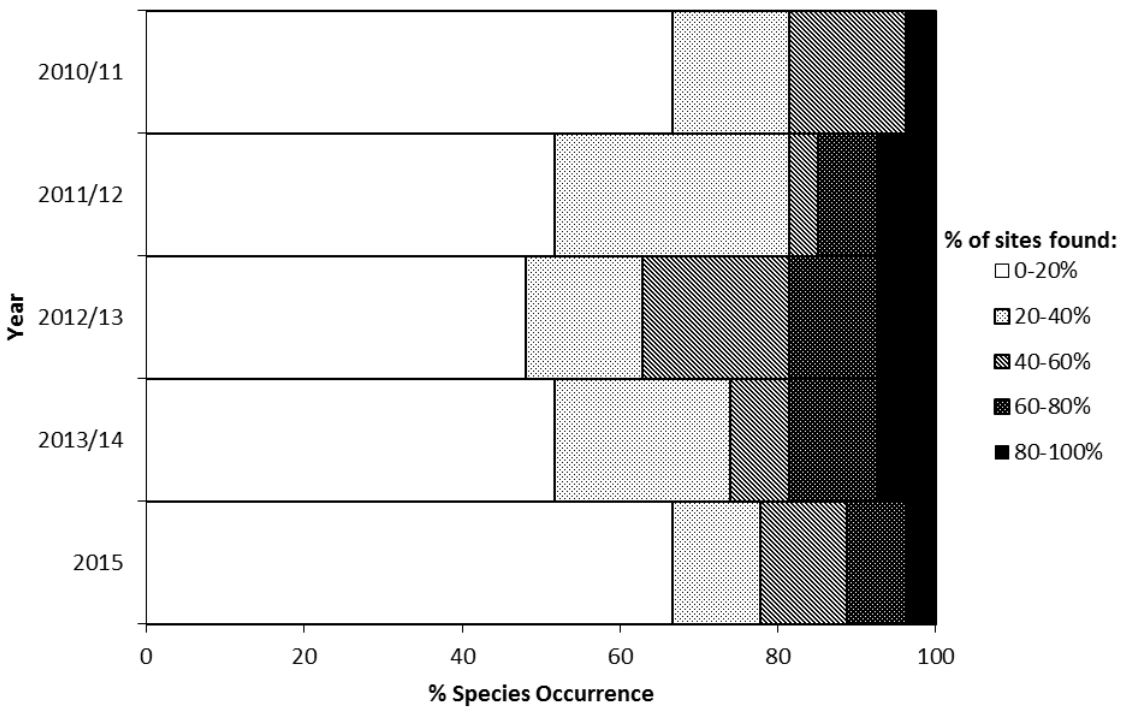


Figure A19. Distribution and relative abundance (averaged by year and site for each depth) of Diptera in the a) intertidal, and b) subtidal sampling sites for each year since flows began in 2010. Bubbles are scaled to relative abundance (over the entire sampling period) and centred on each sampling site. Subtidal locations were not sampled in 2015.

a) Intertidal



b) Subtidal

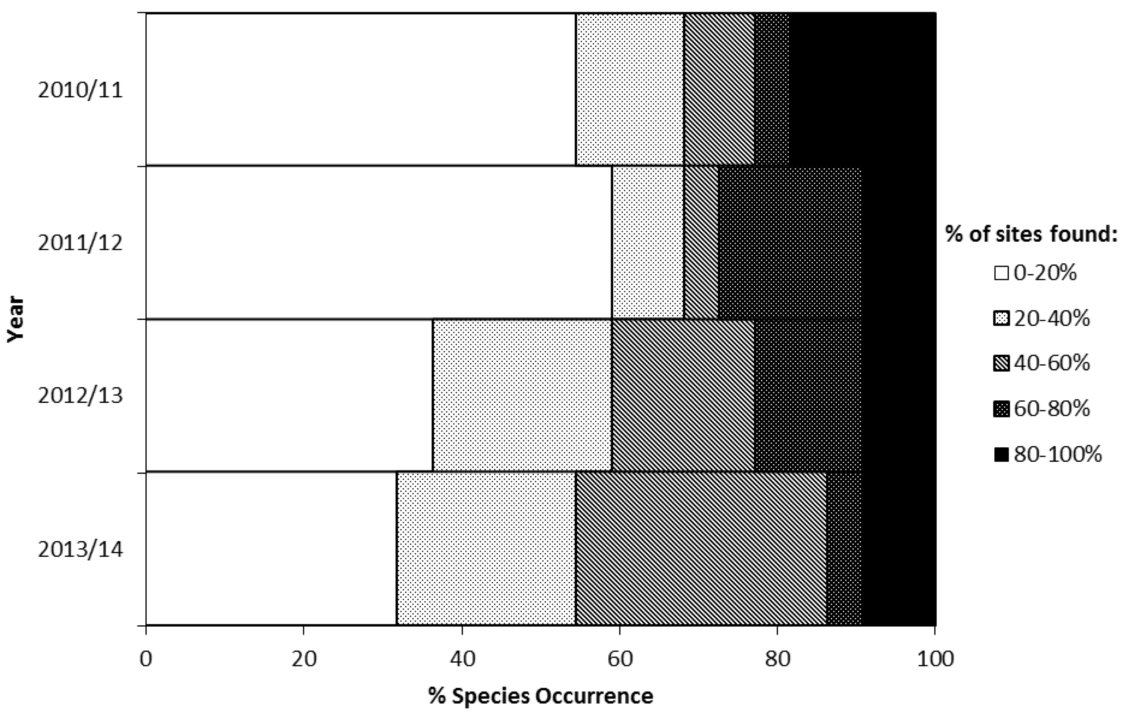


Figure A20. Index of species occurrence plots for a) intertidal and, b) subtidal sampling locations in the Murray Mouth and Coorong Lagoons for each monitoring year since 2010. Years are displayed on the y-axis (note that subtidal sampling was not undertaken in 2015). Shading indicates categorically the percentage of sites at which species were found (i.e. 0 – 20 % of sites [white shading] to 80 – 100 % of sites [black shading]; *i.e.* distribution category, with larger percentages indicating wider distribution ranges). The x-axis indicates the percentage of species (out of all species observed) that were found to occur in each distribution category, called per cent species occurrence.

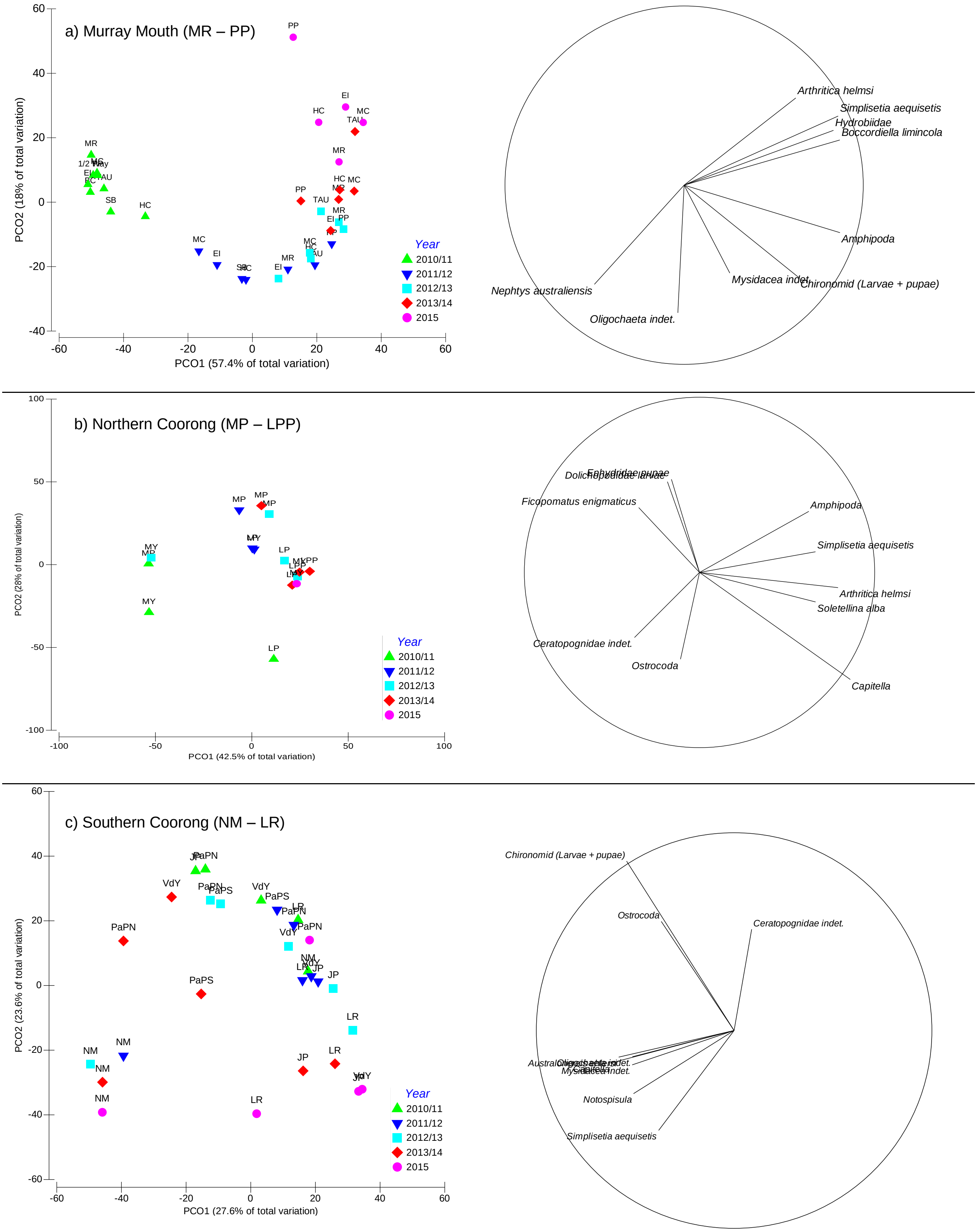


Figure A21. Principle-coordinates ordination (PCO) plots of benthic macroinvertebrate community structure for each site during each sampling year (data are averaged across all replicates collected at that site over all sampling events for that year). Each point represents the macroinvertebrate community (in terms of species composition and relative abundance) for a site. Vector overlays are Spearman correlation (> 0.5).

Table A2. Habitat requirements and important interactions for key benthic macroinvertebrate species, adapted from Tables 2 & 3 in Rolston *et al.* 2010 with additional information on life history strategies from Dorsey 1981; Glasby 1986, Beesley *et al.* 2000 (and references therein) and historical records for these species in the system (Geddes & Butler 1984; Kangas & Geddes 1984; Geddes 1987).

Taxa	Species	Habitat			Trophic Interactions		Other	Life History Strategies		Other
		Substrate	**Salinity**	**Other**	**Feeding Mode**	**Predators**	**Interactions**	larvae	Recruitment	
Annelida	*Ficopomatus enigmaticus*	Hard	35 – 65 ppt	Reef forming species	Filter Feeder	Fish	Ecosystem Engineer (tube reef builder)	Planktonic larvae	Summer, Spring tides	Possibly invasive
	Capitella sp.	Soft	5 – 80 ppt	Tolerant of poor environmental conditions	Deposit Feeder (non-selective)	Birds, Fish	Construct mucus-lined burrows	Multiple spawning events		Pollution indicator
	Nephtys australiensis	Soft	5 – 60 ppt		Predator	Birds, Fish	Burrow, not tube forming	Planktonic		
	Boccardiella limnicola	Soft	5 – 45 ppt	Tolerates freshwater habitats	Filter/Deposit Feeder	Birds, Fish	Sediment stabilisation			
	Australonereis ehlersi	Soft, fine sandy	5 – 45 ppt	Intolerant of low oxygen concentration, adverse environmental conditions	Omnivore, Deposit Feeder, possible suspension feeder	Birds, Fish	Bioturbation, Ecosystem Engineer (tube builder)	Planktonic larvae (unknown duration)	Spring	
	Simplisetia aequisetis	Soft	5 – 45 ppt Adults tolerate riverine conditions	Tolerates low oxygen concentrations, organically enriched sediments	Omnivore, Selective deposit feeder, possible predator of zooplankton	Birds, Fish	Bioturbation, Ecosystem Engineer (burrow builder)	Dioecious, direct developer (brooder)	Spring	
	Oligochaeta	Soft	Freshwater to marine		Deposit Feeder, detritovore	Birds, Fish				
Crustacea	Amphipoda (multiple species)	Both	1 – 62 ppt		Deposit Feeder, omnivore, predator	Birds, Fish	Sediment destabilisation	Brooders		
	Decapoda	Both	35 – 60 ppt		Predator	Birds, Fish	Ecosystem Engineer	Brooders		
Insecta	Insect Larvae	Soft	up to 74 ppt		Predator/Deposit Feeder	Birds, Fish	Burrowers - surface layers	n/a		
Mollusca	*Arthritica helmsi*	Soft	5 – 65 ppt		Filter Feeder	Birds, Fish				
	Spisula trigonella	Soft	5 – 65 ppt		Filter Feeder	Birds, Fish				
	Soletellina alba	Soft	Polyhaline (18-30 ppt)		Filter Feeder	Birds, Fish				

A.3 Annual Trends

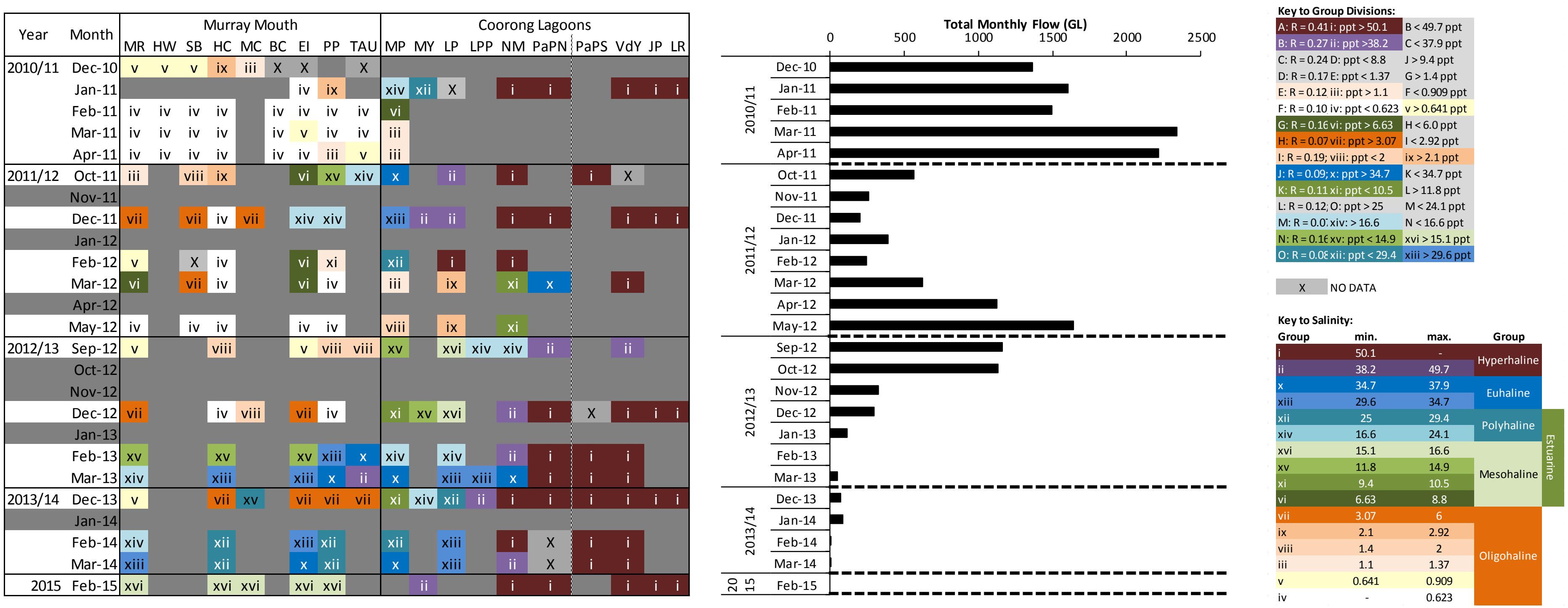


Figure A22: Macroinvertebrate community groupings based on salinity changes across the system for each sampling event from December 2010 to February 2015, plotted against total monthly flow into the system across the barrages. Roman numerals indicate group numbers. Keys to the salinity transition points and ranges for each macroinvertebrate community grouping are given in the keys below the plot, as well as keys to the colour scheme, which reflects salinity conditions defined for estuaries (see Whitfield *et al*. 2012).

Table A3. Summary of SIMPER results. Taxa contributing to 80 % similarity within groups are listed.

				Annelida					Mollusca		Crustacea		Insecta		
Salinity	Group	Salinity Range (ppt) Min	Max	*Capitella*	*Simplisetia aequisetis*	*Nephtys australiensis*	*Boccardiella limnicola*	Oligochaeta	*Arthritica helmsi*	Hydrobiidae	Amphipoda	Mysidaceae	Chironomidae	Ephydridae	Dolichopodidae
Hyperhaline	1	50	-	6.8							10.4		70.4	4.1	
	2	38	50	35.5	3.2			7.3			27.5		18.7		
Euhaline	10	35	38	4.6	21.3				5.7		33.8		25.7		
	13	30	35	8.1	32.5				7.3		30.0		12.6		
Polyhaline	12	25	30	4.7	29.6		5.5	6.9	21.3		15.3		7.6		
	14	16	25		12.0			5.6			49.3		23.5		
Mesohaline	16	15	16.5		24.0		7.5		14.0	6.4	23.2		16.5		
	15	11.5	15		17.9			5.2			44.6		25.3		
	11	9.5	10.5	10.4	14.2			14.2			24.8	5.2	20.1		5.3
	6	6.5	9			7.6					60.0	10.2	19.5		
Oligohaline	7	3	6		10.6	2.4	3.7				49.3		26.1		
	9	2	3		12.1			16.8			27.9		41.2		
	8	1.5	2		13.8			6.6			52.4		20.8		
	3	1	1.4		40.4						28.2		26.5		
	5	0.6	1		8.75						49.9		36.3		
	4	-	0.6		7.25						45.5		42.8		

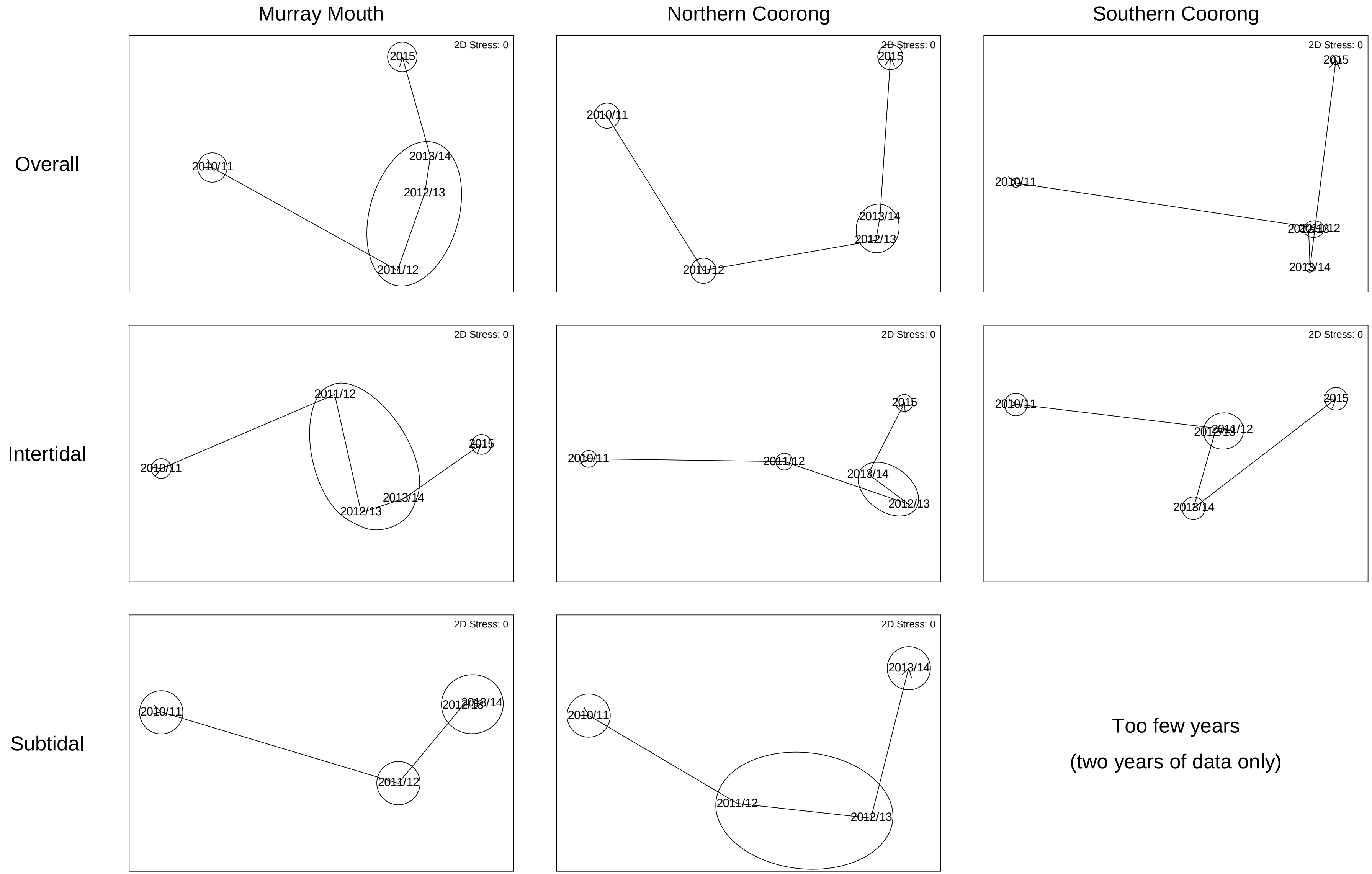


Figure A23. MDS trajectory plots for each region (top row), and each region by depth (intertidal = second row; subtidal = third row).

A.4 Conceptual Models

Table A4: Species list of all taxa collected in all macrobenthic samples (including intertidal and subtidal sites) during the entire monitoring period from 2010/11 to the most recent monitoring event in 2015. Ticks (✓) indicate that taxa was present in that region during that monitoring year, blank spaces indicate that taxa was not recorded. Presence/absence of taxa across years is indicated separately for each region. Summary counts of total number of taxa found in each region during each monitoring event, and total number of taxa found in each region overall are included at the bottom of the table (final two rows).

Taxa		**Murray Mouth**					**North Lagoon**					**South Lagoon**				
		2010/11	**2011/12**	**2012/13**	**2013/14**	**2015**	**2010/11**	**2011/12**	**2012/13**	**2013/14**	**2015**	**2010/11**	**2011/12**	**2012/13**	**2013/14**	**2015**
Annelida	Oligochaeta indet.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	
	Capitella species complex (*C. capitata*)		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	
	Phyllodoce novaehollandiae				✓	✓										
	Simplisetia aequisetis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
	Australonereis ehlersi	✓	✓	✓	✓	✓		✓	✓	✓						
	Nephtys australiensis	✓	✓	✓	✓		✓	✓	✓	✓						
	Boccordiella limincola	✓	✓	✓	✓	✓			✓							
	Ficopomatus enigmaticus	✓		✓	✓		✓	✓	✓							
	Euchone variabilis								✓							
Mollusca	*Arthritica helmsi*	✓	✓	✓	✓	✓			✓	✓	✓				✓	
	Spisula (Notospisula) trigonella		✓	✓	✓			✓	✓	✓						
	Soletellina alba		✓	✓	✓	✓		✓	✓	✓						
	Hydrobiidae (6 spp.)	✓	✓	✓	✓	✓			✓							
	Salinator fragilis	✓	✓	✓	✓	✓		✓	✓							
	Coxiella striata														✓	
Crustacea	Ostracoda	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓	
	Isopoda									✓			✓			
	Amphipoda	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Mysidacea	✓	✓	✓	✓		✓	✓	✓	✓						
	Parartemia sp.											✓				
	Paragrapsus gaimardii	✓	✓	✓	✓			✓	✓		✓					
	Helograpsus haswellianus	✓														
	Amarinus laevis	✓		✓				✓								
Hexapoda	Chironomidae (larvae + pupae)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ephydridae (pupae)	✓		✓	✓		✓		✓	✓		✓		✓	✓	
	Dolichopodidae larvae		✓	✓	✓			✓	✓	✓	✓		✓		✓	
	Muscidae (larvae)									✓						
	Ecnomidae (larvae)									✓					✓	
	Sciomyzidae (larvae + pupae)								✓							
	Tipulidae (larvae)	✓					✓									
	Ceratopognidae (larvae)	✓	✓	✓			✓		✓			✓	✓	✓	✓	
	Culicidae (larvae)	✓					✓	✓					✓			
	Corixidae (larvae)	✓														
	Hydrophilidae (larvae)								✓							
	Coleoptera indet. (larvae + pupae)									✓					✓	
Total # taxa by year and region		21	18	21	20	12	13	17	23	18	8	5	9	7	13	3
Total # taxa by region				26					30					16		

Table A5. Environmental tolerances (as descriptive statistics “Min., Max., Range, Average, Median and Mode”) for nine key species as calculated from data collected in the Murray Mouth and Coorong Lagoons between 2010/11 and 2015. Also included are descriptive statistics for conditions when very low or very high abundances were observed, and for the full range of conditions observed in the system during macrobenthic monitoring.

a) Water Quality

Key Species			Salinity (ppt)						DO (%)					
Taxa		**Species**	**Min.**	**Max.**	**Range**	**Average**	**Median**	**Mode**	**Min.**	**Max.**	**Range**	**Average**	**Median**	**Mode**
Annelida	Oligochaeta	Oligochaeta indet.	0.17	52.40	52.23	14.76	9.93	0.30	63.67	171.70	108.03	107.30	101.00	
	Polychaeta	*Simplisetia aequisetis*	0.17	69.70	69.53	16.19	12.32	0.40	58.80	187.10	128.30	105.50	102.53	96.33
		Capitella spp.	0.23	188.30	188.07	39.81	37.53	49.73	61.83	226.10	164.27	110.10	103.90	
		Nephtys australiensis	0.23	35.37	35.13	7.57	4.30		64.00	171.70	107.70	96.86	90.48	88.63
		Boccordiella limincola	0.40	40.00	39.60	18.23	16.35	24.10	74.13	180.90	106.77	112.73	112.73	
Mollusca	Bivalvia	*Arthritica helmsi*	0.93	43.00	42.07	22.27	26.00	35.33	65.20	180.90	115.70	117.95	113.70	
	Gastropoda	Hydrobiidae	0.25	35.37	35.11	14.63	13.68	12.27	75.80	180.90	105.10	121.15	119.35	
Crustacea	Amphipoda	Amphipoda	0.11	80.13	80.03	15.09	7.17	0.30	58.80	187.10	128.30	101.13	96.93	96.57
Insecta	Diptera	Chironomid (Larvae + pupae)	0.11	109.33	109.23	24.42	12.37	0.30	56.23	236.53	180.30	103.37	98.33	96.33
		Very low abundances (< 1,000 ind.m^{-2})	0.19	104.33	104.14	28.27	1.20		49.80	132.80	83.00	93.01	93.73	100.73
		Very high abundances (> 1,000,000 ind.m^{-2})	0.50	35.93	35.43	13.17	5.83		73.77	173.93	100.17	105.85	103.10	
		Full Range of Conditions Experienced	0.11	188.30	188.19	23.87	10.23	0.30	49.80	236.53	186.73	101.61	97.33	107.33

b) Sediment Characteristics

Key Species			OM (%)						Median GS (µm)					
Taxa		**Species**	**Min.**	**Max.**	**Range**	**Average**	**Median**	**Mode**	**Min.**	**Max.**	**Range**	**Average**	**Median**	**Mode**
Annelida	Oligochaeta	Oligochaeta indet.	0.18	3.03	2.85	0.89	0.87	0.87	18.05	908.72	890.67	265.32	211.89	
	Polychaeta	*Simplisetia aequisetis*	0.18	6.52	6.34	1.26	1.11	1.10	16.59	718.18	701.59	189.25	168.16	
		Capitella spp.	0.37	3.80	3.43	1.22	0.89	0.62	34.00	579.42	545.42	199.50	194.90	
		Nephtys australiensis	0.34	1.37	1.04	0.85	0.96	0.99	130.90	220.20	89.31	179.13	180.22	
		Boccordiella limincola	0.62	6.52	5.90	1.54	1.28		16.59	339.46	322.87	128.86	142.59	
Mollusca	Bivalvia	*Arthritica helmsi*	0.62	6.52	5.90	1.62	1.36		16.59	718.18	701.59	167.33	144.08	
	Gastropoda	Hydrobiidae	0.62	6.52	5.90	1.63	1.19		75.48	339.46	263.98	162.83	147.39	
Crustacea	Amphipoda	Amphipoda	0.18	9.76	9.58	1.18	0.99	0.62	16.59	2549.79	2533.20	215.28	185.86	
Insecta	Diptera	Chironomid (Larvae + pupae)	0.09	18.29	18.19	1.66	1.14	0.62	16.59	1237.90	1221.31	207.59	185.17	
		Very low abundances (< 1,000 ind.m^{-2})	0.42	4.24	3.82	1.96	1.99		121.15	645.27	524.12	278.12	219.83	
		Very high abundances (> 1,000,000 ind.m^{-2})	0.88	2.35	1.47	1.38	1.20		29.60	305.19	275.60	152.78	141.37	
		Full Range of Conditions Experienced	0.09	18.29	18.19	1.58	1.09	0.62	16.59	2549.79	2533.20	229.75	192.02	

c) Chlorophyll-a Content

Key Species			Chl-a (mg.m^{-2})					
Taxa		**Species**	**Min.**	**Max.**	**Range**	**Average**	**Median**	**Mode**
Annelida	Oligochaeta	Oligochaeta indet.	0.00	6.15	6.15	2.24	1.89	
	Polychaeta	*Simplisetia aequisetis*	0.00	6.26	6.26	1.81	1.44	2.07
		Capitella spp.	0.00	4.92	4.92	1.41	0.98	
		Nephtys australiensis	0.11	7.01	6.90	2.20	1.44	
		Boccordiella limincola	0.00	4.68	4.68	1.62	1.44	1.60
Mollusca	Bivalvia	*Arthritica helmsi*	0.07	5.69	5.62	1.21	0.88	0.07
	Gastropoda	Hydrobiidae	0.10	9.43	9.33	2.10	1.31	
Crustacea	Amphipoda	Amphipoda	0.00	9.43	9.43	1.67	1.23	0.37
Insecta	Diptera	Chironomid (Larvae + pupae)	0.00	9.43	9.43	1.58	1.01	0.00
		Very low abundances (< 1,000 ind.m^{-2})	0.03	2.19	2.16	0.97	0.64	
		Very high abundances (> 1,000,000 ind.m^{-2})	0.10	2.07	1.97	0.84	0.68	
		Full Range of Conditions Experienced	0.00	9.43	9.43	1.42	0.93	0.00

Table A6: Taxa traits and preferences as defined from the data for the Murray Mouth and Coorong Lagoons.

a) Taxa size, longevity and life history traits

Taxa		Size & Longevity		Reproduction/Life History			
		Individual Size	**Life span**	**Method**	**Rearing method**	**Deposition**	**Larval Type**
Annelida	Oligochaeta indet.	Large (> 20 mm)	Medium (1 - 3 years)	Sexual	shed eggs	benthic	Benthic
	Capitella species complex (*C. capitata*)	Large (> 20 mm)	Short (< 1 year)	Sexual	brood eggs	carried	Pelagic-planktonic/Pelagic lecithotrophic
	Phyllodoce novaehollandiae	Large (> 20 mm)	Medium (1 - 3 years)	Encapsulation	gelatinous mass	benthic	Pelagic-planktonic
	Simplisetia aequisetis	Large (> 20 mm)	Medium (1 - 3 years)	Sexual	brood eggs	carried	Brooder
	Australonereis ehlersi	Large (> 20 mm)	Medium (1 - 3 years)	Sexual	brood eggs	carried	Pelagic-planktonic/Benthic
	Nephtys australiensis	Large (> 20 mm)	Long (3 - 10 years)	Sexual	shed eggs	pelagic	Pelagic-planktonic
	Boccordiella limincola	Large (> 20 mm)	Medium (1 - 3 years)	Sexual	brood eggs	carried	Pelagic-planktonic/Pelagic lecithotrophic
	Ficopomatus enigmaticus	Large (> 20 mm)	Long (3 - 10 years)	Sexual	shed eggs	pelagic	Pelagic-planktonic
Mollusca	*Arthritica helmsi*	Small (0.5 - 5 mm)	Medium (1 - 3 years)	Sexual	brood eggs	carried	Benthic/Brooder
	Spisula (Notospisula) trigonella	Large (> 20 mm)	Long (3 - 10 years)	Sexual	shed eggs	pelagic	Pelagic-planktonic
	Soletellina alba	Large (> 20 mm)	Medium to Long	Sexual	shed eggs	pelagic	Pelagic-planktonic
	Hydrobiidae (6 spp.)	Small (0.5 - 5 mm)	Medium (1 - 3 years)	Sexual	shed eggs	benthic	Pelagic-planktonic/Benthic
	Salinator fragilis	Medium (5 - 20 mm)	Short to Long	Encapsulation	gelatinous mass	benthic	Pelagic-planktonic
Crustacea	Ostracoda	Small (0.5 - 5 mm)	Short (< 1 year)	Sexual	brood eggs	carried	Pelagic-planktonic/Benthic
	Amphipoda	Small (0.5 - 5 mm)	Short to Medium	Sexual	brood eggs	carried	Brooder
	Paragrapsus gaimardii	Medium (5 - 20 mm)	Medium to Long	Sexual	brood eggs	carried	Pelagic-planktonic
Hexapoda	Chironomidae (larvae + pupae)	Small (0.5 - 5 mm)	Short (< 1 year)	Encapsulation	gelatinous mass	benthic	Pelagic-planktonic/Benthic

b) Taxa roles and environmental preferences

Taxa		Role in the environment				Environmental tolerances	
		Feeding Habit	**Living Habit**	**Environmental position**	**Sediment Movement**	**Salinity**	**Sediment Grain Size**
Annelida	Oligochaeta indet.	Grazer/Surface deposition	Burrow/Free-living	Shallow/Deep	Surficial modifier	Oligohaline	Fine sand (125 - 250 µm)
	Capitella species complex (*C. capitata*)	Surface/Sub-surface deposition/Predator	Burrow-dwelling	Shallow (< 3 cm)/Bentho-pelagic	Surficial modifier	Polyhaline - Hyperhaline	Fine sand (125 - 250 µm)
	Phyllodoce novaehollandiae	Scavenger/Predator	Free-living	Shallow (< 3 cm)	Surficial modifier	Polyhaline - Euhaline	Fine to Medium sand (125 - 500 µm)
	Simplisetia aequisetis	Surface deposition/Predator	Burrow-dwelling	Deep (> 3 cm)	Bio-irragator (deep mixing)	Oligohaline	Fine sand (125 - 250 µm)
	Australonereis ehlersi	Sub-surface deposition/Predator	Burrow-dwelling	Deep (> 3 cm)	Bio-irragator (deep mixing)	Oligohaline - Mesohaline, Euhaline	Fine sand (125 - 250 µm)
	Nephtys australiensis	Sub-surface deposition/Predator	Burrow-dwelling	Deep (> 3 cm)	Bio-irragator (deep mixing)	Oligohaline	Fine sand (125 - 250 µm)
	Boccordiella limincola	Filter/Suspension/ Surface deposition	Free-living	Shallow (< 3 cm)	Surficial modifier	Oligohaline, Euhaline	Very fine - Fine sand (63 - 250 µm)
	Ficopomatus enigmaticus	Filter/Suspension	Tube dwelling	Shallow (< 3 cm)	No bio-turbation	Oligohaline - Mesohaline	Fine to Medium sand (125 - 500 µm)
Mollusca	*Arthritica helmsi*	Filter/Suspension	Burrow-dwelling	Deep (> 3 cm)	Surficial modifier/Bio-irrigator	Polyhaline - Euhaline	Very fine - Fine sand (63 - 250 µm)
	Spisula (Notospisula) trigonella	Filter/Suspension	Burrow-dwelling	Deep (> 3 cm)	Surficial modifier/Bio-irrigator	Polyhaline - Hyperhaline	Fine to Medium sand (125 - 500 µm)
	Soletellina alba	Filter/Suspension/ Surface deposition	Burrow-dwelling	Deep (> 3 cm)	Surficial modifier/Bio-irrigator	Polyhaline - Hyperhaline	Very fine - Fine sand (63 - 250 µm)
	Hydrobiidae (6 spp.)	Surface/Sub-surface deposition	Free-living	Shallow (< 3 cm)	Surficial modifier	Oligohaline - Polyhaline	Very fine - Fine sand (63 - 250 µm)
	Salinator fragilis	Surface deposition	Free-living	Shallow (< 3 cm)	Surficial modifier	Oligohaline, Polyhaline - Euhaline	Fine sand (125 - 250 µm)
Crustacea	Ostracoda	Grazer	Free-living	Bentho-pelagic	No bio-turbation	Oligohaline, Hyperhaline	Very fine - Medium (63 - 500 µm)
	Amphipoda	Filter/Suspension/ Surface deposition	Burrow/Free-living	Shallow (< 3 cm)/Bentho-pelagic	Surficial modifier	Oligohaline	Fine to Medium sand (125 - 500 µm)
	Paragrapsus gaimardii	Scavenger/Opportunist	Burrow/Free-living	Shallow/Deep	Surficial modifier/Bio-irrigator	Oligohaline - Mesohaline, Euhaline	Very fine - Fine sand (63 - 250 µm)
Hexapoda	Chironomidae (larvae + pupae)	Opportunist/Predator	Burrow/Free-living	Shallow (< 3 cm)/Bentho-pelagic	Surficial modifier	Oligohaline - Mesohaline	Fine to Medium sand (125 - 500 µm)

Table A7. Part A. Historical communities for the Coorong from 1981 – 1985. Colour codes are used for ease of comparison to how these salinity ranges correspond to those observed for different community types during 2010 – 2015 monitoring (Part B).

	Historical communities (Geddes and Butler 1984; Geddes 1987)			
Taxa	Freshwater (0 - 2 ppt)	Estuarine (5 - 30 ppt)	Hypermarine (35 - 50 ppt)	Hypersaline (50+ ppt)
Simplisetia aequisetis	absent	abundant		
Australonereis ehlersi	rare	present		
Nephtys australiensis	absent	present		
Ficopomatus enigmaticus		abundant		
Capitella species complex (*C. capitata*)	absent		present	
Arthritica helmsi		present		
Spisula (Notospisula) trigonella	rare	present		
Hydrobiidae (6 species)		abundant	present	
Salinator fragilis	rare		present	
Ostracoda				present
Isopoda				present
Amphipoda		abundant	abundant	
Chironomidae (larvae + pupae)			present	present
Ephydridae (pupae)			present	present

Table A7. Part B. Current communities defined for the Murray Mouth and Coorong from 2010 – 2015. Community types are approximately divided into Oligohaline (0.5 – 5 ppt), Mesohaline (5 – 18 ppt), Polyhaline (18 – 30 ppt), Euhaline (30 – 40 ppt) and Hyperhaline (> 40 ppt) salinity ranges as defined for estuaries by Whitefield *et al.* (2012). Colour coding represents how these community types correspond to historical communities observed in the Coorong Lagoons during the 1980s (Part A) and the new community type not previously observed termed Marine (salinity 30 – 35 ppt).

	Communities identified during LinkTREE and SIMPER analysis during 2010-2015 (see Table A3; Appendix 4.3: this report)															
	Oligohaline						Mesohaline				Polyhaline		Euhaline		Hyperhaline	
	Freshwater					Estuarine							Marine	Hypermarine		Hypersaline
Taxa	4	5	3	8	9	7	6	11	15	16	14	12	13	10	2	1
Simplisetia aequisetis	very rare	very rare	present	present	very rare	present		rare	present	abundant	rare	present	abundant	rare	very rare	
Australonereis ehlersi																
Nephtys australiensis						very rare	very rare									
Ficopomatus enigmaticus																
Capitella species complex (*C. capitata*)								rare				very rare	very rare	very rare	present	rare
Arthritica helmsi										abundant		very rare	present	very rare		
Spisula (Notospisula) trigonella																
Hydrobiidae (6 species)										very rare						
Salinator fragilis																
Ostracoda																
Isopoda																
Amphipoda	present	present	present	abundant	present	abundant	present	present	abundant	present	abundant	rare	present	present	rare	very rare
Chironomidae (larvae + pupae)	present	present	present	abundant	present	abundant	present	present	abundant	present	present	present	present	present	present	present
Ephydridae (pupae)																very rare

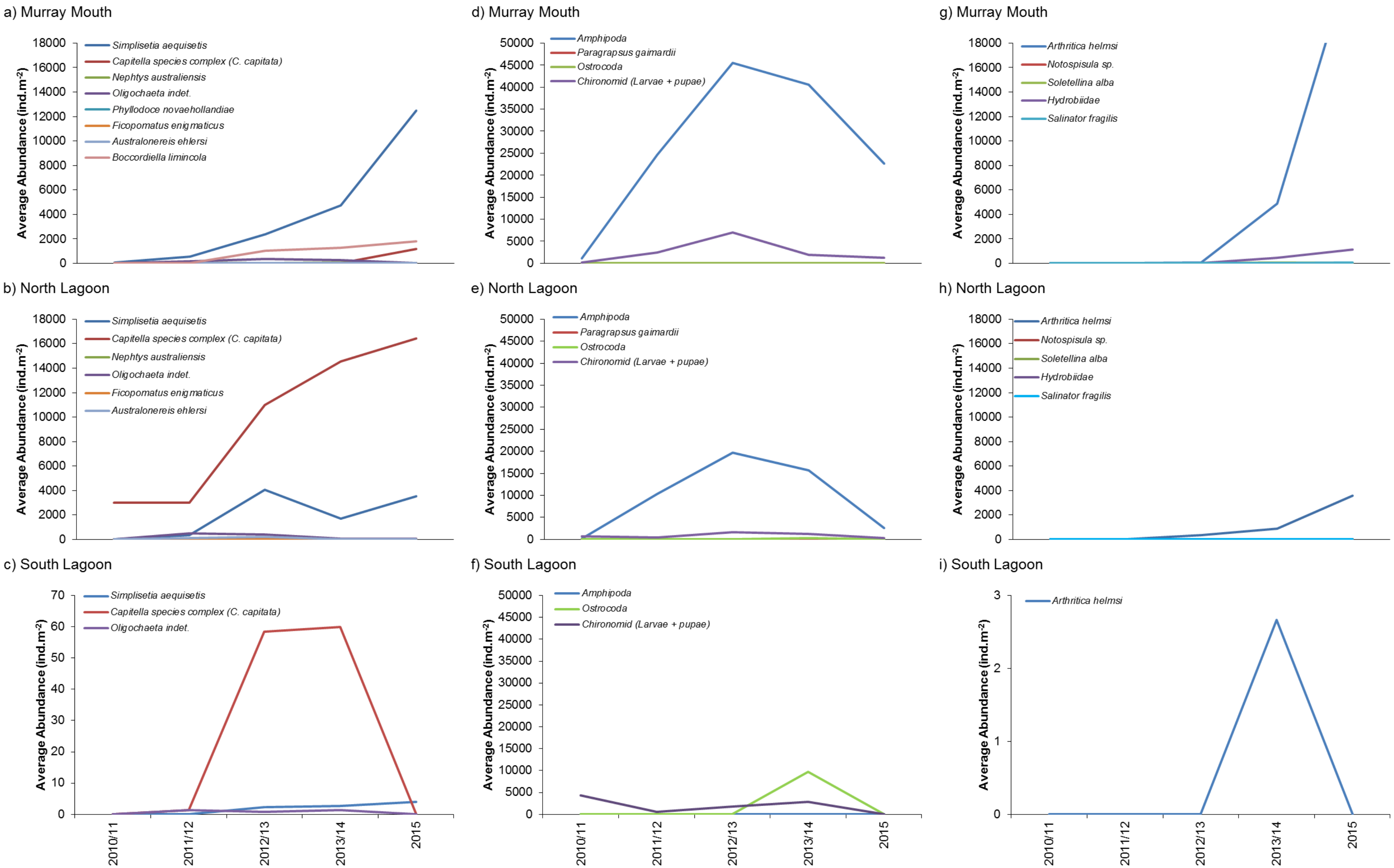
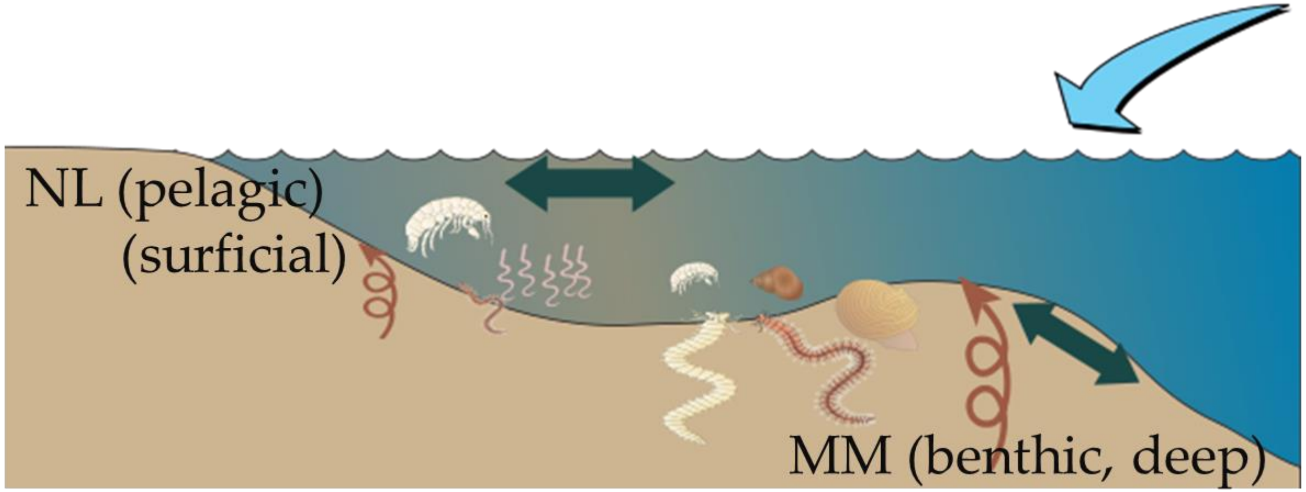


Figure A24: Taxa abundance over time for each region. The plots are arranged for Annelids (left hand column, plots a-c); Arthropods (middle column, plots d-f); and Molluscs (right-hand column, plots g-i). Note the difference in scale of the y-axes for plots in the South Lagoon.

Table A8. Biological traits present in each region across the years from 2010 to 2015. Lighter shade colours indicate the first occurrence of particular traits.

		2010/11			2011/12			2012/13			2013/14			2015		
Categories	**Traits**	**MM**	**NL**	**SL**	**MM**	**NL**	**SL**	**MM**	**NL**	**SL**	**MM**	**NL**	**SL**	**MM**	**NL**	**SL**
Size	Small (0.5-5 mm)															
	Medium (5-20 mm)															
	Large (>20 mm)															
Life span	<1 year															
	1-3 years															
	3-10 years															
Reproductive method (Sexual)	Shed eggs benthic															
	Shed eggs pelagic															
	Encapsulation															
	Brood eggs															
Feeding habit	Filter/suspension															
	Grazer															
	Surface deposition															
	Sub-surface deposition															
	Scavenger															
	Opportunist															
	Predator															
Living habit	Tube dweller															
	Burrow dweller															
	Free living															
Larval type	Pelagic (planktonic)															
	Pelagic (lecithotrophic)															
	Benthic															
	Brood															
Environmental position	Surface shallow (<3 cm)															
	Deep sediment (>3 cm)															
	Bentho-pelagic															

Categories	Traits	2010/11			2011/12			2012/13			2013/14			2015		
		MM	NL	SL	MM	NL	SL	MM	NL	SL	MM	NL	SL	MM	NL	SL
Sediment movement	No bioturbation															
	Surficial modifier															
	Bio-irrigator (deep mix)															
Salinity preferred	Oligohaline (0-5)															
	Mesohaline (5-18)															
	Polyhaline (18-30)															
	Euhaline (30-40)															
	Hyperhaline (>40)															
Sediment affinity	Very fine sand (63-125)															
	Fine sand (125-250)															
	Medium sand (250-500)															
Similarity within region (%)		47	17	67	72	46	49	74	56	26	67	27	25	82	45	6



<u>**NL**</u>		<u>**MM**</u>
shallow	**bioturbation**	deep
commencing	**Benthic-pelagic coupling**	increasing
simple	**Food web**	diversifying

Figure A24: Conceptual model of biological functioning determined from biological traits analysis of the macrobenthos in the Murray Mouth (MM) and North Lagoon (NL) during 2015. North Lagoon macroinvertebrates had pelagic reproductive strategies and surficial benthos modification versus the Murray Mouth with mainly benthic reproductive strategies and deep bioturbation of sediments with low volume but consistent freshwater flows through the barrages. The ecological functions that are currently operating (2015) at the macrobenthic level for each region are displayed.