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Habitat assessment monitoring of revegetated areas in the Lower Lakes: a pilot study in autumn 2013

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inspiring achievement

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SUMMARY

Over the past decade many areas within the Lower Lakes wetlands have been revegetated to arrest erosion, aid in alleviating problems with acid sulphate soils, and/or improve the overall amenity of their shallow water environments. Although these plantings have been examined for the success of their survival, no attempt had yet been made to assess whether they also provide opportunities for other organisms (e.g. invertebrates, fishes, algae, other plants). As a first attempt to look at this question of habitat provision, a team from the Fairweather lab at Flinders University sampled six sites within the Lower Lakes on two occasions during May 2013. These were divided into 3 locations where revegetation of clubrush (*Schoenoplectus validus*) had been carried out between approx. 6 and 7 years previously and matched with 3 nearby sites where no revegetation had occurred (to act as paired Controls). A variety of environmental conditions in both the water column and sediments were measured as were vegetation cover both along the planting or the bank behind, macroinvertebrates in the vegetation and water column or benthos were sampled, and daytime use by fishes and mobile invertebrates was also assessed by trapping. These preliminary findings showed that revegetation is probably affecting the sedimentary and water-column habitats in a similar manner at each location but to different degrees. The overall trend was toward areas with finer and more organic-rich sediments being trapped by vegetation baffling water movements, more plant coverage with different species assemblages (resulting in a richer and lusher biota), and more fishes and mobile invertebrates. Notable was a shift from invertebrates associated with open water (e.g. planktonic crustaceans) to invertebrates associated with vegetation (e.g. insects, annelids, molluscs and benthic crustaceans). This was most clearly seen at one location within Lake Albert but the different plantings were variously more or less effective in achieving these secondary goals. This pilot study probably justifies further effort to assess the use of these areas as habitat by a range of biota in different times of the year but also yielded important insights into what biotic components (e.g. taxa) are worth pursuing further.

INTRODUCTION

The Lower Lakes, situated at the terminus of the Murray-Darling Basin, are the largest permanent lakes in South Australia, covering an area of approximately 400 km^2 across Lakes Alexandrina and Albert. These were designated as a wetland of international importance under the Ramsar Convention in 1985 (Phillips and Muller, 2006). Lake Albert is the smaller of the two lakes and is connected to Lake Alexandrina via a narrow channel and represents a local, inland terminus of the River Murray system (Phillips and Muller, 2006). These lakes are broad and shallow with complex fringing vegetation including a range of sand and mud islands (Phillips and Muller, 2006). Much of the fringing vegetation is dominated by *Phragmites australis* and *Typha domingensis* and has been impacted by the introduction of the barrages (Phillips and Muller, 2006).

Vegetation is a critical component of the ecological character of the Coorong, Lower Lakes and Murray Mouth [CLLMM] site, with its importance ranging from stabilising banks and limiting erosion through the biotic value of vegetation itself to the provision of habitat for a range of other biota. Many places in the Lower Lakes have been revegetated at great cost during the Millennium Drought. The success of this has only been assessed in terms of how the plants have survived by local action groups involved in the planting and the State department responsible. The Department of Environment, Water and Natural Resources (DEWNR) thus commissioned Flinders University to investigate how these compare as habitat with areas that have not been revegetated. Monitoring habitat usage (e.g. by macroinvertebrates, fish) will assist in determining the wider utility of the costly revegetation that has been done in Lakes Alexandrina and Albert as well as telling us about the condition of the habitat, how much connection there is over time and space between habitats (i.e. aquatic-terrestrial connectivity).

Revegetation and native vegetation are two indicators identified (through the Murray Futures frameworks, DENR 2009) that still require monitoring. In 2012/13 Revegetation Monitoring outlined in the Monitoring Framework (DEWNR 2011)should firstly establish a baseline assessment of habitat usage by indicator taxa (e.g. macroinvertebrates and fish) to allow future comparisons and develop ecological trajectories for longer-term responses to revegetation. And secondly, assess habitat structure and cover through time. Thus in 2012/13 Vegetation Monitoring outlined in the Monitoring Framework should provide an assessment of the ecosystem services provided by different vegetation communities, and developing indices for key communities in plants such as samphire and lignum.

This project seeks to provide an initial assessment of the extent of habitat availability and utilisation in Lake Alexandrina and Lake Albert. For the first time, revegetation will be assessed for how organisms are affected by this provision of habitat complexity. The current diversity and coverage of individual vegetation species will be identified and the associated faunal diversity and abundances will be quantified. Thus we shall have an assessment of the use of such actions in providing habitat improvements, which is part of the overall cost effectiveness of revegetation. The new information will provide profiles of usage by a range of animals in comparison with areas that have not been revegetated. This will be the first such critical assessment of habitat value of wetland revegetation in the Lower Lakes.

This project aims to conduct a preliminary investigation into the habitat availability of fringing vegetation in the Lower Lakes and their associated biota. This will allow us to assess the utilisation of revegetated sites by quantifying the biotic associations (e.g. by macroinvertebrates, fish) within each habitat type. Hypotheses predicted for the study were:

- Sites revegetated will have a higher abundance and diversity of vegetation than sites that were not revegetated; and

- Animal taxa, including macroinvertebrates and fish, will have a higher abundance and diversity in revegetated sites than sites that were not vegetated.

Thus we planned to sample several sites within the Lower Lakes (see Figure 1, Appendix 1) that have been revegetated and match those with three sites nearby that have not been revegetated by measuring aspects of the habitat, invertebrate and fish communities. This preliminary comparison was done in the autumn (April-May) of 2013 and shall yield vital baseline data for later assessments as well as raw data for analyses that will allow fine-tuning of any subsequent monitoring program.

METHODS

Site descriptions

Sampling was conducted at two locations (Nurra Nurra Reserve and Dumandang) in Lake Albert and one location (Wellington Lodge) in Lake Alexandrina (Figure 1). Nearby to each revegetated site (hereafter 'Reveg'), another site (hereafter 'Control') was selected based on similar aspect, geomorphological formations and the absence of any revegetated areas. Detailed descriptions of each site and sampling designs can be found in Appendix 1.

Sampling Design

After initial inspection of potential study sites, two sampling trips were undertaken during May 2013 (Table 1). Several methods were used to target different components of the environmental conditions (water, sediments, vegetation) or biodiversity (i.e. biotic assemblages) (Table 1).

At each site, either the Reveg or Control area was divided into 6 segments, along the planted vegetation line, approximately 6-8 m wide. Within each segment, one sample for each method was taken haphazardly as 6 replicates for the whole site, with the exception of fish traps (where only 4 replicates could be used due to permit restrictions). A summary of each method used at each location can be seen in Table 1.

Water Quality

Water temperature (°C) and salinity were measured in situ using a TPS WP-84 Conductivity-Salinity-Temperature Meter, and dissolved oxygen (% saturation) and pH readings were taken using a TPS WP-91 Dissolved Oxygen-pH-mV-Temperature meter.

Turbidity and Sediments

Water was sampled at each site using a 250 mL plastic collection jar submerged in the top 20 cm of water. Sediment was sampled using a 100 mL plastic container with a diameter of 4.2 cm used to penetrate the top (3-5 cm deep) layer of sediment by hand.

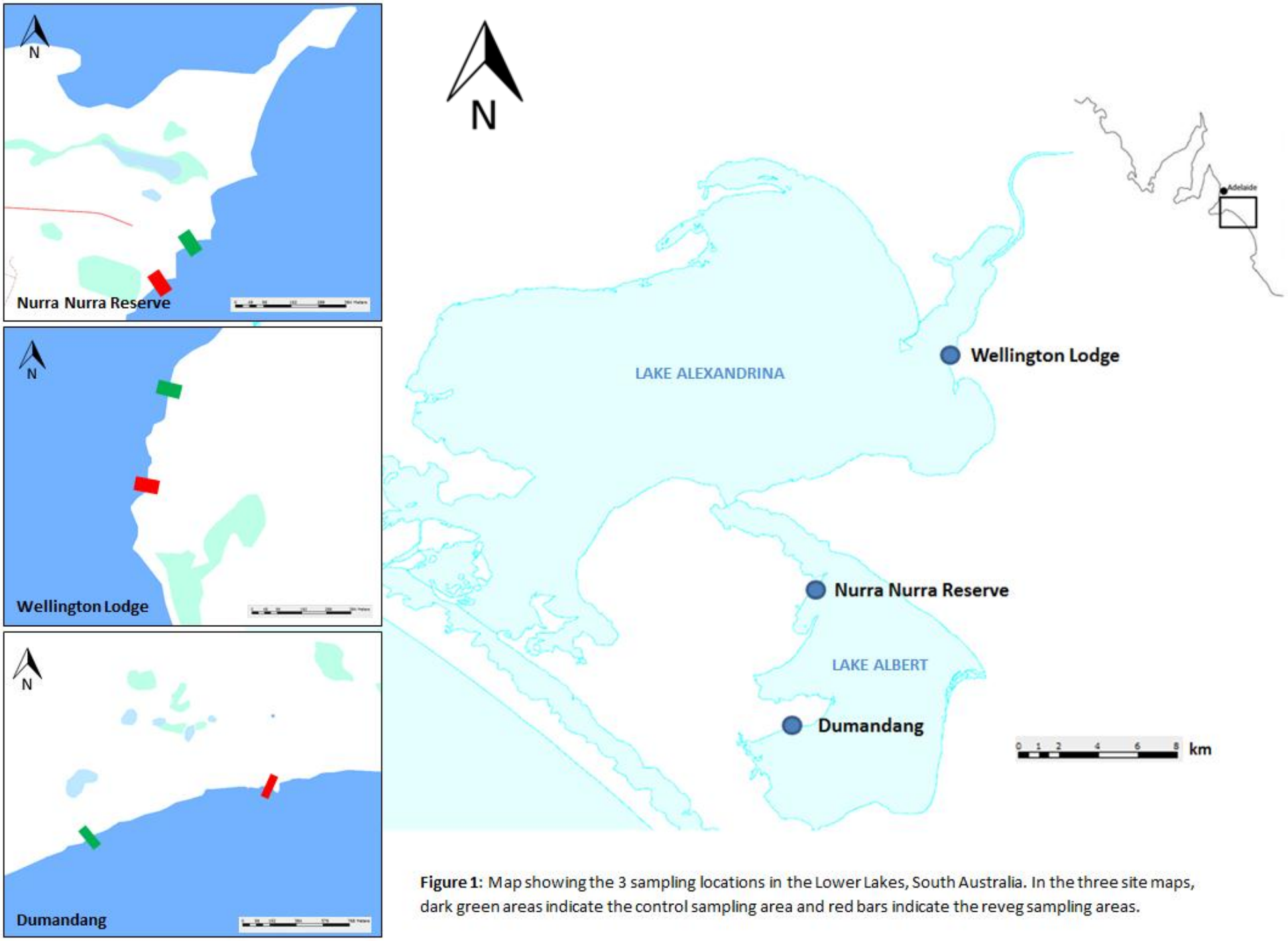

Figure 1: Map showing the 3 sampling locations in the Lower Lakes, South Australia. In the three site maps, dark green areas indicate the control sampling area and red bars indicate the reveg sampling areas.

Table 1: Summary of sampling methods used at each location in the Lower Lakes, South Australia, throughout the May sampling period. ✓ = method was conducted whereas X = method was not conducted for that sampling period. DD = Dumandang, NN = Nurra Nurra Reserve, WL = Wellington Lodge. Loc. = Location

				Methods of sampling [@]							
Loc.	Trip #	Date	Day of study	Sedi-ments	In situ WQ	Water TSS	Baited Traps	Veg LIT	Sweep Nets	Cores	Edge photos
All	-	23/4/13	1	Site inspection only							
WL	1	2/5/13	10	✓	✓	✓[+]	✓	✓	✓	✓	X
DD	1	9/5/13	17	✓	✓	✓	✓	✓	✓	✓	✓
NN	1	16/5/13	24	✓	✓	✓	✓	✓	✓	✓	✓
DD	2	20/5/13	28	✓	✓	✓	✓	✓	✓	✓	✓
WL	2	23/5/13	31	✓	✓	✓	✓	✓	✓	✓	✓
NN	2	28/5/13	36	✓	✓	✓	✓	✓	✓	✓	✓[#]
Data yielded by method:				Grain size, organic matter	Water quality		Fish, mobile inverte-brates (= nekton)	% cover, patchi-ness of vegeta-tion	Water column & veg-associat-ed inverte-brates	Benthic infaunal inverte-brates	% cover, erosion, potential refugia

Superscripts: @ sample size = 6 (unless noted), except for baited traps, which had *n* = 4
+ only 5 samples taken at WL Control site
# no photos taken at NN Reveg site

The sediment collected was later analysed by laser diffraction for grain size using a Malvern Mastersizer 2000 particle-size analyser. A subsample of sediment was taken (approximately 20 g) and weighed before the fraction >1 mm in size was sieved off manually to avoid blocking the machine. This fraction was then weighed and later included in the data for normalisation. Medians and quartiles, as well as percentages of various particle size fractions, were obtained from the Mastersizer output. Sediment sorting was calculated according to the formula $S_o = (P^{25}/P^{75})^{1/2}$, based on the metric scale (Blott & Pye, 2001).

Percent organic matter of sediments was measured by loss on ignition. A subsample of sediment (approximately 4 g) were placed in crucibles and dried in an oven set at 80^0C for at least 24 hours to remove all moisture and then weighed. This was repeated until a constant dry weight was reached. Crucibles (with lids) were then put in a muffle furnace and set at 500^0C for one hour to remove organic matter. Once cooled crucibles were again weighed for possible weight loss. Percent organic matter was expressed as the loss on ignition of the dry weights. Due to some issues with lab ovens, only sediments from Trip 1 were processed.

Total suspended solids concentration in the water sample was used as a measure of turbidity. Filter papers (average retention capacity = 0.7µm) were prepared for use by drying in a 103 °C oven for 1 h, before being weighed then returned to the oven for another hour. If weights were consistent (within 0.0005 g), then papers were deemed ready for use. Then 150 mL of the sampled water was passed through the filter paper with the use of an electric air pump to provide suction. Additional distilled water was also passed through the filter paper to aid cohesion of the solids to the paper. Filter papers were then dried in the oven following the same procedure as above. TSS was expressed as dried grams of sediment per litre of water filtered.

Vegetation

Vegetation present was examined by line-intercept transects (LIT). These transects were 5 metres long and set along the land-ward edge of the vegetation, such as the planting line at Reveg sites or matching places at Control sites. The position of the transect was marked, a bearing was taken using GPS, and a site photograph was taken. Any vegetation that intersected the line was recorded. Changes in vegetation (i.e. different substrates lying under a tape measure) were noted if they were greater than 2 cm in resolution. These LITs thus provided data on percent coverage of each substratum type and the number of different patches per transect as broad descriptors of the vegetation present at each site.

Baited Fish Traps

Funnel traps were used with dimensions 48 x 23 x 23 cm, and a 4 cm circular opening and 2 mm mesh covering. Traps were baited with 50-60 g of chopped lamb liver and a similar amount of cat biscuits. Traps were set at each site for a daytime period of 3 h and were set 6-10 m apart. Traps were submerged, on the outside edge of the vegetation (Nurra Nurra Reserve and Wellington Lodge) or on the inside of the site (Dumandang, where access to the outer edge was restricted) at Reveg sites. At Control sites traps were held in place with stakes and sampling followed the design above at

equivalent depths and distances from the shore. Trap depths varied from 0.4 – 0.7 m. Fish and invertebrates caught in traps were transferred to aerated buckets (as per our animal ethics permit), before being counted, photographed and identified. All native fish were then released alive near the place of capture along with live invertebrates. Any deceased or alien species were kept as voucher specimens.

Core sampling

Core samples were used to target infaunal invertebrates within bottom sediments. Sampling was undertaken on the land-ward edge of the vegetation bands as near to the vegetation where possible. Cores were taken using a 10 cm diameter PVC corer, to a depth of 5 cm. Cores were sieved on site using a 500 µm mesh sieve to remove sediment, before being bagged and stored on ice for transport.

Sweep netting

Sweep netting was used to target invertebrates active in the water column, on the surface and amongst vegetation. This was performed using an equal-sided (30 cm) triangular-shaped opening net (mesh size = 500 µm) with a 70 cm long handle. It was moved in a figure-of-eight motion within a 2 m^2 area for 30 seconds. All material collected in each sample was then washed from the net into a large bag, which was then tied off and stored on ice for transportation. This method was carried out along the land-ward edge of the vegetation.

Photographs of Edge Quadrats for Erosion and Habitat Refugia

In order to see the impact of the vegetation on the bank behind it, photographs along the shoreline were taken. A 0.5 x 0.5 m quadrat was haphazardly thrown along the bank and then photographed. For analysis, substrata seen within the six quadrats per site were classified and their % covers estimated, as well as notes on any obvious erosion.

Taxon Identification

To facilitate processing, samples from sweep netting and core sampling were live sorted in the lab, although time constraints meant that some had to be frozen for later processing. All samples were rinsed over a 500 µm sieve and then emptied onto a sorting tray filled with water allowing most invertebrates to float to the surface, separating them from the unwanted debris. Individuals were then collected onto a petri dish and identified with the use of a dissecting microscope. Once identified, specimens were labelled and stored in 70% ethanol. For this pilot study, a coarse

taxonomic level of resolution was utilised for most invertebrate animals(called “taxa”) and each taxon so identified was counted. Fishes and plants were more often identified to species wherever possible. Identification guides used included Sainty & Jacobs (1988, 2003), Romanowski (1992, 1998), Jones and Morgan (1994),McDowall (1996), Hawking & Smith (1997), Gooderham & Tsyrlin (2002), Poore (2004), Lintermans (2009) and Murray Darling Freshwater Research Centre (2013).

Approach to Statistical Analysis

This pilot study primarily contrasted two types of sites: three areas that had been revegetated some years before by planting with the clubrush *Schoenoplectus validus* (called ‘Reveg’ sites) versus nearby areas that had not (‘Control’ sites). These matched pairs were examined at the three locations and on two occasions (called ‘trips’), thus, the design had three factors: Location (with 3 levels); Type (2 levels); and Trip (2 levels), with either 4 or 6 replicate measurements made at each combination (so total N = 48 or 72). Of these three factors, the one of prime interest to this pilot study was Type, so that main effect or interactions involving it were examined first in an analytical output. The other two factors were then examined to see whether effects on the environment were detectable at each location or on each trip but it was also deemed important that their effects were isolated from the main factor of interest to avoid any confounded explanations.

Univariate analysis of single variables were done for measures of water quality, sediment characteristics, vegetation percentage cover or patchiness, the total number of individual animals caught per replicate, and the number of taxa caught per replicate. This usually involved a three-factor analysis of variance (after assumptions were checked using plots of residuals from the fitted ANOVA model) done with SYSTAT v13 or a univariate Permutational Analysis of Variance (PERMANOVA, based on Euclidean distance as the resemblance metric for a single variable and 999 permutations at a time) using PRIMER v6 and PERMANOVA+ add-on software (Clarke & Gorley 2006; Anderson et al. 2008). Each of the three factors was considered to be fixed (to allow thorough examination of this pilot study, rather than any wider generalisation) and all were arranged orthogonally.

Multivariate analyses were done for suites of biotic assemblages of multiple taxa or water quality variables to ecplore how multiple variables responded together using non-mwetricc multidimensional scaling (MDS) ordinations (based on Bray-Curtis similarities, usually with a dummy variable added to these sparse data matrices). Hypotheses related to the experimental design described above were done as multivariate PERMANOVAs with the same formal design model as

above and used up to 999 permutations of tests of each factor and its interactions. Where some factors were significant, the Similarity Percentages (SIMPER) procedure of PRIMER was then used to determine which taxa contributed most to the dissimilarities between groups. Where MDS ordination plots suggested that different groups of samples were dispersed differently, this was tested with the Permuted Multivariate Dispersion (PERMDISP) routine in PERMANOVA+. The relationship between different ordinations (either biotic samples or for water quality variables) was checked using the RELATE procedure in PRIMER as a non-parametric Spearman correlation between similarity matrices and tested with 999 permutations.

As well as inspecting non-metric multidimensional scaling (MDS) ordinations, the degree of dissimilarity between groups in the data was visualised using group average clustering via the CLUSTER procedure in PRIMER with the number of meaningful groups examined using the SIMPROF routine. Furthermore visualisation of groupings and tests of hypotheses were also done using Canonical Analysis of Principal Coordinates via the CAP routine in PERMANOVA+ (Anderson et al. 2008). This constrained ordination plot was used to visualise and explore groups in multivariate space and to test directly the simpler hypotheses that Type or other factors influenced assemblages. The leave-one-out allocation procedure provided a statistical estimate of the misclassification error between groups (Anderson et al. 2008).

Scatterplots of paired variables were also tested using correlations or regressions where appropriate. Usually Spearman rank correlations were used to match the minimal assumptions embedded in PRIMER. Further details of analysis are given with each result reported below.

RESULTS

Sediment Analysis

At all locations all the sediment types were classified as sand (grain diameters<2.0mm), primarily classified as fine sand (0.125 to 0.25 mm, 58% of samples) with medium sand (0.25 to 0.50 mm) making up the remainder (42%). Overall the majority of sediment was moderately or moderately-well sorted (58% and 37%, respectively), with only a few samples being well or very-well sorted (2.8% and 1.4%, respectively) (Table 2). Dumandang showed a distinct difference between the Reveg versus Control sitesfor sediment classifications, with the Reveg sites having a majority of fine sand while the Controls had all medium-sized sand (Table 2). Please see Appendix 2 for more details of sediment results.

Table 2: Classification of sediments as grades of sand or by degree of sorting. Numbers are the frequency of replicate samples observed in each class, summed across both trips (so out of *n* = 12 for each site). DD = Dumandang, NN = Nurra Nurra Reserve, WL = Wellington Lodge

Location:	**WL**		**NN**		**DD**		**Total**
Classification							
Site:	**Reveg**	**Control**	**Reveg**	**Control**	**Reveg**	**Control**	
Sand:							
Fine	7	10	9	6	10	0	**42**
Medium	5	2	3	6	2	12	**30**
Sorting:							
Moderately	12	9	5	3	1	12	**42**
Moderately-well	0	2	6	9	10	0	**27**
Well	0	0	1	0	1	0	**2**
Very well	0	1	0	0	0	0	**1**

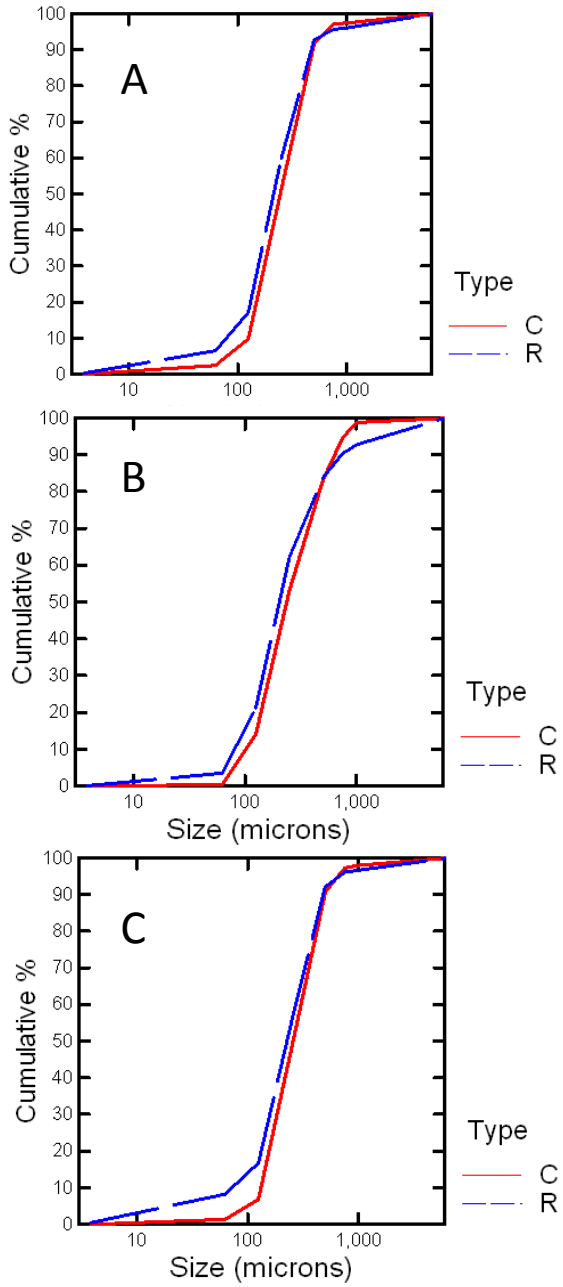

Figure 2: Cumulative frequency histograms of % size classes of sediment from 3 locations in the Lower lakes. Divergence of the two lines on a panel shows more or less sediment up to a certain size, e.g. the Control at Nurra Nurra Reserve had more coarse sediment (above 1 mm in size) than the Reveg site whereas Wellington Lodge Reveg had more finer sediment (less than 125 μm) than the Control. Panel A = Dumandang, Panel B = Nurra Nurra Reserve, Panel C = Wellington Lodge. C = Control, R = Reveg.

Among Locations there appeared to be little variation for sediment grain sizes between Control and Reveg sites, except at Nurra Nurra Reserve Control, which had more coarse (up to 1 mm) sediment

than the corresponding Reveg site (Figure 2). Tukey honestly significant-difference tests showed Dumandang Reveg to be significantly different from all other sites including its paired Control. No other sites were shown to be significantly different. This is most likely due to the higher percentage of 'fine' (<62.5 µm) sediments found at Dumandang Reveg (Figure 3) and supports findings from the sorting coefficient. Wellington Lodge showed the opposite pattern to Dumandang and Nurra Nurra Reserve in terms of fine sediments, with less seen at the Reveg compared to the Control (Figure 3).

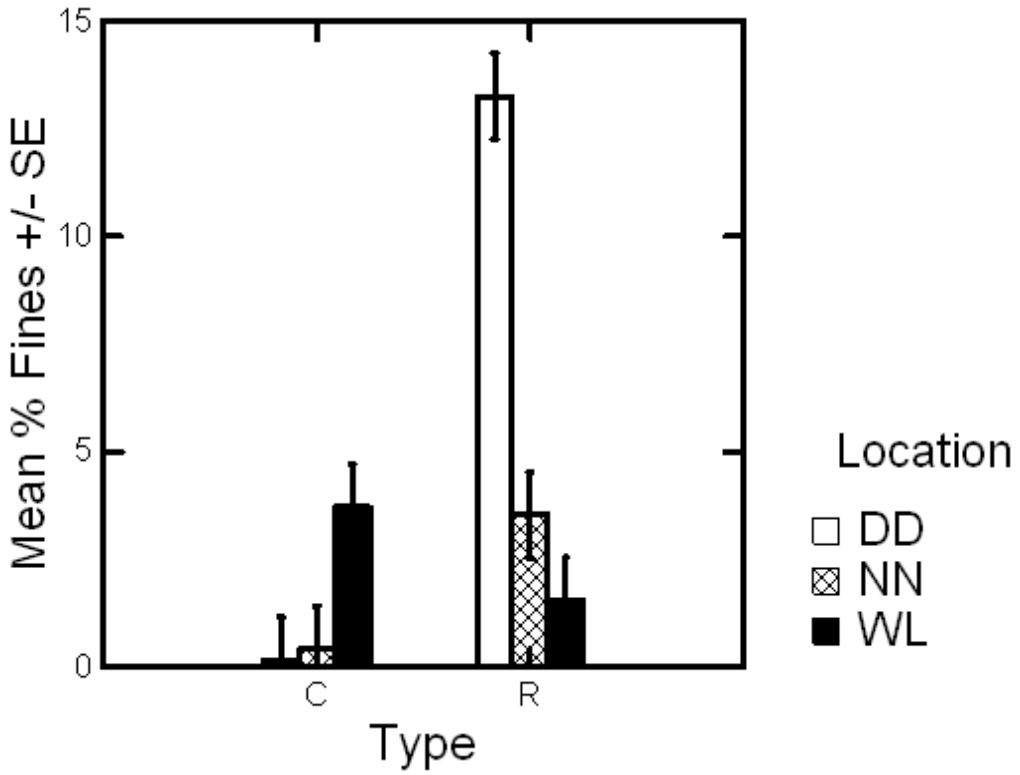

Figure 3: Average percent of 'fine' (<62.5 µm) sediment found at three locations across two trips in the Lower Lakes. DD = Dumandang, NN = Nurra Nurra Reserve& WL = Wellington Lodge. R = Reveg site, C = Control.

The sedimentary percent organic matter (measured as loss on ignition of dry sediment) was mainly low values, less than 2 % of dry weight. Analysis of % OM (from Trip 1 only for logistical reasons) showed that the Dumandang Reveg site had more organic matter in the sediment than all other groups of samples (Figure 4). Although not significant, the trends at each of the other locations (Figure 4) differed with respect to the comparison of Reveg versus Control sites: there as a non-significant increase in organic matter at Nurra Nurra Reserve but a non-significant decrease seen at Wellington Lodge. These results match the findings for fines but are only from one Trip, however, and so caution is advised - they might not be related solely to revegetation *per se*.

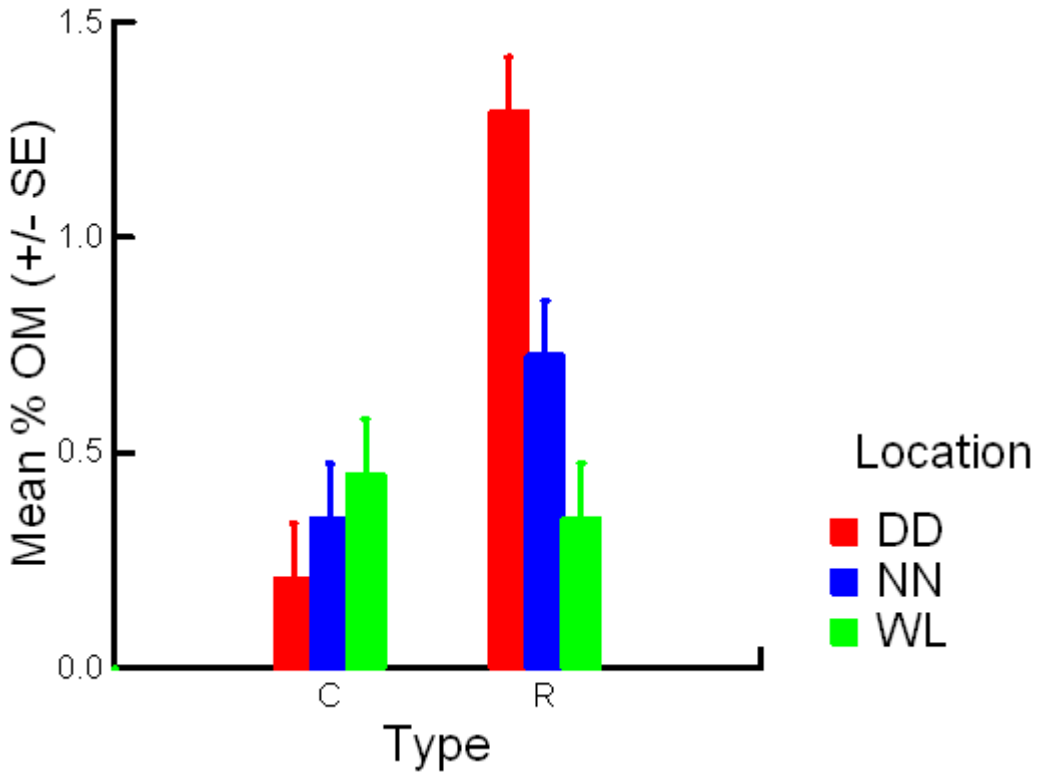

Figure 4: Average percent organic matter (as LOI of dry weights) in sediment found on Trip 1 only at three locations in the Lower Lakes. DD = Dumandang, NN = Nurra Nurra Reserve & WL = Wellington Lodge, R = Reveg site, C = Control.

Water Quality (including TSS)

Salinity was on average lowest at Wellington Lodge (mean = 0.23 ppt) and highest at Dumandang (1.66 ppt) with Nurra Nurra Reserve being similar to Dumandang (1.48 ppt). Salinity did not vary greatly between Trip or Type (Table 3). Average DO percentage saturation was high but similar across locations with the same trend as salinity, with the lowest at Wellington Lodge (88.9%) and highest at Dumandang (98. 2%) (Table 3).

Average pH was similar across locations with Nurra Nurra Reserve having the highest (8.48) and Dumandang the lowest (8.12). There was little variation in pH between Trip or Type, but with a general trend toward lower values on the 2nd trip (Table 3). On average temperature was coldest at Nurra Nurra Reserve (13.2°C) with similar average temperatures for Dumandang and Wellington Lodge (14.7°C and 14.3°C, respectively). There was a trend toward colder temperatures on the 2nd trip for all locations (Table 3).

On average the location with the lowest TSS was Wellington Lodge with only 0.04 g/L compared to 0.14 g/L for Nurra Nurra Reserve and 0.16 g/L for Dumandang (Table 3). Minimal differences were seen between Control and Reveg sites and trips for NN, while at Wellington Lodge the Reveg values were constant between trips, but the Control increased from 0.01 g/L to 0.07 g/L across trips (Table 3). At Dumandang, TSS decreased from Trip 1 to Trip 2 at both the Reveg and Control, with almost half as much seen on Trip 2 at the Control than at Trip 1.

Table 3: Mean water quality variables measured from three locations in the Lower Lakes, South Australia.Locations are DD= Dumandang, NN = Nurra Nurra Reserve& WL = Wellington Lodge,R = Reveg, C = Control.

Location	Trip	Type	Salinity (ppt)	DO (% sat)	pH	Water Temp (°C)	TSS (g/L)
WL	**1**	**R**	0.22	109.63	8.18	13.92	0.04
		C	0.23	77.48	8.17	16.75	0.01
	2	**R**	0.24	91.97	8.52	12.57	0.04
		C	0.25	76.38	8.34	14.13	0.07
		Average	**0.23**	**88.86**	**8.30**	**14.34**	**0.04**
NN	**1**	**R**	1.35	117.72	8.27	13.35	0.14
		C	1.41	92.20	8.47	13.93	0.13
	2	**R**	1.53	77.50	8.61	12.08	0.14
		C	1.64	81.38	8.58	13.47	0.14
		Average	**1.48**	**92.20**	**8.48**	**13.21**	**0.14**
DD	**1**	**R**	1.52	88.40	7.55	14.70	0.13
		C	1.64	133.55	8.50	16.25	0.26
	2	**R**	1.74	79.25	7.71	13.37	0.09
		C	1.76	91.63	8.76	14.50	0.14
		Average	**1.66**	**98.21**	**8.13**	**14.70**	**0.16**

Vegetation

In terms of percent coverage along the LITs, there were three main species seen, the clubrush *S. validus*, cumbungi *Typha domingensis* and common reed *Phragmites australis*. These formed eight substrata classes (described in Appendix 3) at the water surface (not counting open water), including each of those species, various combinations of them, and debris (standing dead vegetation). The

total coverage per transect ranged from 0 to 100 % and the most common species was *S. validus* (mean = 5.1 % cover), then *Typha* (4.6 %), and *Phragmites* and *Typha* combined (4.5 %). The number of substrata observed per transect ranged from zero to five. Not surprisingly, vegetation was more obvious in the Reveg sites (mean = 35 % cover overall) with hardly any observed at Control sites (mean <1 % cover).

Data analysis confirmed those broad generalisations. Total percent coverage was statistically significant for the factor Type and also the interaction of Type and Location. All the Control data points were clustered together in only one of the eight meaningful clusters returned by CLUSTER and SIMPROF in PRIMER, whereas all of the Reveg data points were distributed across the other seven clusters only, and that Control cluster split off from the rest at a similarity of <10%. This means that vegetation % cover very closely corresponded to which Type of site it was. Univariate analysis of total percent coverage confirmed this (Figure 5) with a significant Type X Location interaction showing that the degree of difference varied across locations, with the biggest difference being at Dumandang and the smallest at Nurra Nurra Reserve(Figure 5).

PERMANOVA also revealed that the Location X Type interaction was significant for multivariate data including all substrata classes but the nature of this interaction was again subtle. Each Location had a significant difference of the Reveg site having a greater % cover than the Control but the degree of this difference again varied across locations. Nurra Nurra Reserve was the most similar (15 %) whereas Dumandang was the least (4 %). SIMPER determined that there was a great difference overall (99 % dissimilarity between Reveg and Control sites) and that *S. validus* was the best and most consistent indicator of this difference (e.g. ~10 % cover at Reveg sites versus close to 0 % cover at Controls). The percent covers of *Typha* and mixed stands were also greater at Reveg sites than at Controls. Vegetation cover did not seem to vary much between trips.

PERMDISP indicated that the multivariate dispersion of data was greater at Reveg sites than at Controls (significant at $P = 0.001$) but again the least difference occurred at Nurra Nurra Reserve. CAP analyses also confirmed that Type differed greatly, with >97 % total variation explained and a 100 % success rate at allocating samples to each Type. Thus all data analyses pointed consistently toward a large difference in coverage of vegetation due to the Type of site, with the unsurprising result that Reveg sites had much larger coverage of most types of vegetation than Control sites, but the degree of difference also varied according to the Location.

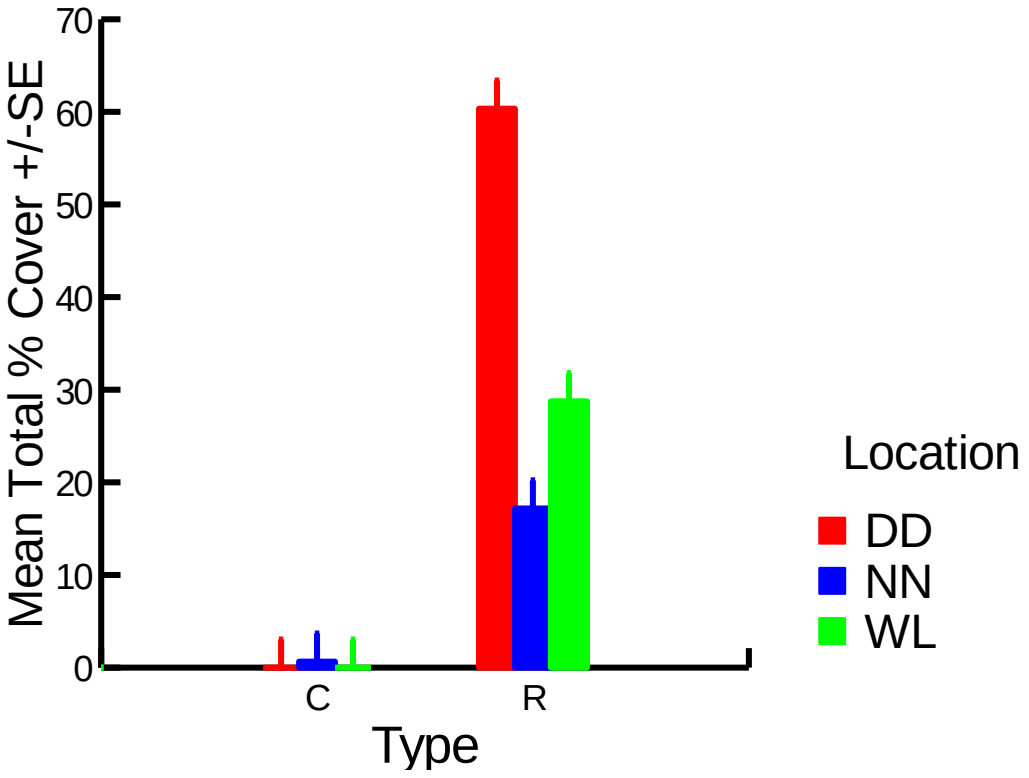

Figure 5: Mean total % cover of vegetation along transects at each Location contrasting the Type of Site (*n*= 12).

Patchiness of the vegetation was assessed as the number of patches detected along each LIT line, which varied from zero to 43 per 5-m transect. Not surprisingly, Control areas had a maximum of 4 patches and a mean of only 1 patch at Nurra Nurra Reserve (and zeroes at the other two locations), all well below the ranges (means) at the Reveg areas: Nurra Nurra Reserve = 20-43 (29.3); Wellington Lodge = 2-26 (12.7) and Dumandang = 2-17 (6.3). All factors and interactions were significant for the number of patches per transect, indicating much patchiness responding to all three factors in combination.

Cores

Eight animal taxa were identified from the core samples across the 3 locations at both Reveg and Control sites (Appendix 3). These had a generally patchy distribution throughout the locations. In total 1,202 individuals were identified, with the great majority (910) being amphipods. Amphipods were also the most widespread taxon appearing in 47 of 72 samples. Oligochaetes and chironomid larvae were the next most abundant taxa contributing to 12.5 and 10.7%, respectively, of the total

abundance and appearing in 25 and 20 samples. The other five taxa contributed to less than 1% of the total abundance. The highest taxon richness recorded in any sample was three, this occurred five times, with four of those samples coming from the Dumandang Reveg site. Wellington Lodge Reveg was the only site to record samples with no taxa.

Multivariate PERMANOVA analyses showed a significant three-way interaction of Location X Type X Trip. When examined further, it was found that for each sampling trip at each location, cores showed a significant difference between Reveg and Control sites (at Wellington Lodge, Trip 1 P = 0.004, Trip 2 P = 0.02; at Dumandang, Trip 1 P = 0.03, Trip 2 P = 0.044; at Nurra Nurra Reserve, Trip 1 P = 0.036, Trip 2 P = 0.032). Similarity between Controls and Reveg sites ranged from 25.8to 65.2%.

Differences in infaunal assemblages were explored by assessing the interaction among Trip X Location X Type factors. For the 1st sampling trip and among Reveg sites, Wellington Lodge was shown to be significantly different from Dumandang and Nurra Nurra Reserve (Wellington Lodge*vs* Dumandang P = 0.03; Wellington Lodge *vs* Nurra Nurra Reserve P = 0.06) but Dumandang and Nurra Nurra Reserve were not significantly different from each other. The same pattern was seen for the Control sites and for Trip 2. This grouping was most likely due to the absence of any amphipods caught at Wellington Lodge.

CAP analysis showed distinct groupings for the combined Reveg versus Control sites (Figure 6). The leave-one-out allocation success rate was quite high with 77.8% for the Reveg site and 94.4% for the Control, with the permutation test being highly significant (for trace and delta statistics P = 0.001). Misclassification error was quite low with a value of 13.9%. Four principal coordinate axes were used to explain 89% of the total variation in the resemblance matrix.

CAP analysis of the interaction between Location and Type showed a distinct separation of Wellington Lodge from the other two locations. Nurra Nurra Reserve Reveg and Dumandang Reveg were clustered closely together and were in close proximity to Dumandang Control and Nurra Nurra Reserve Control which were also closely clustered together (Figure 7). The leave-one-out allocation success rate (where m = 5 principal coordinate axes) was quite high at 68 %. The sites with the lowest individual success rates were Dumandang Control and Nurra Nurra Reserve Control at 50 %, where misclassification was high for opposite site (e.g. 5 samples from Nurra Nurra Reserve Control were classified into Dumandang Control). Overall, both trace and delta statistics showed significant separation between and within groups (P = 0.001).

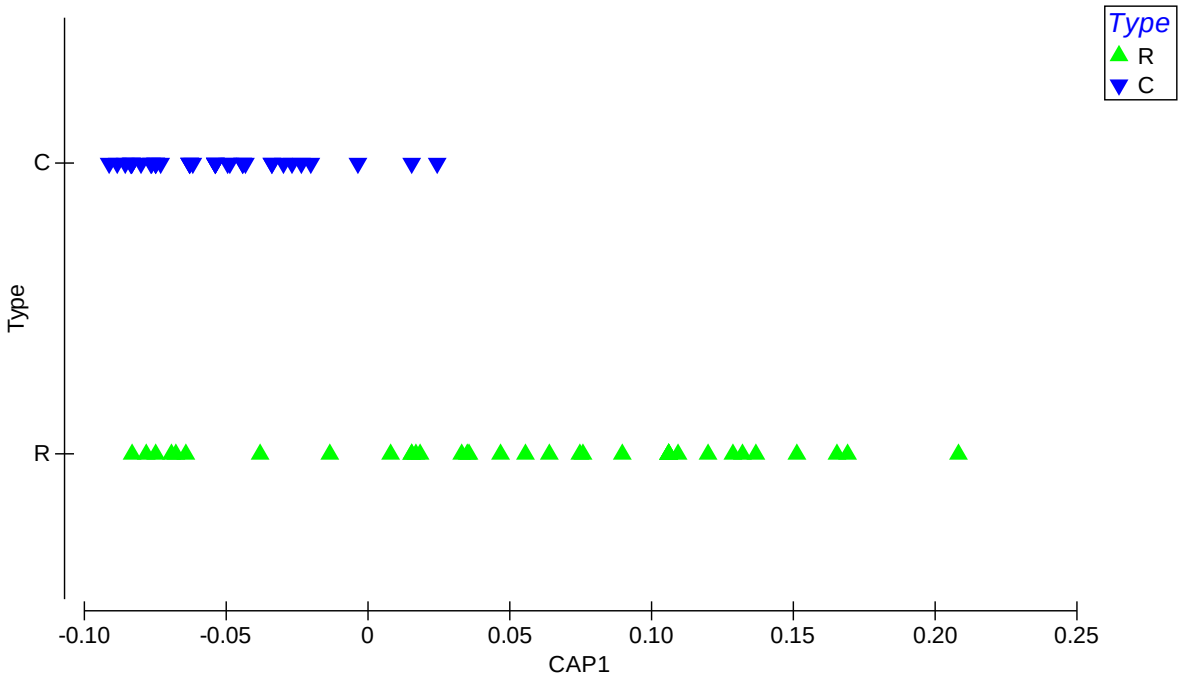

Figure 6: CAP analysis of the core samples combined across 3 locations showing differences between Reveg (R) and Control (C) sites combined across all locations and trips.

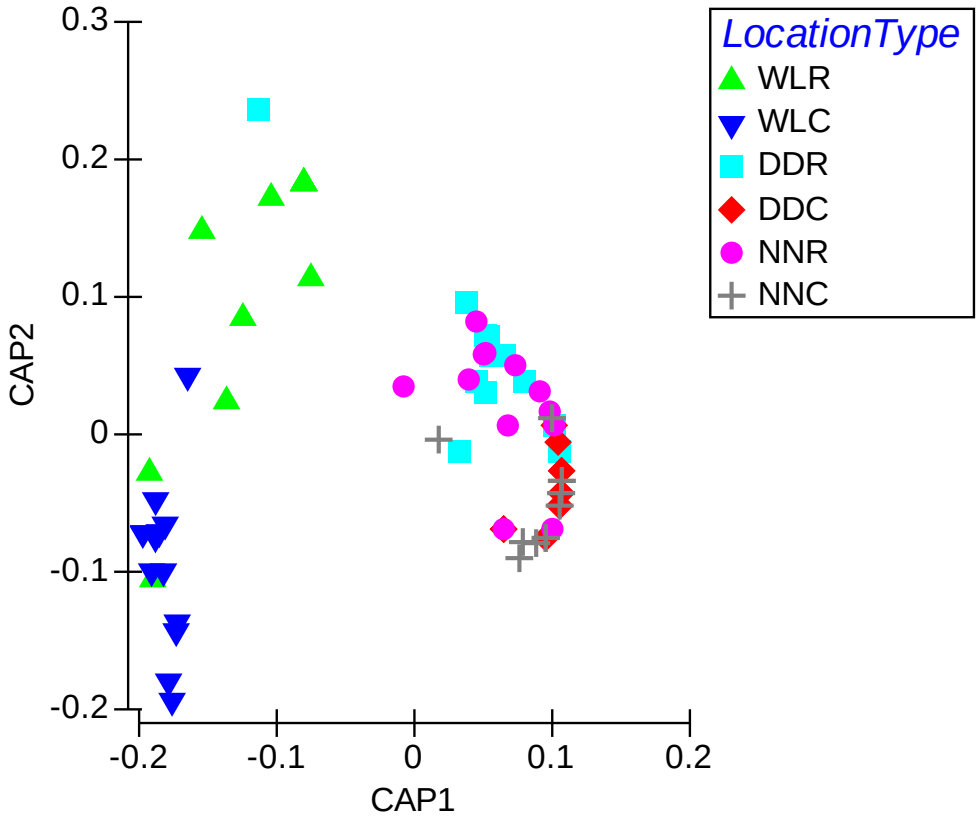

Figure 7: CAP analysis of the core samples separated into each site (i.e. classified by Location and Type) showing differences across three locations from the Lower Lakes. WL = Wellington Lodge, DD= Dumandang, NN = Nurra Nurra Reserve, R = Reveg and C = Control

SIMPER analysis contrasting Reveg and Control areas showed amphipods as being the biggest contributor (49%), followed by chironomid larvae and oligochaetes. Amphipods were just short of being a consistent indicator. Overall these results showed that Reveg areas favoured amphipods and oligochaetes but at the expense of chironomid larvae (which were more common at Controls). SIMPER analysis examining the differences between locations, showed that amphipods contributed to the dissimilarity the most for all three comparisons (between 58 and 90%) and was also a consistent indicator for all comparisons. Chironomid larvae contributed notably to the differences between Wellington Lodge and Dumandang, and Wellington Lodge and Nurra Nurra Reserve, (with a 22% contribution for each), and was again a consistent indicator.

Sweep Nets

From the sweep net samples, 30 taxa were identified (Appendix 3), with a total of 20,681 individuals from all locations. Arthropods dominated the sweep samples with 25 taxa present, 7 of those being crustaceans, 16 insects and 2 arachnids. Other phyla identified included Nematoda, Annelida, Mollusca and Vertebrata (fish, mainly flathead gudgeon, caught incidentally). Cyclopoid copepods were the dominant taxon contributing to 89.6% of the total abundance. These copepods were the 2nd-most widespread taxon occurring in 43 of 72 samples, with amphipods being the most widespread occurring in 49 of 72 samples. Amphipods were the second-most abundant taxon contributing 5.8% of the total abundance.

Multivariate PERMANOVA found significant differences for all interactions. Pairwise tests for the interaction of Location X Type X Trip showed that for Reveg areas during Trip 1 Wellington Lodge was significantly different from Dumandang and Nurra Nurra Reserve; however, Dumandang and Nurra Nurra Reserve were not significantly different. A similar pattern was seen for Trip 2. For the Control areas for Trip 1, all Locations were significantly different as well as in Trip 2. When comparing Reveg and Control sites within a Location, all sites were found to be significantly different for both trip times.

CAP analysis again showed a distinct separation of Wellington Lodge from Nurra Nurra Reserve and Dumandang, with a slight overlap between Wellington Lodge Control and Dumandang Reveg. Dumandang Reveg and Nurra Nurra Reserve Reveg were tightly clustered and distinct from Dumandang Control and Nurra Nurra Reserve Control, which were also clustered (Figure 8). Trace and delta statistics showed significant separation between and within groups (P = 0.001). Overall the

CAP used *m* = 10 principal coordinate axes. The leave-one-out allocation success rate was generally high with 76.4% correct. Dumandang Control had the lowest success rate at only 33%, with most misclassification occurring into Nurra Nurra Reserve Control. CAP analysis between Reveg and Control sites also showed highly significant results (for trace and delta statistics *P* = 0.001). Misclassification error was very low with a value of 9.7%. Four principal coordinate axes explained 77% of the total variation in the resemblance matrix.

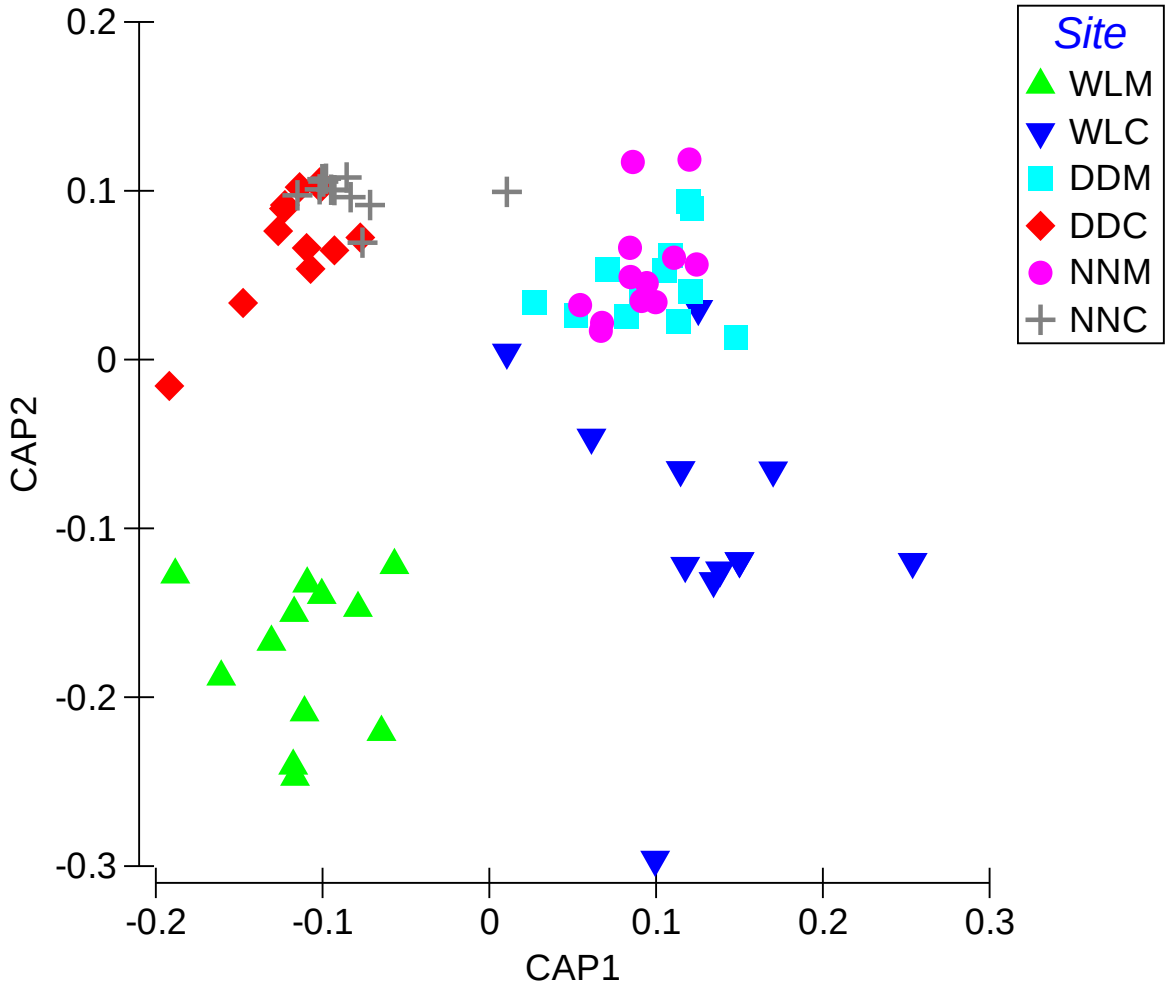

Figure 8: CAP analysis of the sweep samples separated into each site (i.e. classified by Location and Type) showing differences across three locations from the Lower Lakes.WL = Wellington Lodge, DD= Dumandang, NN = Nurra Nurra Reserve, R = Reveg and C = Control

Due to the domination in abundance of the 'planktonic' organisms such as copepods and cladocerans like *Daphnia*(which probably prefer open water to vegetation), some additional analyses were conducted without them to investigate the interactions involving non-planktonic organisms. Planktonic organisms were more abundant at Control sites with an average abundance of 509.5 copepods and 10 *Daphnia* compared to 8.9 individuals per sample for all non-plankton. Reveg areas, on the other hand, had higher average abundances of non-plankton (39.5 individuals) compared to 5.5 copepods and less than 1 individual per sample for *Daphnia*. For each location, mean abundance of non-planktonic organisms was varied. Nurra Nurra Reserve and Dumandang showed a consistent pattern with greater abundance at Reveg than Control sites, while Wellington Lodge had similar abundance for both sites at approximately 20 individuals per sample (Table 4). When averaged across allocations, the contrasting patterns for planktonic versus benthic animals found in sweeps can be seen in Figure 9.

Table 4: Mean abundance (total number per sweep) of non-planktonic versus planktonic organisms caught while sweep netting at three locations in the Lower Lakes pooled across trips (*n* = 12). WL = Wellington Lodge, NN = Nurra Nurra Reserve, DD= Dumandang.

Location	Type	Mean abundance of non-plankton	Mean abundance of plankton
WL	R	23.9	17.2
	C	20.1	95.6
NN	R	48.8	1.25
	C	3.0	712.7
DD	R	45.7	4.9
	C	3.7	467.5
SE		*3.3*	*55.1*

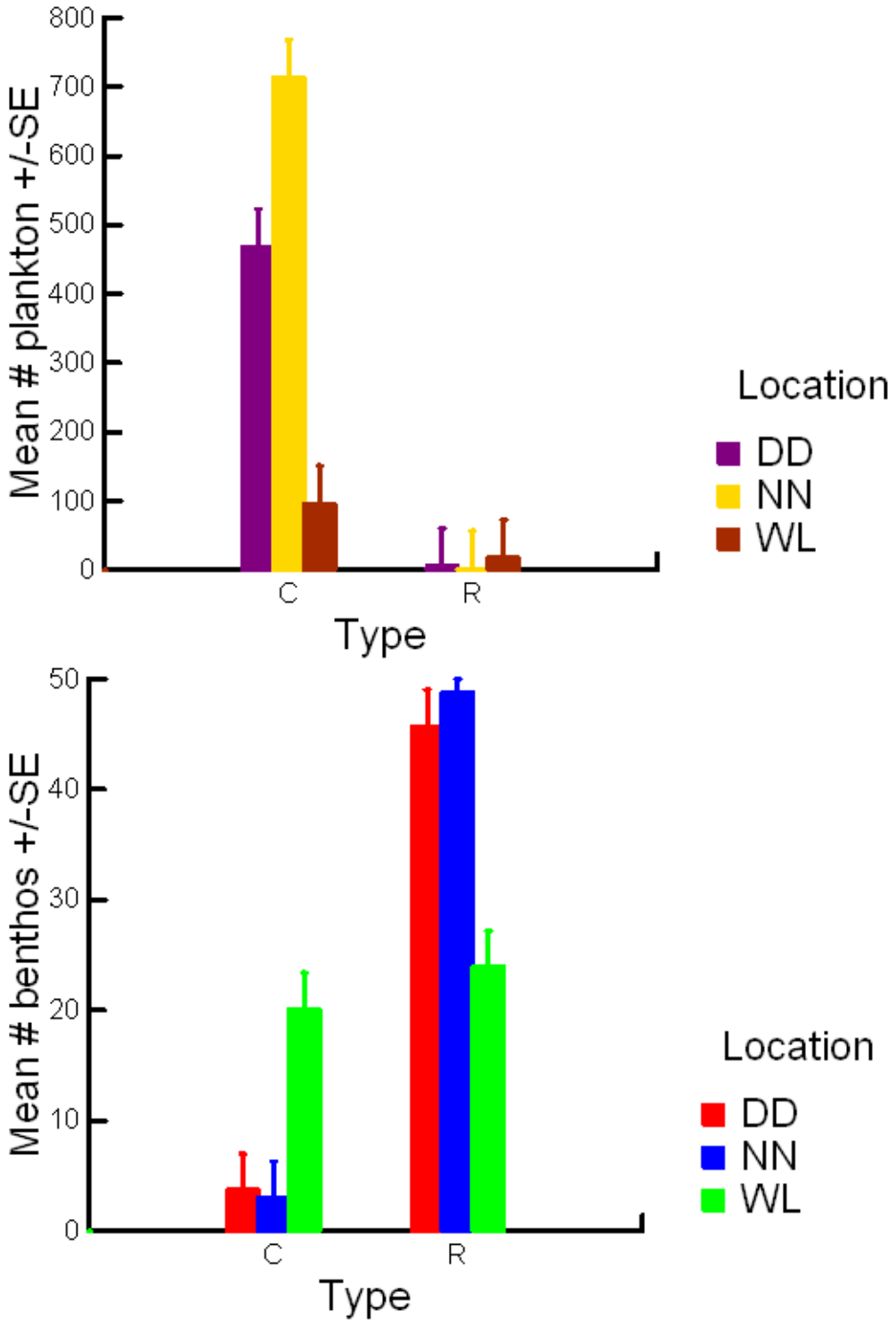

Figure 9: Mean number of animals per sweep sample split into groups favouring either planktonic or benthic habitats, averaged across two trips (i.e. classified by Type or Location), WL = Wellington Lodge, NN = Nurra Nurra Reserve, DD = Dumandang, R = Reveg and C = Control

Baited Fish Traps

Eight taxa were identified using the fish trapping method including five fish, two crustaceans and one insect (Table 5). Of the five fish species found using this sampling method, only one congolli was captured at Dumandang Reveg site on Trip 1 and only one hardyhead at Dumandang Control on Trip 2. In total, 64 individuals were identified across all trips and locations with the common galaxias (26 individuals or 41%) being the most abundant followed by the waterboatmen insect (21 individuals, 33%, Table 6). Galaxias were also the most widespread species found in 10 of 48 samples and were found at both the Control and Reveg sites at Dumandang and Nurra Nurra Reserve and across both trips. The fishes caught were mostly juveniles (Table 5), especially gambusia, congolli, galaxias and gudgeons. Although the waterboatmen had the second highest abundance, contributing 33% of the total abundance, they were only sampled 3 times at Wellington Lodge on the initial trip. The common yabby had the third-highest abundance contributing 9% of the total abundance but was only found at the Dumandang Reveg site on both trips. Thus these data were the patchiest of all components sampled, possibly due to the smaller sample size but also the sparseness of nekton (i.e. mobile animals capable of swimming against currents, as opposed to plankton that move only with currents) more generally.

Multivariate PERMANOVA analysis revealed the Location x Type interaction was significant. When examining this interaction further, it was found that Wellington Lodge exhibited no significant difference between Reveg and Control, while Dumandang was highly significant (P = 0.004) and Nurra Nurra Reserve was also significant (P = 0.044) for this difference. Dissimilarity between the two Types was lowest at Nurra Nurra Reserve at 90% and highest at Dumandang at 100%, with Wellington Lodge having 98% dissimilarity between Reveg and Control.

CAP analysis showed no significant difference between Reveg and Control sites for all Locations combined (Figure 10). The leave-one-out allocation success rate was low for Reveg areas (29.2%) but high for Control areas (95.8%). This is most likely due to the sparsity of the data set overall. CAP results comparing Location and Type(Figure 11), although with overlap largely displayed visual separation between communities and was supported by significant statistics indicating multi-dimensional separation among groups (trace P = 0.001) and significant one-dimensional separation between groups (delta P = 0.001). Taxa characterising the differences among groups were highlighted using a superimposed vector. The results indicated a correlation amongst a group of the yabby, gambusia, hardyhead, corixid and congolli, whereas the shrimp indicated a separate response

possibly due to its presence at Dumandang Reveg and Wellington Lodge Reveg locations. The leave-one-out allocation success rate was low with a large mis-classification error of 58.3%.Nurra Nurra Reserve Reveg had the lowest success rate at 0%, compared with Dumandang Control having 100%. Misclassification error forNurra Nurra Reserve Reveg was most often re-classified into Dumandang Control. Wellington Lodge Reveg had only 12.5% correct with most of the re- classifications being relocated into Dumandang Control. Cross-validation results showed that only three principal coordinate axes provided a reasonable representation of the overall structure, explaining 80% of the total variation inherent in the resemblance matrix.

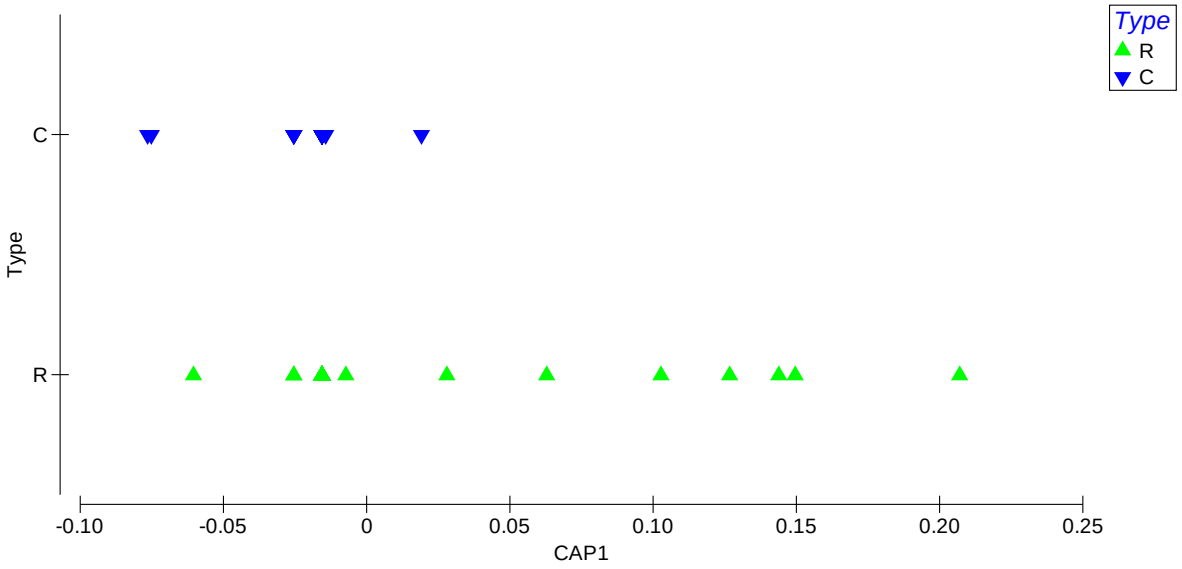

Figure 10: CAP analysis of fish trap data for all locations and trips combined comparing Reveg (R) and Control (C) areas, *n*= 4 for each site.

Table 5: Summary of species caught in baited fish traps by site type (R = Reveg, C = control) and location sampled. Species were sampled at each site on two separate trips indicated by 1 and 2. Loc = locations,i.e.DD = Dumandang, NN = Nurra Nurra Reserve & WL = Wellington Lodge; R = Reveg site, C = Control. Maximum sizes for each species are the longer size estimate from Jones & Morgan (2002)and Lintermans (2009). N/A = not available.

Species			**Trip number when caught**										
Scientific name	**Taxonomic Authority**	**Common name**	**Loc**	**DD**	**DD**	**NN**	**NN**	**WL**	**WL**	**No. sites caught**	**No. days caught**	**Max. size caught (cm)**	**Max. size for species (cm)**	**Total No. caught**
			Type	**R**	**C**	**R**	**C**	**R**	**C**					
Fishes														
Gambusia holbrooki	(Girard, 1859)	Gambusia						1	1	2	1	2.0	6.0	3
Pseudaphritis urvillii	(Valenciennes, 1831)	Congolli		1						1	1	20.5	33.0	1
Galaxias maculatus	(Jenyns, 1842)	Common galaxias		1+2		2	1+2			3	4	9.6	19.0	26
Philypnodon grandiceps	(Krefft, 1864)	Flat-headed gudgeon					1			1	1	4.8	11.5	1
Atherinosoma microstoma	(Günther, 1861)	Hardyhead			2					1	1	4.5	7.6	1
Invertebrates														
Agraptocorixa sp.	-	Waterboatmen						1	1	2	1	N/A	N/A	21
Macrobrachium spp.	-	Shrimp		2				1		2	2	7.5	6.5	5
Cherax destructor	-	Common yabby		1+2						2	2	11.5	16.0	6
No. spp.				**4**	**1**	**2**	**1**	**3**	**2**	**∑ = 6**	**∑ = 6**			

Table 6: Summary of results from the baited fish traps. Values show contrasted sums ignoring other factors, e.g. for the Trip comparisons, values are combined from the 3 sampling locations (WL = Wellington Lodge, DD = Dumandang and NN = Nurra Nurra Reserve) and 2 types of sites (R = Reveg site, C = Control),*n*= 8 at each site. Samples were taken across 2 time periods in May in theLower Lakes, South Australia. Indivs = individuals

Comparison	**States compared**	**# spp.**	**# indivs**	**# fish indivs**	**# invertebrate indivs**	**# fish spp.**	**# invertebrate spp.**	**Most abundant species**
Trip	Trip 1	7	52	23	29	4	3	*Agraptocorixa* sp.
	Trip 2	4	12	9	3	2	2	*Galaxiasmaculatus*
Type	Reveg	6	35	22	13	3	3	*Galaxiasmaculatus*
	Control	5	29	10	19	4	1	*Agraptocorixa* sp.
Location	WL	3	28	3	25	1	2	*Agraptocorixa* sp.
	DD	5	27	20	7	3	2	*Galaxiasmaculatus*
	NN	2	9	9	0	2	0	*Galaxiasmaculatus*
Total		**8**	**64**	**32**	**32**	**5**	**3**	-

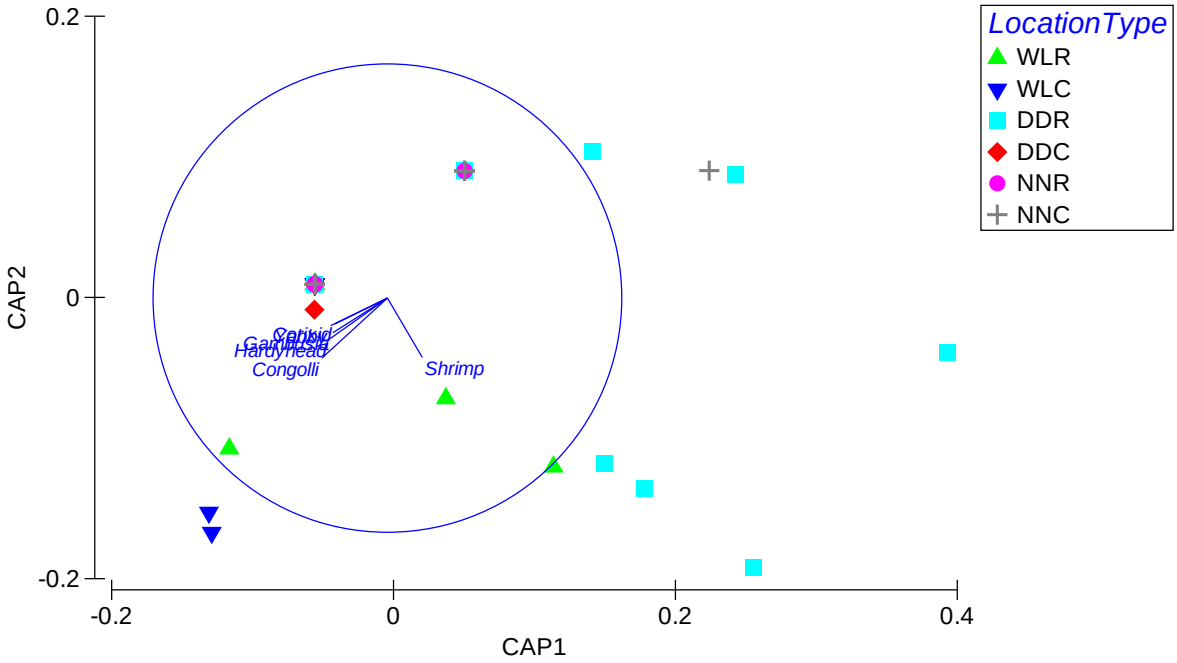

Figure 11:CAP analysis of the baited fish trap samples showing differences across sites(i.e. emphasising the Loc X Type interaction pooling the two trips) from the Lower Lakes. WL = Wellington Lodge, DD= Dumandang, NN = Nurra Nurra Reserve, R = Reveg and C = Control,*n*= 8 for each combination. The vectors plotted show trends for the abundance of individual species where their Spearman correlation coefficients were >0.35.

SIMPER analysis between locations showed galaxias to contribute most to the dissimilarity for all three comparisons, ranging from 32.5% to 68.4%. It was also a consistent indicator between Wellington Lodge and Nurra Nurra Reserve,and Dumandang and Nurra Nurra Reserve,(but not between Wellington Lodge and DD). SIMPER analysis examining the differences between location/types, showed that waterboatmen contributed to the dissimilarity between Wellington Lodge Reveg and Control (50.6%). The common galaxias were a consistent indicator, responsible for differences between Dumandang Reveg and Control contributing 53.03% for the overall dissimilarity between sites. This was also the case when comparing Nurra Nurra Reserve Reveg and Control with common galaxias contributing 94.95%, with higher average abundances at the Reveg area.

Edge Photos of Habitat Refugia Quadrats

Nine categories were used to describe the habitat cover in the refugia photos (described in Appendix 3). On average, Dumandang was dominated by pasture grass, while Nurra Nurra Reserve and

Wellington Lodge were dominated by sand (Figure 12). Wellington Lodge Reveg and Dumandang Control were the most diverse having five categories present on average.

The total percent cover of all living vegetation observed on the bank varied from a high at Dumandang of mean = 83 % cover down to only 10 and 6 % at Wellington Lodge and Nurra Nurra Reserve, respectively (this difference was significant by ANOVA, $P < 0.001$). Only Dumandang showed a significant difference in cover according to Type, with 100 % cover at the Reveg site but a mean of only 67 % cover at the Control site.

Multivariate analyses of % cover of habitat types were significantly different for the interaction between Location and Type. When examining this interaction further, it was found that, at Dumandang and Nurra Nurra Reserve, the Reveg and Control sites were significantly different but at Wellington Lodge they were not. SIMPER analysis showed that, for Dumandang, pasture grass and *Schoenoplectus pungens* were consistent indicators and had higher abundances at the Reveg site, contributing 33 and 30 %, respectively, of the dissimilarity between sites. Overall dissimilarity between Reveg and Control sites was high at 62.5% at Dumandang, whilst very low at only 9.3 % at Nurra Nurra Reserve. Nurra Nurra Reserve had two consistent indicators of this as well with *S. validus* contributing 38 % of dissimilarity with higher abundance at the Reveg site and sand contributing 36 % dissimilarity with a higher abundance at the Control site. At Wellington Lodge, dissimilarity was intermediate (27 %) with sand contributing 32 % with higher cover at the Reveg site than the Control.

Due to some missing data points, separate analyses were run using only bank percent cover data from Trip 2. This test showed significant results for the interaction between Location and Type as well, with Dumandang Reveg being significantly different from the Dumandang Control site but no such significant difference at Wellington Lodge. No such test could be conducted for Nurra Nurra Reserve due to missing data. CAP analysis on Trip 2 data showed this distinction between Dumandang Reveg and Control, with both Wellington Lodge sites intermixed and tightly clustered (Figure 13). The analysis used $m = 3$ principal coordinate axes, which explained 98.3 % of the total variation in the data. The leave-one-out success rate was high at 75.8 %, all mis-classifications occurred at Wellington Lodge, re-classifying replicates into the other Type of site for that Location or into Nurra Nurra Reserve Control. Overall the CAP showed significant differences (both trace and delta $P = 0.001$). The CAP analysis investigating differences between all Reveg and Control sites (factor Type) also showed significant differences ($P = 0.002$, Figure 14). The analysis used m = 3

principal coordinate axes, which explained 98.3 % of the total variation in the data. The leave-one-out success rate was high at 79.3 % and all mis-classification occurred at Wellington Lodge with Reveg cases being mis-classified into Controls.

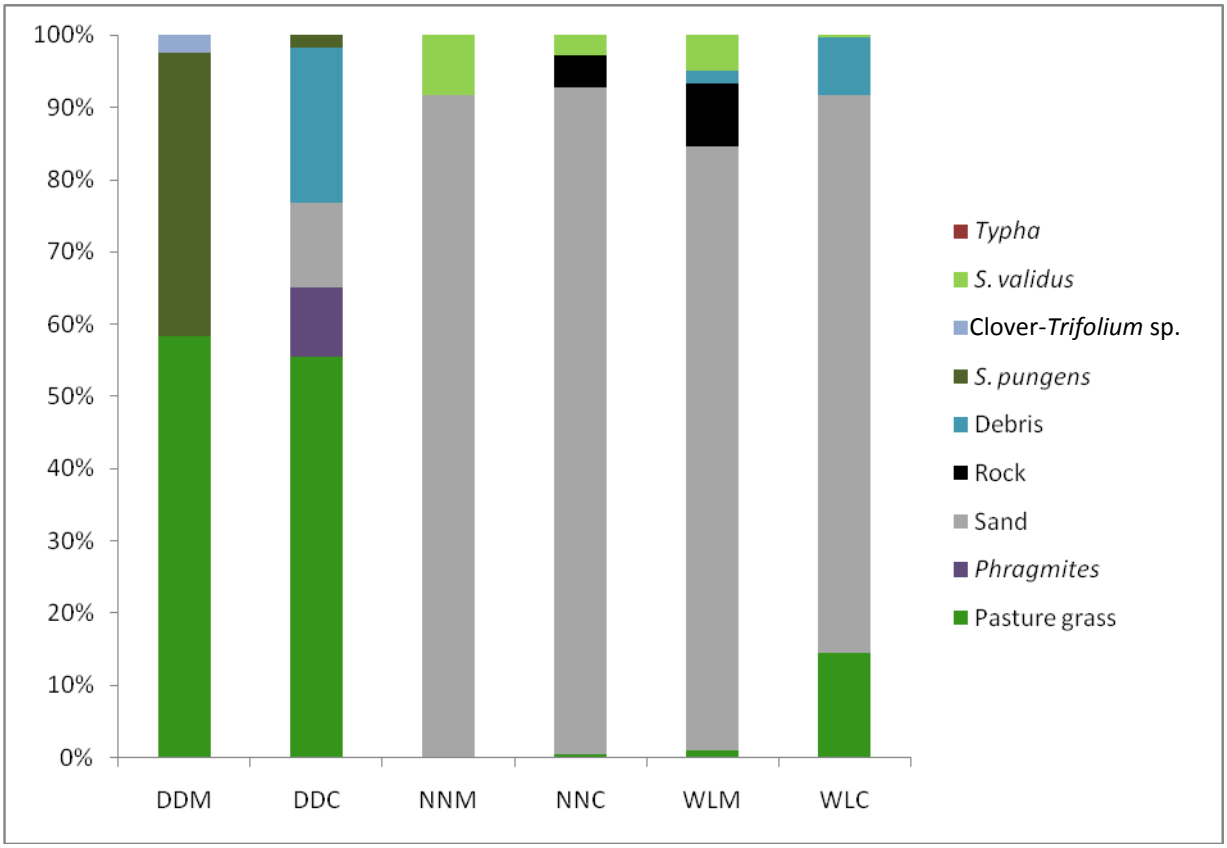

Figure 12: Mean % covers of all habitat types seen from the edge photographs of quadrats taken along the bank at three Locations in the Lower Lakes.WL = Wellington Lodge, DD = Dumandang, NN = Nurra Nurra Reserve, M = Reveg and C = Control, *S.* = the genus *Schoenoplectus, n*= 12 for each combination.

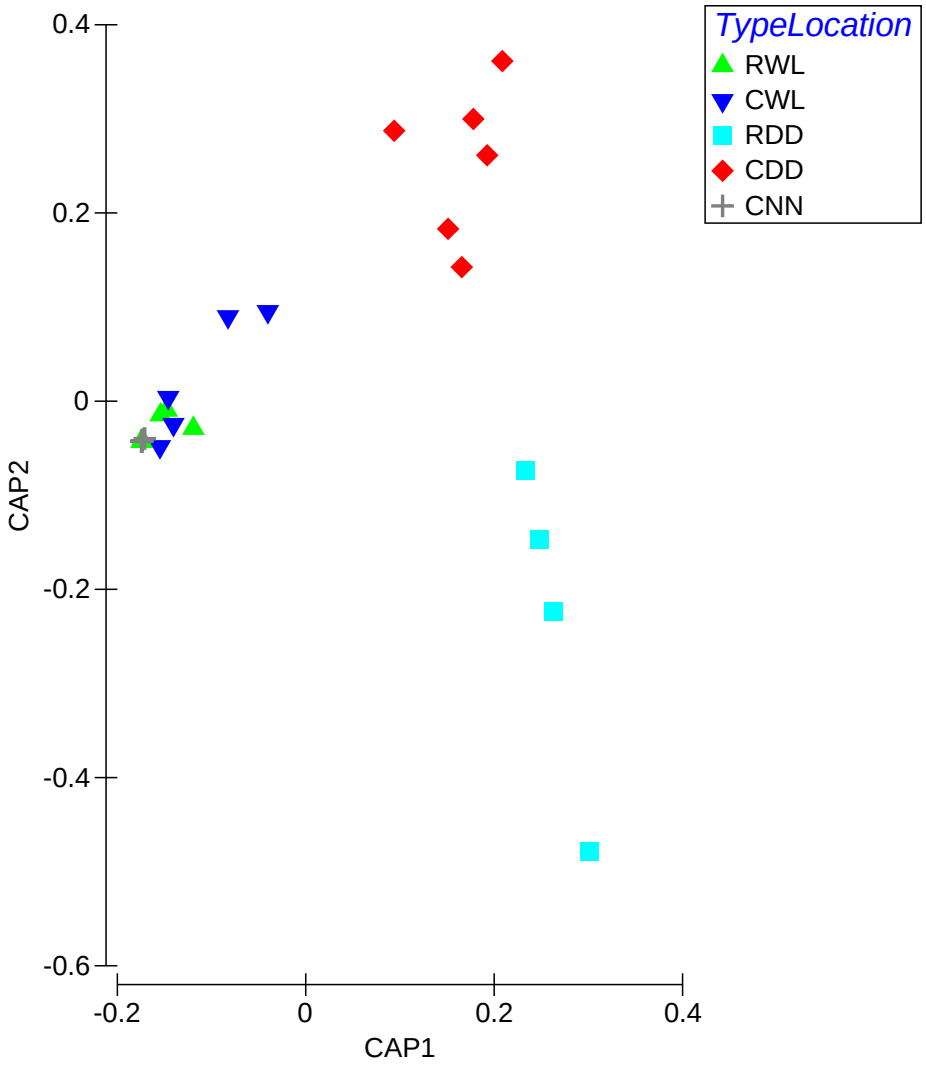

Figure 13: CAP analysis of % covers of classified habitats in the refugia edge photos separated into each site (i.e. classified by Location and Type) showing differences across three locations from the Lower Lakes for Trip 2 only. WL = Wellington Lodge, DD = Dumandang, NN = Nurra Nurra Reserve, R = Reveg and C = Control, *n*= 6 for each site. NN Reveg site is missing from this analysis because photos were not taken there on Trip 2 (nor for much of Trip 1 at all sites).

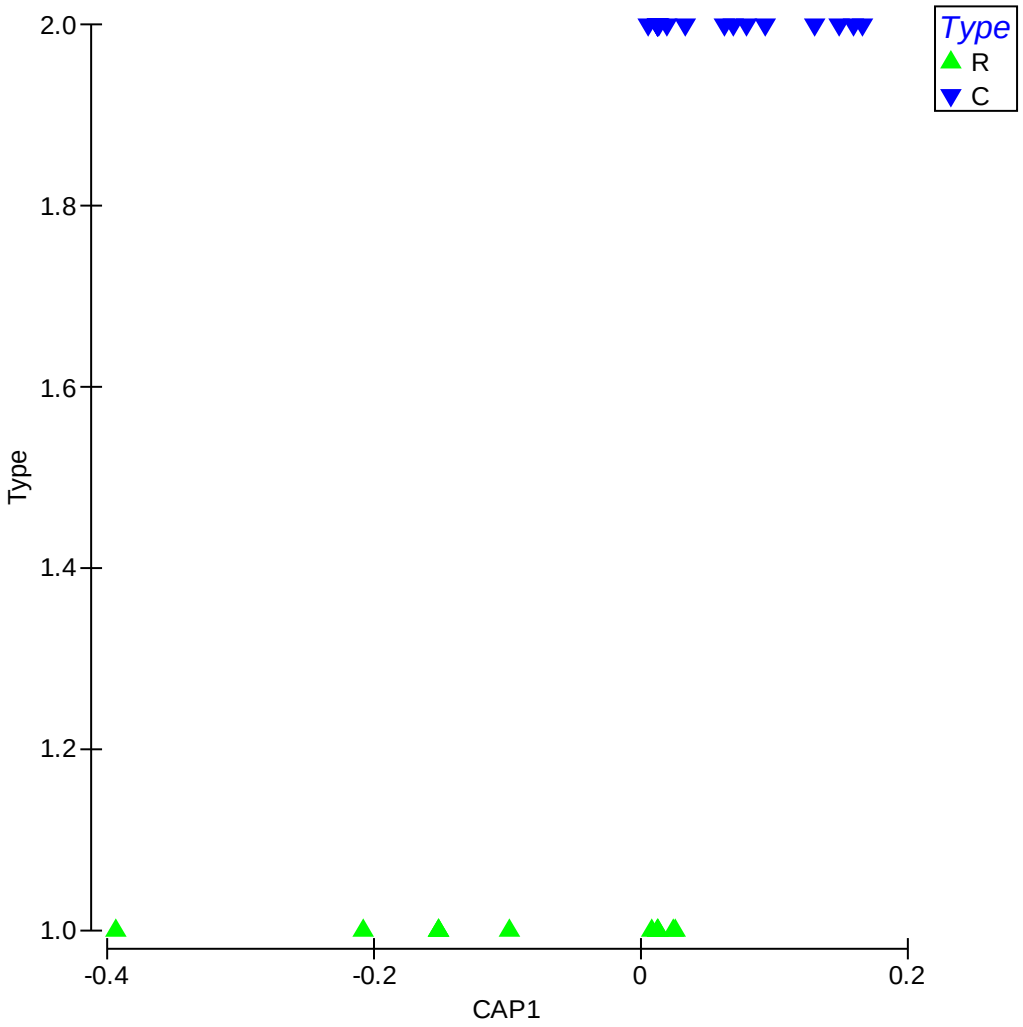

Figure 14: CAP analysis of the refugia edge photos separated by Type alone showing differences between Reveg (R) and Control (C) sites in the Lower Lakes,*n*= 36 for each Type.

The incidence of bank erosion was relatively low overall, being observed on only 12 times out of the 52 edge photos that could be used (i.e. 23 %) but all cases of these were found at Controls and none at Reveg sites. The incidence of 42 % eroded banks at Control sites differed very significantly from the 0 % observed at Reveg sites ($P < 0.001$ by a Fisher exact test) and was observed similarly at Dumandang (7 with erosion out of 11, 77 %) and Wellington Lodge (1 out of 5, 20 %) but not at Nurra Nurra Reserve (only 1 out of 12, 8 %), hence $P = 0.001$, 0.015 and 1.00, respectively, by Fisher exact tests.

DISCUSSION

Efforts to revegetate wetlands that are degraded through erosion, loss of native vegetation or other undesirable aspects are themselves worthy to contemplate. But there are additional benefits possible from bringing vegetation back for a degraded site, to do with altered environmental conditions and the usage of the new vegetation by animals, other plants and microbes. There is additional effort required in monitoring to go beyond observing just the survival of what is planted to assess the condition and usage of it by other taxa. This pilot study sought to characterise such aspects in Lakes Albert and Alexandrina for three sites that had had the clubrush *S.validus* replaced there between 2004 and 2007.

By sampling several measures of the environment (water, sediments and vegetation) and several components of the biota associated with the sites, the values of these measures were used to assess how widespread these further benefits from revegetation might be. Sampling the biotic assemblages required using several different methods and broad taxonomic knowledge to identify (at least coarsely) what was caught but this protocol is the only way to determine directly any usage by the range of biota that potentially could benefit from revegetation (Napier & Fairweather 1998).

The effects of revegetation can thus spread beyond where the planting is done in an area to other biota (including other plants or algae) attracted to the new conditions. These effects might be most apparent at the site level where plantings offshore could lead to diminution of wave action, in turn causing less erosion of the adjacent bank and a more vegetated shoreline over time. In time these offshore and shoreline plants could lead to increased habitat for invertebrate and vertebrate animal species. The pathways of both direct and indirect effects that stem from such plantings are potentially quite complex (Figure 15) but require elucidation from more research.

The findings presented here suggest that the Type of site (i.e. whether revegetated or not, i.e. Reveg versus Controls) did influence most of the variables (both environmental and biotic) that we measured (see Appendix 4 for summaries of statistical outcomes). In a few cases this effect was independent of the other two factors (i.e. Location or Trip) but in most cases an interaction of Type with Location or over all three factors was evident. This has been interpreted to mean that the exact effect of revegetation detected on these aspects of environmental condition will generally depend on where it is done (i.e. Location) and possibly also when the measurements (i.e. Trip) are undertaken.

Those interactions are sometimes then complex to untangle but in most cases there are compelling biological explanations for why they occurred. In some cases, different effects were seen, e.g. depending on whether the type of animals generally like the shelter of vegetation (e.g. benthic insects) or are more likely to be found in open water (e.g. planktonic copepods and cladocerans). Separation of such data sets into ecologically-meaningful subsets was aided by the design of this study, in that it was able to avoid confounding small-scale or site-to-site variation with what the revegetation was doing in each place.

Compared to Control sites, Reveg sites in some instances (especially at Dumandang) had higher percentages of fine sediment, which could indicate slower water movement allowing smaller particles to settle out. The opposite trend may have been seen at Wellington Lodge because this location did not have as great a build-up of vegetation in the Reveg area and the Control site also had potentially sheltering vegetation seen offshore (see Appendix 1). Reveg areas had higher oxygen saturation than control sites (except for Dumandang, possibly due to the thickness of the vegetation there slowing water circulation) as well as cooler temperatures (most likely from shading by vegetation).

Core (infaunal) communities in the Reveg sites were more diverse than Control samples and in general had a higher abundance of organisms. Sweep net samples from the Reveg sites also had higher diversity generally than the Controls but abundance was lower due to the planktonic organisms, such as copepods, favouring the more open water at Control sites. Excluding Wellington Lodge, Reveg sites were also significantly different from Controls and had higher abundance and diversity of benthic animals in sweep nets. The increase in diversity and abundance at Reveg sites of most organisms can likely be attributed to the presence of the replanted vegetation and the shelter, food and additional habitats it provides.

The results indicated a consistent difference between Wellington Lodge and the other two Locations for most methods conducted. Salinity and turbidity were both lower (but not significantly) at Wellington Lodge compared to the other 2 locations and, while vegetation and sediment sizes were similar, distinct communities were seen at Wellington Lodge for both coring and sweep nets. Additionally, Wellington Lodge was the only location for the fish traps that did not display significant difference between Reveg and Control sites. Reasons for these differences may have resulted from the location of Wellington Lodge, being the only site within Lake Alexandrina (much larger than Lake Albert) , or differences in water and energy supplied to the system based on its closer proximity to the River Murray and to the larger fetch with a different aspect (see Figure 1). Wellington Lodge

also has the youngest planting and this could also have contributed to the differences seen. Repeated sampling over time at more locations could resolve these possible explanations.

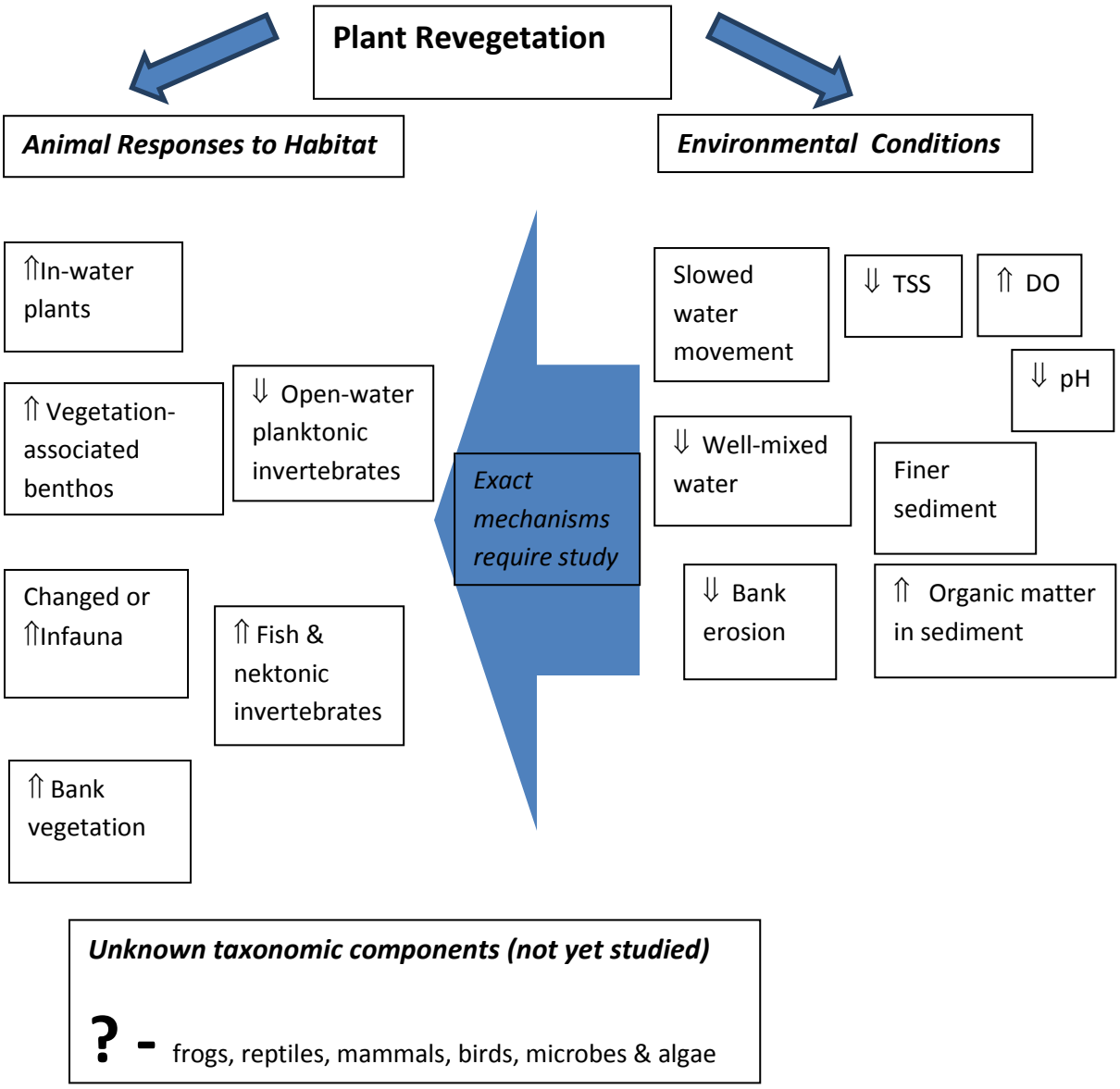

Figure 15: Conceptual diagram of the varied realised and potential effects from revegetation on environmental conditions and habitat effects for different animal and plant components of assemblages.

Recommendations

In order to examine these potential factors and others, it is advised to expand sampling to a greater number of sites, especially increasing the number of sites within Lake Alexandrina, and investigating the potential impacts of 'age of replanting' on the communities observed, by including more sites from a wider range of ages and to sample them repeatedly over coming years. It could also be useful to include sites designed with a BACI sampling design, that is sampling also before revegetation occurs, during and after as well as at a comparable control sites at the same times.

It is important to consider expanding the monitoring program across seasons and years. This pilot study was merely one snapshot for an Autumn season in a single year and so results could change over seasons and across years, especially with the variable nature of water levels and quality (esp. salinity and turbidity) throughout the system. Several methods showed some differences between the two trips for this study, demonstrating that, even within a short time period, significant changes can be observed. This may highlight the key role that short-term weather can have on influencing the animal assemblages observed.

All methods conducted in this study gave useful and interpretable results that usually showed some differences between the Reveg and Control areas. Increased sampling effort for the baited fish traps is advised in order to boost their statistical power and have the potential to sample additional diversity and abundance of fish species. Vegetation surveys were a time-consuming part of the field days; however, different methods of assessing vegetation cover (e.g. from photographs or video) could be useful to detect changes over time, thus providing useful information relating to both the habitat conditions and success of the plantings, and so give insights into further recruitment and successional changes.

The adjacent banks located inshore from the plantings are probably sheltered by the revegetation but this should be checked further in terms of measuring water movement and erosion rates. More sampling of these edge habitats would also reveal whether effects of in-water revegetation extend to amphibious communities o plants and other organisms.

The field program instituted for this pilot study involved a very full day of work in the field for two people to take the suite of measurements at paired Reveg and Control sites as described in this report. Daylight hours available in May, when this pilot study was done, were less than during summer months but there are still logistical limitations to widening the range of measurements to be taken. The amount of lab-based processing time depended, in part, on the size (i.e. volume of

debris, number of organisms caught) of the sample taken using sweep nets as well as the intrinsic time to process a sediment or water sample. The number of samples did yield enough statistical power to detect at least some differences for every measure sampled here but there may be some opportunities to optimise the number of samples (i.e. sample size in terms of replication) as a further step of fine-tuning this sampling design. Such *post hoc* data analyses have not yet been attempted but now we do have the pilot data to that assessment, if required.

A few aspects that were measured probably require further development to attain their full potential. For example, quadrats on the bank adjacent to plantings were photographed (to determine percent coverage in relation to erosion, substrata and potential shelter for organisms) but whether these constitute refugia for any species has not been assessed empirically.

Potential cost savings could come from some refinement of the methods utilised in the future. It would be possible to omit the infaunal coring but keep the sweep netting (even though they target organisms from distinct microhabitats) because the latter gave a better return for effort with more species found from sweeps but with very similar patterns identified across the two methods. Fewer sediment samples probably need to be taken to characterise these sites but the matching of cores to sediments would require similar replication for the assessment of small-scale (within-site) variation. If turbidity of the water is deemed to be important then it might be better measured in the field in terms of nephelometry (i.e. as NTU). Measuring turbidity as TSS was an extra set of lab-processing procedures that added considerably to the time in the lab. Any new method for vegetation assessment would either require a new trial or could adopt the intensive methods used by Dr Jason Nicol of SARDI for other monitoring going on this region.

It is possible to add additional methods to those used in this study in order to investigate the effects of Revegetation on a wider array of communities and factors. This could include investigating sediment and water contaminants in order to assess whether revegetation assists in promoting healthy ecosystems, assessing the sediment pH and alkalinity to see whether the revegetation combats soil acidification, investigating ecosystem processes (like decomposition or recruitment, see Lester et al. 2009, 2011a,b), analysing microbes present from water and sediment samples, targeting different fish assemblages using techniques such as electrofishing, fyke nets or seine nets, or assessing the revegetation areas for potential as frog habitats by doing surveys using calls and identifying spawn sites. Bird activity nearby and within the vegetation was observed on this trip and could be explored further, in particular for assessing vegetation-associated bird species and their

potential for nesting locations. Reptiles in the area could be assessed using pitfall traps or timed searches and these methods, along with live traps could also be used to assess small native mammals within the area. Of course, adding any vertebrates to this monitoring would require additional animal ethics approvals under State law.

Sampling of terrestrial invertebrates on the vegetation extending above the waterline (some of that probably made it into sweep net samples) could be useful because terrestrial invertebrate activity was commonly seen on the vegetation above the surface of the water. This could be done via aerial netting or perhaps the use of a pooter or by banging the vegetation and collecting what falls off onto sheets laid below. More generally airborne invertebrates could be collected using sticky traps, perhaps with baiting or by laying out coloured water pans. It was notable that small birds were seen flying onto the stalks of the vegetation, perhaps to collect small insects.

To conclude, revegetation with clubrush does seem to positively affect other aspects of the environment, including water column and sediment conditions, other vegetation (beyond what was planted), and the use of these shallow areas and adjacent banks by invertebrates and fishes. The degree of these effects varied from location to location where the revegetation had been done. Untangling the full range of such indirect effects of revegetation (Figure 15) within the Lower Lakes probably requires more sampling over longer timeframes (e.g. multiple seasons and years) as well as examining more sites.

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APPENDICES

Appendix 1

A description of each site sampled in the Lower Lakes during the May sampling period. Nurra Nurra Reserve and Dumandang are situated in Lake Albert, while Wellington Lodge is situated in Lake Alexandrina (see Fig. 1).

Nurra Nurra Reserve

Revegetation

Control

	Trip 1- 16/05/2013	**Trip 2 – 28/05/2013**
Coordinates	Reveg: S35 25.258 E139 20.499 Control: S35 25.070 E139 20.603	Same as previous.
Weather	15^{o}C, Overcast, showers, wind 5-10 knots SW, easing in afternoon	Sunny, 10 knots NE easing in the afternoon, 18^{o}C
Access Issues	Roughly 70 m walk down medium gradient slope from access gate into Revegetation area with no track. Approx. height elevation 20 m.	Same as previous.
Description of site	Reveg site had aquatic vegetation in a continuous band that reached the bank (unlike the other two sites) and was approx. 5 m in width. The lakeward edge contained the *Schoenoplectus validus* planting and behind this a mix of 3 vegetation types were seen *Typha*, *S. validus* and *Phragmites*. This area bordered a protected	Same as previous.

	community Revegetation site. A small island of *Phragmites* in the lake was seen approx. 100 m from the planting, which appeared to attract feeding pelicans. Small birds were seen among the *S. validus*. The north side of the planting was bordered by a semi-submerged fence which supports water pumping facilities. The Reveg and Control were divided by an eroding headland and a 2nd, younger *S. validus* planting. The Control site was approx. 150 m south from the Reveg. No land access was available and this site must be accessed via the lake shallows. Little vegetation is seen in the control site, with small patches of *Typha* and *S. validus* on the southern end. Bordering the southern end of the site is another headland with a mix of thicker vegetation present. Grazing land was situated adjacent to site, with cattle activity seen on the bank.	
Order of Methods	Fish traps were baited and set at the Reveg site at 10:00am. Then we waded 100 m to the Control site and set the traps for that site at 10:40am. After that we returned to Reveg, conducted water quality measurements and collected core, sediment and turbidity samples at six positions along the landward edge of the planting. After returning samples to storage, sweep, algae and vegetation transects were undertaken at 3 positions before the traps had to be collected at 1.05pm (3 h duration for traps). Traps were picked up first at the Reveg and processed, before the control traps were visited at 1:40pm and processed. We then returned to the Reveg and completed the last 3 sets of sweeps, algae and transects. The same process was then undertaken at the control without further trap setting. Refugia photos of the banks were taken last.	Same as previous except traps were set at 10:30am and 11:00am for Reveg and Control respectively and picked up at 1:30pm and 2:00pm. Also sweeps and veg surveys were completed before traps needed to be picked up. No refugia photos were taken at the Reveg site.
Month/Year of most recent revegetation planting = Feb 2006		

Dumandang

Revegetation

Control

	Trip 1- 09/05/2013	**Trip 2 – 20/05/2013**
Coordinates	Reveg: S35 38.776 E139 13.513 Control: S35 38.566 E139 14.354	Same as previous.
Weather	Fine, 30°C, wind 10- 15 knots NE	Cloudy, 20°C, wind SE <5 knots increasing in the afternoon to 10 knots
Access Issues	Private land access. 4WD access was needed through boggy and undulating grazing land; access routes had very little use. The Reveg site was accessed five metres from the lake's edge over cattle fence. The Control site was located 1.3 km from the Reveg site, and was roughly a 30 m walk down a gentle slope. Access was via a gate, through thick grass with no track available.	Same as previous.
Description of site	A mix of 3 vegetation types were present at the Reveg; *Typha*, *S. validus* and *Phragmites.* These were present 30 m out from the lakes edge creating a dense/impenetrable barrier roughly 7 m wide. The result of this vegetation was an enclosed, protected backwater with patchy vegetation within and	Same as previous.

	vegetation lining the bank in some areas. Due to this dense line of vegetation, the original Revegetation site was difficult to locate, but is likely to be on the outer (lakeward) edge. This area had a much higher build-up of fine silts with randomly placed submerged and hidden rocks/debris, which made it difficult to traverse within the muddy waters. Bird and fish activity was observed among the vegetation and within the backwater. The Control site was approx. 1.3 km north-east from the Reveg site. Access was only available via 4WD. Little vegetation was present at the control site, with small patches of *Typha* and *S. validus* along the bank away from where samples were taken. Grazing land was adjacent to the site with cattle activity seen on the bank.	
Order of Methods	Fish traps were baited and set at the Reveg site at 11:05am. We then conducted water quality measurements and collected core, sediment and turbidity samples at six positions along the inner edge of the vegetation barrier. After returning samples to storage, sweep, algae and vegetation transects were undertaken at 3 positions before the traps had to be set at the control at 1:45pm . Upon returning to the Reveg, traps were collected and processed at 2:10pm (3 h duration for traps). The final three sweep, algae and vegetation transects were then completed, followed by refugia photos of the bank. We then returned to the Control site and carried out all sampling methods in the order mentioned above, leaving the trap collection until last at 4:50pm.	Same as previous except fish traps were set at Reveg (at 10:50am) and Control (at 11:20am), and then picked up at 1:50pm and 2:30pm. Sweeps and veg surveys were completed at the Reveg site before the traps needed to be picked up.
Month/Year of most recent revegetation planting = May 2006		

Wellington Lodge

Revegetation

Control

	Trip 1- 02/05/2013	**Trip 2 – 23/05/2013**
Coordinates	Reveg: S35 33.502 E139 15.200 Control: S35 33.576 E139 15.141	Same as previous.
Weather	Fine, 20°C, wind 10 knots NE, increasing in the afternoon	Fine, 16°C, wind < 5knots increasing in the afternoon to 5-10 knots SW
Access Issues	Private land access. Reveg site accessed 15 m from lakes edge over electrified cattle fence and through thick grass from where vehicle was parked in grazing land with no track present. The control site was located 370 m from the Reveg site and was driven to using 4WD or 2WD. Site was accessed by a 20 m walk down a gentle slope over an electrified cattle fence, through thick grass with no track.	Same as previous.
Description of site	The Reveg site was dominated by a 3 m wide row of *S. validus* which was roughly 40 m long. The planting connected with the headland and	Same as previous.

	combined with *Typha* and *Phragmites* forming into a denser and wider barrier. Patches of vegetation dominated by *S. validus* were observed along the bank but the area was mostly dominated by bare sand and rock. A large amount of bird activity was also observed in the surrounding area. Open grazing land was located adjacent to the site. The Control site was approx. 370 m from the Revegetation site. Submerged vegetation was present outside the sampling area at the control site. Patches of vegetation were also observed 100-200 m out from the shore and may have provided protection to the habitat closer to shore. Small patches of *Phragmites* were observed along a mostly unprotected bank. Grazing land was adjacent to the site with cattle activity seen on the bank.	
Order of Methods	Fish traps were baited and set at the Reveg site at 10:00am. We then drove to the Control and set traps at 10:30am and returned to Reveg site. Water quality measurements were conducted, and we then collected core, sediment and turbidity samples at six positions along the landward edge of the planting. After returning samples to storage, traps had to be collected first from the Reveg at 1:00pm and processed and secondly from the Control site at 1:30pm (3 h duration for traps). After returning to the Reveg site, sweep, algae and vegetation transects were undertaken at 6 positions. We then returned to the Control and carried out all sampling methods as mentioned above (excluding traps). Refugia photos of the banks were taken last.	Same as previous except that traps were set at 9:40am at the Reveg and 10:00am at the Control, and were picked up at 12:45pm and 1:10pm. All sampling was completed at the Reveg site before returning to Control site to retrieve traps. Sampling was then carried out at the Control.
Month/Year of most recent revegetation planting = February 2007		

Appendix 2

Table A1. Sediments summary table. Values are means for each Loc X Type X Trip combination (*n* = 6) with an overall error estimate (SE) value that came from the ANOVA also given. % OM was only calculated for Trip 1 due to logistical difficulties.

Loc	Type	Trip	Class (sand)	Sorting	Median Size μg	Sorting coefficient μg	% Fines <63 μg	% Coarse >1000 μg	% OM LOI
WL	**Reveg**	**1**	Medium-Fine	M	247.9	0.735	1.1	0.9	0.35
		2	Fine-Medium	M	209.0	0.851	1.9	1.4	-
	Control	**1**	Fine-Medium	M-MW	223.2	0.736	2.4	4.5	0.46
		2	Fine-Medium	M-VW	221.8	0.739	5.0	5.3	-
NN	**Reveg**	**1**	Fine	M-MW	191.1	0.688	4.1	6.2	0.73
		2	Medium-Fine	MW (M-W)	245.6	0.542	3.0	12.8	-
	Control	**1**	Fine-Medium	MW/M	207.8	0.723	0.1	9.3	0.35
		2	Medium-Fine	MW	323.6	0.627	0.7	6.2	-
DD	**Reveg**	**1**	Fine-Medium	MW-M	237.9	0.665	11.2	7.1	1.29
		2	Fine	MW-W	209.6	0.600	15.3	6.7	-
	Control	**1**	Medium	M	275.3	0.739	0.0	0.3	0.21
		2	Medium	M	294.2	0.735	0.3	0.8	-
				SE	***17.3***	***0.031***	***1.4***	***2.3***	***0.07***

Appendix 3:

Table A2: Summary of occurrence of all identified taxa or habitat classes for the different methods used in at three Locations in the Lower Lakes showing distribution of taxa across Locations, Types and Trips for vegetation transects, cores, sweep nets and edge quadrat photographs. Superscripts: x = present, blank = absent, @ - dead standing vegetation, # - bare unconsolidated substrate, $ - bare rock, ^ - dead roots or other vegetation, sticks& logs

Method	Taxon	Location			Type		Trip	
		DD	NN	WL	R	C	1	2
Vegetation Transects	*Schoenoplectus validus*		x	x	x	x	x	x
	Typhadomingensis	x	x	x	x	x	x	x
	Phragmites australis	x	x	x	x		x	x
	S. validus/T. domingensis/P. australis mix	x	x	x	x	x	x	x
	T. domingensis/P. australis mix	x		x	x		x	x
	T. domingensis/S. validus mix		x	x	x		x	x
	S. validus/P. australis mix			x	x			x
	Debris[@]	x			x		x	
Cores	Oligochaete sp.	x	x	x	x	x	x	x
	Chironomid Larvae sp.	x	x	x	x	x	x	x
	Bivalvia sp.		x	x	x	x	x	x
	Trichoptera Larvae sp.			x		x	x	
	Amphipoda sp.	x	x		x	x	x	x
	Formicidae sp.	x					x	
	Ostracoda sp.	x			x			x
	Copepoda sp.		x		x		x	
Sweep Nets	Cyclopoida sp.	x	x	x	x	x	x	x
	Amphipoda sp.	x	x	x	x	x	x	x
	Sphaeromatidae sp.	x				x		x
	Cladocera sp.	x			x		x	x
	Daphnia sp.		x	x	x	x	x	x
	Ostracod sp.	x		x	x	x	x	x
	Paratya australiensis	x	x	x	x	x	x	x
	Chironomid Larvae sp.	x	x	x	x	x	x	x
	Chironomid Pupae sp.		x	x	x	x	x	x
	Chironomid adult sp. 1	x	x		x	x	x	x
	Chironomid adult sp. 2			x	x	x		x
	Chironomid adult sp. 3		x		x			x
	Chironomid adult sp. 4		x		x			x
	Caenidae sp.			x	x	x	x	x
	Formicidae sp.	x		x	x	x	x	x
	Aphididae sp.	x	x			x	x	x
	Coleoptera sp.			x	x			x
	Staphylinidae sp.		x			x		x
	Thysanoptera sp.	x			x			x
	Hydrobiosidae sp.	x			x		x	
	Leptoceuridae sp.	x			x		x	x
	Tricoptera sp.	x	x		x		x	x
	Protoneuridae sp.	x			x		x	x
	Acarina sp.		x		x			x

	Araneae sp.			x	x		x	x
	Nematoda sp.			x	x			x
	Oligochaete sp.			x		x		x
	Viviparidae		x			x		x
	Sphaeriidae			x	x		x	x
Edge quadrat photos	*Schoenoplectus validus*		x	x	x	x	x	x
	Schoenoplectus pungens	x			x	x	x	x
	Trifolium sp.	x			x		x	
	Phragmites australis	x				x	x	x
	Pasture grass	x	x	x	x	x	x	x
	Sand[#]	x	x	x	x	x	x	x
	Rock[$]		x	x	x	x	x	x
	Debris[^]	x		x	x	x	x	x

Appendix 4:

Table A3: Summary of results from the variety of methods for describing habitatsor environmental conditions, showing the significance of each test conducted in PERMANOVA or ANOVA along with brief comments on the interpretation of results. * = *P*< 0.05 or NS = not significant from permutation tests. Loc = the Location factor, NA = not applicable to that design.

Component: variable	Sig. effect of							Interpretation
	Loc	Type	Trip	Loc X Trip	Loc X Type	Type X Trip	Loc X Type X Trip	
Sediments:								Evidence for vegetation enabling finer sediment deposits in some places
median size	NS	NS	NS	*	*	*	NS	
sorting	NS	NS	*	NS	*	NS	NS	
% fines	NS	NS	NS	*	*	*	NS	
% coarse	*	NS	NS	*	*	NS	NS	
% OM	*	*	NA	*	NA	NA	NA	
Water quality:	*	*	*	*	*	NS	*	May suggest a reason for WL being different in other methods, in terms of influence of River Murray water (WL being the location closest to the river – should be testable using data from EPA, SA water and/or DEWNR?
temperature	*	*	*	*	*	*	*	
salinity	*	*	*	*	NS	NS	NS	
pH	*	*	*	NS	*	NS	NS	
DO	NS	NS	*	NS	*	NS	*	
TSS	*	*	*	*	*	NS	*	
Vegetation:								A more thorough survey could be used to track recruitment & germination of vegetation in the area potential to correlate density & richness of vegetation with animal assemblages
# substrata	NS	*	NS	NS	NS	NS	NS	
total cover	*	*	*	NS	*	*	NS	
% covers	*	*	NS	NS	*	NS	NS	
patchiness	*	*	*	*	*	*	*	
Edge quadrat photos:								Showed differences between R and C, method could be improved by a greater detail of habitat assessment or including searches for invertebrates, reptiles, frogs, etc.
% covers	*	NS	NS	NS	*	NS	NS	
bank cover	*	NS	*	NA	NA	NA	NA	

Table A4: Summary of results from the variety of taxon-specific organism-collection methods showing the significance of each test conducted in multivariate PERMANOVA or univariate ANOVA along with brief comments on the interpretation of the results. * = *P*< 0.05 or NS = not significant from permutation tests. Loc = the Location factor, Indiv. = Total individuals (univariate), Taxa = Number of taxa (univariate), Assemb. = assemblage (multivariate), Benthos = non-planktonic animals summed (univariate),

Method:		**Sig. effect of**							**Interpretation**
Measure	**Organisms**	**Loc**	**Type**	**Trip**	**Loc X Trip**	**Loc X Type**	**Type X Trip**	**Loc X Type X Trip**	
Cores:	Benthic & infaunal inverte-brates								Could potentially be cut to save money because these sparse data showed many similar results to sweeps but for less information return
Indiv.									
Assemb.		*	*	NS	*	*	NS	NS	
		*	*	*	*	*	NS	*	
Sweep Nets:	Water-column, vegetation-associated,demersal & benthic inverte-brates								Sampled a diverse & abundant range of organisms. Showed a similar pattern to cores & confirms the difference of WL from the other 2 locations in assemblages& patterns observed. Plankton versus benthos patterns were interpretable from likely preferences for open water over vegetated substrata (or vice versa).
Benthos									
Assemb.		NS	*	NS	NS	*	*	NS	
		*	*	*	*	*	*	*	
Baited Fish Traps:	Mobile fish & inverte-brate nekton								Showed strong differences between R & C for 2 out of 3 sites. WL was again different. Clarity of results may be improved or more outcomes seen with increased sample size or longer soak periods or more sites sampled.
Indiv.									
Taxa		NS	NS	*	NS	*	NS	NS	
Assemb.		NS	NS	*	NS	*	NS	NS	
		*	NS	NS	NS	*	NS	NS	