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EFFECT OF TYPHA CONTROL ON MACROINVERTEBRATE ASSEMBLAGES

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

DRAFT

Prepared by:

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Effect of Typha Control on Macroinvertebrate Assemblages

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Summary

Effect of Typha Control on Macroinvertebrate Assemblages

The Department of Conservation and Land Management previously commissioned Ecoscape to undertake trials to design and implement experiments to test the effectiveness of various herbicide applications for controlling *Typha orientalis* at Forrestdale Lake in 2004-2005. Further studies were then proposed to determine what incidental effects the control of *Typha* might have on the aquatic ecosystem. This provided the impetus for the trial presented in this report, which examines the impact of *Typha* control and removal on macroinvertebrate species richness and community structure.

The study was undertaken using three lakes which were used as replicates for the following four treatments:

1. *Typha* present but no control undertaken;
2. *Typha* sprayed with herbicide
3. *Typha* sprayed with herbicide and slashed; and
4. No *Typha* but with some native species present.

Although no statistically significant difference was found, the results appeared to showed an apparent difference which suggested the treatment; *Typha sprayed with herbicide and slashed* is having an adverse effect on macroinvertebrate species richness and community structure.

The following recommendations were made based on the results of the study:

- A larger sample size is required to increase the statistical power of the analysis. Either by sampling;
    - Five lakes with two replicates of all four treatments; or
    - Three lakes with three replicates of each treatment.
- Water and sediment sampling and analysis for major nutrients (nitrogen and phosphorus) should be included as organic enrichment has a major impact on macroinvertebrate richness and community structure;
- Removal of slashed material is recommended to reduce the amount of decaying biomass, therefore improving water quality and macroinvertebrate habitat;
- If Typha is to be removed then rehabilitation of the foreshore should proceed to maintain food source and habitat for macroinvertebrates as well as other fauna e.g. birds; and
- Sampling should ideally be undertaken during peak macroinvertebrate production which is usually autumn and/or spring.

1.0 Introduction

Effect of Typha Control on Macroinvertebrate Assemblages

1.1 Background

1.1.1 Previous Trials

The Department of Conservation and Land Management previously commissioned Ecoscape to undertake trials to test the effectiveness of various herbicide applications for controlling *Typha orientalis* at Forrestdale Lake in 2004-2005.

The results of these trials were that:

- a 5% concentration of Roundup® Biactive™ was sufficient for controlling Typha;
- the addition of Pulse® did not increase the effectiveness of Roundup® Biactive™;
- a single application of the herbicide at the right time of year, which was found to be at the start of summer (prior to flowering), was adequate to kill *Typha orientalis*; and
- slashing was found to be unnecessary in terms of the effectiveness of the herbicide.

Further studies were proposed to determine what incidental effects the control of *Typha* might have on the ecosystem of Lake Forrestdale. This provided the impetus for the trial presented in this report, which examines the impact of *Typha* control and removal on macroinvertebrate species richness and community structure.

1.1.2 Macroinvertebrates as Bioindicators

Macroinvertebrates are an important component of wetland food webs, comprising much of the diet of many faunal species, including migratory waders and other water birds and tortoises. They can also act as indicators for the assessment of wetland health (Davis, Rosich et al., 1993).

Macroinvertebrates offer many advantages in evaluating aquatic systems. This is because they are;

1. Ubiquitous (present in most wetlands);
2. The number of taxa present offers a spectrum of response to environmental stresses;
3. Their sedentary nature enables effective spatial analyses of point source pollutants or other impacts; and
4. Long life cycles compared to other groups enables elucidation of temporal changes caused by environmental impacts (Rosenberg and Resh, 1993).

Also from an ecological perspective, they are ideal integrators between the micro organisms, which are responsible for most of the nutrient cycling and the larger aquatic biota such as fish. They also respond well to external stressors and sensitivity indexes and sampling methods have been well designed, which is extremely beneficial when studying man made impacts (Cummins, 1975).

1.2 Study Area

Three lakes were sampled for the purpose of this project. Each was chosen due to the presence of at least three of the four *Typha* treatments to be sampled, accessibility to the sites, water depth and *Typha* density. Whilst the impetus for the project was weed control at Forrestdale Lake, this lake did not meet the criteria for trial sites in terms of the number of different treatments being examined. A brief description of the lakes is provided below.

1.2.1 Yangebup Lake

Lake Yangebup lies 18 km south of Perth, and makes up part of the Beeliar wetland chain. Yangebup is a permanently inundated basin wetland, and covers an area of approximately 90.5 hectares. Previous investigations have shown Lake Yangebup to sustain high nutrient loads, and are classified as hypertrophic with respect to both nitrogen and phosphorous. The majority of this contamination appears to have originated from industry located in the near vicinity of the lake (Davis, Rosich *et al.*, 1993; Ecoscape Pty Ltd, 1995; Linge, 2002).

The extent of *Typha orientalis* occurs mostly on the western fringe of Yangebup Lake and mainly in pure stands, although it is occasionally intermingled with Eucalyptus rudis. The City of Cockburn is the managing authority and undertakes control of *Typha* surrounding the Lake.

1.2.2 Kogalup Lakes (North and South)

Kogalup Lakes (north and south) are also a part of the Beeliar wetland chain, forming a wetland linkage with Yangebup to the north as well as Thompson Lake to the south. They are both permanently inundated basin wetlands with Kogalup north being fed by a freshwater spring.

The reserve in which these lakes are situated covers an area of approximately 156 hectares with Kogalup north covering 44 hectares and Kogalup south 14 hectares (Davis, Rosich *et al.*, 1993).

Kogalup south is surrounded by *Typha orientalis* which is the only emergent sedge on site. Kogalup north contains extensive stands of *Typha* however; there are also naturally vegetated areas of *Melaleuca* woodland.

1.3 Assumptions of Experimental Design

The following assumptions were made in the experimental design:

1. Herbicide application would not have a direct impact upon macroinvertebrate populations as sampling was undertaken a minimum of 8 weeks after any herbicide application and herbicides have been used in accordance with the purposes for which they have been tested and registered; and
2. Variations in wetland characteristics (e.g. depth, temperature, and sediments) were not significantly different between sites within each lake.

1.4 Study Aims

The aim of this study was to determine whether there was a significant change in macroinvertebrate populations as a result of the impact of habitat changes occurring due to *Typha* control.

To determine whether there was any statistically significant difference in macroinvertebrate assemblages, equivalent areas were sampled amongst the following treatments;

1. Typha was not present;
2. Typha was present in high densities;
3. Typha was sprayed with herbicide; and
4. Typha was sprayed with herbicide and slashed.

It is the intention of this study to aid management authorities in implementing programs to help reduce *Typha orientalis* within wetlands with the knowledge of what impacts its removal has upon aquatic invertebrates and their use of *Typha* as habitat.

2.0 Method

Effect of Typha Control on Macroinvertebrate Assemblages

2.1 Rapid Assessment

The Rapid Assessment technique was used to sample macroinvertebrates from the four treatment sites, and at the three lakes previously identified. This sampling technique is commonly used as it provides a 'rapid turnaround of results' (Norris and Georges, 1993), costs less than more detailed biological assessments and can potentially be undertaken by non-specialists. The rapid assessment methodology involves the collection of a set number of invertebrates, from defined habitats, the use of simple field equipment and a relatively coarse level of taxonomy (identification is usually to family, but species where possible).

This technique satisfied the requirements for the scope of this project.

2.2 Sampling Sites

The study was undertaken using three lakes which were used as replicates for the following four treatments:

5. *Typha* present but no control undertaken in last 6 months;
6. *Typha* sprayed with herbicide at least 8 weeks to ensure *Typha* rhizomes are completely dead and are rotting;
7. *Typha* sprayed with herbicide as per treatment 2 but with leaf material slashed at least three weeks prior to sampling;
8. Good condition littoral zone with an abundance of native species present and no *Typha* present.

Lakes were selected under certain criteria; these included;

- the depth of water in the sampled area to be at most knee height to minimise macroinvertebrate drift into the adjacent sampling areas through mixing of the waterbody and optimise collection of macroinvertebrates from the substrate and sediment;
- the sampled area to be a minimum of 20 m wide to minimise macroinvertebrates being carried into the sampling area through general mixing of the waterbody;
- access to be relatively easy at each site and within the Perth Metropolitan Area; and
- areas of *Typha* must have a percentage cover less than 80% to allow sampling to be consistently undertaken in all areas, allowing enough space to stir up sediment and substrate with a scoop net along a 10 m transect.

Whilst it was intended that 12 sites were to be sampled (4 treatments in 3 lakes), only ten sites were sampled due to one of the treatment sites drying up before the time of sampling occurred and the inability of finding a third lake that abided by the criteria above as well as having all four treatments.

2.3 Timing and Frequency

Only one sampling period was carried out for this experiment and this was achieved over two days, the 27th and the 28th of February, 2006.

2.4 Sample Collection

Since the loss of habitat through *Typha* control was to be tested, the emergent macrophyte habitat was the focus of the sampling.

A 250µm net was vigorously forced through the *Typha* from the bases of the plants to the water surface. Each sample took about 3 minutes and spanned 10 meters of the study area, making sure the bed material was being disturbed.

Samples were then sorted 'on-site' by spreading them out onto large trays to maximise visibility of smaller invertebrates. Due to there being few invertebrates in any one sweep, further samples had to be taken and these were 'picked' until the 30 minute time period expired.

All invertebrates were preserved in 95% ethanol prior to identification in the laboratory. All specimens were identified to family and species level where possible.

Keys and descriptions of invertebrates recorded from Western Australian wetlands were taken from Davis and Christidis (1997), Gooderham and Tsyrlin (2002) and Williams (1980).

2.5 Environmental Variables

Environmental variables (physicochemical parameters) were recorded at the time of sampling to determine the conditions on the sampling day, as well as to eliminate the possibility of site conditions contributing to macroinvertebrate distributions. The suite of parameters measured included:

- Temperature;
- Dissolved oxygen;
- pH;
- conductivity/salinity; and
- TDS.

These were recorded at each sampling site prior to macroinvertebrate collection.

2.6 Analysis

A range of tests was applied due to the different parameters that were surveyed. The tests displayed in Table 2.1 were chosen because of their relevance to the parameter to be tested as well as the restrictions of the tests due to the data (e.g. sample size).

Table 2.1: Parameters analysed with corresponding statistical tests

Parameters tested	Statistical Tests	Basis of test	Reason for test	Weaknesses of tests
Environmental Variables (pH, Dissolved Oxygen, Temperature, Conductivity, TDS)	Kruskal Wallis Test	Differences in rank means of a population/ sample	▪ To Determine whether species data influenced by environmental variables ▪ Small sample size	▪ Has low statistical power

			▪ Data not normally distributed	
Species Richness	One-Way ANOVA	Differences in the means of a population/ sample	▪ To Determine if there is a population difference between sites	▪ Needs a large sample size ▪ Does not indicate which samples are more different than the other
Community structure	Shannon H Diversity and J Evenness	Provides information on community composition	▪ To Determine species diversity and evenness at each site	▪ No statistical inference
	Kruskal Wallis Test	Differences in rank means of a population/ sample	▪ To Determine if there is a difference in community structure between treatments ▪ Small sample size	▪ Has low statistical power

A more comprehensive description of these tests is in Appendix Four.

SPSS was the statistical program used to conduct all statistical tests with the significance level of α=0.05 and a 95% confidence level.

3.0 Results

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3.1 Environmental Variables

The physicochemical data for three lakes collected on the 27th and 28th of February 2006 are presented in the tables below. The data violated the stringent assumptions of a one-way ANOVA, so the non-parametric alternative Kruskal-Wallis test was conducted on the results to determine if a significant difference existed ($\alpha=0.05$) between the different physicochemical parameters and the sites where *Typha* was either; sprayed with herbicide, sprayed and then slashed, not treated at all or where *Typha* was not present.

3.1.1 Yangebup Lake

Within Yangebup Lake there appeared to be differences in the physiochemical properties of the water, between the sites where *Typha* was treated and the sites where it was not, as shown in Table 3.1.

Table 3.1 Physicochemical results from Lake Yangebup

Treatment	pH	TDS (ppm)	Conductivity (um)	Temperature	Dissolved Oxygen mg/L
No *Typha*	7.1	908	1669	25.1	8.30
Typha Untreated	7.1	791	1489	25.3	7.12
Typha Sprayed and Slashed	7.4	911	1629	29.1	12.21**
Typha Sprayed only	7.4	916	1705	29.8	12.50**

However, no significant difference (all p values=0.392>α=0.05) was found between the treatment sites for any of the above parameters.

(**The dissolved oxygen results seen for *Typha sprayed and slashed* and *Typha sprayed only* was incredibly high. This is due to sampling error and the water at the time being quite turbulent. Therefore, the results are not a true representation of the dissolved oxygen levels at these sites).

3.1.2 Lake Kogalup North

From the results for Lake Kogalup north higher readings were recorded for all parameters where the treatment *No Typha* was present (Table 3.2).

Table 3.2 Physicochemical results from Lake Kogalup North

Treatment	pH	TDS (ppm)	Conductivity (um)	Temperature	Dissolved Oxygen mg/L
No *Typha*	7.0	412	7100	32.4	7.91
Typha Untreated	6.4	336	5920	24.6	2.67
Typha Sprayed and Slashed	6.7	313	5250	23.5	1.14
Typha Sprayed only	n/a	n/a	n/a	n/a	n/a

However, no statistically significant difference was found between the sites and each physicochemical parameter (all p values>α=0.05).

3.1.3 Lake Kogalup South

The treatment sites within Lake Kogalup South appeared to show no overt differences in parameters, seen in Table 3.3. No statistically significant difference was found between the treatment sites and each environmental variable (all p values> α=0.05).

Table 3.3 Physicochemical results from Lake Kogalup South

Treatment	pH	TDS (ppm)	Conductivity (um)	Temperature	Dissolved Oxygen mg/L
No *Typha*	n/a	n/a	n/a	n/a	n/a
Typha Untreated	7.0	699	1307	29.9	4.25
Typha Sprayed and Slashed	6.9	685	1288	27.5	1.86
Typha Sprayed only	7.0	702	1309	31.0	2.73

3.2 Macroinvertebrate Data

There were 868 specimens collected among which; 28 species within 21 families were identified from all three lakes sampled.

3.2.1 Yangebup Lake

A total of 13 invertebrate taxa were recorded from Yangebup Lake. This included 9 insect taxa one annelid, one arachnid, one mollusc and one crustacea, richness varied between 13 families. The treatment site with the highest number of species present was *Typha sprayed only* and the treatment site with the lowest number of species was *Typha sprayed and slashed.*

3.2.2 Lake Kogalup North

There were 19 species within 15 families collected from Lake Kogalup North. Of which there were 16 insect taxa, one annelid, one crustacea and one mollusc. *Typha Untreated* supported the greatest number of species with *Typha sprayed and slashed* again supporting the least number.

3.2.3 Lake Kogalup South

A total of 15 species was recorded from Lake Kogalup South. Of these, there were 13 insect taxa, one crustacea and one mollusc. A total of 13 families were collected during the sampling. The treatment site *Typha sprayed only* contained the greatest number of species while *Typha sprayed and slashed* maintained its position as having the least number of species.

3.3 Macroinvertebrate Community Structure

The results of the Shannon-Weiner Diversity and Evenness Indices for all *Typha* treatments on each lake are presented in the Tables 3.4 and 3.5 below. Evaluation of the indices showed that the treatment site; *Typha sprayed and slashed* displayed the lowest scores consistently across all of the three lakes sampled.

Table 3.4 Shannon H Diversity for Yangebup Lake and Lake Kogalup North and South

Treatment	Yangebup Lake	Lake Kogalup North	Lake Kogalup South
Typha Sprayed only	1.67	n/a	1.76
Typha Sprayed and Slashed	1.33	1.07	1.09
No *Typha*	1.47	2.10	n/a
Typha Untreated	1.52	. 1.98	1.44

Table 3.5 Shannon J Evenness for Yangebup Lake and Lake Kogalup North and South

Treatment	Yangebup Lake	Lake Kogalup North	Lake Kogalup South
Typha Sprayed only	0.76	n/a	0.85
Typha Sprayed and Slashed	0.82	0.55	0.67
No *Typha*	0.83	0.85	n/a
Typha Untreated	0.73	0.73	0.69

The non-parametric Kruskal-Wallis test was performed on the results to determine if there was a statistically significant difference between each treatment site and the diversity and evenness of the species found. Results showed that there was no statistically significant difference (all p values>0.05) found between the treatment sites at any of the lakes sampled.

3.4 Species Richness

One-Way between-groups ANOVA's were used on the presence/absence species data to determine if there was a significant difference in macroinvertebrate assemblages between *Typha* treatments for each of the three lakes. There was no significant difference found between species richness and each treatment site for any of the lakes sampled (p>0.05).

3.4.1 Yangebup Lake

Descriptive statistics for each treatment within Yangebup Lake with mean, inter-quartile range, maximum and minimum, are plotted in Figure 3.1.

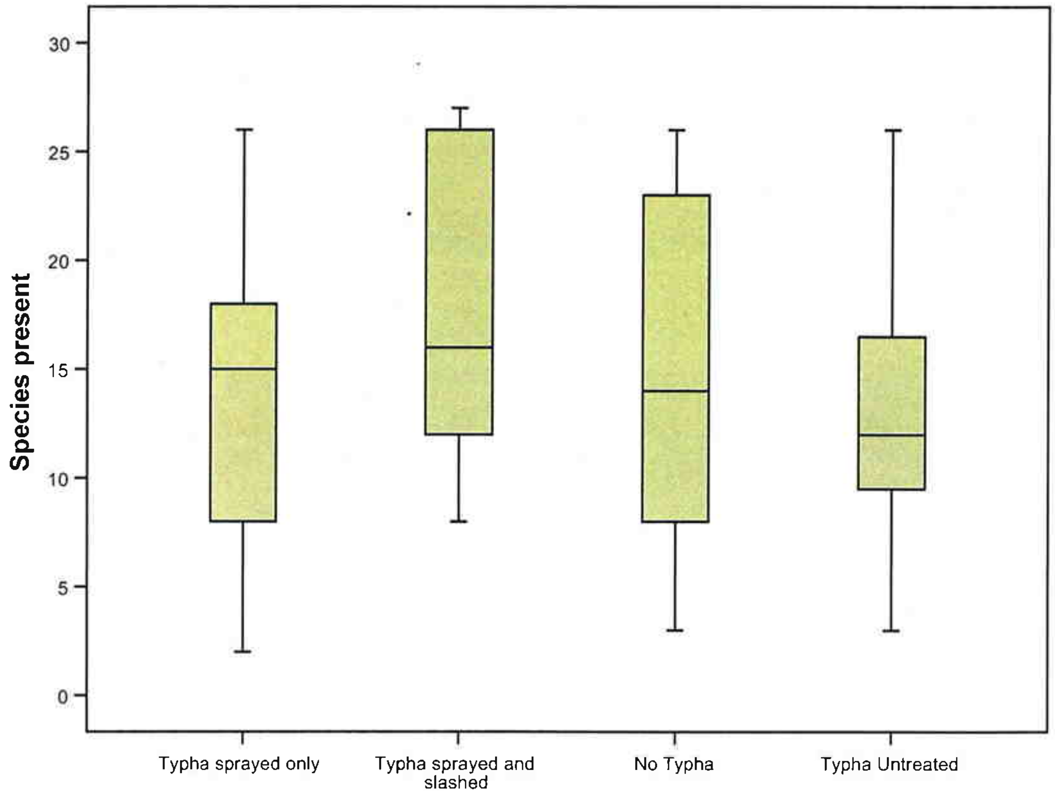

Figure 3.1: Mean, inter-quartile range, maxima and minima of species at Yangebup Lake

The results of the One-way ANOVA for Yangebup Lake are shown in Table 3.6. There was no significant difference (p=0.6538>α=0.05) in the species present between any of the treatment sites.

Table 3.6: ANOVA Results Yangebup Lake

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	89.884	3	29.961	0.55	0.6538
Within Groups	1255.079	23	54.569		
Total	1344.963	26			

3.4.2 Lake Kogalup North

Descriptive statistics for each treatment within Lake Kogalup North with mean, inter-quartile range, maximum and minimum, are plotted in Figure 3.2.

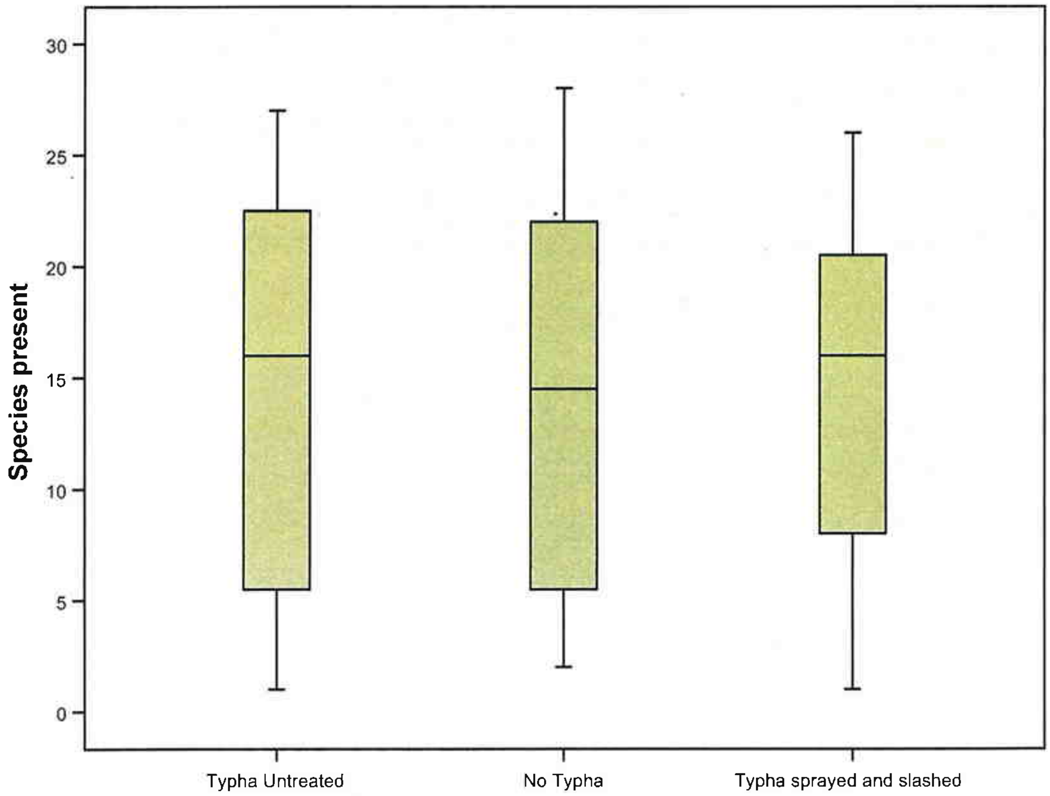

Figure 3.2: Mean inter-quartile range, maxima and minima of species at Lake Kogalup North

The results of the One-way ANOVA for Lake Kogalup North are shown in Table 3.7. No significant difference was found (p=0.7525>α=0.05) between the species present and the treatment sites.

Table 3.7: ANOVA Results Lake Kogalup North

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	42.025	2	21.013	0.29	0.7525
Within Groups	2269.857	31	73.221		
Total	2311.882	33			

3.4.3 Lake Kogalup South

Descriptive statistics for each treatment within Lake Kogalup South with mean, inter-quartile range, maximum and minimum, are plotted in Figure 3.3.

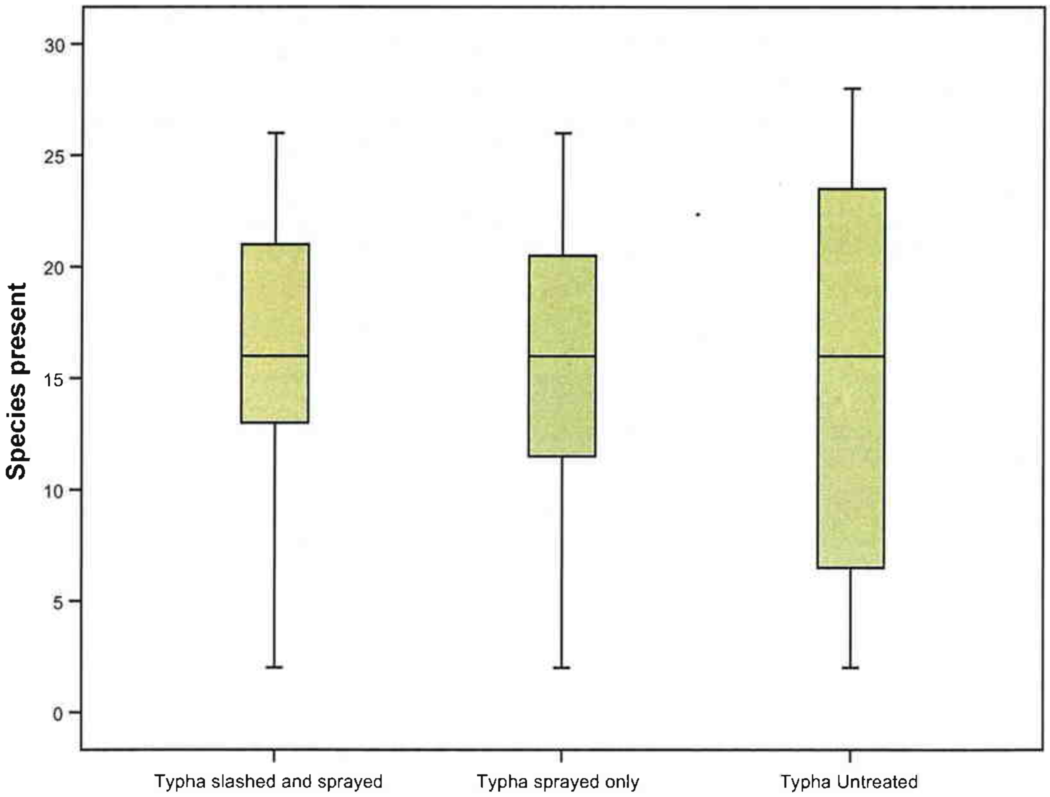

Figure 3.3: Mean inter-quartile range, maxima and minima of species at Lake Kogalup South

The results of the One-way ANOVA for Lake Kogalup South are shown in Table 3.8. There was no significant difference found (p=0.8983>α=0.05) in the species present between any of the treatment sites.

Table 3.8: ANOVA Results Lake Kogalup South

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.252	2	7.126	0.11	0.8983
Within Groups	1188.700	18	66.039		
Total	1202.952	20			

4.0 Discussion and Conclusions

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4.1 Equivalence of sites between lakes

Although not statistically significant ($p>0.05$), the lakes did show slight differences in physicochemical parameters between treatment sites. Yangebup Lake showed changes in pH, temperature and dissolved oxygen for the sites where *Typha* was treated and those where is was not. Lake Kogalup North showed consistently higher readings for the treatment site *No Typha*, while Lake Kogalup South showed a small increase in dissolved oxygen levels where *Typha* was untreated.

General physicochemical conditions may contribute to distribution patterns of macroinvertebrate species, for example; low levels of dissolved oxygen can often result in a reduction in faunal diversity, as only the most tolerant of species can survive (Davis and Christidis, 1999). However, past attempts made to correlate macroinvertebrate distribution and abundance with various specific physicochemical parameters has been found to be inherently weak. The possibility exists then, that the relationship is only indirect and a given macroinvertebrate distribution and abundance is in fact controlled by other factors such as; food quantity and/or water quality (Cummins, 1975).

Conclusion:
There was no statistically significant difference between the physicochemical parameters of the treatment sites; therefore, it is assumed that any change to the macroinvertebrate populations is not directly associated with these parameters.

4.2 Macroinvertebrate Interaction with Typha

Typha orientalis is an aggressive coloniser of wetland areas; however, it still forms an important relationship as a fringing species since it provides a food source and habitat for macroinvertebrates and other fauna (e.g. reptiles, waterbirds and fish).

4.2.1 Species Richness and Community Structure

It was observed that for all three lakes the treatment site, *Typha sprayed and slashed* consistently had the least amount of species present but a higher abundance compared to the other treatments. This was confirmed by the results of the Shannon-Weiner Diversity and Evenness indices. This type of community structure will commonly occur as a result of some form of organic enrichment (Gee and Warwick, 1985), which in this case could be caused by the large biomass of decaying *Typha* found at the sites. In these conditions, only the most tolerant species (e.g. midge larvae (Chironomids), backswimmers (Notonectidae) and water boatman (Corixidae)) are usually able to survive the low oxygen levels that accompany organic enrichment and take advantage of the altered conditions (Water & Rivers Commission, 1996; Davis and Christidis, 1999).

Macroinvertebrates can be classed as either sensitive or tolerant depending on their response to specific changes in the water conditions (Water & Rivers Commission, 1996). Unlike the treatment, *Typha sprayed and slashed*, the treatment *No Typha* displayed a lower abundance but a higher diversity of more sensitive species (e.g. Isopoda (crustaceans), Ephemeroptera (mayflies) and Odonata (dragonflies and damselflies)) suggesting there was less organic enrichment at this treatment site.

Even though apparent differences were observed for the number of species present and their abundances between *Typha* treatments, no statistically significant difference was found ($p>0.05$), suggesting that the treatment of *Typha orientalis* and subsequent habitat loss does not have an adverse impact on macroinvertebrate populations. However, due to the small sample size ($n<20$), and the loss of a treatment site on two of the three lakes there is a possibility that the non-significant result obtained was due to insufficient statistical power (Pallant, 2002).

Conclusion:
An apparent difference was observed, which suggested the treatment; *Typha sprayed with herbicide and slashed* had an adverse effect on macroinvertebrate species richness and community structure.

However, no statistically significant difference was detected in terms of species richness or community structure between the different Typha treatments of: *Typha not present; Typha present in high densities; Typha sprayed with herbicide; and Typha sprayed with herbicide and slashed.*

4.2.2 Habitat Alteration

Typha orientalis is a fringing species that provides food and a range of habitats for aquatic and terrestrial faunas. The loss of *Typha* as macroinvertebrate habitat can contribute to low species richness and diversity as the loss of cover increases the accessibility of macroinvertebrates to predators (Balla and Davies, 1993). This could have contributed to the low abundance of species collected from Lake Kogalup South where the presence of the introduced fish *Gambusia holbrooki* (mosquito fish) was noted, as well as the overall low abundance of macroinvertebrates sampled from the treatment sites *No Typha,* as the vegetation at these sites was sparse.

Macroinvertebrates are an important part of wetland processes, they feed on dead and decaying plant materials, and play a significant role in the decomposition of litter (Davis and Christidis, 1999), they are also a major food source for other wetland fauna (e.g. reptiles, waterbirds and fish). Litter quality and quantity can effect macroinvertebrate populations, with fragmentation of vegetation (e.g. *Typha* control) increasing the surface area for macroinvertebrate colonization and temporarily enhancing production. A balance is required between litter removal and accumulation to maximise macroinvertebrate production (Magee, 1993), as small litter accumulations (e.g. complete vegetation removal) may not provide adequate substrate or food source for invertebrates, while large accumulations (e.g. *Typha* sprayed and slashed) may alter the surface hydrology through peat formation and nutrient binding. Habitats with diverse litter layers in various stages of decay would therefore be optimal for the management of macroinvertebrates (Magee, 1993), which is provided by the treatment of; *spraying Typha only.*

Conclusion:
***Typha orientalis* is an aggressive coloniser of wetland areas and whilst its control is necessary, the loss of the habitat it provides is of concern.**

From this survey it appeared that the treatments; *Typha sprayed with herbicide and slashed* and *No Typha* provided the least amount of diverse habitat for adequate macroinvertebrate colonization.

4.3 Further Studies

Due to the relatively small sample size and the loss of treatment sites, the results were ultimately inconclusive, and since apparent differences were observed further exploration into the reasons why would be beneficial.

The power of a statistical test is dependant on the size of the sample used. When the sample size is large then power is not an issue (Pallant, 2002). Therefore, increasing the sample size of the experiment would increase statistical power giving a more interpretable result. This can be achieved by replicating samples taken for each treatment on the lakes and/or increasing the number of lakes sampled.

Finding lakes with all four treatments was an issue during this study. To minimise this issue in further studies, treatments could be set up at the lakes chosen. Lakes should be of suitable size as to complete replicates of each treatment on the lakes and have areas of *Typha* and No *Typha*.

The nutrient input from rotting *Typha* is an important factor in terms of macroinvertebrate community structure. Organic enrichment of water and sediments can deteriorate water quality, which will impact on macroinvertebrate ability to colonize and survive in a specific area. By including the analysis water and sediment samples from each *Typha* treatment the amount of nitrogen and phosphorus released from *Typha* at different stages of decay can be determined helping to correlate any relationship between *Typha* control and its effect on macroinvertebrate species richness and community structure.

The sampling period chosen was not ideal for obtaining maximum macroinvertebrate data as the lakes were beginning to dry out. Mid autumn and/or spring are the more appropriate Seasons for macroinvertebrate sampling.

5.0 Recommendations

Effect of Typha Control on Macroinvertebrate Assemblages

The following recommendations are based upon the results of the study.

1. A larger sample size is required to increase the statistical power of the analysis. Sample size should be greater than 20 and can be achieved either by sampling;
   - Five lakes with two replicates of all four treatments; or
   - Three lakes with three replicates of each treatment.

2. Water and sediment sampling and analysis for major nutrients (nitrogen and phosphorus) should be included as organic enrichment has a major impact on macroinvertebrate richness and community structure.

3. Removal of slashed material is recommended to reduce the amount of decaying biomass, therefore improving water quality and macroinvertebrate habitat.

4. If Typha is to be removed then rehabilitation of the foreshore should proceed to maintain food source and habitat for macroinvertebrates as well as other fauna e.g. birds. Rehabilitation will also reduce excess nutrients from runoff entering the waterbody.

5. Sampling should ideally be undertaken during peak macroinvertebrate production which is usually autumn and/or spring.

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Effect of Typha Control on Macroinvertebrate Assemblages

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Appendix One: Glossary

Species Richness

Species richness is the simplest measure of biodiversity and is a count of the number of different species in a given area. It is one of the most intuitive and frequently used measures of biological diversity and is used to compare such things as: the conservation value of different areas; to reflect the effects of variables such as area, latitude and altitude on community and population dynamics; and as an index of environmental change following isolation of a vegetation remnant or exposure of a community to a disturbance (Burgman and Lindenmayer, 1998).

Community Structure

Community structure is the organization of a biological community based on numbers of individuals within different taxonomic groups and the proportion each taxonomic group represents of the total community (Burgman and Lindenmayer, 1998).

Parametric Tests

Statistical tests that involve assumptions about, or estimation of, population parameters. Parametric tests are more powerful. Distinguishing feature of parametric tests is that the populations from which samples are drawn should be normally distributed.

Non Parametric Tests

Statistical tests that do not rely on strict parameter estimations or assumptions for example; they do not need to be normally distributed. Are also less powerful than parametric counterpart.

Peat

Partially carbonized vegetable matter saturated with water.

Appendix Two: Species list

Effect of Typha Control on Macroinvertebrate Assemblages

		Lake Kogalup South			Lake Kogalup North			Lake Yangebup			
Family	**Genus/species**	**Slashed and Sprayed**	**Sprayed**	**Typha untreated**	**Sprayed and slashed**	**No Typha**	**Typha untreated**	**Slashed and sprayed**	**Sprayed**	**No Typha**	**Typha untreated**
Aeshnidae	*Hemianax papuensis*		1				1				
Amphisopidae	*Paramphisopus palustris*		8			6	32				1
Caenidae	*Tasmanocoenis*								1	1	
Ceinidae	*Austrochiltonia subtenuis*			1						5	4
Ceratopogonidae	*Ceratopogonidae*					2		5			
Chironominae	*Chironomus sp*	4	4	8	1	3	9	56	22	12	34
Coenagrionidae	*Ischnura aurora*	1				3					
Coenagrionidae	*Xanthagrion erythroneurum*						1				
Corduliidae	*Hemicordulia tau*			1							
Corixidae	*Agroptocorixa sp*				2		16				
Corixidae	*Micronecta sp*	16			37	14	9	11	22	31	45
Corixidae	*Sigara sp*	2		8	3		4				
Dytiscidae	*Lancetes lanceolatus*		1	2	1		1				
Dytiscidae	*Megaporus solidus*		1						3		
Dytiscidae	*Rhantus suturalis*		2								
Ecnomidae	*Ecnomus sp*							40	18	16	42
Hirudinea	*Hirudinea sp*					1					1
Hydrachnidae	*Hydrachna sp*							17	16	7	36
Hydrophilidae	*Berosus sp*					1	2				
Hydrophilidae	*Berosus sp larvae*					3	1				
Leptoceridae	*Triplectides australis*						1				
Lestidae	*Austrolestes sp*					1	2				
Libellulidae	*Diplacodes bipunctata*								1		
Notonectidae	*Anisops sp*	29	9	30	66	8	39		1		

		Lake Kogalup South			Lake Kogalup North			Lake Yangebup			
Family	**Genus/species**	**Slashed and Sprayed**	**Sprayed**	**Typha untreated**	**Sprayed and slashed**	**No Typha**	**Typha untreated**	**Slashed and sprayed**	**Sprayed**	**No Typha**	**Typha untreated**
Physidae	*Physa acuta*			1		16	3		1		
Scirtidae	*Scirtidae sp*				5						
Stratiomyidae	Stratiomyidae		3								
Tanypodinae	*Procladius villosimanus*			5			5				
Total Species		5	8	8	7	11	15	5	9	6	7
Total count		**52**	**29**	**56**	**115**	**58**	**126**	**129**	**85**	**72**	**163**

Appendix Three: Site Photos

Effect of Typha Control on Macroinvertebrate Assemblages

Yangebup Lake: *Typha* Sprayed only

Yangebup Lake: *Typha* Sprayed and Slashed

Yangebup Lake: No *Typha*

Lake Kogalup North: No *Typha*

Lake Kogalup North: *Typha* Untreated

Lake Kogalup North: *Typha* Sprayed and Slashed

Lake Kogalup South: *Typha* Untreated

Lake Kogalup South: *Typha* Sprayed only

Lake Kogalup South: *Typha* Sprayed and Slashed

Appendix Four: Statistical Tests Used

Effect of Typha Control on Macroinvertebrate Assemblages

Kruskal-Wallis Test

The Kruskal-Wallis Test is the non-parametric alternative to a one-way analysis of variance (ANOVA) and allows for the comparison of scores on a continuous variable for three or more groups. It was chosen as there are less stringent assumptions placed on the data compared to that of the parametric tests. However, non-parametric alternatives are usually less powerful than their parametric counterparts.

Non-parametric tests are useful when there is only a very small sample size which is why this test was used to compare the physicochemical data between the treatments on each of the lakes, as well as the Shannon Diversity index.

One-Way Analysis Of Variance (ANOVA)

Analysis of variance is used to test the hypothesis that several means are equal. One-way between group ANOVA's specifically are used when you have one independent variable (Typha Treatment) with three or more levels or groups (*Typha* sprayed, *Typha* sprayed and slashed, No *Typha* and *Typha* untreated) and one dependant continuous variable (species presence/absence).

There are a number of Assumptions underlying its use, these include;

- The populations from which the samples were obtained must be normally or approximately normally distributed;
- The samples must be independent; and
- The variances of the populations must be equal.

Shannon-Wiener Diversity and Eveness Index

A diversity index is a mathematical measure of species diversity in a community. Diversity indices provide more information about community composition than simply species richness; they also take the relative abundances of different species into account.

Diversity indices provide information about rarity and commonness of species in a community, and having the ability to quantify diversity in this way is important when trying to understand community structure (Burgman and Lindenmayer, 1998).