An Investigation of Aquatic Macroinvertebrate Occurrence & Water Quality at Lake Chandala, Western Australia

Prepared for the Western Australian

Department of Environment and Conservation

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Executive Summary

Lake Chandala is a permanent freshwater wetland found between Muchea and Gingin on the Swan Coastal Plain. Listed on the Directory of Nationally Important Wetlands Chandala also meets one of the Ramsar criteria for Wetlands of International Significance. The wetland is an important breeding area for wetland birds and supports one of WAs largest breeding straw necked ibis colonies. From a regional perspective Lake Chandala is one of a limited number of coloured wetlands remaining on the Swan Coastal Plain. These wetlands are considered to be of significant value to conservation due to the distinct composition of algal and invertebrate communities, attributed to the fringing vegetation and the qualities associated with the colour of the water.

There are limited data available on the present state of Chandala Lake, as such the overall aim of this research was to collect and collate physico-chemical and aquatic macroinvertebrate data allowing some interpretation of the wetland's condition and its conservation value. It is hoped this research will assist the Department of Environment and Conservation by filling a gap in knowledge and bringing management up to date with the current state of Lake Chandala. More specifically the aims of the study are to:

1. *Collect data that allows us to assess invertebrate richness and endemism at Lake Chandala, facilitating a comparison with other wetlands on the Swan Coastal Plain and an interpretation of conservation status.*
2. *Collect and use water quality and macroinvertebrate data to gain an understanding of the Lake Chandala's condition and to assess the influence of water quality and habitat on the distribution of macroinvertebrates within the wetland.*
3. *Determine whether there has been any significant change in the composition of macro-invertebrate assemblages since the last surveys were undertaken in 1989-1990.*

Surveys were undertaken in spring 2009 at seven sites. Sites showing variation in habitat and water permanence were intentionally selected to get a good representation of macroinvertebrate occurrence and water quality throughout the wetland system. Aquatic macroinvertebrate surveys were carried out at each of the seven sites, along with the collection of standard physico chemical data. Water samples were collected from 4 of these sites for more detailed analysis of water quality.

An invertebrate species list was compiled for the wetland as a whole, allowing for an assessment of richness and endemism. These values were then compared to richness and endemism values for other SCP wetlands, to gauge where Lake Chandala stands when compared to other wetlands in the region. This list was also used to evaluate whether there had been a significant change in species composition since prior surveys. Species lists compiled for each survey site also allowed a comparison of macroinvertebrate occurrence throughout the wetland.

Physico-chemical data was collected to gain a general understanding of water quality and wetland condition, while also allowing some interpretation to be made of factors affecting of the distribution of aquatic macro-invertebrate species at different sites.

Results of this research show Lake Chandala to support relatively rich invertebrate communities and a high level of regional endemism in comparison to other wetlands on the Swan Coastal Plain. Invertebrate surveys potentially collected 77 different taxa from 72 genera and 47 families. When

merged with past surveys this resulted in richness values for Lake Chandala of 110-133 species from 99-109 genera and 55 families. The results of the combined datasets produced 63 named species, of which 21% were determined to be regionally endemic. Of the SCP wetlands that have been assessed for richness less than 20% recorded over 90 species and 40% recorded over 40 families. Thus it appears that Lake Chandala is of relatively high species richness and at least in the upper portion for family richness when compared to other SCP wetlands. Regional endemism also seems to be relatively high at Chandala with just over 16% of SCP wetlands having greater than 20% regionally endemic species.

The Sorensen similarity index, used to demonstrate the proportion of species in common at two sites, found that species composition varied greatly across the sites. The low similarity scores are quite unusual and could be attributed to experimental design and survey effort or to the high level of heterogeneity exhibited throughout the wetland. Sites showed variation in habitat type, water quality and water permanence. The wetland is also unusual in that it overlies three different sediment types - Cretaceous Sand, Guildford Clay and Bassendean Sand, which contribute further to the heterogeneity. There is also the possibility that Lake Chandala is being fed water from a mound spring towards the northern end of the wetland, contributing to the very different water qualities. While the occurrence of a spring at this site has not been documented, the difference in water quality and the local stratigraphy make it quite probable. Springs on the SCP occur where Bassendean Sand meets Guildford Clay (which does appear to be the case at Lake Chandala) and the changing hydraulic pressure leads to a continuous discharge of ground water at the surface. The situation of the Lake, quite close to the Dandaragan Plateau could also be a factor influencing the level of aquatic macroinvertebrate diversity at Lake Chandala.

The degree of change in invertebrate composition over time was quite difficult to establish, due to the differences in the level of identification and experimental design. Available data suggests there has been no real obvious change in the wetlands condition over time however ongoing monitoring programmes have been limited to a certain part of the wetland and to certain parameters. The main areas of concern for management of this wetland appear to be the high nutrient levels and the low dissolved oxygen levels at some sites.

The level of invertebrate richness and endemism, the unusual trends in distribution and the occurrence shield shrimp *Lepidurus apus viridis* a species not previously recorded on the SCP, suggest Lake Chandala is quite unique and of high conservation significance. The discovery of two species of freshwater fish at Lake Chandala, in particular the restricted *Galaxiella nigrostriata* also adds to the value of the wetland, as would the confirmation of a mound spring.

Introduction

Good management of wetland systems requires up to date knowledge of their biological composition and water quality. Assessment and monitoring of the ecological condition of wetlands is an important tool used to 'guide protective and restorative measures.' (Chessman et al. 2002 p.919) Biological surveys can be used to outline areas of high biodiversity, endemism and uniqueness. Ecosystem managers regularly turn to measures of richness, endemism and biodiversity to guide conservation efforts (Horwitz et al. 2009).This type of information helps to determine where investment of time and money can achieve the greatest conservation outcome. Invertebrates are often selected for biological surveys because, as well as providing information about biodiversity, richness and endemism, the composition and structure of invertebrate communities also tells us about the environment in which they are found. Combined with water quality monitoring, invertebrate surveys can build a picture of the state or condition of a wetland and highlight areas of concern that need to be addressed by management. This is especially important in wetlands with high conservation value and where, as is the case on the Swan Coastal Plain, many wetlands have been drained, filled or degraded (Chessman et al. 2002).

Invertebrates have an important role to play in wetland ecosystems (nutrient cycling, grazing on algae & food source for other invertebrates and vertebrates) and are regularly used in biological surveys. As different species have different preferences and tolerances for environmental conditions the presence of certain species can indicate water quality and habitat condition. Changes in invertebrate species over time may suggest that changes in water quality and habitat availability have been favouring some species over others. An example of this is the identification of acid sensitive and acid tolerant invertebrate taxa (Sommer and Horwitz et al. 2009). Similarly invertebrate taxa have been found to have different tolerances for salinity, often being more vulnerable to increased salinities at earlier stages of their life cycle than as adults (Halse et al. 2003). The SWAMPS biotic index takes this idea further assigning values to invertebrate groups (families or species) present to obtain a score which indicates the wetland's level of disturbance (Davis et al no date; Chessman et al 2002).

Similarly physical and chemical components of a wetland can also be used to interpret the health or condition of the system. These components influence which organisms will inhabit the wetland, the structure of food webs and biological interactions and (along with the biota) control the chemical processes that occur (ANZECC 2000). Changes to the naturally occurring physical and chemical parameters can place stress on the system reducing water quality and resulting in changes to species composition, abundance and diversity (ANZECC 2000). The ANZECC (2000) guidelines give levels at which physical and chemical stressors are considered high or low enough to degrade aquatic ecosystems. These guidelines, combined with background or baseline data for the site give management a way of measuring change in water quality and offer an understanding of when unacceptable levels of change are likely to occur.

Some examples of parameters used in wetland monitoring programmes include dissolved oxygen, temperature, total nitrogen and phosphorus, pH and chlorophyll 'a'. Dissolved oxygen levels are often measured as low levels adversely affect aquatic organisms and can lead to the release of nutrients and toxicants from sediments into the water column (ANZECC 2000). Low oxygen levels can also indicate that an increase in organic material is driving high levels of microbial decomposition. Nutrients such as nitrogen and phosphorus are regularly included in monitoring programmes as they increase productivity and can lead to algal blooms, while the amount of phytoplankton in the water can be measured using chlorophyll a concentrations. Similarly different ionic compositions can indicate if a wetland is prone to acidification or salinisation. It is suggested that for ecosystems of high conservation value the objective for water quality should be that there is no measurable change in physical or chemical stressors beyond natural variation, or that changes do not negatively impact on biological diversity (ANZECC 2000).

Lake Chandala is a permanent freshwater wetland found between Muchea and Gingin on the Swan Coastal Plain (DEWHA 1992). Listed on the Directory of Nationally Important Wetlands (Table 1) Chandala also meets one of the Ramsar criteria for Wetlands of International Significance (DEWHA 1992). The wetland is an important breeding area for wetland birds and supports one of WAs largest breeding straw necked ibis colonies (DEWHA 1992). From a regional perspective Lake Chandala is one of a limited number of coloured wetlands remaining on the SCP. Davis et al (1993) noted that these wetlands exhibit a distinct composition of algae and invertebrate communities, attributed to the fringing vegetation and the qualities associated with the colour of the water. With many of SCP wetlands suffering the removal of fringing vegetation, the remaining coloured wetlands are of particular value to conservation (Davis et al. 1993). As well as having the fringing vegetation removed many SCP wetlands have been affected by altered hydrological regimes, nutrient enrichment, salinisation and the introduction of pollutants while other have been filled (Chessman et al 2002; Horwitz et al. 2009). Since European settlement these actions have resulted in approximately 70% of the wetland habitat that once occurred on Swan Coastal Plain being lost (Chessman et al. 2002).

There is limited data available on the present state of Chandala Lake, as such the overall aim of this research is to collect and collate physico-chemical and aquatic macroinvertebrate data allowing some interpretation of the wetland's condition and its conservation value in regards to macroinvertebrates. It is hoped this research will assist the Department of Environment and Conservation by filling a gap in knowledge and bringing management up to date with the current state of Lake Chandala.

Thus, the specific aims of the study are to:

1. *Collect data that allows us to assess invertebrate richness and endemism at Lake Chandala, facilitating a comparison with other wetlands on the Swan Coastal Plain and an interpretation of conservation status.*
2. *Collect and use water quality and macroinvertebrate data to gain an understanding of the Lake Chandala's condition and to assess the influence of water quality and habitat on the distribution of macroinvertebrates within the wetland*.
3. *Determine whether there has been any significant change in the composition of macro-invertebrate assemblages since the last surveys were undertaken in 1989-1990.*

Site Description

The open water area of the lake covers approximately 5ha, however during wetter months the wetland's limits expand, flooding the surrounding vegetation (Davis et al 1993). The main lake in the centre rarely dries (DEWHA 1992) and it has been suggested by a local resident that over summer water levels in the lake are maintained by a fresh water spring. Found about 1km west of the Dandaragan Plateau (DEWHA 1992) Lake Chandala overlies cretaceous Sand, typical to the east, Guildford Clays, found along the Ellenbrook Channel and Bassendean Sand, which is common to the west of the catchment but also occurs in pockets along the central channel (Smith and Shams, 2002). Physical, hydrological and ecological features are listed in more depth in Appendix 1.

Lake Chandala (Figure 1) is within a Nature Reserve with vegetated land to the north east proposed for inclusion in the reserve (DEWHA 1992). Approximately 60% of the fringing vegetation has been cleared (Davis et al. 1993) and there is little to no vegetation buffer above the high water mark (DEWHA 1992). The surrounding land use is primarily cattle grazing (Smith & Shams 2002) with the area having a relatively low human population (DEWHA 1992). Past and present threats to the wetland include salinisation of inflow, eutrophication and grazing of vegetation by cattle and goats, with water diversion listed as a potential threat (DEWHA 1992). Deer have also been observed within the reserve (Bob Huston DEC, pers. comm.). The introduced fish *Gambusia holbrooki* has been recorded from Lake Chandala (Davis et al. 1993).

Table 1: A General Description of Lake Chandala, showing location, tenure, significance, surrounding land use and threats and the criteria for which Chandala is listed in the Directory of Import ant Wetlands in Australia

Location	31° 30' S, 115° 59' E
Level of Importance	National - Directory of Important Wetlands in Australia
Reference	WA075
Shire	Chittering
Biogeographic Region	Swan
Area	100ha
Elevation	65 m
Other Wetlands listed in Aggregation	None
Wetland Type	B14
Significance	A good example of a wooded swamp typical of the Swan Coastal Plain
Land Tenure	Nature Reserve 37060
Surrounding Land Use	Low human population, cattle grazing, cleared
Threats	Salinisation of inflow, eutrophication, grazing by cattle and wild goats
Criteria for Inclusion in Directory (1, 2, 3, 4, 6)	
1) It is a good example of a wetland type occurring within a biogeographic region in Australia	
2) It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.	
3) It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles or provides a refuge when adverse conditions such as drought prevail.	
4) The wetland supports 1% or more of national populations of any native plant or animal taxa.	
6) The wetland is of outstanding historical or cultural significance.	

Data retrieved from Australian Wetlands Database (DEWHA), Criteria for inclusion in Directory from Chapter 12 of A Directory of Important Wetlands in Australia.

There is a limited amount of information available on aquatic macroinvertebrate occurrence and water quality at Lake Chandala. However the research which has been undertaken gives some understanding of background levels, and offers an opportunity for temporal and spatial comparisons. Salinity and pH levels at Chandala have been documented, between 1977 and 2008, as part of the South West Wetlands Monitoring Program (Lane et al. 2009). Physico-chemical and macoinvertebrate data were also collected for Chandala between 1989 and 1990, documented in Davis et al (1993) and Davis and Christidis (1997). Invertebrate surveys were carried out between 1989 and 1990 once during summer and twice during spring, focusing on littoral vegetation (Davis et al. 1993). In an assessment of the richness and local and regional endemism of aquatic invertebrates in the SCP region Horwitz et al (2009) compiled wetland invertebrate data from 66 wetlands and across 18 studies (including that of Davis et al. 1993), taking account of different techniques and periods of time to consider the varying levels of effort associated with invertebrate collections. They showed a total richness for Lake Chandala of 72 species; of these 38 were identified to the species level with 34 considered widespread and 4 considered regionally endemic (Horwitz et al. 2009).

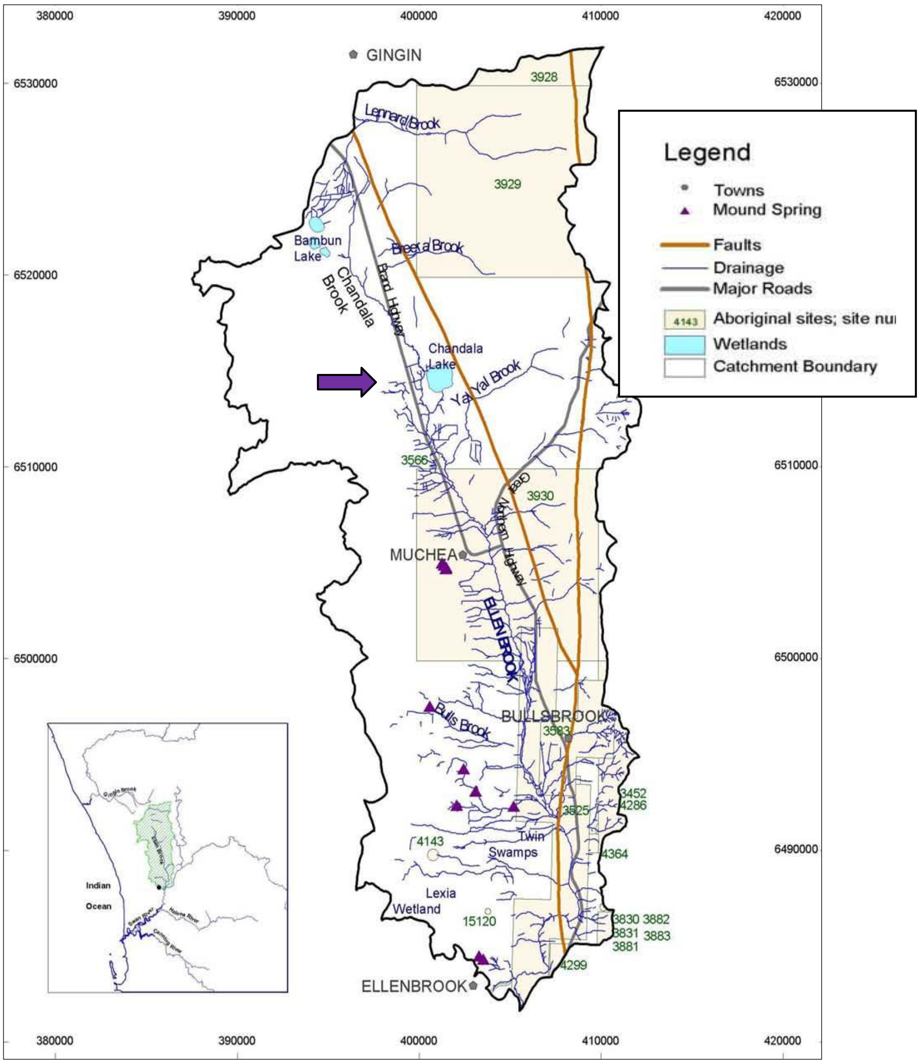

Figure 1: Lake Chandala's location in the Ellen Brook Catchment and associated drainage and environmental features. Source: Waters and Rivers Commission. *Hydrological Information for Management Planning in the Ellen Brook Catchment.*

Research plan, Method & Techniques

Research Plan

Invertebrate surveys were undertaken in spring 2009. At the time of surveying water levels were at or near peak levels with the wetland expanding into surrounding land inundating vegetation. This offered a variety of habitats for macro-invertebrate sampling. Seven sites potentially representing different macro-invertebrate habitat were chosen to carry out surveys (Table 2). This approach was seen as the best way to get a good representation of macro-invertebrates present throughout the wetland system.

The distribution of species collected during surveys was investigated to determine richness and endemism. These values were then compared to richness and endemism values for SCP wetlands, documented by Horwitz et al (2009).

General water physico-chemical data was collected at each of the sites where macro-invertebrate surveys were undertaken. Water samples were also collected at LC1, LC4, LC6 and LC7 for further analysis of nutrient levels, chlorophyll a levels, alkalinity, ion composition and metal content. The purpose of this was to gain a general understanding of water quality and wetland condition, while also allowing some interpretation to be made of factors affecting of the distribution of aquatic macro-invertebrate species at different sites.

Macro-invertebrates collected in surveys were scored using the SWAMPS biotic index, as described by Chessman et al (2002), to gauge the level of disturbance at each site and for the wetland as a whole. Scores not only demonstrate the level of disturbance but also how any potential disturbance is favouring some species over others. To assess the influence of the different conditions and habitat types the Sorensen similarity index was chosen to demonstrate the similarity, or difference, in species composition across the sites. Species lists were also been examined for 'indicator' species.

To interpret changes in species composition over time a comparison of species collected in our surveys and those collected in macro-invertebrate surveys at Lake Chandala between January 1989 and November 1990 was undertaken.

Table 2: Location and Description of Survey Sites, showing water depth, colour & clarity and outlining habitat features.

Site Number & GPS Location	Water Depth	Water Colour & Clarity	Habitat Type, % Surface Area and Density of Cover (1-5) 1=Sparse, 5=Dense	Habitat Description/ notes
LC1 31° 30" 03' S 115° 57. 25 E	38cm	Slightly coloured. Slightly turbid. Cannot see bottom.	20% Subm. Macrophytes 3 <1% Floating Macrophytes 5 5-10% Algal Cover 3 Detritus	Ephemeral, open water. Western side of wetland, closest to grazing land. Submerged & floating aquatic plants, filamentous green algae in water column and floating on the surface. Bird & frog calls.
LC2 31° 30" 07' S 115° 57" 30' E	31cm	Red-brown colour. Slightly turbid. Cannot see bottom.	<1% Subm. Macrophytes 3 Detritus 80% Canopy Cover 4	Flooded ephemeral Melaleuca Woodlands (patches of Melaleucas 4-5m in height amongst open water), some submerged macrophytes. Detrital layer of twigs, branches & leaves.
LC3 31° 29" 96' S 115° 57" 37' E	81cm	Dark red colour. Slightly Turbid. Cannot see bottom.	<1% Floating macrophyte 3 Detritus 80% Canopy Cover 4	Flooded Melaleuca and *Eucalyptus rudis* Woodland bordering permanent lake. Trees (~ 10m in height) on mounds of litter and soil. Large branches in the water.
LC4 31° 29" 94' S 115° 57" 41' E	88cm	Red-brown colour. Turbid. Cannot see bottom.	100% Floc	Open water, possibly permanent lake. Floc stiring in water column as we move through. Start to sink in when stand still for some time. Wind blowing on water surface.
LC5 31° 29" 69' S 115° 57" 50' E	34cm	Red-brown/ murky brown. Turbid	80% Emergent Sedges 5 20% Detritus 60% Canopy Cover	Melaleucas, Eucalypts and sedges (lepidosperma) growing along waters edge/ some partly submerged. Northern section of wetland, seperated from waters further north by raised ground with Claypans (possible salt scalding).
LC6 31° 29" 68' S 115° 57" 55' E	8cm	Slightly coloured. Slightly turbid.	55% Submerged *Ruppia* 3 30% Emergent Sedges 4 10% Detritus 5% Mineral Substrate 50% Canopy Cover	Open Melaleuca woodlands (2 species, 1 not seen previously in wetland); emergent sedges (Restionaceae) and submerged macrophytes. Most Northern & Eastern survey site. Frog calls (*Litoria adelaidensis, Crinia glauerti*, *Limnodynastes dorsalis*). Tiger snake sighted. Bycatch - 1 x *Galaxiella nigrostriata*, 3 x juvenille *Bostokia porosa*
LC7 31° 30" 24' S 115° 57" 69'E	35cm	Red/brown, slightly turbid. Cannot see bottom.	40% Floating Macrophyte (5) 10% Emergent (grass) 4 Detritus 80% Canopy Cover	Drainage channel, Southeastern end of wetland. Melaleucas & patches of grass line banks. To North water in the drain is blanketed in floating macrophytes. The area has been sprayed to remove Arum Lillies.

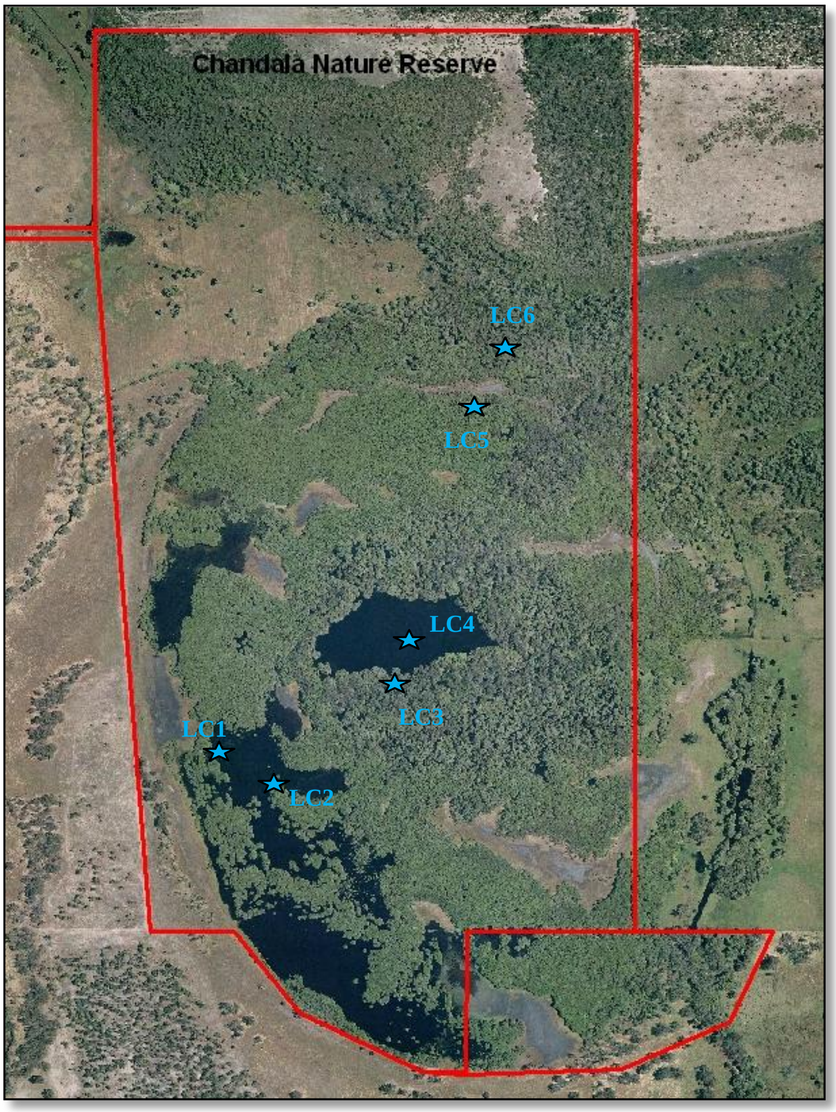

Figure 2: Map of Chandala Nature Reserve, showing sites where invertebrates and water quality data collected. Map supplied by Bob Huston, DEC.

Methods and Techniques

Macro-invertebrate surveys were undertaken at the 7 sites (shown in Map 1) following, with some deviations, methods outlined in the Wetland Bioassessment Manual – Macroinvertebrates (Davis et al. no date). The location of sites was recorded using a Magellan GPS. The water depth, observations of water colour and clarity and a description of the site/ habitat features were also recorded (Table 2). Water samples and measurements of various parameters were taken before aquatic macroinvertebrate samples to reduce disturbance of sediments.

Two minutes was spent sweeping a long handled (250µm mesh) net through the aquatic habitats at the site. At the end of the 2 minutes the content of the net was examined and accidental bycatch removed before being emptied into a plastic zip lock bag and preserved with ethanol. Due to time restraints invertebrate sorting was undertaken in the laboratory 1 week after collection. Invertebrate samples were washed through four different sieve sizes and 'picked' in the lab. The two larger sieve sizes were sorted by eye, under a lamp, and the smaller sieve sizes sub-sampled and picked under a microscope. A total of four hours was spent picking each sample with very broad estimations of abundances made during this time. Macro-invertebrates were identified to the species level, where possible, by ECU invertebrate taxonomist Kirsty Geldart. To allow identification to the species level for the ostracods, calanoids and cyclopoids voucher specimens were taken to Bennelongia Consultancy.

Water physico-chemical parameters measured at each site while in the field included temperature (°C), field conductivity (µS/cm), pH and oxygen (% saturation & mg/L). Water samples were collected for turbidity and gilvin, and measured in the laboratory. Methods are outlined in Table 3. Additional water samples were collected at LC1, LC4, LC6 & LC7, in cleaned rinsed bottles, for analysis by the Perth Chemistry Centre. Variables measured at the four sites include nutrients, chlorophyll a, alkalinity, cation and anion composition and metal content. The parameters tested at the four sites and methods of analysis are outlined in Table 4.

Table 3: Water Physico-chemical Parameters Measured at Each Site and Methods.

Temperature °C	Measurements taken in the field using a portable meter. Measured at the top and bottom of water column. (in case of stratification)
Field Conductivity (µS/cm)	
Field pH	
Oxygen (% saturation &mg/l)	
Turbidity (NTU)	Collected in clean rinsed bottles for analysis in lab. Measured spectrophotometrically (using an unfiltered sample).
Colour (Gilvin)	Collected in clean rinsed bottles for anaysis in lab. Spectrophotometer used to measure absorbance of filtered sample (Gilvin). Absorption coefficient then calculated.

Table 4: Water Chemistry Analysis and Methods for Samples Collected at LC1, LC4, LC6 & LC7. Information given under 'method' is the code supplied by Perth Chemistry Centre.

Analyte	Method	Description
N_total	iNP1WTFIA	Nitrogen, nitrate + nitrite fraction by FIA
N_NO_3	iNTAN1WFI	Nitrogen, persulphate total by FIA
P_total	iPP1WTFIA	Phosphorus, persulphate total by FIA
Chloro_a	iCHLA1WAC	Chlorophyll"a" as per APHA (21^{st} ed) Method 1020
Alkalin	iALK1WATI	Alkalinity, total expressed as $CaCO_3$ mg/L
HCO_3	iALK1WATI	Bicarbonate
Na	iMET1WCIC	Sodium
Ca	iMET1WCIC	Calcium
Mg	iMET1WCIC	Magnesium
K	iMET1WCIC	Potassium
Mn	iMET1WCIC	Manganese
Fe	iMET1WCIC	Iron
Cl	iCO1WCDA	Chloride
Sio_2	iCO1WCDA	Silica , molybdite reactive
SO_4	iMET1WCIC	Sulphate, sulphur expressed as sulphate

Analysis

On completion of identifications a species list was compiled for aquatic macroinvertebrates recorded in surveys. For those identified to the species level it was then possible to investigate their distribution. Classifications of richness and endemism followed that outlined in Horwitz et al (2009) & Sommer et al (2008). Invertebrates classified as regionally endemic were those with a distribution confined to the South West Botanical Province. Species with a distribution extending beyond this province have been classified as widespread. Locally endemic refers to those with a distribution confined to the SCP, and rarity, to species recorded in 3 or less wetlands. Distribution was determined with the use of an unpublished database prepared by Horwitz et al (2008), the Australian Faunal Database (DEWHA), and from information accompanying identifications by Stuart Halse. Richness, endemism and rarity values were also calculated for a species list that combined our results with the results of past surveys. These richness and endemism values were then used to make a comparison with other wetlands on the SCP. Richness, rarity and endemism for other SCP wetlands was obtained from Table 1 in *Wetland richness and endemism on the Swan Coastal Plain, Western Australia* (Horwitz et al. 2009).

To gain an understanding of Lake Chandala's condition the results of water physico-chemical testing were assessed against background data and against ANZECC guidelines. As water parameters varied significantly between the sites, analysis has focused on the condition at sites, more so than for the wetland as a whole. Invertebrate lists were compiled for each site to perform analysis that would indicate both the condition at each site and the effect of the different habitats and water quality on invertebrates. The SWAMPS index for aquatic macroinvertebrates created by Chessman et al (2002) was used to obtain a disturbance score for each survey site and for the wetland as a whole. This was done by scoring each individual at a given site, using the family index (Appendix 2). Scores were than assessed against a key to interpret the likelihood of cultural eutrophication. The presence of 'indicator species' and the occurrence of species with specific water quality requirements have also been used to interpret condition.

The Sorensen similarity index was used to highlight the sites which showed the greatest similarity in species composition and to get an idea of species diversity throughout the wetland. This was done by finding the total number of species at two sites, then dividing the total by the number of species common between the sites. The similarity scores, number of species and number of species found only at one site were compared with habitat and water quality data to gain an understanding of factors affecting distribution.

Finally the combined species list, containing past and present results, was used to compare the level of similarity between species, family and genera present in the 1989/1990 surveys and our surveys. This was used to assess change in composition over time.

Results

Macroinvertebrate Distribution, Richness and Endemism

Table 5 shows results for richness and endemism determined first using only the species list created from the recent survey, and second using the species list created from the combination of recent and past surveys. Results for richness include two values, the first value indicates the number of species or genera present if all taxa are assumed to be different species.

Richness values have been determined for family, genus and species. Taxa collected from recent surveys were from 77 species, 72 genera and 47 families. When our species list was combined with that produced from past surveys the richness values for Lake Chandala increased to 133 species from 109 genera and 55 families.

Thirty four taxa collected in recent surveys have been identified to the species level of which 11 species have been classified as regionally endemic. The combined dataset produced 63 named species for Lake Chandala of which 13 are regionally endemic.

Table 5: Family, Genus and Species Richness, Number of Named Species and for these, the Proportion Regionally Endemic, Widespread and Unknown Distribution. Values are shown for recent surveys, our results, and the combined species list containing past and recent results. RE- regionally endemic, restricted to the South West Botanical Province, Widespread – range extends beyond this province, Unknown – insufficient data to determine distribution. The values given in brackets are more conservative excluding individuals (sp, spp, juvenile) which have only been identified to the genus or family level, and could potentially be the same as others identified to a lower taxonomic level.

	Richness			No. Named Species	No. RE	% Regionally Endemic	% Widespread	% Unknown
	Family	Genus	Species					
Recent Surveys	47	72 (68)	77 (73)	34	11	32%	56%	12%
Results Combined	55	109 (99)	133(110)	63	13	21%	73%	6%

Table 6 lists aquatic macroinvertebrate taxa recorded during surveys of Lake Chandala, showing their distribution and the sites at which they were collected. Of the 77 taxa recorded at Lake Chandala approximately one third were only recorded at one site. LC1 and LC3 were the richest with 36 species recognised at each site. This was followed by 28 species at LC2, 25 at LC7, 23 at LC6 and 22 at LC5. LC4 recorded the lowest species richness with only 13 species collected at this site.

Table 6: Species List Recent Surveys of Lake Chandala, Including Distribution and Occurrence at the Seven Sites. Distribution could only be established for taxa identified to the species level, RE = regionally endemic, ie only found within the south west botanical province, W = widespread, recorded outside this province, ? = data unavailable. Species that were only recorded at one site are shown in purple, those which could be at only 1 site are in green (juveniles at other sites could be the same species), those found at more than 1 site are in blue.

PHYLUM/ SUBPHYLUM CLASS	**ORDER**	**Family/Subfamily**	**Genera/Spp**	**Distribution**	LC1	LC2	LC3	LC4	LC5	LC6	LC7
ANNELIDA											
OLIGOCHAETA	MICRODRILI	spp	*Sp*					purple			
HIRUDINEA		Glossiphoniidae	*Sp*						purple		
MOLLUSCA											
GASTROPODA	BASOMMATOPHORA	Ancylidae	*Ferrissia petterdi*	*W*	blue		blue		blue		
		Planorbidae	*Glyptophysa sp*		blue	blue	blue		blue	blue	blue
ARTHROPODA/ CRUSTACEA											
MAXILLOPDA	COPEPODA	Cyclopoida	*Mesocyclops brooksi*	*W*	blue	blue	blue	blue	blue	blue	blue
		Calanoida	*Boeckella robusta*	*RE*	blue	blue	blue				
		Centropogidae	*Boeckella sp.*			blue	blue		blue	blue	blue
			Calamoecia tasmanica subattenuata	*RE*	blue	blue	blue	blue		blue	
OSTRACODA	PODOCOPIDA	Cyprididae	*Alboa worooa*	*W*		blue	blue	blue			blue
			Bennelongia australis sensu strict	*?*	blue	blue	blue	blue		blue	
			Cypricercus sp422 undescribed	*W*	blue	blue	blue				
			Cypretta aff globosa	*RE*	blue		blue				blue
			Cypretta sp272 undescribed	*RE*					purple		
		Candonidae	*Candonocypris novaezelandiae*	*W*		blue	blue				blue
BRANCHIOPODA	CLADOCERA	Chydoridae	*Chydorus sphericus*	*W*	blue	blue	blue		blue		blue
			Camptocercus sp				purple				
		Aloninae	*?Biapertura sp*				blue				blue
		Daphniidae	*Simocephalus sp*		blue		blue				blue
			Ceriodaphnia sp			blue			blue		
			Daphnia sp				blue	blue			
		Macrothriscidae	*Sp*							purple	
MALACOSTRACA	ISOPODA	Amphisopidae	*Paramphisopus palustris*	*RE*	blue						blue
	AMPHIPODA	Ceinidae	*Austrochiltonia subtenuis*	*W*	blue	blue	blue		blue		
	DECAPODA	Parastacidae	*Cherax quinquecarinatus*	*RE*			blue		blue	blue	blue
	NOTOSTRACA	Triopsidae	*Lepidurus apus viridis*	*W*	purple						

ARTHROPODA/ CHELICERATA											
ARACHNIDA	ACARIFORMES	Oxidae	*Oxus sp*								
		Arrenuridae	*Arrenurus balladoniensis*	*W*							
		Eylaidae	*Eylais sp*								
		Limnesiidae	*Limnesia sp*								
		Pionidae	*Piona cumberlandiensis*	*W*							
			Acercella falcipes	*W*							
		Hydrachnidae	*Hydrachna sp*								
		Halacaridae	*Sp*								
		Oribatidae	*Sp*								
		Trombidioidea	*Sp*								
ARTHROPODA											
HEXAPODA	COLLEMBOLLA (Diplura)	Hypogastruridae	*Sp*								
		Sminthuridae	*Sp*								
INSECTA	ODONATA-ANISOPTERA	Corduliidae	*Procordulia affinis*	*RE*							
	ODONATA-ZYGOPTERA	Lestidae	*Austrolestes sp*								
	DIPTERA	Chironomidae	*pupae sp 1*								
		Chironominae	*Tanytarsus sp 2*								
			Dicrotendipes sp								
			Ablablesmyia notabilis	*W*							
		Tanypodinae	*Paramerina levidensis*	*W*							
			Procladius paludicola	*W*							
		Orthocladiinae	*Corynoneura sp*								
			Compterosmittia sp								
			Polypedilum 'K5'	*?*							
		Ceratopogonidae	*sp 1*								
		Ceratopogonidae	*sp 2*								
		Culicidae	*sp pupae*								
			Anopheles sp								
			Culex sp								
	TRICHOPTERA	Hydroptilidae	*Acritoptila/Helleythira sp*								
		Leptoceridae	*Genus C*								
	HEMIPTERA	Corixidae	*Micronecta halei*	*W*							

			Micronecta robusta	*W*							
			Sigara mullaka	*RE*							
		Notonectidae	*Paranisops endymion*	*RE*							
		Psylloidea	*Sp*								
	NEUROPTERA	Sisyridae	*Sisyra sp*								
	LEPIDOPTERA		*Sp*								
	COLEOPTERA	Dytiscidae	*Rhantus suturalis*	*W*							
			Liodessus dispar	*RE*							
			Megaporus solidus	*RE*							
			Antiporus sp juvenile								
			Copelatus sp juvenile								
			Homeodytes scutellaris	*W*							
		Halipilidae	*Haliplus sp*								
		Hydraenidae	*sp juvenile*								
			Hydraena sp								
		Hydrophilidae	*sp juvenile*								
			Berosus approximans	*W*							
			Berosus ?dallasi	*?*							
			Berosus sp juvenile								
			Coelostoma sp juvenile								
		Scirtidae	*sp juvenile*								
Totals				**77**	**36**	**28**	**36**	**13**	**22**	**23**	**25**

Sorensen Similarity Index

The percentage similarity in aquatic macroinvertebrate assemblages between the different sites is shown in Table 7. Overall similarity between the sites was quite low ranging from 3% of species in common between LC4 and LC5 to 39% of species in common between LC1 and LC2.

LC1, LC2 and LC3 were more similar to one another than they were to the other sites. LC3 and LC7 were also more similar to one another, as were LC5 and LC6. LC4 appeared to be the most dissimilar site in terms of species assemblages.

Table 7: Sorenson Similarities Index. Values indicate the similarity in species composition between given sites, shown as a percentage of the total number of taxa at two sites.

Site	LC1	LC2	LC3	LC4	LC5	LC6	LC7
LC1							
LC2	39						
LC3	36	36					
LC4	11	17	20				
LC5	21	28	32	3			
LC6	23	28	28	13	36		
LC7	20	23	36	6	24	17	

SWAMPS Results

Table 8 shows the SWAMPS biotic index score for each site and the whole wetland. The lowest score of 41 was produced for LC4. This was the only site to score below 42 indicating that cultural eutrophication or other human disturbance is likely. LC1 scored 44.61, just outside the range indicating that cultural eutrophication could be a problem. LC7 scored slightly higher at 45.42, LC3 scored 46 and LC2 scored 46.15. The highest score, indicating lowest level of disturbance was 47.09 at LC6. The whole wetland produced a score of 46.41.

Table 8: Results of SWAMPS Biotic Index for Each Site and the Whole Wetland. SWAMPS family scores were applied to each species at the given site and the mean value calculated. An average score <42 indicates cultural eutrophication or other human impact is likely, 42-44 indicates these impacts may be present & further investigation is required, >44 cultural eutrophication is unlikely but an impact which SWAMPS is not sensitive to cannot be ignored.

LC1	LC2	LC3	LC4	LC5	LC6	LC7	Chandala
44.61	46.15	46	41	46.24	47.09	45.42	46.41

Species Found at 1 Site

Table 9 lists the species that were found at only one site in the wetland. Those shown in green have been listed as being found at only one site, but this is uncertain due to the collection juveniles identified to the genus level at another site. With 7 species LC1 recorded the greatest number of aquatic macroinvertebrates restricted to one site. This was followed by LC6 and LC7 which both recorded 5 species not collected at any of the other sites. LC3, LC4 and LC5 all recorded 3 species not found at other sites. LC2 recorded the lowest number of unique species with 2 species not found elsewhere at Lake Chandala.

Table 9: Species Found at 1 Site Only

Site	Species
LC1	NOTOSTRACA, Triopsidae, *Lepidurus apus viridis* ACARIFORMES, Hydrachnidae, *Hydrachna sp* DIPTERA, Chironominae, *Dicrotendipes sp* TRICHOPTERA, Hydroptilidae, *Acritoptila/Helleythira sp* HEMIPTERA, Notonectidae, *Paranisops endymion* COLEOPTERA, Halipilidae, *Haliplus sp* DIPTERA, Orthocladiinae, *Corynoneura sp*
LC2	ACARIFORMES, Halacaridae sp HEMIPTERA, *Micronecta halei*
LC3	ACARIFORMES, *Trombidioidea sp* CLADOCERA, Chydoridae, *Camptocercus sp* COLEOPTERA, Hydraenidae, *Hydraena sp*
LC4	OLIGOCHAETA, MICRODRILI spp DIPTERA, Ceratopogonidae sp1 DIPTERA, Ceratopogonidae sp2
LC5	HIRUDINEA, *Glossiphoniidae sp* PODOCOPIDA, Cyprididae, *Cypretta sp272* COLEOPTERA, Dytiscidae, *Homeodytes scutellaris*
LC6	DIPTERA, Culicidae, *Culex sp* COLEOPTERA, Dytiscidae, *Liodessus dispar* COLEOPTERA, Hydrophilidae, *Coelostoma sp* juvenile CLADOCERA, *Macrothriscidae sp* DIPTERA, Orthocladiinae, Compterosmittia sp
LC7	DIPTERA, Culicidae, *Anopheles sp* HEMIPTERA, Psylloidea sp LEPIDOPTERA sp COLEOPTERA, Dytiscidae, *Rhantus suturalis* HEMIPTERA, Corixidae, *Sigara mullaka*

Water Physico-chemical Data, Nutrient Levels, Ions and Metals

Table 10 contains water physico-chemical data, nutrient levels, cation and anion composition and metal levels.

Physico-chemical Data

Temperature (°C), values were generally the same at the top and bottom, indicating well mixed water columns. The only exception was LC3, in sheltered woodland, where stratification was evident. LC3 showed 1°C variation between top and bottom readings.

LC1, where significant algal growth and macrophytes occurred, recorded the highest dissolved oxygen (mg/L) and was the only site to record higher % dissolved oxygen at the bottom of the water column than the top. LC7 showed significant variation between top and bottom readings with dissolved oxygen recorded at 63% at the surface and 12% at the bottom. Dissolved oxygen levels for LC3 also suggest stratification with surface readings of 3.71mg/L and 43.9% and the bottom readings of 2.91mg/L and 31.5%. The lowest dissolved oxygen readings were taken at LC5 where 0.91mg/L and 9.9% were recorded in surface waters and 0.47mg/L and 5.3% at the bottom of the water column.

Table 10: Water Physico-chemical Data, Nutrient Levels, Cation & Anion Composition and Metal Levels. Includes parameters measured at each of the sites and those tested at only four of the seven sites.

Parameter/ Site	LC 1		LC 2		LC3		LC4		LC5		LC6		LC7	
	Top/ Bottom		Top/ Bottom		Top/ Bottom		Top/ Bottom		Top/ Bottom		Top/ Bottom		Top/ Bottom	
Physiochemistry														
Temp °C	14.1	14.1	14.1	14.1	14.3	13.3	15.1	14.9	13.7	13.5	15.8	n/a	15.0	14.6
DO mg/L	7.80	7.80	4.25	4.12	3.71	2.91	3.30	3.15	0.91	0.47	6.41	n/a	5.30	1.10
DO %	76.5	77.1	50.3	47.4	43.9	31.5	40.1	37.5	9.9	5.3	78.9	n/a	63	12
pH	6.98	6.98	6.42	6.39	6.37	6.27	6.28	6.28	5.98	5.95	5.29	n/a	5.30	5.28
Cond. us/cm	1112	1094	1050	1031	1136	1188	1140	1140	1036	1044	585	n/a	815	1507
Gilvin	51.13		54.58		52.05		53.20		49.28		35.70		74.62	
Turb. NTU	61.00		25.50		44.50		7.50		60.10		9.00		38.00	
Chl "a" mg/L	0.007						<0.001				0.001		0.006	
Alkalin mg/L	40						40				25		40	
Nutrients														
N_total mg/L	2.4						2.3				1.2		3	
N_NO3 mg/L	<0.10						<0.10				<0.10		<0.10	
P_total mg/L	0.78						0.74				0.03		0.36	
SiO2 mg/L	8						12				5.3		25	
Cations														
Na mg/L	167						168				101		122	
Mg mg/L	18.8						20.9				16		15	
Ca mg/L	8.6						7.7				3.3		5.8	
K mg/L	6.8						6.7				2.5		1.8	
Anions														
Cl mg/L	334						334				166		218	
HCO3 mg/L	49						49				31		49	
SO4_S mg/L	25.3						24.8				28.6		16.1	
CO3 mg/L	<1						<1				<1		<1	
Metals														
Fe mg/L	0.27						0.32				0.25		0.71	
Mn mg/L	0.004						0.012				0.005		0.006	

LC1 recorded the highest pH of 6.98 in top and bottom waters. The lowest pH levels were at LC6 (5.29) and at LC7 where pH was 5.30 at the surface and 5.28 at the bottom. Alkalinity was the same at LC1, LC4 and LC7 which all recorded 40mg/L, while LC6 recorded 25mg/L

Conductivity at the seven sites ranged from the lowest reading of 585µs/cm at LC6 to the highest reading of 1507µs/cm in the bottom waters of LC7. The greatest variation between the top and bottom of the water column was also recorded LC7 where the surface water recorded a conductivity reading of 815µs/cm. All the other sites had conductivity values of between 1000µs/cm and 1150µs/cm.

All the gilvin values reflect the darkly coloured waters. The highest gilvn value at 74.62, was recorded at LC7. This was followed by 54.48 at LC2, 53.20 at LC4, 52.05 at LC3, 51.13 at LC1 and 49.28 at LC5. LC6 recorded the lowest gilvin value of 35.70. Turbidity was similar at LC1 and LC5 which recorded 61 NTU and 60.10 NTU respectively. LC3 recorded 44.50 NTU, LC7 recorded 38.00 NTU and at LC2 turbidity was recorded at 25.50. LC6 and LC4 recorded much lower turbidity values of 9.00 NTU and 7.50NTU respectively, suggesting much clearer water.

The highest chlorophyll 'a' reading of 0.007mg/L was recorded at LC1, followed by 0.006mg/L at LC7, 0.001 mg/L at LC6 and the lowest level at <0.001mg/L was recorded at LC4.

Nutrients

Total nitrogen was highest at LC7 which recorded 3mg/L, LC1 and LC4 showed similar results of 2.4mg/L and 2.3mg/L respectively, while total nitrogen was significantly lower at LC6 where 1.2mg/L was recorded. Nitrate (NO_3) concentrations were recorded as being <0.10mg/L at all sites. Total phosphorus levels were very high at LC1 (0.78mg/L), LC4 (0.74mg/L), and LC7 (0.36 mg/L) while LC6 recorded the lowest result at only 0.03mg/L. Silica dioxide was the greatest at LC7 where 25mg/L was recorded, followed by 12mg/L at LC4, 8mg/L at LC1 and again the lowest levels were recorded at LC6 where silica dioxide was 5.3mg/L.

Ions & Metals

Of the cations sodium was by far the most abundant, followed by magnesium, calcium and potassium (Na>Mg>Ca>K), and were found to occur in roughly the same proportions at each site. Concentrations generally followed the same pattern between sites as conductivity, with similar results at LC1, LC4 and LC7 and lower results recorded at LC6.

Anions measured at LC1, LC4, LC6 and LC7 include chloride (Cl^-), carbonate (CO_3^{2-}),bicarbonate (HCO_3^-) and sulphate (SO_4^{2-}). Chloride value were proportional to conductivity, with LC6 and LC7 having lower concentrations.LC1, LC4 and LC7 all recorded 49mg/L for bicarbonate, while at LC6 HCO_3 was 31mg/L. Sulphate was highest at LC6 which recorded 28.6mg/L, followed by LC1 with 25.3mg/L and LC4 with 24.8mg/L. LC7 recorded the lowest level of sulphate at 16.1mg/L. Carbonate was below detection limits for all sites.

Iron concentrations were highest at LC7. LC1, LC4 and LC6 recorded similar values. The highest result for manganese was recorded at LC4 (0.012mg/L), with values for LC1, LC6 and LC7 ranging from 0.006mg/L to 0.004mg/L.

Discussion

Species Richness and Endemism

Invertebrate surveys potentially collected 77 different taxa from 72 genera and 47 families. When compiled with past surveys this resulted in richness values for Lake Chandala of 110-133 species from 99-109 genera and 55 families. Combining the two datasets produced 63 named species, of which 21% were determined to be regionally endemic. No locally endemic or rare species were recorded in recent or past surveys. This could be due to the limitations of identification and the lack of information on aquatic macroinverterates. However low levels of rarity and locally endemic species are quite common in SCP wetlands (Horwitz et al. 2009).

Seven wetlands on the SCP have been recognised as being 'significant' with five of these recording a species richness value well over 100 and the other two recording 68 and 78 families (Sommer et al. 2008). While Chandala is not necessarily comparable with these wetlands, of those that have been assessed for richness less than 20% recorded over 90 species and 40% recorded over 40 families (based on Horwitz et al. 2009 Table 1, p 1013-1014,). Thus it appears that Lake Chandala is of relatively high species richness and at least in the upper portion for family richness when compared to other SCP wetlands. Regional endemism also seems to be relatively high at Chandala with just over 16% of SCP wetlands having greater than 20% regionally endemic species (Horwitz et al. 2009).

While the shield shrimp *Lepidurus apus viridis* is considered widespread its occurrence at Lake Chandala is the first record of this species in SCP wetlands. This species belongs to the order Notostraca, found in temporary waters that typically do not contain fish (SA EPA 2004). Members of this order produce desiccation resistant eggs which can survive in dried mud for relatively long periods of time and which are small enough to be transported by wind and water (SA EPA 2004). It has also been suggested that eggs could be transported on the feet of birds (Williams 1966). Recorded in wetlands to the east of the SCP it is possible that Lake Chandala's close proximity to the Dandaragan Plateau has enabled the dispersal of *Lepidurus apus viridus* from the nearby escarpment. This close proximity to the escarpment could also be a factor influencing the richness levels at Lake Chandala and the relatively low similarities that has been seen across the wetland.

Water Physico-chemistry

Background data for Lake Chandala is available for pH, salinity and phosphorus. The South West Wetlands Monitoring Program Report (SWWMPR) 1977-2008 outlines the pH range for Chandala as being between 6 and 8 (Lane et al. 2009). Sites LC1-LC4 had pH readings within this range. LC5 fell just outside this range, at 5.98, while the pH at LC6 and LC7 was between 5.28 and 5.30. ANZECC guidelines suggest pH in south west wetlands should range between 7 and 8.5, and in coloured wetlands pH can be expected to be between 4.5 and 6.5 (ANZECC 2000). Prior surveys for Lake Chandala have also documented significant changes in pH throughout the year, with higher values occurring during times of higher primary productivity which consumes CO_2 and reduces pH (Davis et al. 1993). The SWWMP report has found that salinity at Chandala typically ranges from 0.5ppt- 1-5ppt classifying these water as very fresh (<1ppt) to fresh (1<3ppt). LC1-LC5 & LC7 fell within this range, while LC6 was fresher with a salinity reading of approximately 0.35ppt. ANZECC guidelines for salinity suggest a very broad range of 300µs/cm- 1500µs/cm in winter, with higher levels expected in summer due to evaporation.

Salts contributing to conductivity measures typically include calcium, magnesium, sodium and potassium cations and carbonate, sulphate and chloride anions (MDFRC 2006). Concentrations of these ions were, not surprisingly, lower at LC6 than the other sites. The exception to this was sulphate, which was the highest at LC6 and potassium which was higher at LC6 than LC7. All sites followed the trend of Na>Mg>Ca>K. The dominance of Na^+ in ionic composition is characteristic of SCP wetlands due to the precipitation of airborne sea spray (Davis et al. 1993). The dominance of magnesium over calcium is also expected in wetlands overlying Bassendean Sands and Guildford formations (Davis et al. 1993).

When comparing nutrient levels in water samples LC1, LC4 and LC7 recorded significantly higher concentrations of nitrogen, phosphorus and silica than at LC6. Total phosphorus levels recorded at LC1, LC4 and LC7 were relatively high ranging between 360ug/L and 780ug/L. Using the OECD boundary values for fixed trophic classification systems (outlined in Ryding & Rast 1989), if phosphorus were the only variable being considered these values would indicate a Hypertrophic system, with chlorophyll levels expected to exceed a mean value of 25 ug/L. However at Lake Chandala our results found chlorophyll 'a' to range from 1ug/L to 7ug/L. Similar results have been documented by Davis et al (1993) in earlier surveys where very high levels of phosphorus in coloured wetlands such as Lake Chandala (mean of 649ug/L) equated to surprisingly low primary productivity. Wetlands exhibiting this trend have been described as 'dystrophic' (Davis et al. 1993). The trait has been associated with the highly coloured wetlands of the SCP and is thought to be linked to the reduced euphotic zone (< 0.5m), the affect of the red colour on underwater light and the lower pH associated with the gilvin/ humic content (Davis et al. 1993).

At LC1, LC4 and LC7 total phosphorus and total nitrogen exceed the ANZECC guidelines of $60\mu g/L^{-1}$ for total phosphorus and $1500\ \mu g/L^{-1}$ for total nitrogen (ANZECC 2000). Results for nitrates fall inside the recommended level of $100\mu g/L^{-1}$ (ANZECC 2000).

Oxygen levels at all sites were below the ANZECC trigger values of 90%. Low oxygen levels can result from the bacterial break down of organic matter and limited mixing of water. This can be made worse during stratification events. The lowest levels recorded at LC5 and LC7 are of concern due to the affect on organisms and the potential for the release of nutrients and metals.

Invertebrate Distribution- Water Quality and Habitat

The Sorensen Similarity index indicated that species composition varied significantly between the sites. This could be due to diversity of habitats and water quality experienced at the different sites which showed the wetland to be quite heterogeneous. The sites with the highest similarities tended to be those that were close together and either demonstrated similar water qualities or habitats. For example LC1, LC2 and LC3 showed quite similar water chemistry and shared a number of species in common even though the habitats varied. LC5 and LC6 also recorded one of the higher similarity scores. While water quality parameters such as dissolved oxygen and conductivity showed substantial difference between these two sites they were quite close together and the habitat was similar. At LC4 however the degree of difference in habitat, ie open water with no vegetation present, seemed to make a greater difference to composition than the apparent likeness in water quality to LC1, LC2 & LC3.

The influence of habitat and water quality also became evident when assessing the distribution and abundance of specific taxa or taxonomic groups throughout the wetland. Samples of LC1 were described as a ‘zooplankton soup’ when being examined under the microscope due to the density of animals in the sample. This site recorded the highest levels of total nitrogen, total phosphorus and chlorophyll ‘a’ of all sites suggesting elevated productivity and greater algal biomass, were responsible for the large populations of invertebrate grazers. Sites LC2 and LC3 also possessed rich and abundant zooplankton populations, and it is probable that had further water testing been carried out at these sites the results would have been similar to LC1. The occurrence of *Dicrotendipes sp*. and *Corynoneura sp* only at LC1 is likely attributed to the presence, at this one site, of filamentous algae which is part or their food source (Davis & Christidis 1997). LC1 also recorded the greatest number and diversity of water mites likely linked to the suitability of habitat. They are most abundant in shallow, vegetated areas of wetlands (Davis and Christidis 1997). Their abundance and diversity could also be linked to the high diversity and abundance of hosts, Hemipterans and Coleopterans, at this site (Davis & Christidis 1997). More telling of water quality at LC1 was the occurrence of *Hydrachna sp.* not found elsewhere within the wetland. This species belongs to the Hydrachnidae family which has been assigned the lowest possible SWAMPS score of 1, indicating its presence in wetlands showing signs of cultural eutrophication.(Chessman et al. 2002).

Other taxa that can be used as indicators of water quality are Microdrilli sp and Glossiphonidae sp. The only Oligochaete worm Microdrilli sp was found at LC4. Some oligochaetes are particularly tolerant of organic pollution and as such are seen as an indication of this kind of disturbance (Davis and Christidis 1997). Oligochaetes also prefer soft mud bottoms and feed by ingesting sediment and filtering it for organic material (US EPA 2009). Leeches can also be an indicator of poor water quality (US EPA 2009). This is reflected by their relatively low SWAMPS score of 22 (Chessman et al. 2002).

Lower than expected chlorophyll ‘a’ levels at Lake Chandala could also be attributed the presence of zooplankton and the timing of sampling. Species known to respond positively to eutrophication, include *Daphnia carinata* (Dapnia sp. at LC3, LC4) *Candocypris novaezelandae* (at LC2, LC3, LC7), and *Micronecta robusta* (LC1, LC4, LC6). The presence on these species in significant numbers during early spring is seen as potential warning water quality problems could arise in summer (Davis & Christidis 1997). Algal grazers such as *Daphnia* can have a strong influence on algal biomass, and when these species die off over summer the reduced grazing pressure increases the likelihood of algae blooms (Davis & Christidis 1997). The time of year in which samples were taken could also be underestimating the potential for eutrophication as productivity could be expected to increase during summertime when water temperature is warmer and light availability is higher.

Comparison of Past and Present Results

Making a comparison between invertebrate lists collated from past and recent surveys was difficult due to the difference in the level of identification of some species. Of the 63 species identified to species level only 9 were common to both data sets. A comparison of genera found that just over half were present in both datasets, and a similar result was obtained for a comparison of families. The low level of similarity could be attributed to changes in wetland condition, however a comparison between background levels for some of the water quality parameters indicate no significant change in the wetland. Monitoring of depth, salinity and pH over the last 20 years also found that these parameters have stayed within expected ranges and that there is no evidence of trends that should raise concern (Lane et al. 2009). It is therefore more likely that differences are attributed to the variation in the time of year in which surveys were undertaken, the type of habitat present at survey sites and the position within the wetland.

Conclusion

Results of this research show Lake Chandala to support relatively rich invertebrate communities and a high level of regional endemism in comparison to other wetlands on the Swan Coastal Plain. The low similarity between species recorded at different sites is quite unusual and could be attributed to factors such as survey effort and the high level of heterogeneity exhibited throughout the wetland. Sites showed variation in habitat type, water quality and water permanence. The wetland is also unusual in that it overlies three different sediment types - Cretaceous Sand, Guildford Clay and Bassendean Sand which contribute to the heterogeneity. There is also the possibility that Lake Chandala is being fed water from a mound spring towards the northern end of the wetland, contributing to the very different water qualities. While the occurrence of a spring at this site has not been documented, the difference in water quality and the local stratigraphy make it quite probable. Springs on the SCP occur where Bassendean Sand meets Guildford Clay (which does appear to be the case at Lake Chandala) and the changing hydraulic pressure leads to a continuous discharge of ground water at the surface (Smith & Shams 2002). The situation of the Lake, quite close to the Dandaragan Plateau could also be a factor influencing the level of aquatic macroinvertebrate diversity at Lake Chandala. The level of change in invertebrate composition over time was quite difficult to establish, due to the differences in the level of identification and experimental design. Available data suggests there has been no real obvious change in the wetlands condition over time however ongoing monitoring programmes have been limited to a certain part of the wetland and to certain parameters. The main areas of concern for management of this wetland appear to be the high nutrient levels and the low dissolved oxygen levels at some sites.

The level of invertebrate richness and endemism, the unusual trends in distribution and the occurrence a species not previously recorded on the SCP suggest Lake Chandala is quite unique and of high conservation significance. The discovery of two species of freshwater fish at Lake Chandala, in particular the restricted *Galaxiella nigrostriata* also adds to the value of the wetland, as would the discovery of a mound spring.

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Appendices

Appendix Figures 1&2: LC1

Pictures by Bob Huston & Pierre Horwitz

Appendix Figure 3: LC2

Picture by Pierre Horwitz

Appendix Figure 4: LC3

Picture by Pierre Horwitz

Appendix Figure 5 & 6: LC4 and fresh water sponge

Pictures by Pierre Horwitz

Appendix Figure 7: LC5

Picture by Pierre Horwitz

Appendix Figure 8: LC7

Picture by Pierre Horwitz

Appendix Table 1: Physical, hydrological and ecological features of Chandala Wetland and richness, rarity and endemism values (established from past surveys of Swan Coastal Plain Wetlands) for aquatic invertebrates.

Physical Features	
Landform	Mesoscal ovoid lake
Geological Setting	Perth Basin, northern Swan Coastal Plain 1km West of the Dandaragan Plateau, Sand and alluvium overlaying marine limestone.
Mean Annual Rainfall	745 mm, mostly over May-August
Annual Evaporation	2200 mm
Hydrological Features	
Hydrological Role	Significant for recharge of the Gnangara mound
Water Supply	Receives inflow from drains (from 1km NE) and diffuse inflow from north
Catchment	Partly cleared (Ellenbrook Catchment)
Permanent	In autumn wetland recedes to innermost area, but rarely dries completely
Water Depth	0.2m - 1.02m (1983-1984 records)
Water Salinity	0.5ppt- 2.5ppt (1981- 1983)fresh- poikilohaline
Water pH	6.2-9.1
Water Colour	Brown
Ecological Features	
Ecological Role	Major breeding area for waterbirds in WA. 40sp recorded in area, 22 sp breeding and roosting. 2 sp protected under treaties. One of WAs largest breeding Straw-necked Ibis colonies. (Local concerned over Ibis)
Vegetation Structure/ Communities	Grassland (incl. *Sporobolus virginicus*)
	Low shrubland (incl. samphire *Sarcoconia blackiana*)
	Closed scrub - Low closed forest (incl. *Melaleuca uncitata*)
	Closed forest (*M. Raphiophylla*, some *Eucalyptus rudis* near inner area of open water)
	Open woodland and cleared areas (previously closed scrub) along edge
Special Communities	Area of paperbarks.
Aquatic Invertebrate Data*	
Richness	Family - 34
	Genus - 64
	Species - 71
Rarity	6%
Regionally Endemic	10.50%

Data retrieved from Australian Wetlands Database (DEWHA), * From Wetland invertebrate richness and endemism on the Swan Coastal Plain,

Appendix Table 2: Combined Species List Showing Species Found in Previous Records, Species Found in Recent Records and SWAMPS Family Scores.
X- denotes no score for species in SWAMPS.

Order	Family/Subfamily	Genera/Spp	Family Grade	Previous Records	Recent Surveys	LC1	LC2	LC3	LC4	LC5	LC6	LC7
	Hydrazoa	Hydra sp or spp.	55	**55**								
	Turbellaria	sp. or spp	58	**58**								
MICRODRILI	spp	*sp*	*43*		**43**				43			
	Glossiphoniidae	*sp*	*22*	***22***	**22**					22		
BASOMMATOPHORA	Ancylidae	*Ferrissia sp. or spp*	*53*	***53***								
		Ferrissia petterdi	*53*		**53**	53		53		53		
	Physidae	*Physa sp. or spp.*	*38*	***38***								
		Physa acuta	*38*	***38***								
	Planorbidae	*Glyptophysa sp*	*62*	***62***	**62**	62	62	62		62	62	62
COPEPODA	Cyclopoida	*Mesocyclops sp.*	*29*	***29***								
		Mesocyclops brooksi	*29*		**29**	29	29	29	29	29	29	29
		Microcyclops sp.	*29*	***29***								
	Calanoida - Centropagidae	*Boeckella robusta*	*51*		**51**	51	51	51				
		Boeckella sp.	*51*		**51**		51	51		51	51	51
		Calamoecia attenuata	*51*	***51***								
		Calamoecia tasmanica subattenuata	*51*		**51**	51	51	51	51		51	
	Harpacticoida	*Canthocamptus sp. or spp.*	*39*	***39***								
PODOCOPIDA	Cyprididae	*Alboa worooa*	*34*	***34***	**34**		34	34	34			34
		Bennelongia australis	*34*	***34***								
		Bennelongia australis sensu stricto	*34*		**34**	34	34	34	34		34	
		Cypricercus sp422	*34*		**34**	34	34	34				
		Cypretta aff globosa	*34*		**34**	34		34				34
		Cypretta sp272	*34*		**34**					34		
		Ilyodromus sp. or spp.	*34*	***34***								
		Mytilocypris sp.	*34*	***34***								
		Mytilocypris ambiguosa	*34*	***34***								
		Sarscypridopsis aculeata	*34*	***34***								
	Candonidae	*Candonocypris novaezelandiae*	*53*		**53**		53	53				53
CLADOCERA	Chydoridae	*Chydorus sphericus*	*43*	***43***	**43**	43	43	43		43		43
		Camptocercus sp.	*43*		**43**			43				
		Dunhevedia aff. Crassa	*43*	***43***								
		Pleuroxus sp.	*43*	***43***								
		Pseudochydorus globulosa	*43*	***43***								
	Aloninae	*?Biapertura sp.*		***x***	**x**							
	Daphniidae	*sp. or spp.*	*29*	***29***								

		Simocephalus sp.	*29*		**29**	29		29				29
		Simocephalus vetulus	*29*	***29***								
		Ceriodaphnia sp.	*29*		**29**		29			29		
		Daphnia sp.	*29*		**29**			29	29			
	Macrothrisidae	*sp.*	*64*		**64**						64	
		Eschinisca capensis capensis	*64*	***64***								
		Eschinisca sp.	*64*	***63***								
		Macrothrix breviseta	*64*	***64***								
		Neothrix armata	*64*	***64***								
	Ilyocryptidae	*Ilyocryptus spinifer*		***x***								
ISOPODA	Amphisopidae	*Paramphisopus palustris*	*34*	***34***	**34**	34						34
AMPHIPODA	Ceinidae	*Austrochiltonia subtenuis*	*41*	***41***	**41**	41	41	41		41		
DECAPODA	Parastacidae	*Cherax quinquecarinatus*	*47*		**47**			47		47	47	47
NOTOSTRACA	Triopsidae	*Lepidurus apus viridis*			**x**							
ACARIFORMES	TUR	*sp. or spp*		***x***								
	Oxidae	*Oxus sp*	*89*		**89**			89		89		
	Arrenuridae	*Arrenurus balladoniensis*	*57*	***57***	**57**	57	57					
	Eylaidae	*Eylais sp*	*53*		**53**	53		53				
	Limnesiidae	*Limnesia sp*	*38*	***38***	**38**	38	38			38	38	
	Pionidae	*sp. or spp*	*14*	***x***								
		Piona cumberlandiensis	*14*		**14**	14	14	14	14			
		Piona murleyi	*14*	***14***								
		Acercella falcipes	*14*		**14**					14	14	
	Hydrachnidae	*Hydrachna sp*	*1*		**1**	1						
	Halicaridae	*sp*	*75*		**75**		75					
	Oribatidae	*sp*	*62*	***62***	**62**	62		62		62		
	Trombidioidea	*sp*			**x**							
COLLEMBOLLA (Diplura)	Hypogastruridae	*sp*			**x**							
	Sminthuridae	*sp*			**x**							
ODONATA/ANISOPTERA	Corduliidae	*Procordulia affinis*	*61*		**61**	61	61					61
ODONATA/ZYGOPTERA	Lestidae	*Austrolestes sp*	*50*		**50**	50	50					
		Austrolestes annulosus	*50*	***50***								
EPHEMOPTERA	Baetidae	*Cloeon sp. 1*	*57*	***57***								
DIPTERA	Chironomidae	*pupae sp 1*			**x**							
	Chironominae	*Chironomus alterans*	*43*	***43***								
		Chironomus occidentalis	*43*	***43***								
		Cryptochironomus griseidorsum	*43*	***43***								
		Dicrotendipes sp	*43*		**43**	43						
		Dicrotendipes conjunctus	*43*	***43***								
		Tanytarsus sp 2	*43*		**43**			43				43
		Tanytarsus fuscithorax	*43*	43								

	Tanypodinae	*Ablablesmyia notabilis*	*52*		**52**	52	52	52		52	52	
		Paramerina levidensis	*52*	***52***	**52**		52	52		52	52	52
		Procladius paludicola	*52*		**52**		52	52	52			
		Procladius villosimanus	*52*	***52***								
	Orthocladiinae	*Corynoneura sp*	*52*	***52***	**52**	52						
		Compterosmittia sp	*52*		**52**						52	
		Paratrichocldius sp.	*52*	***52***								
		Polypedilum nubifer	*52*	***52***								
		Polypedilum 'K5'	*52*		**52**		52	52		52	52	52
	Ceratopogonidae	*sp 1*	*60*		**60**				60			
	Ceratopogonidae	*sp 2*	*60*		**60**				60			
		Nilobezzia sp. or spp.	*60*	***60***								
		Culicoides sp. or spp.	*60*	***60***								
		Bezzia sp.	*60*	***60***								
		Palpomyia sp.	*60*	***60***								
	Culicidae	*sp pupae*	*66*		**66**				66			
		sp. or spp	*66*	***66***								
		Anopheles sp	*66*		**66**							66
		Culex sp	*66*		**66**						66	
	Tabanidae	*sp. or spp.*	*30*	***30***								
TRICHOPTERA	Hydroptilidae	*Acritoptila/Helleythira sp*	*66*		**66**	66						
	Leptoceridae	*Genus C*	*47*		**47**	47		47			47	
HEMIPTERA	Corixidae	*Agraptocorixa eurynome*	*20*	***20***								
		Micronecta halei	*20*		**20**		20					
		Micronecta robusta	*20*	***20***	**20**	20			20		20	
		Sigara truncatipala	*20*	***20***								
		Sigara mullaka	*20*		**20**							20
	Notonectidae	*Anisops thienemanni*	*39*	***39***								
		Notonect handlischi	*39*	***39***								
		Paranisops endymion	*39*		**39**	39						
NEUROPTERA	Sisyridae	*Sisyra sp*			**x**							
LEPIDOPTERA		*sp*			**x**							
COLEOPTERA	Dytiscidae	*Allodessus sp.*	*49*	49								
		Antiporus sp juvenile	*49*		**49**	49		49				49
		Copelatus sp juvenile	*49*		**49**			49			49	
		Homeodytes scutellaris	*49*	***49***	**49**					49		
		Hyphydrus elegans	*49*	***49***								
		Liodessus dispar	*49*	***49***	**49**						49	
		Megaporus sp.	*49*	***49***								
		Megaporus solidus	*49*		**49**					49	49	
		Necterosoma darwini (A&L)	*49*	49								

		Rhantus suturalis	*49*		**49**							49
		Sternopriscus sp. or spp.	*49*	***49***								
		Sternopriscus maedfooti	*49*	***49***								
		Sternopriscus multimaculatus	*49*	***49***								
	Halipilidae	*sp. or spp.*	*60*	***60***								
		Haliplus sp	*60*		**60**	60						
	Hydraenidae	*sp juvenile*			**x**							
		Hydraena sp			**x**							
	Hydrophilidae	*sp juvenile*	*55*		**55**					55		55
		Berosa sp. (A)	*55*	***55***								
		Berosa sp. (L)	*55*	***55***								
		Berosus approximans	*55*		**55**	55	55				55	
		Berosus ?dallasi	*55*		**55**	55	55					
		Berosus sp juvenile	*55*		**55**	55	55					
		Coelostoma sp juvenile	*55*		**55**						55	
	Scirtidae	*sp juvenile*	*48*		**48**	48		48		48	48	
Average Value/ SWAMPS Family Scores				**45.235**	**46.409**	**44.61**	**46.15**	**46**	**41**	**46.24**	**47.09**	**45.42**