Snapshot Survey of the Distribution and Abundance of the Macrophytes, Macroalgae, Phytoplankton and Macroinvertebrates of the Vasse – Wonnerup Lagoons - February, 2009

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EXECUTIVE SUMMARY

The Vasse Wonnerup wetlands are an extensive, shallow, nutrient enriched system with wide ranging salinities. Water levels in the two major areas of the wetlands, the Vasse and Wonnerup Lagoons (formerly estuaries), are partially managed through the use of floodgates to minimise flooding of adjoining lands and largely exclude seawater. The wetlands support tens of thousands of resident and migrant waterbirds of a wide variety of species and the largest regular breeding colony of Black Swan in south-western Australia and as such became listed as a Ramsar wetland in 1990. Many waterbirds, particularly the black swans, are dependent either directly or indirectly on the aquatic flora for food. Therefore an assessment of the flora is integral to the conservation and management of the waterbirds, as well as providing information on the ecological health of the lagoons.

Surveys to identify the major phytoplankton, macroalgal and macrophyte species and their distribution and to provide an estimate of the quantity of plant material have been carried out in spring 2006, 2007 and 2008. This report extends this work to investigate these communities in late summer, at a time of low water level, and include another important waterbird food source: macroinvertebrates. Water quality and sediment samples were taken at various positions along the Vasse and Wonnerup Lagoons to determine areas of high nutrient concentration, with the potential to relate nutrient content of the water with the type of algae or macrophyte present. Comparisons are drawn between this and previous surveys.

Submerged aquatic flora sampling of the Vasse and Wonnerup Lagoons was conducted in February 2009 as a single snapshot survey. Due to low water levels most of the two lagoons were dry and so stratified sampling was carried out at only five sites in the each of Wonnerup and Vasse Lagoons. Water quality and sediment sampling was also carried out at three sites in the Wonnerup and Vasse Lagoons and one at the Vasse Gates.

In the February 2009 sampling, water quality in both the Vasse and Wonnerup lagoons was highly eutrophic except near the gates. All forms of nitrogen and phosphorus (except nitrate) and chlorophyll *a* exceeded ANZECC guidelines at all sites in both the Vasse and Wonnerup Lagoons except at Vasse Gates, which were open to the ocean but still exceeded ANZECC guidelines for all nutrients except TN and NH_4. Both nutrient concentration and salinity increased with distance from the gates with concentrations reaching up to 100x ANZECC trigger values at site 12 in the Wonnerup Estuary and seven times guidelines at Vasse site 20. The entire system was hypersaline, with minimum salinities being 5ppt greater than seawater (40 ppt) and maximum salinities being more than three times seawater (113ppt). This provided an extreme environment inhospitable to most forms of life, resulting in reduced biodiversity and abundances.

Highest sediment nutrients were found at Site 14 in the Wonnerup Lagoon. There was no correlation between sediment and water nutrients or macroalgal or macrophyte abundance. Concentrations were comparable to those sampled in February 2008.

Despite very high chlorophyll *a* concentrations across both estuaries, but particularly in the Vasse Lagoon and at the site (12) furthest from the gates in the Wonnerup Lagoon, the types of algae present were non-toxic and benign. Phytoplankton was dominated by prasinophytes and cryptophytes with some dinoflagellates and diatoms.

Macrophytes were absent from the Vasse Lagoon in the February 2009 and occurred only in a small area near the open ocean gates in the Wonnerup Lagoon. At this site (15A) macrophyte biomass (20 g dry wt m^{-2}) was more than half macroalgal biomass at 38 g dry wt m^{-2}. Macrophyte biomass in the Wonnerup Lagoon was dominated by *Ruppia megacarpa* (Mason) at 1.6 tonnes, with traces of *Lamprothamnium papulosum* (Wallr.) J. Gr. If the macrophyte biomass was incorporated with the macroalgal biomass, the macrophytes would comprise only 1.6 % of the total biomass of the Wonnerup Lagoon. As in previous surveys, no macrophytes were present when TP exceeded 150μg L^{-1} (*Wilson et al* 2007, 2008a) and this excluded all sites where flora were surveyed except the Wonnerup gates.

Macroalgal biomass in the Vasse and Wonnerup Lagoons was dominated by green algae (Chlorophyta); primarily *Cladophora vagabunda* (Linnaeus) van den Hoek with a total biomass of 152 tonnes representing 95% of the total macroalgal biomass and 35 tonnes representing 99% of the biomass in the Vasse and Wonnerup Lagoons respectively. The other two macroalgal species present were *Ulva flexuosa* Wulfen and *Ulva paradoxa* (Dillwyn) Kuetzing. However, maximum biomass for both of these species was a fraction of that of *Cladophora* at 5.8 tonnes for *U. flexuosa* and 2.9 tonnes for *U. paradoxa* in the Vasse Lagoon. *Ulva* species combined made up 5% of the total macroalgal biomass in the Vasse Lagoon. Only *Ulva paradoxa* occurred in the Wonnerup Lagoon with a total biomass of 0.3 tonnes or 1% of total biomass. Areal biomass of individual sampling sites ranged from 58 to 466 g dry wt m^{-2}, the highest biomass occurring at site 12 furthest away from the gates in the Wonnerup Lagoon, which was totally comprised of *Cladophora.*

Macroalgal dominance changed between Spring 2006 and 2007 and the 2009 sampling. In previous spring sampling, *Ulva spp.* dominated and in late summer 2009 *Cladophora vagabunda,* strongly dominated both lagoons at 95-99% of the biomass probably due to its high salinity tolerance and production rate. The maximum biomass of *Cladophora* in this survey (466 g m^{-2}) though higher than previous spring studies per unit area (up to 268 g m^{-2}

- *Wilson et al* 2007, 2008a) was considerably less than maximum values obtained in the Peel Harvey Estuary at 4400 g m^{-2} (Lavery *et al*, 1991). Importantly, despite high chlorophyll *a* and nutrient concentrations, the Vasse and Wonnerup Lagoons were dominated by macroalgae, not toxic cyanobacterial blooms.

The hypersaline conditions of the Vasse Wonnerup Estuary in February 2009 resulted in poor macroinvertebrate biodiversity and abundance. The solar heating of the shallow water resulting in high temperatures, and the large amount of biotic material, would likely result in very low oxygen content, further impeding the survival of fauna. Not surprisingly then there was little live fauna and a large proportion of dead animals in all sites surveyed, except at the ocean gates where marine water reduced temperature and salinity.

Taxa surviving in the basins of both Vasse and Wonnerup lagoons were reduced to a few specimens of copepods, fly larvae, midge larvae and seed shrimps, occurring sporadically at different sites. The more benign conditions at the Wonnerup gate meant that nearly all these taxa were found, with the addition of oligochaete and polychaete worms, Hydrobiidae snails, Ceindae amphipods and large numbers of Daphniidae eggs.

There were small differences in the taxa present in the two lagoons. Daphniidae eggs were abundant in the Vasse Lagoon but only present at the gates of the Wonnerup Lagoon. Hapacticoid copepods were present in the Vasse, while cyclopoid copepods occurred in the Wonnerup Lagoon. Midge larvae (Chironomidae and Tanyponidae) where only found in the Vasse Lagoon. Dead Coxiella snails occurred in vast numbers only in the Wonnerup Lagoon. There was no macroinvertebrate life in the Wonnerup Lagoon apart from one site with a few cyclopoid copepods (site 12) and a few Ostracods (Cypridae) at Site 14.

In summary, the Vasse-Wonnerup Lagoons in February 2009 were both highly eutrophic and hypersaline. This resulted in a strong reduction in biodiversity with >95% of the biomass of both macroalgae and macrophytes being dominated by the one species of green alga, *Cladophora vagabunda* and macroinvertebrate abundance reduced to a few specimens of copepods, fly larvae, midge larvae and seed shrimps. The large number and diversity of dead macroinvertebrates indicated the inhospitable conditions present in the lagoons. The only sites showing biodiversity and abundance of both flora and fauna were next to the open gates of both lagoons where dilution of salt and nutrients by ocean water improved conditions, although these sites were still eutrophic and hypersaline.

1.0 Introduction

The Vasse-Wonnerup wetlands are located east of the township of Busselton in the South-West Region of Western Australia (Figure 1). Originally the wetlands consisted of two estuarine basins, the Vasse and the Wonnerup, that discharged directly to Geographe Bay. There were several rivers, the Capel, Ludlow, Abba, Sabina, Vasse and Buayanup that flowed into these estuaries. However, since 1907 the wetlands have been extensively modified by an artificial drainage network (English, 1994). The modern day wetlands consist of two lagoons (formerly estuarine basins) separated by two sets of floodgates, the purpose of which is to regulate water levels, exclude seawater and minimise flooding of the adjoining lands and Busselton township. Further, the drainage network reroutes part of the Sabina and part of the Vasse rivers away from the lagoons and directly into Geographe Bay via the Vasse Diversion drain, while the Buayanup River also discharges directly into Geographe Bay (Department of Environment, 2004).

The Vasse-Wonnerup System experiences periods of poor water quality (it has the greatest input of nutrients per square metre than any other estuary in Western Australia (McAlpine *et al*, 1989)), with algal blooms common in spring, summer and autumn. The frequent occurrence of potentially toxic blue-green algal blooms has resulted in permanent health warning signs posted at the Vasse floodgates (Sinclair, Knight, Merz, 2003). The nutrient enriched conditions are thought to stem from catchment land uses of agriculture principally for cattle grazing, the point sources of septic tanks and dairy sheds and the reduced flushing caused by the river diversions (Department of Environment, 2004). There is also a major residential canal estate being constructed at the northern side of the Vasse estuary. The nutrient enrichment creates a cycle of algal blooms, their collapse and decomposition of which depletes the dissolved oxygen concentrations to levels low enough to cause fish deaths. The deoxygenation of water also causes release of nutrients from the sediment into the water column fuelling further algal blooms (Department of Environment, 2004).

Despite the nutrient problems, the Vasse-Wonnerup wetlands are an important habitat for waterbirds. The area features tens of thousands of resident and migratory birds of a wide variety of species and the largest regular breeding colony of Black Swan in South-Western Australia and as such became listed under the Ramsar Convention in June 1990 (Government of Western Australia, 1990; Wetlands International, 2002).

The diversity and abundance of waterbirds on which the Ramsar nomination for the Vasse-Wonnerup wetlands is based, is dependent on phytoplankton, macroalgal and macrophyte (charophytes and aquatic angiosperms) communities. As such it is crucial that the quality of this food source be

maintained if waterbirds are to be conserved on the wetlands. Surveys to identify the major phytoplankton, macroalgal and macrophyte species and their distribution, and to provide an estimate of the quantity of plant material have been carried out in spring 2006, 2007 and 2008. This report extends this work to investigate these communities in late summer, at a time of low water level, and include another important waterbird food source: macroinvertebrates. Water quality and sediment samples were taken at various positions along the Vasse and Wonnerup Lagoons to determine areas of high nutrient concentration, with the potential to relate nutrient content of the water with the type of algae or macrophyte present. Comparisons are drawn between this and previous surveys.

2.0 Methods

2.1 Phytoplankton and water quality sampling

Phytoplankton and water quality sampling of the Vasse and Wonnerup Lagoons was conducted in February 2009 as a single snapshot survey. Sampling was carried out at two sites in Vasse Lagoon as well as one at Vasse gates and then, because the gates were open and marine water was flowing strongly into the estuary and would reflect oceanic conditions rather than estuarine, a second site further up the inlet channel at EVD was sampled on 24th February 2009 (see Figure 1). Two sites were sampled in the Wonnerup Lagoon and one at the Wonnerup Gates on the 24th February 2009 (Figure 1). Water samples were taken to identify phytoplankton species and quantity. Phytoplankton samples were fixed with Lugol's solution in the field and sent to Dalcon Environmental for identification. Chlorophyll *a* concentrations were analysed from GF/C filters (pore size 1.2 μm, Whatman Ltd. England) and inorganic nutrients from water filtered through 0.45 μm cellulose nitrate. Water samples were collected from the surface water of each site for the determination of ammonium, nitrate-nitrite, total nitrogen, filterable reactive phosphate, total phosphorus and chlorophyll *a*. A salinity sample was collected at each site and analysed with a Vista A366ATC refractometer (measurement range of 0 – 100 ppt) and a RHS-28 ATC (measurement range of 0 – 280 ppt). Samples were stored on ice for transport to the laboratory and then frozen until analysis.

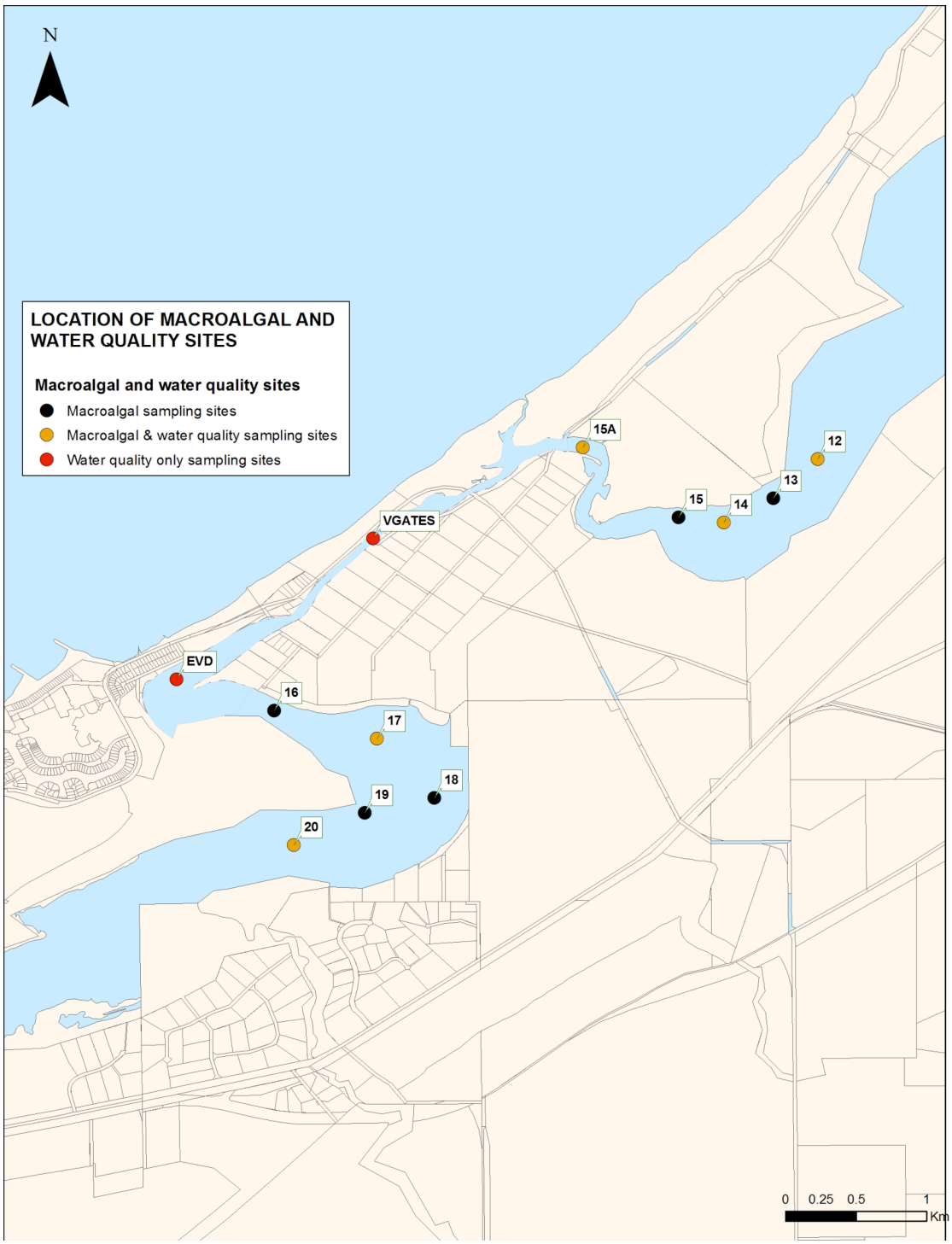

Figure 1: Location of macroaglal and water quality sites in the Vasse Wonnerup Wetland System, Busselton, Western Australia.

2.2 Sediment sampling

Sediment sampling was conducted at the same time as the water quality sampling at the same sites with the exception of Vasse Gates (Figure 1). At each site three replicate samples were gathered by gently pressing 9.4 cm diameter polycarbonate cores into the sediment so as not to disturb the fine organic surface layer. The 0 - 2 cm layer of the five replicate cores was then extruded, mixed and placed into polypropylene vials and stored on ice prior to being frozen at the end of each day.

2.3 Chemical analyses

All analyses were carried out by the Marine and Freshwater Research Laboratory. Chlorophyll *a* was extracted from filter papers kept for 24 hours in the dark at 4°C, after grinding in 90% acetone and measured spectrophotometrically (Varian Cary 50 Spectrophotometer; Greenberg *et al.*, 1992). This method does not detect picoplankton which is less than 0.8 µm in diameter.

Filterable reactive phosphorus was analysed by the ascorbic acid method (Johnson, 1982); nitrate plus nitrite by copper-cadmium reduction (Johnson, 1983) and ammonium by the alkaline phenate method (Switala, 1993). Total nitrogen and total phosphorus were determined from autoclave digests with potassium persulphate (Valderrama, 1981). Sediment samples were digested in concentrated sulphuric acid in the presence of a copper catalyst for total Kjeldahl nitrogen (TKN) and total Kjeldahl phosphorus (TKP). All analyses were carried out on a Lachat Quick-Chem 8000 Automated Flow Injection Analyser.

2.4 Submerged aquatic flora sampling

Submerged aquatic flora sampling of the Vasse and Wonnerup Lagoons was conducted in February 2009 as a single snapshot survey. Stratified sampling was carried out at five sites in the Vasse Lagoon on the 23rd February 2009 and five sites in the Wonnerup Lagoon on the 24th February 2009 (Figure 1). The reduction in sites was due to extremely low water levels rendering the majority of the lagoons dry. At each site, the percentage of aquatic plant cover was estimated and five replicate cores were collected using a perspex corer (9 cm diameter x 50 cm length). The core was pushed into the sediment surface over the benthic flora and sealed. Extracted plant material was sieved to remove excess sediment and the samples bagged for transport to the laboratory. At the laboratory, each sample was sorted into species categories, then dried at 70 °C until they had reached a constant weight. Dry weights were determined to two significant figures and species biomass was converted to grams per unit area (g m^{-2}). Estimates for biomass on the species presented are the mean of five replicates. Total biomass for an

individual site could vary significantly and standard errors calculated for particular sites were generally between 10 and 50% of the mean.

Aerial photographs of the Vasse – Wonnerup were taken on the day before the survey and were used to verify coverage of the macrophytes and macroalgae present at the time.

This report will use two terms to describe the aquatic flora present in the Vasse – Wonnerup wetlands. Macrophytes will be the term used to describe the aquatic angiosperm species *Ruppia megacarpa* and the green alga (Charophyte) *Lamprothamnium papulosum* (Wallroth) Groves. Charophytes are often treated separately to the rest of the green algae due to their superficial resemblance to flowering plants, however in this case it is due more to their importance as a food source to herbivorous birds. The other term used here is macroalgae, which will encompass the different (non-charophyte) green algae found in the Vasse-Wonnerup in February 2009. *Ulva* species were formerly *Enteromorpha* species (Hayden *et al*, 2003)

The term 'biomass' is used in two ways in this report; one refers to the amount of plant material over a given area (i.e. grams dry weight per m^2 or g dry wt m^{-2}), the other refers to the total amount of biomass estimated to be present in the Vasse or Wonnerup Lagoons on any particular sampling occasion (usually given in tonnes). For clarity, species names are only used when necessary, at all other times the plant types are referred to by their genus name.

2.5 Macroinvertebrate sampling

Macroinvertebrates sampling was conducted at the same time as the water quality sampling at the same sites with the exception of EVD and Vasse Gates (Figure 1). Macroinvertebrate sampling was problematical in the very shallow water and dense macroalgal beds present in the lagoons. For this reason samples were taken by two methods. Three replicate ten metre sweeps using a 0.3m wide sweep net (250µm mesh) were taken at each of the water quality sites in the lagoons (not gate sites). Resulting composite samples containing macroinvertebrates and algae were placed into vials and covered in 70% ethanol. Where algae was very dense and the efficacy of sweep samples were compromised, core samples (9.4cm ID) were also taken. The top five centimetres of sediment was extruded, placed into vials and covered in 70% ethanol. Both sweep and core samples were returned to the lab, sorted and macroinvertebrates identified to family and occasionally to species where there were multiple taxa from a single family. Abundance was estimated as orders of magnitude of individuals (1-10, 11-100. 101-1000 etc) per metre squared.

2.6 Data manipulation

Data manipulation and submerged aquatic flora distribution patterns were achieved using ArcView^{TM} mapping software. The overlay maps of catchment boundaries and streams were supplied by the Department of Water. For each site the biomass of each macroalgal and macrophyte species category was calculated (grams dry weight per metre squared). Maps of distribution patterns for each species were created using Spatial Analyst and interpolating to raster using the inverse distance weighted method. The area of each resulting biomass class was calculated by digitising the class polygon and using X Tools^{TM} to calculate each area. Biomass of the area was extrapolated from g dry wt m^{-2} to tonnes per estuary.

3.0 Results

Water levels were very low in the late summer sampling of 2009. Much of the Vasse and Wonnerup Lagoons were dry and the most of the remaining areas were very shallow (<0.3m depth). The extent of water can be seen as the area shaded green in Figure A2 in Appendix 1, together with the channels to the gates.

3.1 Phytoplankton and water quality in the Vasse Lagoon

Total nitrogen (TN), ammonium (NH_4), total phosphorus (TP), filterable reactive phosphorus (FRP) and chlorophyll *a* exceeded the ANZECC (2000) estuaries in south-west Australia trigger values of 750, 40, 30, 5 and 3 µg L^{-1} respectively at all sites (except Vasse Gates for TN and NH_4) in the Vasse Lagoon on the 23rd of February 2009 (Table 1). The highest total nitrogen concentration was recorded at near the entrance of the north-west channel (site 20 - 5300 µg L^{-1}). Site 17 had the highest concentrations of total phosphorus (500 µg L^{-1}) and filterable reactive phosphorus (120 µg L^{-1}) and was the only site in the estuary where nitrate exceeded the ANZECC (2000) trigger value of 45 µg L^{-1} at 110 µg L^{-1} (Table 1). At the ocean end of the north-west channel at Site EVD, the ammonium concentration was 660 µg L^{-1} and this site had the highest chlorophyll *a* at 120µg L^{-1} (Table 1).

The phytoplankton cell counts corresponded to chlorophyll *a* concentrations reasonably well except that site 17 had the highest phytoplankton cell counts, while site EVD had the highest chlorophyll *a* concentrations (Table 1). This may be due to disturbing the sediment during water quality sampling at Site EVD suspending benthic algae. The dominant phytoplankton at most sites were primitive, unicellular green algae of the class Prasinophyceae (66-76%), although at Site 17 Cryptophytes (motile, unicellular algae usually with two flagella) dominated at 76% of the count. At this site Prasinophytes still made up 21% of the phytoplankton community. At sites 17 and 20 the cyanobacteria *Oscillatoria* was present in trace amounts, while diatoms (Bacillariophyceae)

occurred at most sites. The Dinophyceae or dinoflagellates also occurred throughout the lagoon becoming more dominant near the ocean, representing 15% of the count at EVD and 22% at the Vasse gates (Appendix 1). None of the phytoplankton species identified were toxic during the February sampling occasion.

Salinities ranged from 40 g L^{-1} at the Vasse gates, which were open to the ocean at the time, increasing to 113 g L^{-1} at Site 20 (Table 1). Turbidity was very low perhaps due to the highly saline conditions flocculating particles.

Table 1: Nutrient concentrations of water collected from the Wonnerup (sites 11-15A, shaded) and Vasse (sites Vgates - 20) Lagoons on 23-24 February 2009. All nutrient concentrations were measured in µg L^{-1}, salinity in g L^{-1} and phytoplankton cell counts in cells mL^{-1}. Concentrations highlighted in bold were above the ANZECC (2000) trigger values for estuaries in south-western Australia. NH_4^+ = ammonium, NO_x = oxides of nitrogen (nitrate-nitrite), FRP = filterable reactive phosphorus, TN = total nitrogen, TP = total phosphorus and Chl *a* = chlorophyll *a*.

Site	NH_4^+	NO_x	FRP	TN	TP	Chl *a*	Cell Counts	Salinity	Turbidity NTU
12	**68**	14	**520**	**10000**	**1600**	**93**	32166	72	1.0
14	**43**	12	**220**	**4600**	**490**	**15**	14508	67	0.8
15A	**47**	3	**20**	**890**	**82**	**17**	24345	40	0.5
Vgates	14	13	**27**	680	**74**	**31**	2610	40	0.5
EVD	**660**	11	**76**	**2300**	**240**	**120**	14598	46	0.4
17	**49**	**110**	**120**	**4100**	**500**	**75**	46710	60	1.2
20	**44**	8	**12**	**5300**	**210**	**38**	18909	113	1.6

3.2 Phytoplankton and water quality in the Wonnerup Lagoon

Total nitrogen (TN), ammonium (NH_4), total phosphorus (TP), filterable reactive phosphorus (FRP) and chlorophyll *a* exceeded the ANZECC (2000) estuaries in south-west Australia trigger values of 750, 40, 30, 5 and 3 µg L^{-1} respectively at all sites in the Wonnerup Lagoon on the 24th of February 2009 (Table 1). All sites were below the ANZECC trigger value for nitrate-nitrite (45 µg L^{-1}). As seen in the Vasse Lagoon, the salinity in the Wonnerup Lagoon increased from the gates (40 g L^{-1} at Site 15A), which were open to the ocean at the time, to 72 g L^{-1} at Site 12 furthest from the ocean (Table 1). Turbidity was again low.

The dominant phytoplankton in the basin of the Wonnerup Lagoon were cryptophytes at 68%, with prasinophytes making up most of the rest of the community at 30-32%. The few percent left comprised diatoms and dinoflagellates. At the site near the gates (15A) prasinophytes made up 97% of the community with traces of diatoms, cryptophytes, dinoflagellates and the

green unicellular alga, *Dictyospharium*. None of the phytoplankton was reported as toxic during the February sampling occasion.

3.3 Sediment nutrient content in the Vasse and Wonnerup Lagoons

Total Kjeldahl nitrogen and total phosphorus concentrations were similar throughout the Vasse Estuary at approximately 5mg N/ g and 0.5 mg P/ g. Sediment nutrient concentrations were slightly lower in the Wonnerup Estuary at 1.4-2.0 mg N/ g and 0.3-0.4 mg P/ g except at Site 14 which had a extremely high concentration of both nitrogen and phosphorus (Table 2).

Concentrations were largely comparable to those sampled in February 2008 (Wilson *et al*, 2008b) except that site 12 in the Wonnerup Estuary had much lower concentrations (approx 3x lower) and EVD in the Vasse Estuary had concentrations approximately three times higher.

Table 2: Nutrient concentrations of sediment collected from the Wonnerup (sites 12-15A, shaded) and Vasse (sites EVD - 20) Lagoons on 23-24 February 2009.

Site	TKN (mg N/g)	TP (mg P/g)
12	1.4	0.30
14	11.0	1.20
15A	2.0	0.43
EVD	5.4	0.53
17	5.0	0.53
20	5.8	0.45

3.4 Macroalgal and macrophyte biomass and distribution in the Vasse Lagoon

Macroalgal biomass in the Vasse Lagoon was dominated by green algae (Chlorophyta) primarily *Cladophora vagabunda* (Linnaeus) van den Hoek with a total biomass of 152 tonnes representing 95% of the total macroalgal biomass (Figures 2 and A3 in Appendix 1). The other two macroalgal species present were *Ulva flexuosa* Wulfen and *Ulva paradoxa* (Dillwyn) Kuetzing. However, maximum biomass for both of these species was a fraction of that of *Cladophora* at 5.8 tonnes for *U. flexuosa* and 2.9 tonnes for *U. paradoxa* and less than 10 g dry wt m^{-2} (Figures 2 and A4 and A5 in Appendix 1). *Ulva* species combined made up 5% of the total macroalgal biomass in the Vasse Lagoon.

Areal biomass of the individual sampling sites ranged from 27 to 309 g dry wt m^{-2}. The maximum biomass recorded was for *Cladophora* at 299 g dry wt m^{-2} at site 18. There were no Phaeophyta (brown), Rhodophyta (red) or Cyanophyta (blue-green) algae recorded during this survey but epiphytic

growth, particularly on Cladophora at sites 17 and 18, was extensive and was comprised primarily of mixed diatoms.

The area of highest macroalgal biomass in the Vasse Lagoon in February 2009 was near the entrance of the north-west channel (sites 18 and 19). *Cladophora* dominated at the entrance of the north-west channel (sites 18 and 19), while highest *Ulva* biomass occurred at site 16 (*U. paradoxa*) and sites 17 and 18 (*U. flexuosa*) (Figures A3, A4 and A5 in Appendix 1).

No live macrophytes were found in the Vasse Lagoon although there was evidence of extensive beds that had died before sampling at Site 20 (Figures A1 and A2 in Appendix 1).

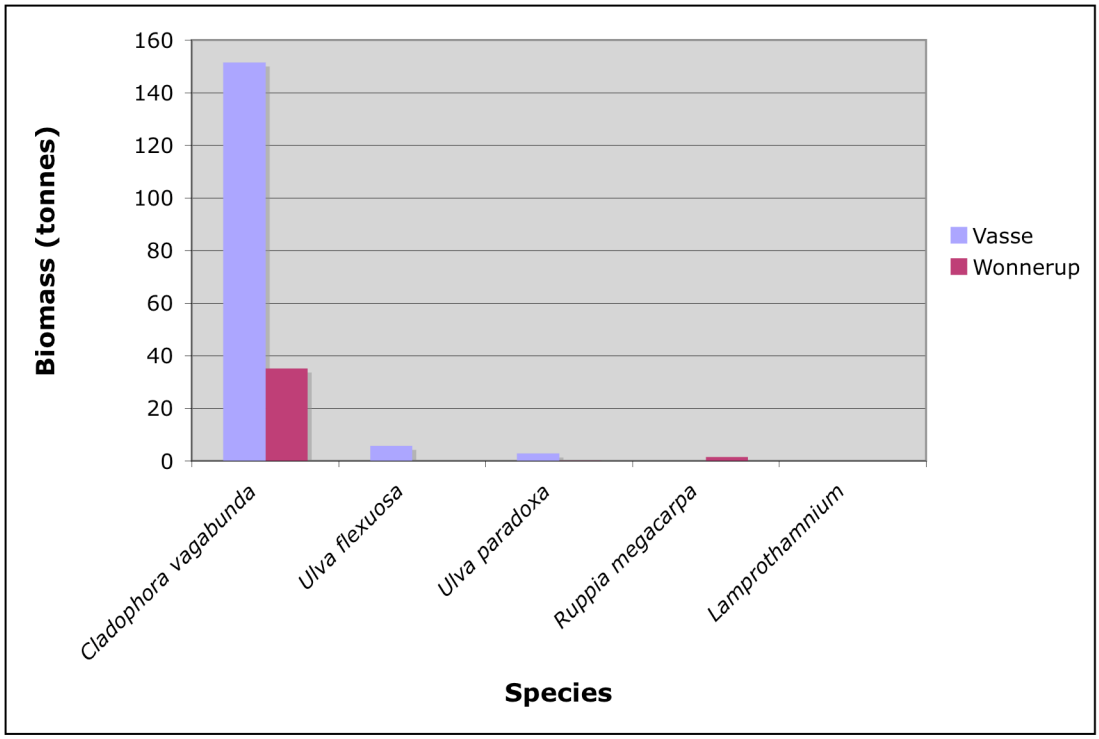

Figure 2: Total macrophyte (*Ruppia* and *Lamprothamnium*) and macroalgal (*Cladophora,* and *Ulva*) biomass (tonnes) in the Vasse and Wonnerup Lagoons, February 2009.

3.5 Macrophyte and macroalgal biomass and distribution in the Wonnerup Lagoon

The Wonnerup Lagoon was similarly dominated by Chlorophyta and again by *Cladophora vagabunda* (Linnaeus) van den Hoek with a total biomass of 35 tonnes representing 99% of the total macroalgal biomass and 98% of the combined macrophyte and macroalgal biomass (Figures 2 and A3 in Appendix 1). The total macroalgal biomass was less than a quarter of that in the Vasse Lagoon at 35.4 tonnes. The only other alga occurring was *Ulva paradoxa* at sites 13 and 14, with a maximum biomass of 3 g dry wt m^{-2} (Figures 2 and A5 in Appendix 1). Areal biomass of individual sampling sites

ranged from 58 to 466 g dry wt m^{-2}, the highest biomass occurring at site 12 furthest away from the gates, which was totally comprised of *Cladophora* (Figure A3 in Appendix 1).

Macrophyte biomass in the Wonnerup Lagoon was dominated by *Ruppia megacarpa* (Mason) at 1.6 tonnes, with traces of *Lamprothamnium papulosum* (Wallr.) J. Gr. occurring near the Wonnerup gates (1 g dry wt m^{-2}) (Figures 2 and A1 and A2 in Appendix 1). If the macrophyte biomass was incorporated with the macroalgal biomass, the macrophytes would comprise only 1.6 % of the total biomass of the Wonnerup Lagoon.

The highest density of seagrass was at the south western end, closest to the Wonnerup gates at site 15A where macrophyte biomass (20 g dry wt m^{-2}) was more than half macroalgal biomass at 38 g dry wt m^{-2}. Otherwise the lagoon was dominated by *Cladophora* with a small amount of *Ruppia* (11 g dry wt m^{-2}) at site 13 (Figures 2 and A1 and A2 in Appendix 1).

3.6 Macroinvertebrate distribution in the Vasse and Wonnerup Lagoons

The very high salinities (60-113 ppt) together with shallow water that became very warm during the day provided inhospitable conditions for macroinvertebrates in the Vasse Estuary. Despite this, at both sites 17 and 20, harpacticoid copepods and Ephydridae dipterans (fly larvae) were present, although not in large numbers (Table 3). Site 20 also had low numbers of midge larvae of the families Chironomidae and Tanyponidae. Large numbers of water flea eggs (Daphniidae) occurred at both sites, which would no doubt hatch once conditions became more favourable. The effects of declining conditions due to evapoconcentration could be seen in the number of dead organisms present, including large numbers of mussels (Hydriidae), snails (Hydrobiidae) and ostracods or seed shrimps (Cyprididae).

While conditions in the Wonnerup Lagoon were slightly more benign (salinities reaching only 72ppt) there was actually very little live macroinvertebrate fauna present except near the open gates (site 15A) where ocean water moderated salinities (40ppt) (Table 3). In the basin of the lagoon (sites 12 and 14), the only live fauna were low numbers of Cyclopoid copepods, seed shrimps (Ostracoda) and Ephydridae fly larvae. That conditions had previously been more favourable was shown in the large number of dead organisms including mussels (Hydriidae), snails (highly abundant *Coxiella striatula* and Hydrobiidae) and three species of ostracod. Not surprisingly, the highest diversity and abundance of macroinvertebrates was near the open gate of the Wonnerup Lagoon. Here there were large numbers of both cyclopoid and harpacticoid copepods and water flea (Daphniidae) eggs, and the presence of both polychaete and oligochaete worms, snails (Hydrobiidae), ostracods, amphipods and Ephydridae fly larvae.

CLASS and			Site 12 sweep		Site 12 Core		Site 14 sweep		Site 15A sweep		Site 17 sweep		Site 20 sweep		Site 20 Core	
Order	**Family**	**Species**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**
ANNELIDA Oligochaeta	Naididae (?)									*						
Polychaeta										*						
MOLLUSCA	Hydriidae				***						***					
Gastropoda	Pomatiopsidae	*Coxiella striatula*	****		****		****									
	Hydrobiidae				***				**	*	***		**			
CRUSTACEA Cladocera	Daphniidae (eggs)									***		**		***		***
Ostracoda	Cyprididae		**		**		**	**	**	*			**			
	Cyprididae	*Mytilocypris tasmanica chapmani*			***		**		**				**			
	Cyprididae	*M. ambiguosa*											**			
	Cyprididae	*Ilyodromus*	**													
Copepoda	Harpaticoid									***		**		*		
	Cyclopoid			**						***						
Amphipoda	Ceinidae									*						
INSECTA Diptera	Ephydridae							**		*		**		**		
	Chironomidae													*		
	Tanyponidae													**		

Table 3: Macroinvertebrate diversity and abundance in the Vasse-Wonnerup estuary. Sites 12-15A in the Wonnerup estuary. sites 17 and 20 in the Vasse Estuary.
Key: * = 1-10 individuals, ** = 10-100, *** 100-1000, **** = >1000 individuals per square metre.

3.7 Comparisons of macrophyte and macroalgal biomass between late summer 2009 and spring 2006- 2007

The primary difference between the previous spring sampling events and the late summer sampling in 2009, apart from seasonal differences (which are important particularly to macrophyte life cycles) was the markedly reduced area and depth of water. This resulted in a decrease in the overall biomass present in the lagoons but also a change in species dominance. All macrophyte species (including the charophyte, *Lamprothamnium papulosum*) were absent from the Vasse Lagoon in 2009 and were restricted to the site nearest the gates in the Wonnerup Estuary where nutrient and salinity concentrations were lowest (Table 1). As in previous years, macrophytes did not occur in any location where TP was greater than 150µg L^{-1}. Site 15A at the Wonnerup gates was the only site sampled for flora that had a TP concentration less than 150µg L^{-1}. TN:TP ratios were also highest at this site, being >10, as has been found to be the macrophyte preference in previous years (Wilson *et al*, 2007, 2008a).

Macroalgal dominance also changed between Spring 2006 and 2007 and the 2009 sampling. In previous spring sampling, *Ulva spp.* dominated and while they were still present in late summer 2009, they were in low abundance. Instead a previously minor species, *Cladophora vagabunda,* strongly dominated both lagoons at 95-99% of the biomass.

Table 3: Biomass (tonnes) of the different types of macroalgae or macrophytes of the Vasse and Wonnerup Lagoons between the two surveys 2006 and 2007.

	Spring 2006		Spring 2007		Late summer 2009	
	Vasse	**Wonnerup**	**Vasse**	**Wonnerup**	**Vasse**	**Wonnerup**
Ruppia	141	26	105	16	0	1.6
Lepilaena	10	2.5	33	7.3	0	0
Lamprothamnium	5	61.5	27.6	58.5	0	0.04
Cladophora	1.5	8	31	0	152	35
Ulva	175	62	72.6	10.6	8.7	0.3
Rhizoclonium	1	3.7	0	33.5	0	0

4.0 Discussion

4.1 Water quality and sediment nutrient concentrations

The reduction in the area and depth of the water in both lagoons due to evapoconcentration resulted in the concentration of nutrients and salt in the water column. The water quality in both the Vasse and Wonnerup Lagoons would be considered hypereutrophic except near the gates. The entire system was hypersaline, with minimum salinities being 5ppt greater than seawater (40ppt) and maximum salinities being more than three times seawater (113 ppt). This provided an extreme environment inhospitable to most forms of life, resulting in reduced biodiversity and abundances.

The evapoconcentration affected the nutrient content of the water with all forms of nitrogen and phosphorus (except nitrate) and chlorophyll *a* exceeding ANZECC guidelines at all sites in both the Vasse and Wonnerup Lagoons except at Vasse Gates, which were open to the ocean but still exceeded ANZECC guidelines for all nutrients but TN and NH_4. Both nutrient concentration and salinity increased with distance from the gates with concentrations reaching up to 100x ANZECC trigger values at site 12 in the Wonnerup Estuary and seven times guidelines at Vasse site 20. This corresponds to previous years, which indicate the Wonnerup to be the more eutrophic of the two estuaries (*Wilson et al* 2007, 2008a).

Highest sediment nutrients were found at Site 14 in the Wonnerup Lagoon. There was no correlation between sediment and water nutrients or macroalgal or macrophyte abundance. Concentrations were comparable to those sampled in February 2008.

4.2 Phytoplankton

Despite very high chlorophyll *a* concentrations across both estuaries, but particularly in the Vasse Lagoon and at the site (12) furthest from the gates in the Wonnerup Lagoon, the types of algae present were non-toxic and benign. Phytoplankton was dominated by prasinophytes and cryptophytes with some dinoflagellates and diatoms. These groups are all very small-celled taxa that may allow them better adaptation to the high salinities. All these groups are common in marine systems (S.Helleren, pers comm..12June 2009) Trace amounts of the cyanobacteria, *Oscillatoria*, occurred in the Vasse Estuary away from the gates. This species composition is quite different to the phytoplankton present in Spring 2007, which was dominated by cyanobacteria and to a lesser extent by green algae (Chlorophyta) (*Wilson et al*, 2008a).

4.3 Macroalgae and Macrophytes

The absence of macrophytes except near the open gates of the Wonnerup Lagoon is likely to be the combined effect of season, high salinities and

extremely high nutrient concentrations. Many macrophyte species die back after flowering in summer but even if they maintained a population the salinities present in both lagoons exceed their tolerances. *R. megacarpa* will survive in water with salinities up to 46 ‰ (Brock, 1982) while *L. papulosum* has been found in salinities varying from nearly fresh to twice that of seawater (Bisson and Kirst, 1980), however it does not grow satisfactorily at salinities of over 60 ‰ (Delroy 1974). As in previous surveys, no macrophytes were present when TP exceeded 150μg L^{-1} (*Wilson et al* 2007, 2008a) and this excluded all sites where flora were surveyed except the Wonnerup gates. Over this concentration macroalgae appear to have a competitive advantage, taking up nutrients more effectively through their thalli while macrophytes rely more strongly on their roots for nutrient uptake (Carignan and Kalff, 1980).

Cladophora vagabunda is able to tolerate high salinities with values of up to 65ppt recorded in the literature (Gordon 1981, Rani 2007) and up to 100ppt for some species of *Cladophora* (Dodds and Gudder, 1992). No records of the maximum salinity tolerance specifically for *C. vagabunda* could be found although this study found it alive, if stressed, at Site 20 at 113 ppt. In contrast *Ulva* species such as *U. intestinalis,* closely related to *U. flexuosa*, while also able to tolerate high salinities, are thought to be more competitive at lower salinities (< 35ppt, Fong et al 1996). Lavery et al (1991) found *Cladophora sp.* to have twice the rate of photosynthetic production than *Ulva sp.* in trials with species from the Peel Harvey Estuary. These two factors would explain the relative dominance in the Vasse-Wonnerup, as most of the basin of both lagoons was at 40-70ppt.

The maximum biomass of *Cladophora* in this survey (466 g m^{-2}) though higher than previous spring studies per unit area (up to 268 g m^{-2} - *Wilson et al* 2007, 2008a) was considerably less than maximum values obtained in the Peel Harvey Estuary at 4400 g m^{-2} – Lavery *et al*, 1991). Importantly, despite high chlorophyll *a* and nutrient concentrations, the Vasse and Wonnerup Lagoons were dominated by macroalgae, not toxic cyanobacterial blooms.

4.4 Macroinvertebrates

The hypersaline conditions of the Vasse Wonnerup Estuary in February 2009 resulted in poor macroinvertebrate biodiversity and abundance. The solar heating of the shallow water resulting in high temperatures, and the large amount of biotic material, would likely result in very low oxygen content, further impeding the survival of fauna. Not surprisingly then there was little live fauna and a large proportion of dead animals in all sites surveyed except at the ocean gates where marine water reduced temperature and salinity.

Taxa surviving in the basins of both Vasse and Wonnerup Lagoons were reduced to a few specimens of copepods, fly larvae, midge larvae and seed shrimps, occurring sporadically at different sites; all species that occur in

saline systems (K. Strehlow pers comm. 2nd June 2009). The more benign conditions at the Wonnerup gate meant that nearly all these taxa were found, with the addition of oligochaete and polychaete worms, Hydrobiidae snails, Ceindae amphipods and large numbers of Daphniidae eggs.

There were small differences in the taxa present in the two lagoons. Daphniidae eggs were abundant in the Vasse Estuary but only present at the gates of the Wonnerup Estuary. Hapacticoid copepods were present in the Vasse, while cyclopoid copepods occurred in the Wonnerup Lagoon. Midge larvae (Chironomidae and Tanyponidae) where only found in the Vasse Lagoon. Dead Coxiella snails occurred in vast numbers only in the Wonnerup Lagoon. There was no macroinvertebrate life in the Wonnerup Lagoon apart from one site with a few cyclopoid copepods (site 12) and a few Ostracods (Cypridae) at Site 14.

The reduction in macroinvertebrate fauna is shown by comparing this data to sampling in spring (16 November) 2008 in the Vasse Lagoon close to sites 17 and 18, carried out by Adrian Pinder (Department of Conservation and Environment, unpublished data). While midge larvae (Chironomidae and Tanyponidae), Cladocerans and Hapacticoid copepods were also found in the spring sampling additionally calanoid and cyclopoid copepods, ostracods, oligochaete worms, palaemonid shrimps, amphipods and a number of beetle families were also found.

5.0 Conclusion

The Vasse-Wonnerup Lagoons in February 2009 were both highly eutrophic and hypersaline. This resulted in a strong reduction in biodiversity with >95% of the biomass of both macroalgae and macrophytes being dominated by the one species of green alga, *Cladophora vagabunda* and macroinvertebrate abundance reduced to a few specimens of copepods, fly larvae, midge larvae and seed shrimps. The large number and diversity of dead macroinvertebrates indicated the inhospitable conditions present in the lagoons. The only sites showing biodiversity and abundance of both flora and fauna were next to the open gates of both lagoons where dilution of salt and nutrients by ocean water improved conditions, although these sites were still eutrophic and hypersaline.

6.0 Acknowledgements

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7.0 References

ANZECC (2000). *Australian Water Quality Guidelines for Fresh and Marine Waters.* Volume 1, The guidelines/Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand. (National water quality management strategy; no.4).

Bisson, M.A. and Kirst, G.O. (1980). *Lamprothamniim* a Euryhaline Charophyte. I. Osmotic relations and membrane potential at steady state. *J. Exp. Botany* **31**:1223 – 1235.

Brock, M.A. (1982). Biology of the salinity tolerant genus *Ruppia* L. in the saline lakes in South Australia I. Morphological variation within and between species and ecophysiology. *Aquatic Botany* **13**: 219-248.

Carignan R. and Kalff J. (1980) Phosphorus Sources for Aquatic Weeds: Water or Sediments? *Science, New Series,* **207 (4434):** 987-989

Delroy, L.B. (1974). The food of waterfowl (Anatidae) in the southern Coorong saltwater habitats of South Australia. *J. S. Aust. Ornithol. Assoc.* **26:** 157-163.

Department of Environment. (2004). Aggregated Emissions of Total Nitrogen and Total Phosphorus to the Vasse-Wonnerup Catchment, Western Australia.

Dodds, W.K. and Gudder, D.A (1992) The Ecology of *Cladophora. J. Phycol* **28**: 415-427

English, L. B. (1994). Country Drainage – Busselton Drainage District. *Water Authority of Western Australia, Pub. No. RS0042.*

Fong P., Boyer K.E., Desmond, J.S. and Zedler, J.B. (1996) Salinity stress, nitrogen competition, and facilitation: what controls seasonal succession of two opportunistic green macroalgae? *J. Exp. Mar. Biol and Ecol.* **206**: 203-221

Gordon, D.M. (1981) The autecology of *Cladophora* in The Peel_Harvey Estuarine System, Western Australia. PhD thesis, Department of Botany, the University of Western Australia.

Government of Western Australia (1990). *Wetlands nominated by the Government of Western Australia for inclusion on the List of Wetlands of International Importance, Ramsar Convention.* Nominating document prepared by WA Department of Conservation and Land Management, Perth. 43pp.

Greenberg, A.E., Clesceri, L.S. and Eaton, A.D. (1992). *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, Maryland, USA.

Hayden, H.S., Blomster, J. Maggs, C.A., Silva, P.C., Stanhope, M.J. and Waaland, J.R. (2003). Linnaeus was right all along: *Ulva* and *Enteromorpha* are not distinct genera. *Eur. J. Phycol.* **38:** 277 – 294.

Johnson, K.S. (1982). Determination of phosphate in seawater by flow injection analysis with injection of reagent. *Anal Chem*. **54**: 1185-1187.

Johnson, K.S. (1983). Determination of nitrate and nitrite in seawater by flow injection analysis with injection of reagent. *Limnology and Oceanography*. **28(6):** 1260-1266.

Lavery, P. S. Lukatelich, R.J. and McComb, A.J. (1991). Changes in the biomass and species composition of macroalgae in a eutrophic estuary. *Est. Coastal Shelf Sci*. **33:** 1-22.

McAlpine, K. W., Spice, J. F. and Humphries, R. (1989). The Environmental Condition of the Vasse Wonnerup Wetland System and a Discussion of Management Options. Environmental Protection Authority, Perth, W.A. *Technical Series No. 31, May 1989.*

Rani, G. (2007) Changes in protein profile and amino acids in *Cladophora vagabunda* (Chlorophyceae) in response to salinity stress. *J. Appl. Phyco*l **19**: 803–807

Sinclair, Knight, Merz (2003). Integrated Nearshore Marine Monitoring Program for Southern Geographe Bay. *Report to the Water Corporation of Western Australia.*

Switala, K. (1993). *Determination of ammonia by flow injection analysis colorimetry (dialysis)*. Latchet Instruments, Milwaukee, USA.

Valderrama, J. (1981). The simultaneous analysis of total nitrogen and total phosphorus in natural waters. *Marine Chemistry*. **10:** 109 – 122.

Wetlands International (2002). *Ramsar Sites: Directory and Overview, a guide to the Ramsar Convention's Wetlands of International Importance*. Global Series 13, WI, Wageningen, The Netherlands.

Wilson, C. Chambers, J.M. and Paling, E.I (2007) Snapshot Survey of the Distribution and Abundance of the Macroalgae and Macrophytes of the Vasse – Wonnerup Lagoons (Report No. MAFRA 07/1) Murdoch University, Murdoch WA 6150

Wilson, C. Chambers, J.M., Clarke A. and Paling, E.I (2008a) Snapshot Survey of the Distribution and Abundance of the Macrophytes, Macroalgae and Phytoplankton of the Vasse – Wonnerup Lagoons 2007. (Report No. MAFRA 08/1) Murdoch University, Murdoch WA 6150

Wilson, C. Chambers, J.M., Wienczugow, K. and Paling, E.I (2008b) Sediment Characterisation of the Vasse – Wonnerup Lagoons 2008. (Report No. MAFRA 08/4) Murdoch University, Murdoch WA 6150

Appendix 1: Distribution maps of the macrophytes and macroalgae in the Vasse – Wonnerup Wetland System in February 2009. To interpret the maps is important to look at the biomass classes (g dry wt m^{-2}). This scale shows six classes. Note that each map will have a different biomass scale, so for comparisons between maps it is necessary to ensure that the scaling is taken into account. Therefore, an area shaded in red on one map may represent ten times the biomass of a particular macroalgal species compared to that on another.

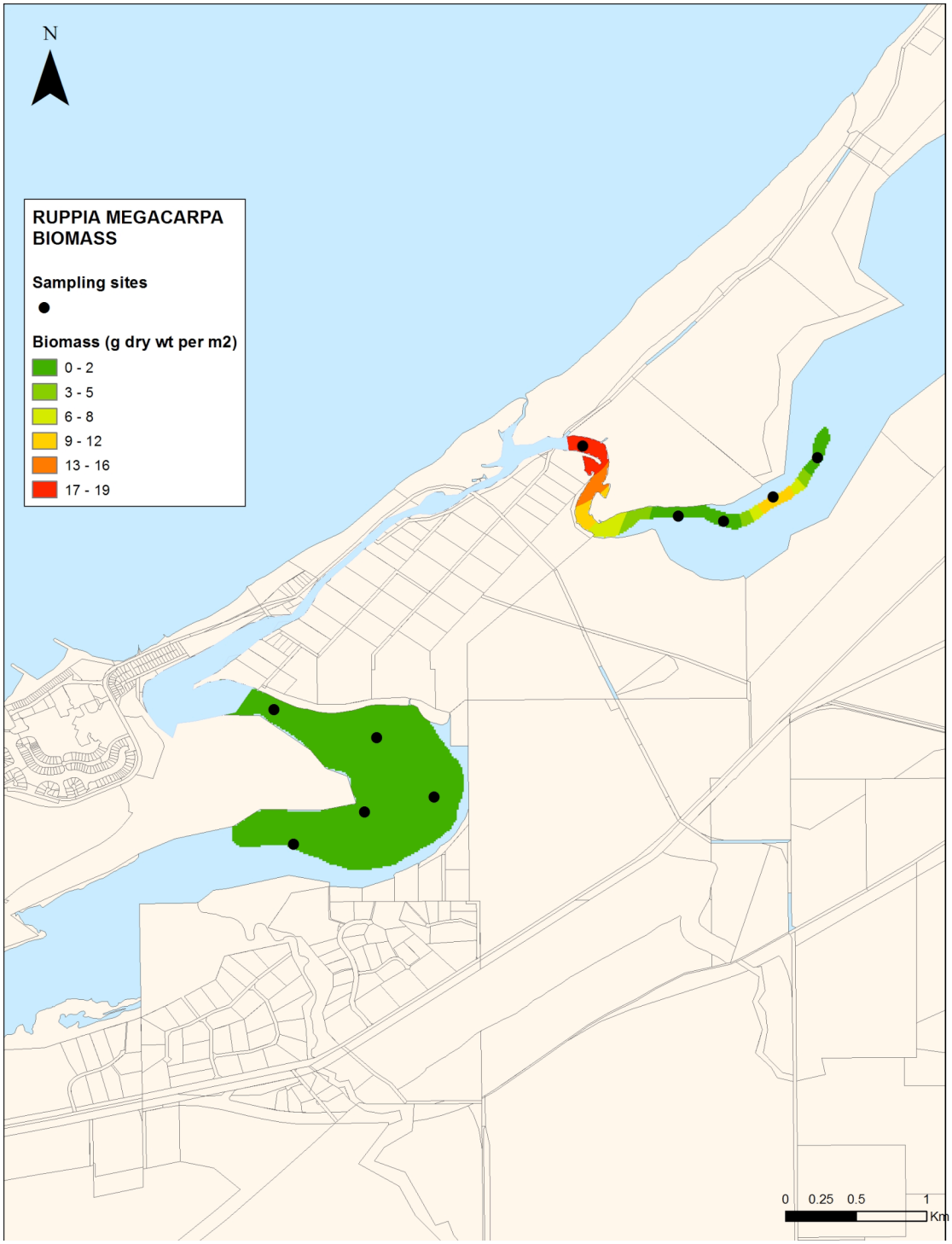

Figure A1: Distribution of *Ruppia megacarpa* biomass (g dry wgt m^2) in the Vasse Wonnerup Wetland System, Busselton, Western Australia.

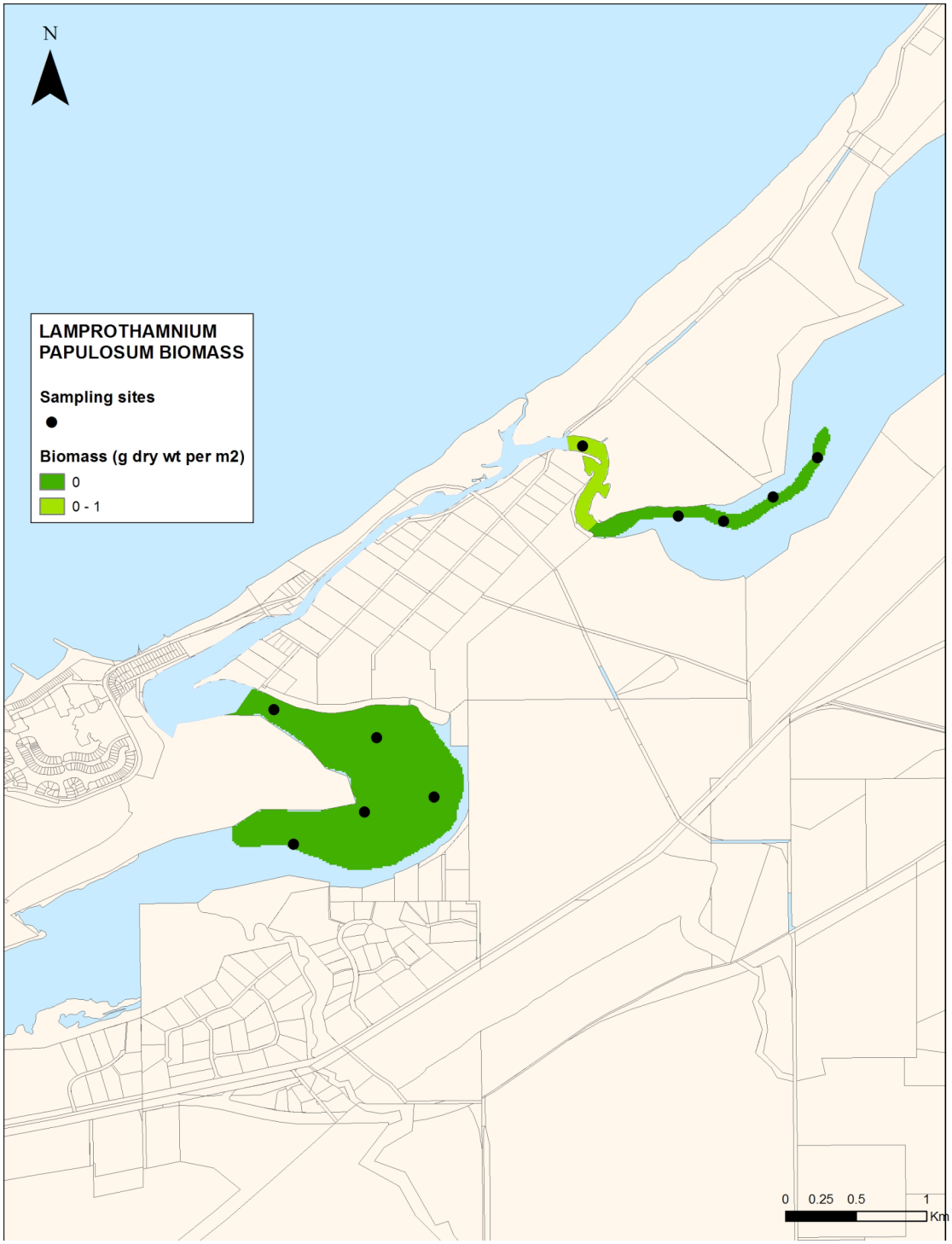

Figure A2: Distribution of *Lamprothamnium papulosum* biomass (g dry wgt m^2) in the Vasse Wonnerup Wetland System, Busselton, Western Australia.

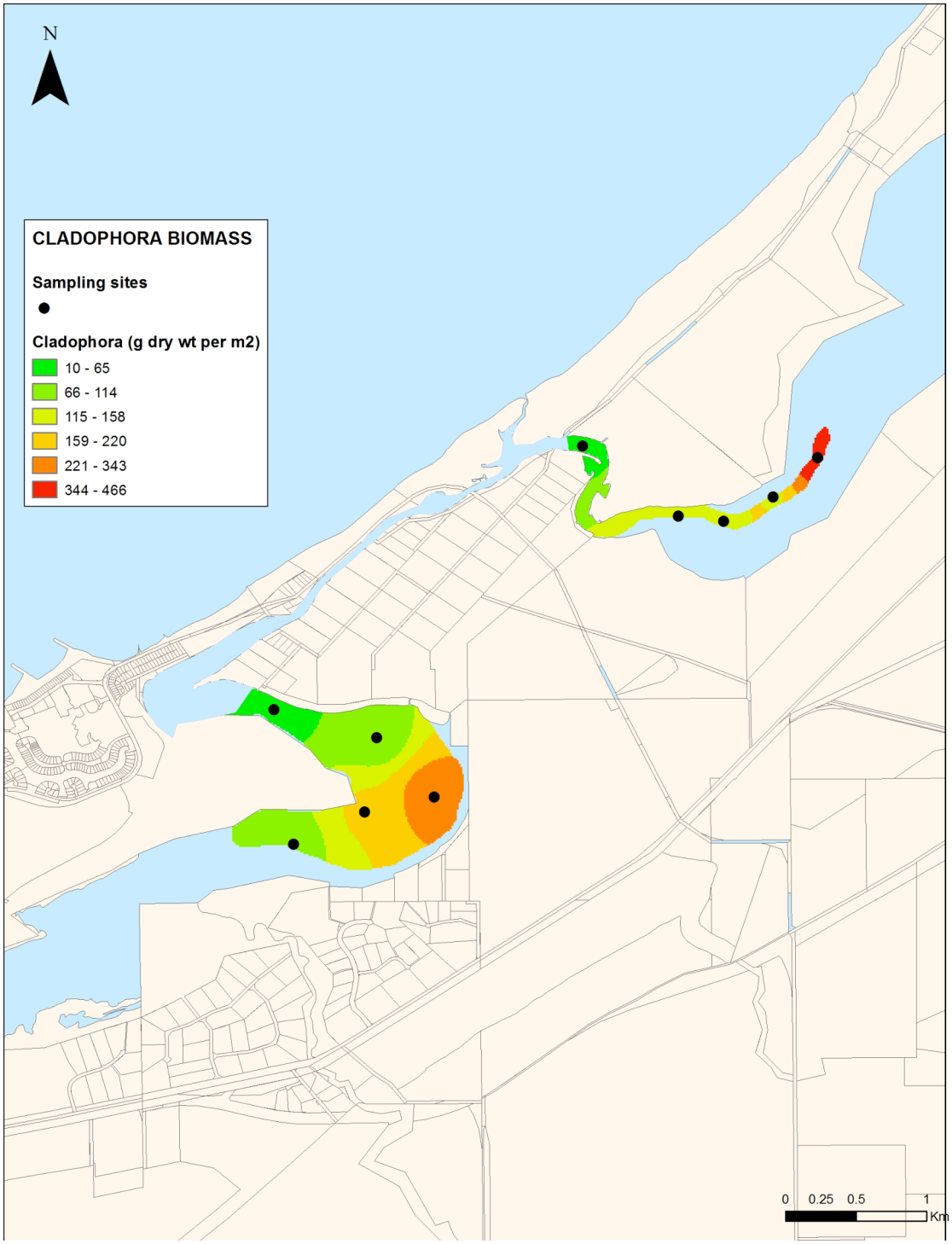

Figure A3: Distribution of *Cladophora vagabunda* biomass (g dry wgt m^2) in the Vasse Wonnerup Wetland System, Busselton, Western Australia.

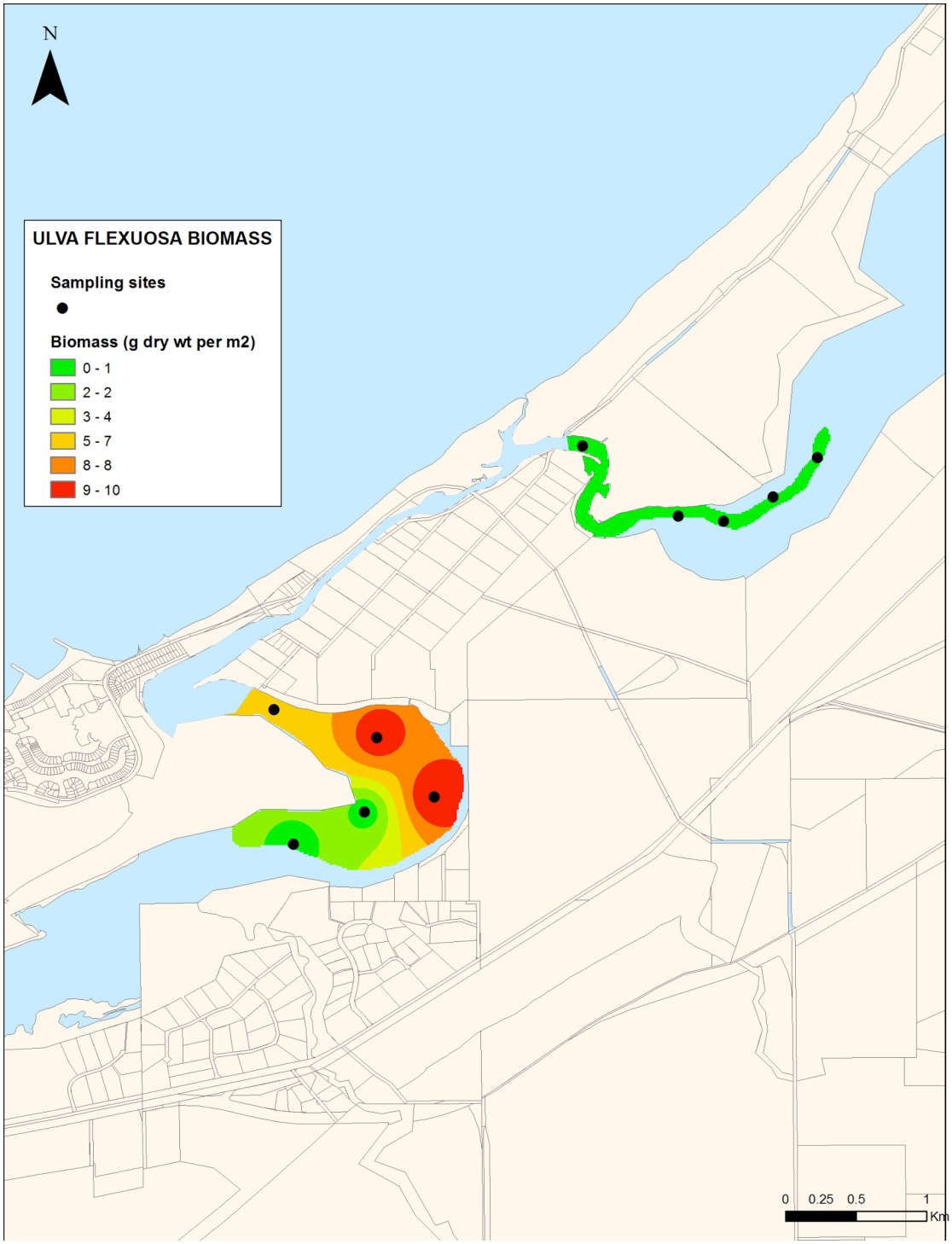

Figure A4: Distribution of *Ulva flexuosa* biomass (g dry wgt m^2) in the Vasse Wonnerup Wetland System, Busselton, Western Australia.

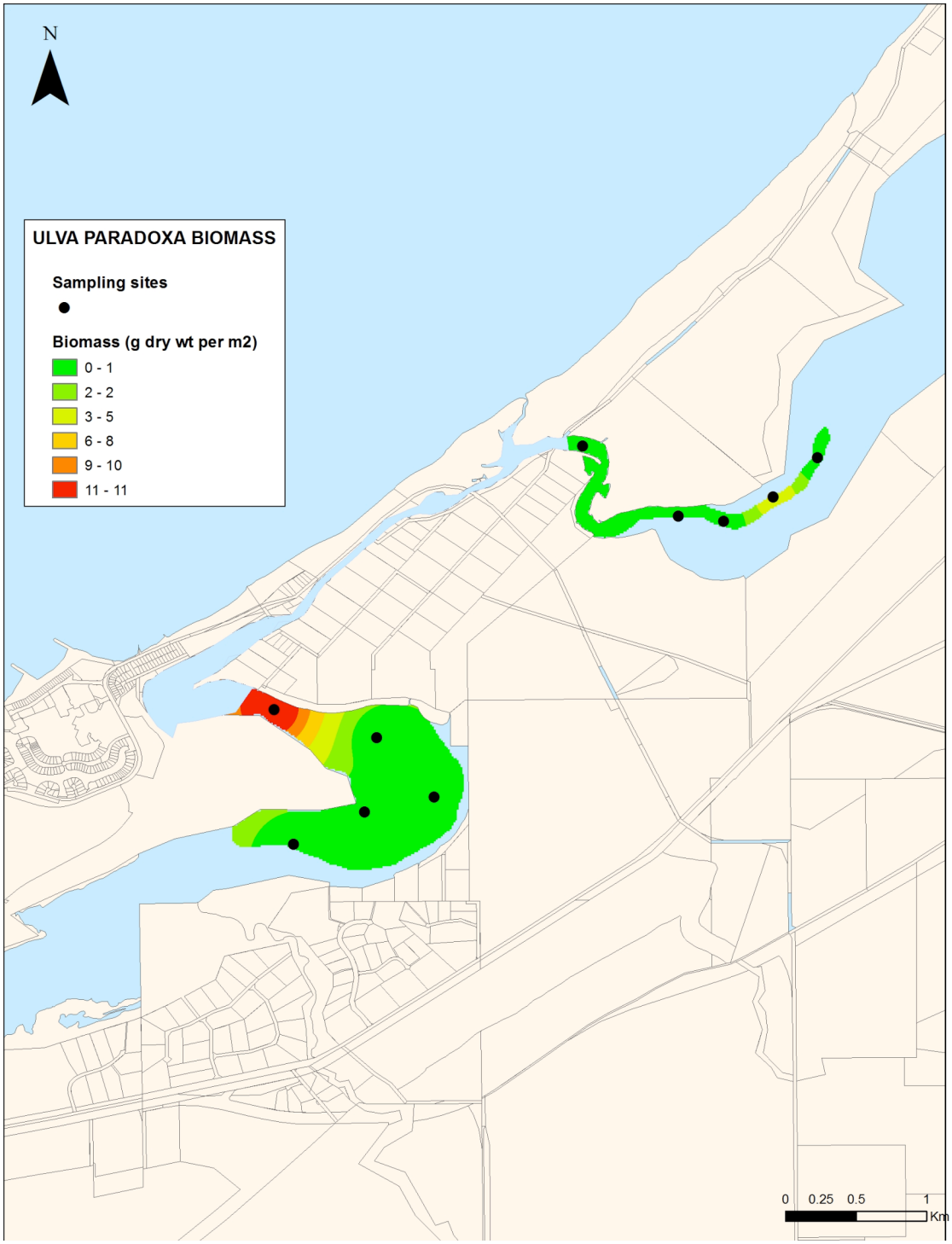

Figure A5: Distribution of *Ulva paradoxa* biomass (g dry wgt m^2) in the Vasse Wonnerup Wetland System, Busselton, Western Australia.

Appendix 2: DALCON phytoplankton identification and cell count report

Dalcon Environmental

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DATA REPORT

Project
MUVWE
Vasse-Wonnerup Estuary

Customer
Dr Jane Chambers
Environmental Science
Murdoch University
South Street, Murdoch, WA 6150

Analyst ID
stuart

DSID
7085

Report Date
26/05/2009

Batch Number
090302145634

Sample ID
4 EVD

Date Collected
24/02/2009

Monitoring Point
4 EVD

Sample Type
Phytoplankton

Date Received
2/03/2009

Functional Location ID
4 EVD

Method (Detection Limit)
SRC CAMP (9)

Analysis Date
26/05/2009

Units Reported Cell Density:cells mL^{-1}

Biovolume: mm^3 L^{-1}

%: Percentage of total cells counted

Sampler Notes

Laboratory Notes

Field Data Recording

Total Density
14,598.0 cells mL^{-1}

Total Counted
1,622

Uncertainty
5.0%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Achnanthes sp. 002	108		0.74
Amphora sp. 002	126		0.86
Chaetoceros socialis	135		0.92
Cocconeis heteroidea	198		1.36
Diatom 018	126		0.86
	693	**0.0000**	**4.75**
Cryptophyceae			
Cryptophyte 006	387		2.65
	387	**0.0000**	**2.65**
Dinophyceae			
Heterocapsa sp. 001	576		3.95
Scrippsiella trochoidea	1,557		10.67
	2,133	**0.0000**	**14.61**
Prasinophyceae			
Prasinophyte 001	657		4.50
Tetraselmis sp. 001	9		0.06
	666	**0.0000**	**4.56**

Species Name	Density	BioVolume	%
Raphidiophyceae			
Chattonella sp. 001	10,719		73.43
	10,719	**0.0000**	**73.43**

End Of Report

This report contains coloured shading. Dalcon Environmental intends that this report be viewed and/or printed in colour.

Dalcon Environmental Pty Ltd makes no claim that the taxa list provided herein is exhaustive. Some taxa, including potentially problematic taxa, may be present in the sample but not recorded during analysis, this is particularly the case for small or inconspicuous taxa or taxa present in low numbers. Guidance presented herein is based on published research , whilst Dalcon Environmental make every attempt to remain up to date, it is possible that scientific consensus may differ from that presented herein.

Shading Key
Potentially toxic species

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DATA REPORT

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Analyst ID
stuart

DSID
7081

Report Date
26/05/2009

Batch Number
090302145634

Sample ID
11

Date Collected
24/02/2009

Monitoring Point
11

Sample Type
Phytoplankton

Date Received
2/03/2009

Functional Location ID
11

Method (Detection Limit)
SRC CAMP (9)

Analysis Date
25/05/2009

Units Reported: Cell Density:individuals mL^{-1} | Biovolume: $mm^3 L^{-1}$ | %: Percentage of total cells counted

Sampler Notes

Laboratory Notes

Field Data Recording

Total Density
32,166.0 individuals mL^{-1}

Total Counted
3,574

Uncertainty
3.3%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Amphora sp. 002	9		0.03
Cylindrotheca closterium	18		0.06
Diatom 010	27		0.08
Diatom 018	9		0.03
Diatom 019	18		0.06
	81	**0.0000**	**0.25**
Cryptophyceae			
Cryptophyte 006	21,699		67.46
	21,699	**0.0000**	**67.46**
Dinophyceae			
Heterocapsa sp. 001	9		0.03
Torodinium sp. 001	18		0.06
	27	**0.0000**	**0.08**
Prasinophyceae			
Prasinophyte 001	10,359		32.20
	10,359	**0.0000**	**32.20**

Species Name	Density	BioVolume	%

End Of Report

Shading Key
Potentially toxic species

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Analyst ID
stuart

DSID
7082

Report Date
26/05/2009

Batch Number
090302145634

Sample ID
14

Date Collected
24/02/2009

Monitoring Point
14

Sample Type
Phytoplankton

Date Received
2/03/2009

Functional Location ID
14

Method (Detection Limit)
SRC CAMP (9)

Analysis Date
26/05/2009

Units Reported Cell Density:cells mL^{-1}

Biovolume: $mm^3 L^{-1}$

%: Percentage of total cells counted

Sampler Notes

Laboratory Notes

Field Data Recording

Total Density
14,508.0 cells mL^{-1}

Total Counted
1,612

Uncertainty
5.0%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Amphora sp. 002	27		0.19
Cocconeis heteroidea	9		0.06
Cylindrotheca closterium	297		2.05
	333	**0.0000**	**2.30**
Cryptophyceae			
Cryptophyte 006	9,837		67.80
	9,837	**0.0000**	**67.80**
Prasinophyceae			
Prasinophyte 001	4,329		29.84
Tetraselmis sp. 001	9		0.06
	4,338	**0.0000**	**29.90**

End Of Report

Shading Key

Species Name	Density	BioVolume	%

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Potentially toxic species

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DATA REPORT

Project
MUVWE
Vasse-Wonnerup Estuary

Customer
Dr Jane Chambers
Environmental Science
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South Street, Murdoch, WA 6150

Analyst ID
stuart

DSID
7080

Report Date
26/05/2009

Batch Number
090302145634

Sample ID
15A

Date Collected
24/02/2009

Monitoring Point
15A

Sample Type
Phytoplankton

Date Received
2/03/2009

Functional Location ID
15A

Method (Detection Limit)
SRC CAMP (9)

Analysis Date
25/05/2009

Units Reported Cell Density:cells mL^{-1}

Biovolume: mm^3 L^{-1}

%: Percentage of total cells counted

Sampler Notes

Laboratory Notes

Field Data Recording

Total Density
24,345.0 cells mL^{-1}

Total Counted
2,705

Uncertainty
3.8%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Achnanthes sp. 002	9		0.04
Amphora sp. 002	9		0.04
Chaetoceros socialis	189		0.78
Cocconeis heteroidea	9		0.04
	216	**0.0000**	**0.89**
Chlorophyceae			
Dictyosphaerium sp. 001	99		0.41
	99	**0.0000**	**0.41**
Cryptophyceae			
Cryptophyte 001	207		0.85
	207	**0.0000**	**0.85**
Dinophyceae			
Heterocapsa sp. 001	45		0.18
Protoperidinium sp. 006	9		0.04
Torodinium sp. 001	9		0.04
	63	**0.0000**	**0.26**
Prasinophyceae			

Species Name	Density	BioVolume	%
Prasinophyte 001	23,760		97.60
	23,760	**0.0000**	**97.60**

End Of Report

This report contains coloured shading. Dalcon Environmental intends that this report be viewed and/or printed in colour.

Dalcon Environmental Pty Ltd makes no claim that the taxa list provided herein is exhaustive. Some taxa, including potentially problematic taxa, may be present in the sample but not recorded during analysis, this is particularly the case for small or inconspicuous taxa or taxa present in low numbers. Guidance presented herein is based on published research , whilst Dalcon Environmental make every attempt to remain up to date, it is possible that scientific consensus may differ from that presented herein.

Shading Key
Potentially toxic species

Dalcon Environmental

www.dalconenvironmental.com.au

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Inglewood, WA 6053

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DATA REPORT

Project
MUVWE
Vasse-Wonnerup Estuary

Customer
Dr Jane Chambers
Environmental Science
Murdoch University
South Street, Murdoch, WA 6150

Analyst ID
stuart

DSID
7084

Report Date
26/05/2009

Batch Number
090302145634

Sample ID
17

Date Collected
24/02/2009

Monitoring Point
17

Sample Type
Phytoplankton

Date Received
2/03/2009

Functional Location ID
17

Method (Detection Limit)
SRC CAMP (9)

Analysis Date
25/05/2009

Units Reported Cell Density:cells mL^{-1}

Biovolume: $mm^3 L^{-1}$

%: Percentage of total cells counted

Sampler Notes

Laboratory Notes

Field Data Recording

Total Density
46,710.0 cells mL^{-1}

Total Counted
5,190

Uncertainty
2.8%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Achnanthes sp. 002	153		0.33
Amphora sp. 002	81		0.17
Chaetoceros socialis	162		0.35
Cocconeis heteroidea	36		0.08
Diatom 018	243		0.52
	675	**0.0000**	**1.45**
Cryptophyceae			
Cryptophyte 006	35,640		76.30
	35,640	**0.0000**	**76.30**
Cyanobacteria			
Oscillatoria sp. 002	657		1.41
	657	**0.0000**	**1.41**
Dinophyceae			
Heterocapsa sp. 001	54		0.12
	54	**0.0000**	**0.12**
Prasinophyceae			
Prasinophyte 001	9,576		20.50

Species Name	Density	BioVolume	%
Tetraselmis sp. 001	63		0.13
Tetraselmis sp. 002	45		0.10
	9,684	**0.0000**	**20.73**

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Shading Key
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DATA REPORT

Project
MUVWE
Vasse-Wonnerup Estuary

Customer
Dr Jane Chambers
Environmental Science
Murdoch University
South Street, Murdoch, WA 6150

Analyst ID
stuart

DSID
7083

Report Date
26/05/2009

Batch Number
090302145634

Sample ID
20

Date Collected
24/02/2009

Monitoring Point
20

Sample Type
Phytoplankton

Date Received
2/03/2009

Functional Location ID
20

Method (Detection Limit)
SRC CAMP (9)

Analysis Date
25/05/2009

Units Reported Cell Density:cells mL^{-1}

Biovolume: $mm^3 L^{-1}$

%: Percentage of total cells counted

Sampler Notes

Laboratory Notes

Field Data Recording

Total Density
18,909.0 cells mL^{-1}

Total Counted
2,101

Uncertainty
4.4%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Amphora sp. 002	261		1.38
Cylindrotheca closterium	2,709		14.33
Synedra sp. 002	387		2.05
	3,357	**0.0000**	**17.75**
Cryptophyceae			
Cryptophyte 006	495		2.62
	495	**0.0000**	**2.62**
Cyanobacteria			
Oscillatoria sp. 002	747		3.95
	747	**0.0000**	**3.95**
Dinophyceae			
Heterocapsa sp. 001	18		0.10
	18	**0.0000**	**0.10**
Prasinophyceae			
Prasinophyte 001	12,267		64.87
Prasinophyte 002	36		0.19
Tetraselmis sp. 001	1,989		10.52

Species Name	Density	BioVolume	%
	14,292	**0.0000**	**75.58**

End Of Report

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Potentially toxic species

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DATA REPORT

Project
MUVWE
Vasse-Wonnerup Estuary

Customer
Dr Jane Chambers
Environmental Science
Murdoch University
South Street, Murdoch, WA 6150

Analyst ID
stuart

DSID
7079

Report Date
26/05/2009

Batch Number
090302145634

Sample ID
V Gates

Date Collected
24/02/2009

Monitoring Point
V Gates

Sample Type
Phytoplankton

Date Received
2/03/2009

Functional Location ID
V Gates

Method (Detection Limit)
SRC CAMP (9)

Analysis Date
21/05/2009

Units Reported Cell Density:cells mL^{-1}

Biovolume: mm^3 L^{-1}

%: Percentage of total cells counted

Sampler Notes

Laboratory Notes

Field Data Recording

Total Density
2,610.0 cells mL^{-1}

Total Counted
290

Uncertainty
11.7%

Species Name	Density	BioVolume	%
Bacillariophyceae			
Achnanthes sp. 002	9		0.34
Amphora sp. 005	9		0.34
Amphora sp. 007	9		0.34
Chaetoceros socialis	252		9.66
Navicula sp. 003	9		0.34
	288	**0.0000**	**11.03**
Cryptophyceae			
Cryptophyte 008	9		0.34
	9	**0.0000**	**0.34**
Dinophyceae			
Gyrodinium sp. 002	18		0.69
Heterocapsa sp. 001	117		4.48
Prorocentrum sp. 001	369		14.14
Protoperidinium sp. 005	9		0.34
Scrippsiella trochoidea	72		2.76
	585	**0.0000**	**22.41**
Prasinophyceae			
Prasinophyte 001	1,710		65.52

Species Name	Density	BioVolume	%
Tetraselmis sp. 001	9		0.34
	1,719	**0.0000**	**65.86**
Raphidiophyceae			
Heterosigma sp. 001	9		0.34
	9	**0.0000**	**0.34**

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