Mallee Catchment Management Authority

The Hattah Lakes Aquatic Ecosystem and Vegetation Monitoring Program 2018

Report title:

The Hattah Lakes Vegetation and Aquatic Ecosystem Monitoring Program 2018

Authors:

Dr Peter Lind

GHD Pty Ltd

180 Lonsdale Street, Melbourne, Victoria, 3000

peter.lind@ghd.com

Mr Greg Cranston

GHD Pty Ltd

57 Orange Avenue, Mildura, Victoria, 3500

greg.cranston@ghd.com

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Cover photo: Boich Wetland with *Eucalyptus camaldulensis* (River Red-gum) in background, taken on 11 November 2018.

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Jennifer Munro: jennifer.munro@malleecma.com.au

Executive summary

This study has established baseline aquatic ecosystem and vegetation conditions in eight wetlands in the Hattah Lakes Icon Site based on monitoring undertaken during November and December 2018. Ultimately, this study assessed the current conditions of the aquatic ecosystem and vegetation in the littoral zone and provides information on productivity, food sources and habitat available for fauna that utilise the lakes. Major findings from this study are:

- Generally, the monitoring occurred following a period of decreasing water levels in all wetlands although Lakes Marramook and Kramen had been dry for an extended period.
- *In situ* water quality of the lakes was similar to previous studies of the Hattah Lakes with high dissolved oxygen and pH which was likely driven by the high algal biomass.
- High nutrient concentrations are likely to be contributing to increased algal abundances and the risk of Cyanobacteria (Blue-green algal) blooms.
- The composition of the zooplankton and macroinvertebrate communities are similar to other floodplain wetlands in the region. Variation in the hydrology of the wetlands is a major driver in the composition of these communities.
- Wetlands associated with the Lake Hattah Icon Site are highly productive eutrophic or even hyper-eutrophic ecosystems characterised by high nutrients, turbidity and high primary productivity.
- Highest species richness and cover of native flora occurs in the 'Upper' depth zone; as water level recedes, moisture-dependent terrestrial vegetation is expected to colonise the exposed substrate.
- Anecdotal evidence suggests that vegetation in the littoral zone is being actively utilised by waterbirds during foraging activities, with evidence (i.e. nests) of colonial breeding.
- Manipulation of water levels in the Hattah Lake wetlands has the potential to influence the aquatic ecosystem and vegetation communities.
- Further intervention monitoring at difference water levels would add knowledge on the dynamics of the wetlands and how water level changes can best be used to manage ecological health.
- In additional to the management of water levels, catchment wide land and water management (e.g. nutrients controls) would also be required for maximum benefits of the lake.

This report is subject to, and must be read in conjunction with the limitations, assumptions and qualifications contained throughout the Report.

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Glossary

CMA	Catchment Management Authority
DELWP	Department of Environment, Land, Water and Planning
EC	Electrical Conductivity
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EVC	Ecological Vegetation Class
FFG Act	Victorian *Flora and Fauna Guarantee Act 1988*
GHD	GHD Pty Ltd
IWC	Index of Wetland Condition
PMST	Protected Matters Search Tool
TLM	The Living Murray
VBA	Victorian Biodiversity Atlas

1. Introduction

1.1 Background to study

The Living Murray (TLM) is Australia's largest long-term river restoration project and aims to achieve a healthy, working river by returning water to the environment including wetlands, floodplains and forests. Six icon sites are part of the restoration project including the Hattah Lakes Icon Site in Victoria.

The Hattah Lakes Icon Site comprises a floodplain containing 20 interconnected lakes with 12 recognised as Ramsar wetlands. The Icon Site is part of the 48,000 hectare Hattah-Kulkyne National Park and provides important habitat for numerous bird species, including a number listed under international and national agreements (MDBA, 2012).

Under natural conditions, the Hattah Lakes were seasonally filled by creeks connected to the Murray River. However, river regulation and water extraction has altered the timing and duration of medium to large flow events in the Murray River. This has subsequently altered the natural flooding regime of the Hattah Lakes with negative impacts on flora and fauna. To mitigate this impact, the TLM program has attempted to replicate the natural hydrograph through environmental watering. Furthermore, wetlands within the Hattah Lakes Icon Site fall within a range of water regime classes, each with different hydrological regimes, aquatic habitat and vegetation characteristics (see Ecological Associates, 2007). Broadly, the hydrological characteristics of the water regime classes are:

- Semi-permanent – Almost permanently flooded and full or nearly full. Decreased water levels in summer/autumn and increases in winter due to freshes in the Murray River. May dry completely during major droughts.
- Persistent temporary – Water normally present but subject to greater fluctuations than semi-permanent wetlands and areas of bed more likely to dry. Increased water levels due to Murray River freshes in spring/winter with decreased levels over summer/autumn. Deepest areas rarely exposed.
- Temporary – Frequently filled by seasonal flooding but water not retained for long periods.
- Episodic – Rarely receive water and may remain dry for many years between flooding events.

This study aimed to provide information related to the response of the aquatic ecosystem and vegetation communities to the variable water levels in eight wetlands associated with the Hattah Lakes Icon Site. Specifically, the study assessed the current baseline conditions of the aquatic ecosystem and vegetation in the littoral zone to provide information on productivity, the food reserve and habitat available for birds and fish that currently or potentially utilise the lakes.

1.2 Purpose of this report

The purpose of this study was to provide information on the productivity, food reserve and habitat in eight wetlands within the Hattah Lakes Icon Site. The wetlands were selected to reflect a range of water regime classes in an attempt to assess differences in the dynamics of the ecosystems:

- Semi-permanent – Lakes Mournpall and Hattah
- Persistent temporary – Lakes Cantala, Boich and Bitterang
- Temporary – Lakes Nip Nip and Marramook

- Episodic – Lake Kramen

In addition, wetlands were chosen to capture the diversity of wetland sizes and the spatial distribution across the Hattah Lakes system. This report presents the results of aquatic ecosystem and vegetation monitoring undertaken during November and December 2018 to establish baseline conditions that can be compared to results of future monitoring at different water levels. The components of the monitoring that are presented and discussed are:

- Water quality (*in situ* and nutrients)
- Phytoplankton abundance (via chlorophyll-a concentrations)
- Zooplankton abundance and diversity
- Macroinvertebrate abundance and diversity
- Vegetation communities

Information gained through this study can aid the objective of the Mallee Regional Catchment Strategy (Mallee CMA, 2013) that aims *to protect and enhance the environmental values of the Mallee's wetlands and, in turn, the social, economic and environmental services that they provide to the community*. Furthermore, the development of a wetland monitoring program to facilitate adaptive management of priority wetlands such as several of the Hattah lakes has been identified as an action in the Mallee CMA River Health Strategy (Mallee CMA, 2006).

1.3 Scope and limitations

This report has been prepared by GHD for the Mallee Catchment Management Authority (Mallee CMA) and may only be used and relied on by Mallee CMA for the purpose agreed between GHD and the Mallee CMA. GHD otherwise disclaims responsibility to any person other than the Mallee CMA arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with this report were limited to those specifically detailed and are subject to the scope limitations set out in the report. The opinions, conclusions and any recommendations are based on conditions encountered and information reviewed at the date of preparation. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

Opinions, conclusions and any recommendations are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any assumptions being incorrect.

GHD has prepared this report on the basis of information provided by the Mallee CMA and others (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information. The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific monitoring locations. Site conditions may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

This ecological assessment covers vascular plant species and aquatic invertebrates. The flora assessment was conducted in late spring and early summer, when most wetlands were at various stages of water recession, leaving the wetland substrate available for plant colonisation. Additional species are likely to be recorded at other times of the year, particularly in late winter/early spring.

2. Study area

2.1 Mallee region

The Hattah Lakes Icon Site is located 35 km north of Ouyen and 74 km south of Mildura in the semi-arid Mallee region of Victoria (Figure 1). The Mallee region covers 39,939 km^2 and the landscape is dominated by two broad landforms; the Riverine Plain that encompasses the floodplain of the River Murray and the undulating aeolian Mallee Dunefields (Mallee CMA, 2013). Approximately 52% of the native vegetation within the region is estimated to have been cleared for agriculture (Mallee CMA, 2013). Around 62% of the region is now dedicated to agriculture with important irrigation areas along the River Murray and extensive dryland cropping and grazing in other areas (Mallee CMA, 2013).

There are around 2,170 km of rivers and more than 900 wetlands across the region with 14 wetlands listed as Nationally Significant (Mallee CMA, 2013). Semi-permanent saline wetlands are the dominant wetland type in the region, having increased since European settlement due to altered hydrological regimes, native vegetation clearing, changes to land use, and the use of natural wetlands and other low lying areas for salinity management (Mallee CMA, 2013). The condition of waterways in the region are threatened by a range of pressures including altered flow regimes, salinity, invasive plants and animals, recreational activities, and adjacent land use practices (Mallee CMA, 2006; Mallee CMA, 2013).

Average annual rainfall is 250 mm although this is exceeded by evaporation, particularly over summer (DNRE, 1995). The climate is reflected in the hydrology of the Mallee Basin; despite being the largest in Victoria (28,027 km^2) it contributes least to total annual streamflow across the State with a median annual runoff of ≤10 mm (DSE, 2005). Flooding tends to occur infrequently and is caused by heavy rainfall in localised areas (Mallee CMA, 2006).

2.2 Hattah Lakes

The Hattah Lakes Icon Site is part of the 48,000 hectare Hattah-Kulkyne National Park, and includes a number of nationally important wetlands due to the following attributes (DNRE, 1995):

- They are good examples of the wetland type occurring within a biogeographic region in Australia
- They are important habitat for animal taxa at a vulnerable stage in their life cycles, or provide a refuge when adverse conditions such as drought prevail

The 18 km long Chalka Creek connects the lakes to the Murray River, with the lakes supporting substantial occurrences of vegetation communities dominated by *Eucalyptus camaldulensis* (River Red Gum) and *E. largiflorens* (Black Box), as well as many rare and threatened plants and animals. Recent engineering works under *The Living Murray* project have facilitated the delivery of water to many of the lakes, including the twelve lakes that are Wetlands of International Importance under the Ramsar convention. This has allowed the Mallee CMA to manage flows and 'mimic' natural wetting and drying regimes.

During dry periods, the beds of the various lakes at Hattah support the herbaceous community Lake Bed Herbland (EVC 107). The majority of the lakes are fringed by Intermittent Swampy Woodland (EVC 813) dominated by River Red-gum or Black Box. When inundated, the wetlands support aquatic flora grown from both dormant seeds and propagules present in the lakebed, as well as those washed in by floodwaters. As the lakes dry, aquatic vegetation gives way to wetland herb communities.

A search of the Victorian Biodiversity Atlas (VBA) on 6 February 2019 indicated that a total of 819 flora taxa (660 native, 159 introduced) have been recorded within a 10 km radius of the Hattah Lakes. Of these taxa, two are listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), a further 16 are listed as threatened under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) and an additional 108 are listed as rare or threatened on the *Advisory List of Rare or Threatened Plants in Victoria – 2014* (DEPI, 2014). In addition, the Department of the Environment and Energy *Protected Matters Search Tool* (PMST) predicts the occurrence of four additional flora species listed under the EPBC Act. There is suitable wetland habitat at the Hattah Lakes for some of these 130 rare or threatened species to occur.

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

Hattah Lakes Surveyed

GHD mallee catchment management authority

Malee CMA
Lake Wallawalla and Hattah Productivity Monitoring

Overview

Job Number 31-36516
Revision B
Date 04 Mar 2019

Figure 1

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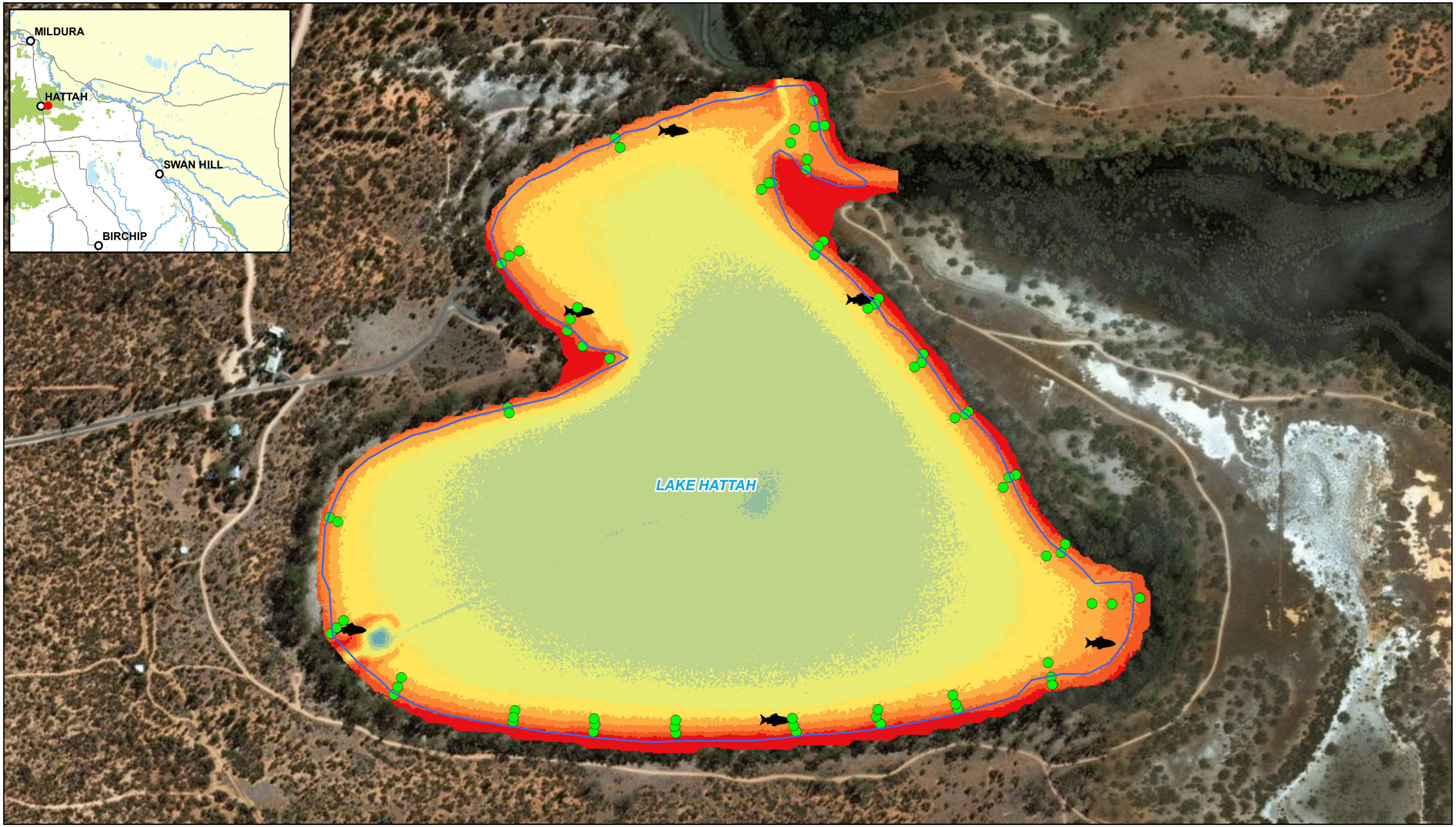

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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Hattah Lakes Surveyed	
Vegetation Sites	
Aquatic Sites	

0.5m interval depths from LiDAR data

- 38-38.5
- 38.5-39
- 39-39.5
- 39.5-40
- 40-40.5
- 40.5-41
- 41- 1.5
- 41.5- 2
- 42-42.5
- >42.5

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE HATTAH

Job Number	31-36516
Revision	A
Date	06 Mar 2019

Figure 2

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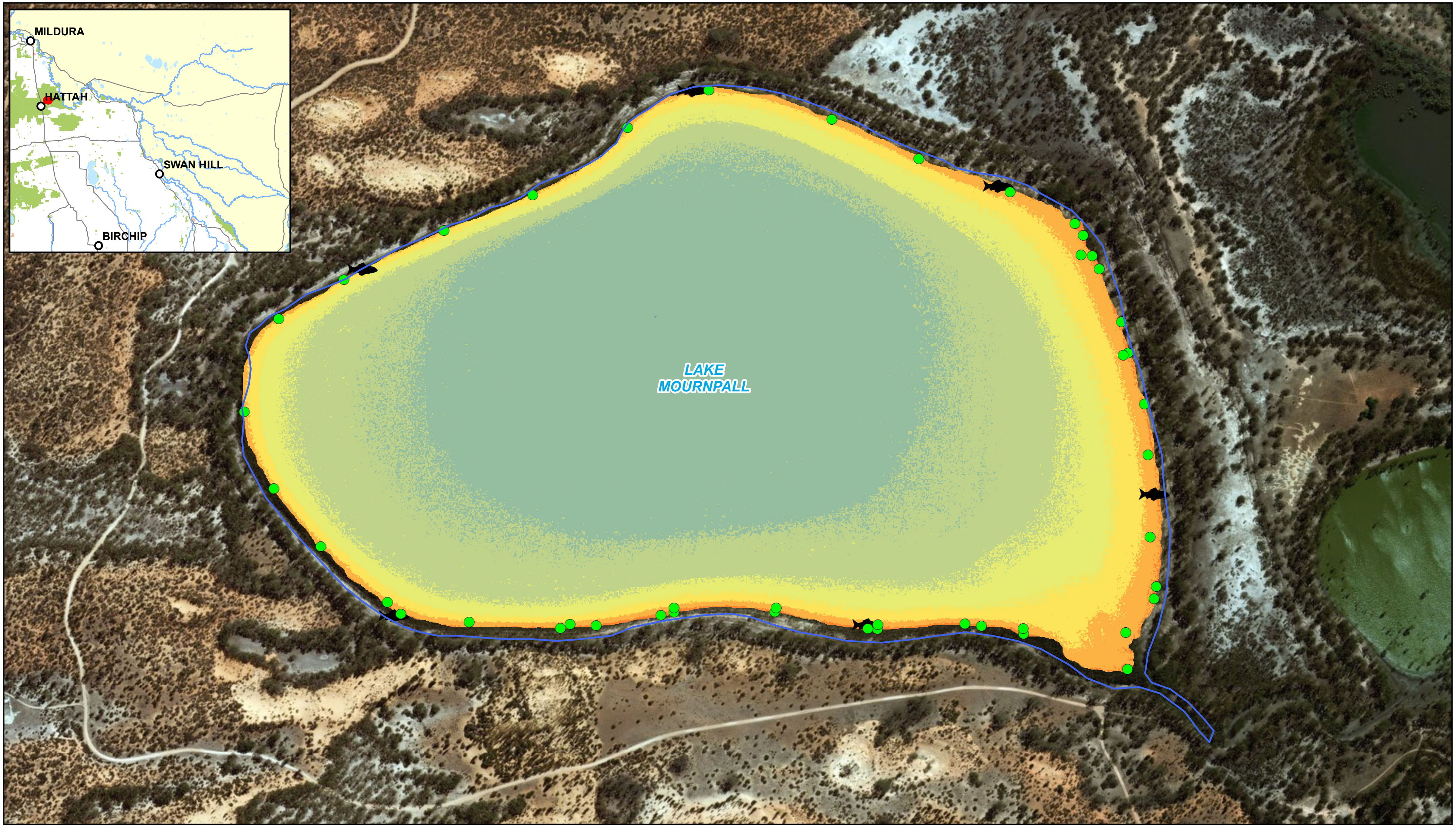

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

Hattah Lakes Surveyed

Vegetation Sites

Aquatic Sites

0.5m interval depths from LiDAR data

38.5-39	39.5-40
39-39.5	40-40.5
	40.5-41
41- 1.5	
41.5- 2	

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE MOURNPALL

Job Number	31-36516
Revision	A
Date	06 Mar 2019

Figure 2

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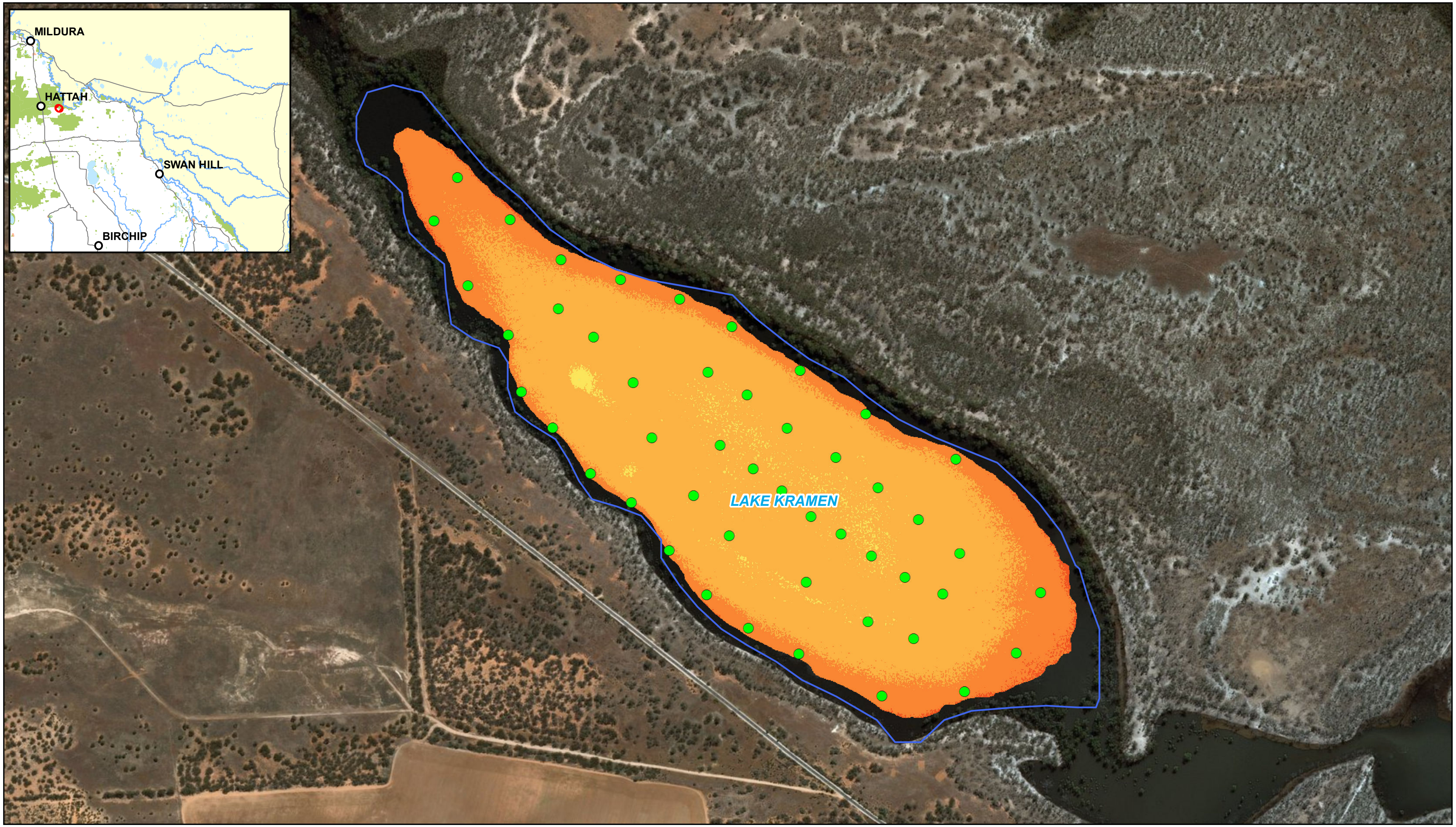

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

Hattah Lakes Surveyed

Vegetation Sites

0.5m interval depths from LiDAR data

40-40.5

40.5-41

41- 1.5

41.5- 2

42-42.5

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE KRAMEN

Job Number	31-36516
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Date	06 Mar 2019

Figure 2

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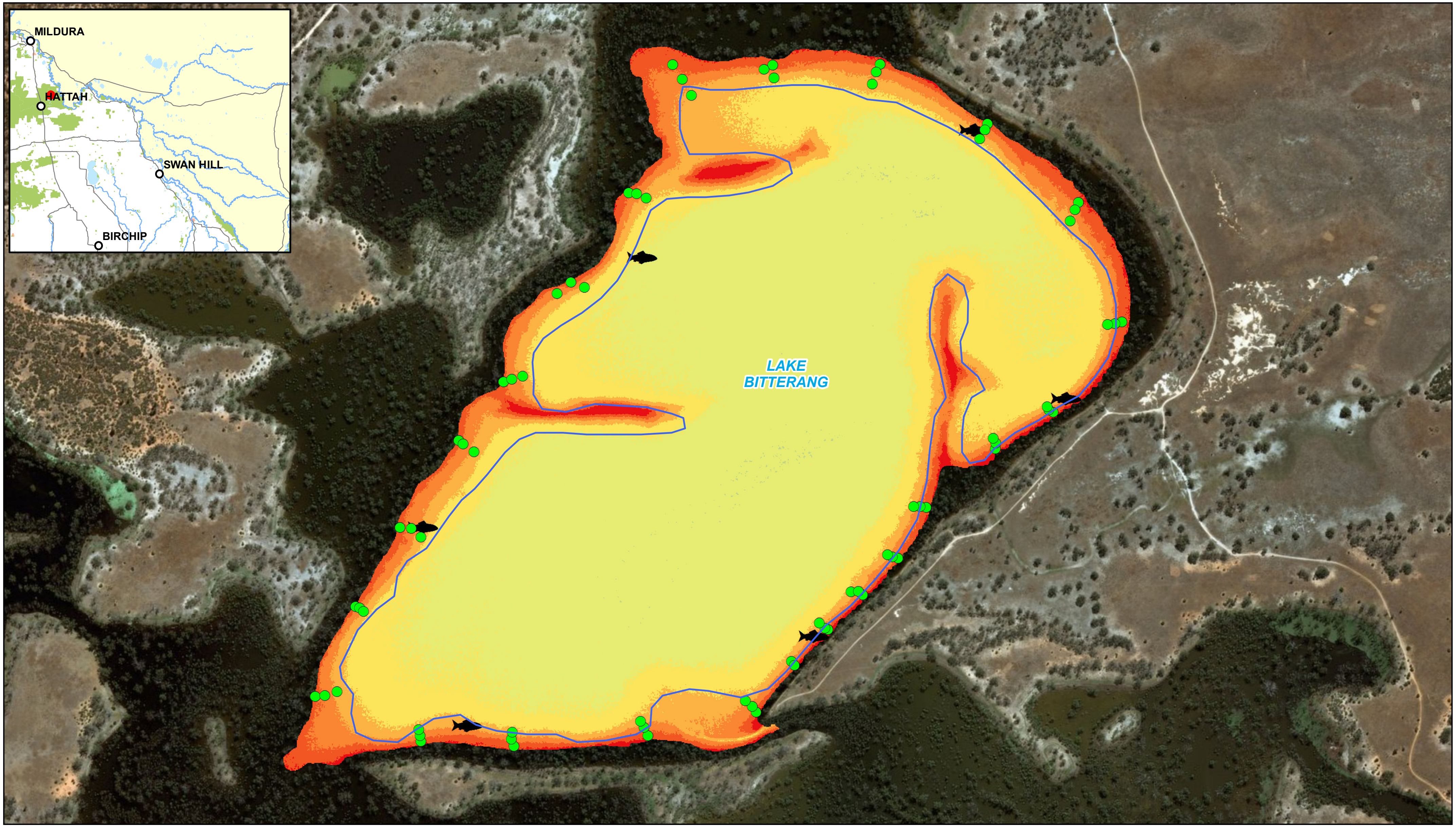

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Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 54

N

Hattah Lakes Surveyed

Vegetation Sites

Aquatic Sites

0.5m interval depths from LiDAR data

39.5-40

40-40.5

40.5-41

41- 1.5

41.5- 2

42-42.5

>42.5

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE BITTERANG

Job Number	31-36516
Revision	A
Date	06 Mar 2019

Figure 2

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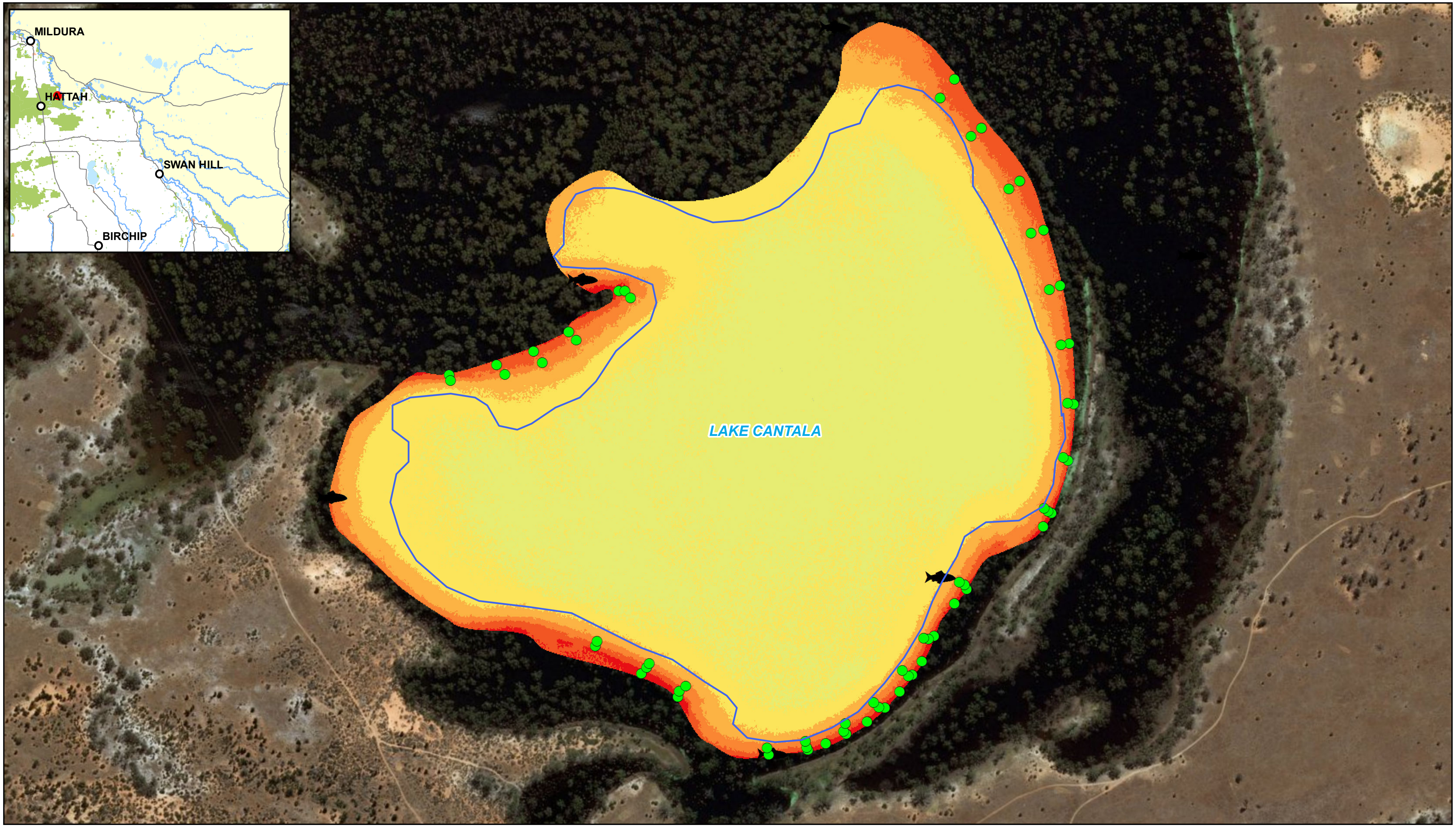

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Grid: GDA 1994 MGA Zone 54

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Hattah Lakes Surveyed

Vegetation Sites

Aquatic Sites

0.5m interval depths from LiDAR data

39.5-40

40-40.5

40.5-41

41- 1.5

41.5- 2

42-42.5

>42.5

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE CANTALA

Job Number	31-36516
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Figure 2

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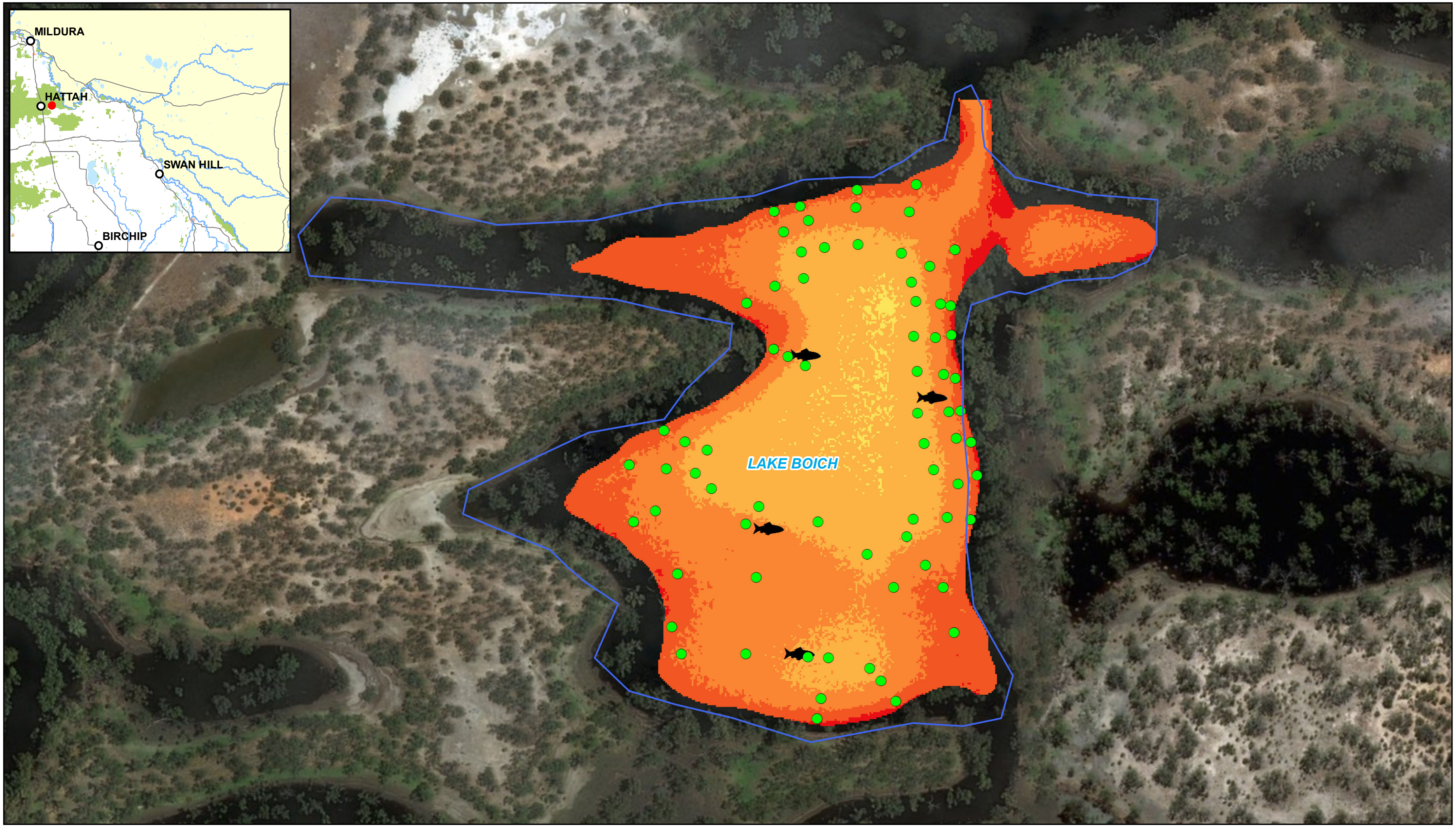

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Metres

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Hattah Lakes Surveyed

Vegetation Sites

Aquatic Sites

0.5m interval depths from LiDAR data

40.5-41

41- 1.5

41.5- 2

42-42.5

>42.5

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE BOICH

Job Number	31-36516
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Figure 2

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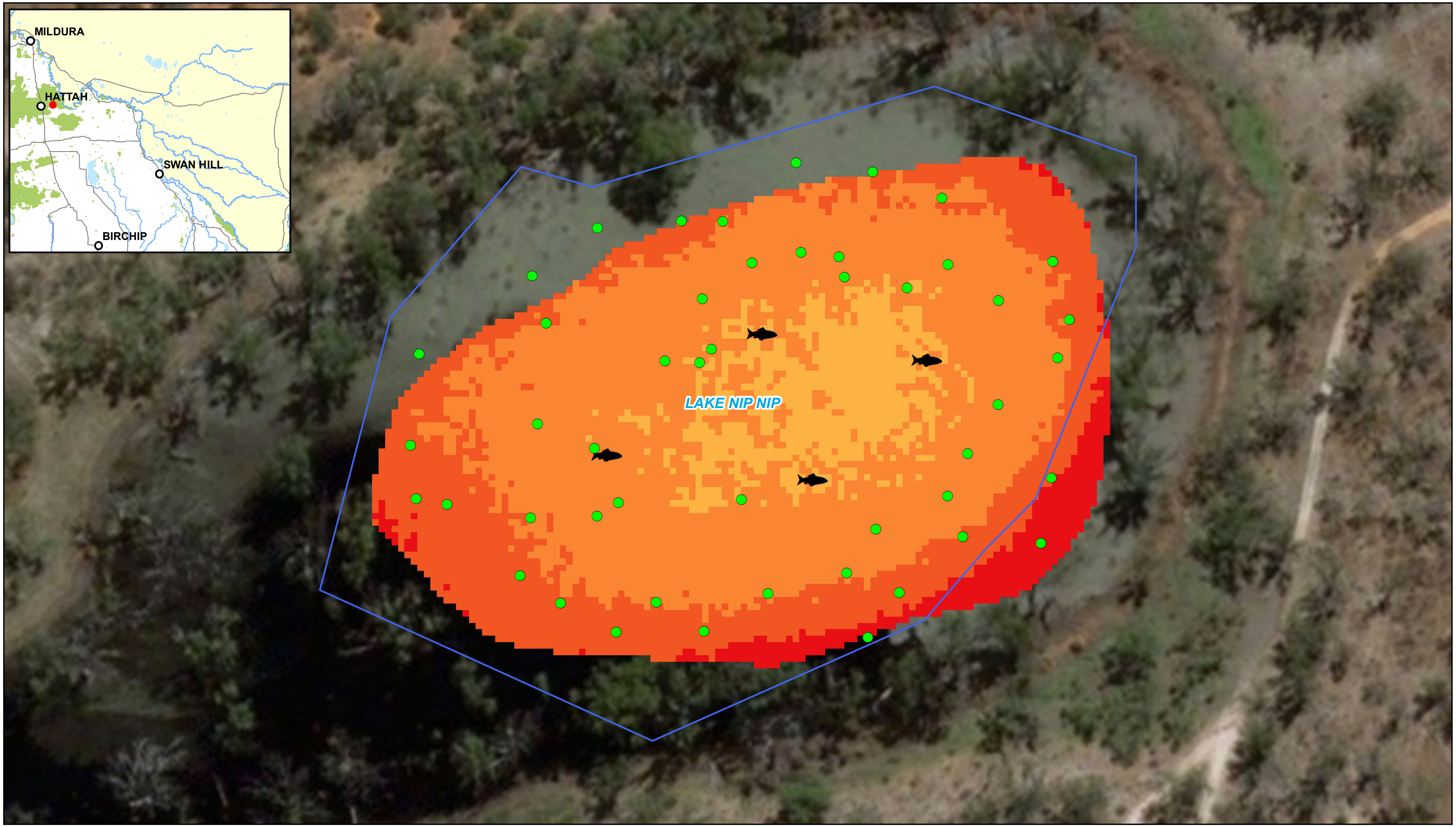

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0 4.75 9.5 19 28.5 38

Metres

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Hattah Lakes Surveyed

Vegetation Sites

Aquatic Sites

0.5m interval depths from LiDAR data

41- 1.5

41.5- 2

42-42.5

>42.5

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE NIP NIP

Job Number 31-36516
Revision A
Date 06 Mar 2019

Figure 2

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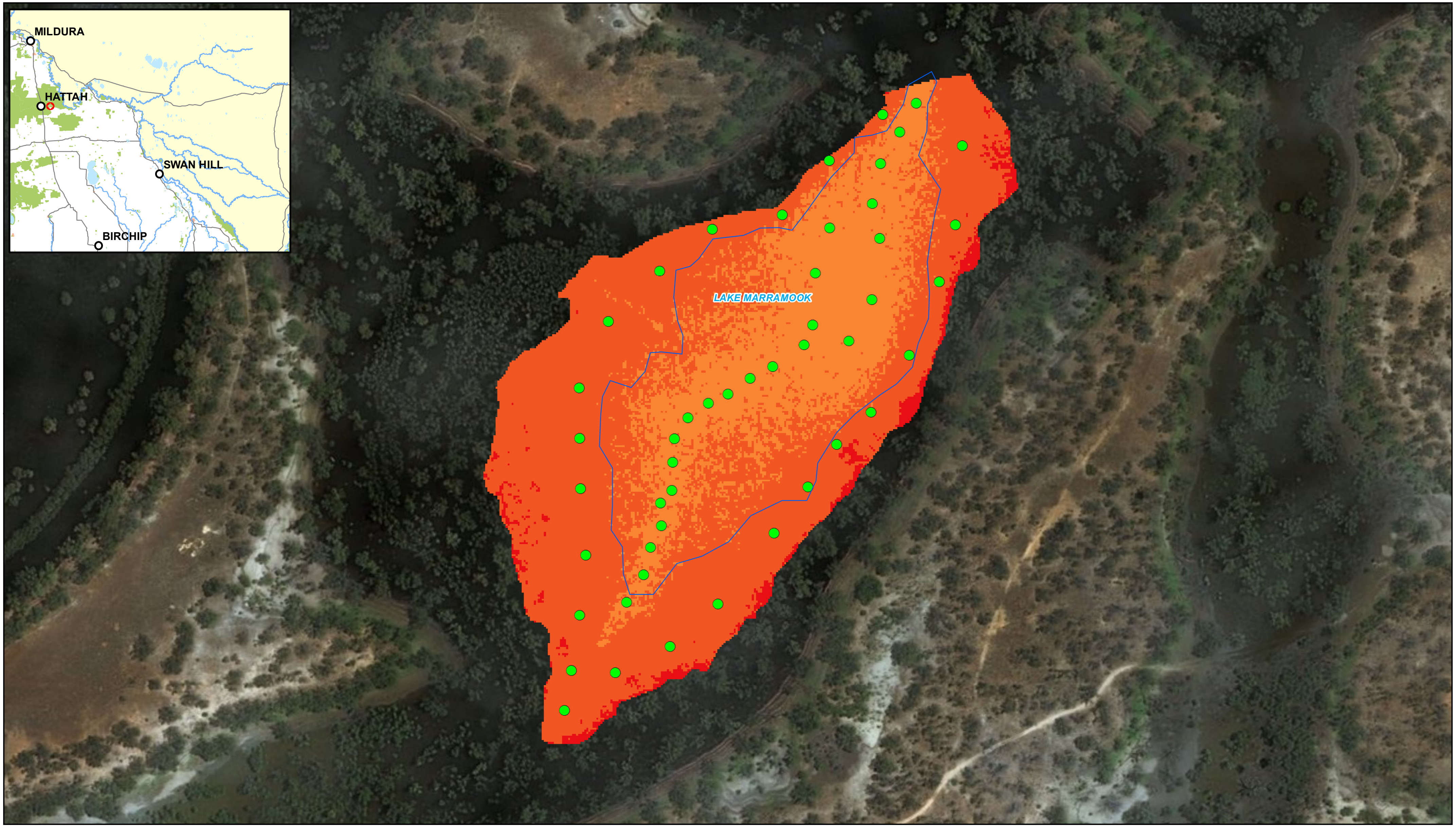

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Hattah Lakes Surveyed

Vegetation Sites

0.5m interval depths from LiDAR data

41.5- 2

42-42.5

>42.5

Malee CMA

Lake Wallawalla and Hattah Productivity Monitoring

LAKE MARRAMOOK

Job Number	31-36516
Revision	A
Date	06 Mar 2019

Figure 2

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:sacevedo

3. Study locations

3.1 Aquatic locations

Of the eight wetlands planned for aquatic ecosystem monitoring, Lakes Kramen and Marramook were dry and no aquatic monitoring was undertaken. In the wetlands that contained water, the shallow littoral area of six locations were monitored within Bitterang, Cantala, Hattah and Mournpall while four locations were monitored in the smaller Boich and Nip Nip. The locations were generally spread evenly around the perimeter of each wetland where access permitted (Figure 1). GPS coordinates for each location are included in Table 1.

Table 1 Aquatic monitoring site locations, Region 54H (Datum UTM GDA94)

Wetland	Location	Eastings	Northings		Wetland	Location	Eastings	Northings
Mournpall	North	623263	6159277		Bitterang	Northeast	626415	6163962
	Northeast	623929	6159069			East	626610	6163388
	East	624269	6158397			Southeast	626072	6162881
	South	623644	6158112			South	625333	6162691
	Southwest	622613	6158132			Southwest	625238	6163114
	Northwest	622544	6158888			Northwest	625706	6163691
Hattah	North	623143	6153503		Cantala	North	632823	6163559
	Northeast	623401	6153270			East	633479	6163140
	Southeast	623730	6152797			Southeast	633017	6162550
	South	623283	6152691			South	632709	6162226
	Northwest	623013	6153255			West	631902	6162697
	Southwest	622699	6152816			Northwest	632361	6163095
Nip Nip	North	628033	6153846		Boich	North	627037	6153279
	East	628074	6153840			East	627153	6153240
	South	628046	6153810			South	627031	6153004
	West	627995	6153816			West	627003	6153119

3.2 Vegetation sites

Each wetland was divided into two or three LIDAR AHD elevation zones (e.g. 42 to 42.5 m AHD) based on flood mapping supplied by the Mallee CMA. Within each zone, approximately 24 locations were surveyed that were spread haphazardly around the perimeter of each wetland. Where possible, vegetation survey locations coincided with aquatic monitoring locations.

At each location two or three 1 m^2 plots were surveyed at random points along a transect running perpendicular to the wetland margin in each zone. Water levels during the surveys, and therefore depth and/or distance from the water, differed at each wetland. Some wetlands were also completely dry. Given this, each elevation zone was labelled according to one of the following water level categories, which were based off the AHD colour coding from elevation profiles across the lakes system:

- Upper
- Mid
- Lower

This enabled comparisons of water depth zones to be made across wetlands rather than comparisons of elevation zones that may have experienced different hydrological regimes.

4. Methods

Monitoring of the Hattah Lakes occurred from 15th November to 14th December 2018. Weather conditions during the monitoring were generally clear skies and little rain, with warm to hot air temperatures. The monitoring was designed to be repeatable and allow statistical comparisons to be made following intervention monitoring at different water levels. As such, the results are generally presented here in a descriptive format to illustrate baseline conditions only.

4.1 Aquatic monitoring

4.1.1 Hydrology

Ultimately, the specific aim of this study was to establish baseline conditions in the aquatic ecosystem and vegetation communities. Changes in the conditions in relation to environmental watering can be made in the future based on additional results from intervention monitoring. To identify the water levels prior to and at the time of monitoring, data were obtained from the Mallee CMA.

4.1.2 Water quality

In situ recordings of surface water temperature, dissolved oxygen (DO), pH and electrical conductivity (EC) were made with a calibrated YSI multiprobe at all wetlands monitored. Turbidity was recorded with a Turbiquant Turbidity Meter and alkalinity using a HACH field titration kit. Recordings were taken from a single location in areas where depth was approximately 0.3 m.

In addition to *in situ* recordings, water samples were collected from a single location in each wetland and transported to the NATA accredited ALS laboratory in Springvale, Victoria. The parameters assessed were total nitrogen (TN), ammonia (NH_3), total Kjeldahl nitrogen (TKN), nitrogen oxides (NOx), nitrate (NO_3), nitrite (NO_2), total phosphorus (TP) and soluble reactive phosphorus (SRP).

4.1.3 Phytoplankton communities

The concentration of chlorophyll-a present in water is directly related to the amount of algae/phytoplankton. Therefore, an assessment of phytoplankton, and hence primary production, was made by assessing the concentration of chlorophyll-a. From a single location in each wetland, a one litre sample was collected and sent to the NATA accredited ALS laboratory.

4.1.4 Zooplankton communities

At each location, five replicates were collected to encompass spatial variability with replicates pooled to form a single composite sample. Each replicate consisted of 100 litres of water filtered through a 53 µm mesh. Samples were preserved in 70% ethanol. Individuals in the sample were identified to a broad taxonomic resolution to distinguish between the main forms (e.g. Copepoda, Rotifera, Cladocera and Ostracoda).

4.1.5 Macroinvertebrate communities

Macroinvertebrate communities were collected by sweep netting a 1 x 1 m quadrat using a hand-held sweep net (250 µm mesh). At each location, five replicate samples were collected to encompass spatial variability with replicates pooled to form a single composite sample. Samples were preserved in 70% ethanol. Individuals in the sample were identified in the GHD Aquatic Ecology laboratory to taxonomic resolutions consistent with EPA Victoria (2003).

4.1.6 Data analyses

Water quality and chlorophyll-a data were compared to relevant trigger values in the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) and guidelines in the *State Environment Protection Policy (Waters)* Version for DELWP Legal as at 16 January 2018.

To demonstrate potential analyses following future intervention monitoring, patterns in the multivariate macroinvertebrate community data were investigated using PRIMER V7 (see Clarke & Warwick, 2001). Initially, all data were square–root transformed to reduce the influence of highly abundant taxa. A similarity matrix was then calculated between all samples based on the Bray-Curtis similarity measure. Non-metric multidimensional scaling (nMDS) was used to produce ordination plots as graphical representations of key spatial trends in the macroinvertebrate communities. Stress values associated with the ordinations were examined to identify accuracy of the ordinations (<0.2 indicates a potential useful 2-dimensional ordination). Tests for significance were completed using non-parametric analyses of similarity (ANOSIMs).

4.2 Vegetation monitoring

4.2.1 Quadrat sampling

Sample locations were not permanently marked to enable re-randomisation of plots in subsequent sampling rounds. A total of 469 1 x 1 m vegetation quadrats were surveyed across the eight wetlands (Figure 1).

The following data were recorded for each 1 x 1 m quadrat:

- General information: plot identification code, date, assessor, GPS waypoint
- Water depth (cm)
- LIDAR AHD elevation and water level zone (see Section 3.2)
- Water cover, bare ground cover, litter cover[1], coarse woody debris cover, cryptogam cover, bryophyte cover (%)
- General notes on bird activity, e.g. footprints, droppings, etc
- Saplings <2 m high (number, height)
- Seedlings <0.25 m (number)
- Native vegetation cover, introduced vegetation cover (%)
- Full vascular flora species list, including cover abundance estimate for each taxon using the following percentage cover scale:
    - + Few individuals, no measurable cover (converted to 0.1% for data analysis)
    - 1 Few to many individuals, *c.* 1% cover
    - 2 Few to many individuals, *c.* 2% cover
    - 5 *c.* 5% cover
    - Thereafter in 5% increments

[1] Note: in areas of open water, litter cover recorded where observable underwater.

4.2.2 Plant functional groups

The 'functional group' approach has been widely used to assist in interpreting and predicting change in community function and dynamics (Brock and Casanova 1997; Kattel *et al.* 2009). Minor changes in species composition or inconsistencies in taxonomic resolution between years may affect between-year comparisons and the ability to detect ecologically significant changes in community structure. However, the use of functional groups helps detect changes in community structure based on plant responses to water regimes (Kattel *et al.* 2009).

For this study, each species was assigned a Plant Functional Group (PFG) based on common ecological, morphological and functional responses to inundation (PFGs are described in Table 2). PFGs were assigned to each species using an unpublished master list provided by Casanova *et al.* (2015)[2].

Table 2 Definitions of Plant Functional Groups used in the data analysis

Abbreviation (Casanova 2015)	Plant Functional Group Name	Description	Photo of example species
S (Se, Sk or Sr)	Seed/spore born aquatic flora	Submerged Adult plants do not survive prolonged exposure of the wetland substrate (drying) and lack perpetuating rootstocks. Seed or spores may persist in soil during dry times.	
ARp	Rhizomatous aquatic flora	Amphibious fluctuation – responders floating Aerial parts of plants survive exposure of the wetland substrate (drying) for sustained periods of time. Plants survive drying by dying back to rootstocks.	
ARf	Semi-aquatic flora	Amphibious fluctuation – responders plastic (includes strictly aquatic floaters) Can actively grow when substrate exposed but still moist, but may die back to rootstocks or seed during sustained dry periods.	

[2] Casanova *et al.* (2015). Unpublished master list of Plant Functional Groups. List was developed by experts in workshops.

Abbreviation (Casanova 2015)	Plant Functional Group Name	Description	Photo of example species
Atw	Perennial	Amphibious fluctuation tolerator, woody: Perennial woody species that require water to be present in the root zone but will germinate in shallow water or on a drying profile. Generally restricted to permanently saturated areas.	
ATl	Perennial mudflat flora	Amphibious fluctuation – tolerates low growing Perennial – maintain same general growth form during brief periods of inundation, but may dieback to rootstocks if unable to develop emergent growth during sustained inundation.	
ATl	Annual mudflat flora	Amphibious fluctuation – tolerates low growing Annual (or functionally so) – may tolerate very brief periods of shallow flooding during growth phase, but essentially short-lived plants which germinate following flood water recession and produce inundation-tolerant seed during the drying phase.	
ATe	Floodplain flora	Amphibious fluctuation – tolerates emergent Rootstocks tolerate shallow inundation but plant intolerant of sustained total immersion. Recruitment and/or long-term maintenance.	
Tda	Moisture dependent	Terrestrial damp Rootstocks intolerant of more than superficial inundation, but occurring in areas of good soil moisture conditions, which may be influenced by proximity to river and water seepage through soil.	

Abbreviation (Casanova 2015)	Plant Functional Group Name	Description	Photo of example species
Tdr	Terrestrial dry	Terrestrial dry Dry-land plants (i.e. flood intolerant and going through life cycles independently of flooding regime).	
NA	Not-vegetated	Bare ground, litter, logs, water, etc	
NA	Not assigned	Species for which there is insufficient information to assign them a PFG.	

Source: Casanova *et al.* (2015). Note: images not necessarily from Hattah Lakes

4.2.3 Plant identification

Taxa unable to be identified in the field were initially recorded to the nearest possible family or genus and a sample collected in accordance with the protocols of GHD's Research permit / permit to take / keep protected flora under the *Flora and Fauna Guarantee (FFG) Act 1988* and *National Parks Act 1975* (No. 10008653). Taxa were subsequently identified to the finest possible level of taxonomic resolution using a dissecting microscope and the Flora of Victoria (https://vicflora.rbg.vic.gov.au/). One grass taxon was unable to be identified to species or genus level and has been labelled as 'Poaceae' for the purpose of this report.

4.2.4 Nomenclature

Unless otherwise noted, common and scientific names for flora follow the VBA (Version 3.0.7). Flora conservation significance was determined in accordance with the Commonwealth *EPBC Act*, the Victorian *FFG Act*, and the *Advisory List of Rare or Threatened Plants in Victoria – 2014* (DEPI, 2014).

5. Results

5.1 Hydrology

Water level data were only available for a selection of Hattah Lakes (Figure 3). The semi-permanent lakes, Hattah and Mournpall, have experienced a gradual and generally consistent decrease in water level since April 2018.

The persistent temporary lakes, Cantala and Bitterang, have experienced noticeably different patterns in water levels over the last 12 months. While Bitterang had a similar decrease to that of the semi-permanent wetlands, Cantala experienced irregular fluctuations over short time periods.

The water level data for the episodic Kramen also suggests highly variable water levels over short time periods despite the fact that the wetland has remained dry for an extended period (since at least spring 2018). The telemetry poles in the wetlands can show high levels of fluctuation due to disturbance by wind, particularly when they are dry (pers. comm. J. Munro, Mallee CMA). Consequently, it is likely that the water level data for Kramen are not reflected of the true, dry conditions in the wetland. With consideration given to the wind disturbance, the pattern in Cantala was a general decline in water similar to the semi-permanent wetlands.

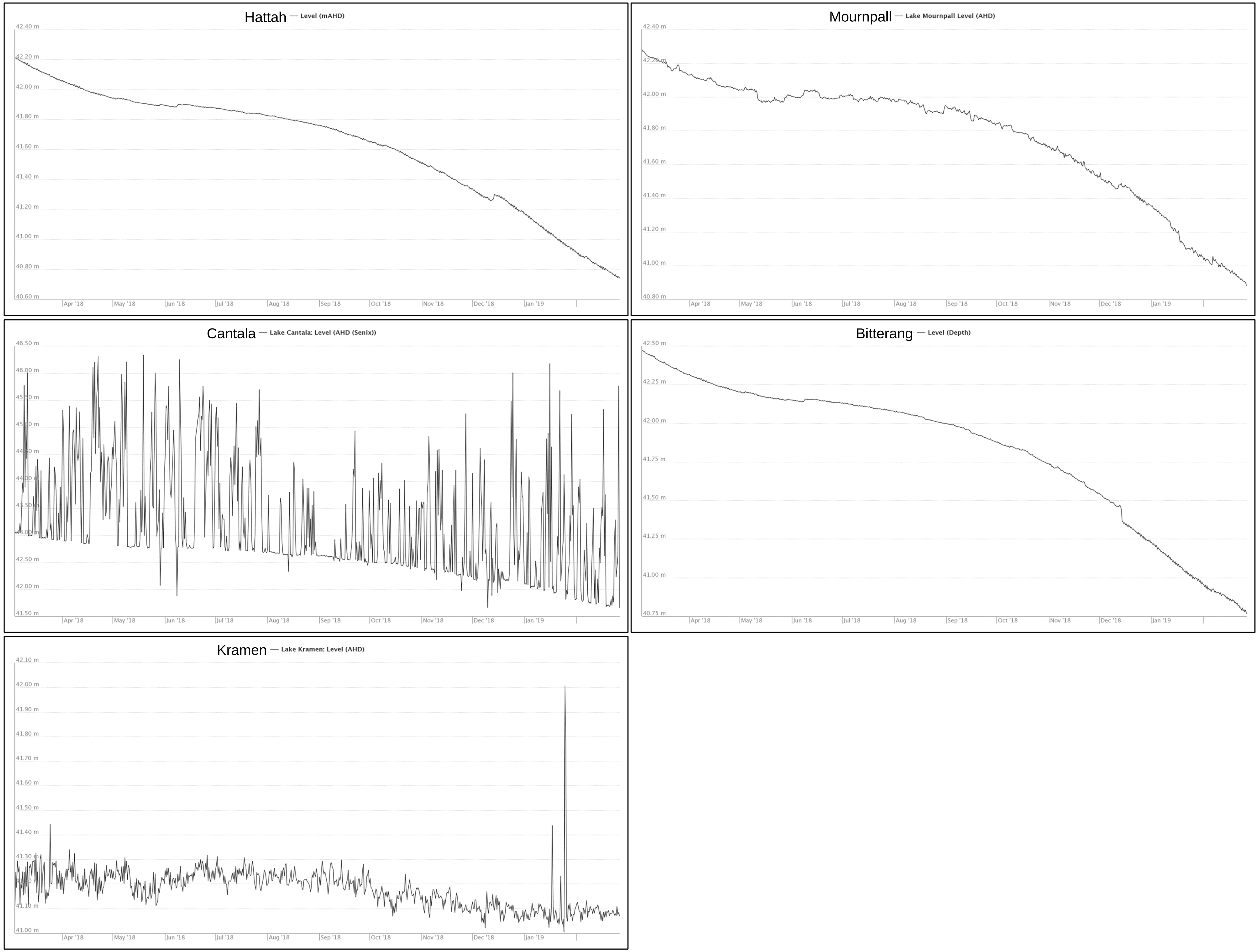

Figure 3 Water level (m AHD) of some Hattah Lakes from around April 2018 to February 2019. Figures supplied by the Mallee CMA

5.2 Aquatic monitoring

5.2.1 Water quality

The *in situ* water quality results for each wetland are included in Table 3. Water temperature was relatively warm in all wetlands and ranged from 20.1 to 27.6°C. Temperature would have been influenced by both the time of day that recordings were made and daily variations. Dissolved oxygen was high at all wetlands and exceeded 100%. The exception was at Cantala where it was only 77.3%. Cantala was below both guideline values for dissolved oxygen while several other wetlands exceeded the guidelines due to the high values. ANZECC (2000) suggest that exceedance of guidelines should trigger an investigation to determine if the guidelines are appropriate based on the type of waterbody and the region. All wetlands also exceeded the trigger value for electrical conductivity that ranged from 343 to 1,120 µS/cm. However, the electrical conductivity trigger value is typical of values found in lakes and reservoirs in Tasmania and may be overly conservative for semi-arid wetlands.

The levels of pH also exceeded the ANZECC (2000) trigger value at the majority of wetlands and ranged from 8.0 to 9.5. Turbidity was high at a number of wetlands although ANZECC (2000) acknowledges that shallow waterbodies may have naturally higher turbidity due to wind-induced resuspension of sediments. Alkalinity varied amongst wetlands and ranged from 85 to 400 mg/L.

Table 3 *In situ* water quality results from each wetland. Bold values exceed relevant ANZECC (2000) trigger values. Underlined values exceed DRAFT SEPP Waters of Victoria guidelines

	Water regime class	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Electrical Conductivity (µS/cm)	pH	Turbidity (NTU)	Alkalinity (mg/L)
Hattah	Semi-permanent	20.1	9.4	103.7	**362**	**8.5**	**<u>43</u>**	85
Mournpall		26.0	11.4	**<u>140.7</u>**	**343**	**<u>8.7</u>**	**<u>96</u>**	100
Bitterang	Persistent temporary	27.6	9.0	**114.3**	**390**	**8.2**	11	140
Boich		22.8	11.3	**<u>131.7</u>**	**940**	**<u>9.2</u>**	<u>18</u>	260
Cantala		25.7	6.3	**<u>77.3</u>**	**390**	8.0	11	400
Nip Nip	Temporary	25.2	12.8	**<u>156.1</u>**	**1120**	**<u>9.5</u>**	**<u>24</u>**	100
Marramook		Dry						
Kramen	Episodic	Dry						
ANZECC trigger value[3]		-	-	90 - 110	20 - 30	6.5 - 8.0	1 - 20	-
Draft SEPP (Waters) Guidelines[4]		-	-	80 - 120	-	6.5 - 8.5	15[5]	-

[3] ANZECC (2000) trigger values are those relevant to lakes and reservoirs in slightly disturbed ecosystems of south-eastern Australia

[4] DRAFT SEPP guidelines for riverine floodplain wetlands

[5] Based on 75th percentile of monthly data collected over a minimum 11 month period

Nutrient results for all wetlands are included in Table 4. Cantala and especially Bitterang had high levels of ammonia while nitrite and nitrate (and hence NOx) was noticeably higher in Mournpall compared to other wetlands. All wetlands with the exception of Boich exceeded the ANZECC (2000) trigger value for total Kjeldahl nitrogen. Overall, there were high concentrations of total nitrogen in all wetlands, particularly Nip Nip. The high total nitrogen was primarily due to contribution from organic nitrogen. Total phosphorus concentrations were also high in the wetlands and all exceeded the ANZECC (2000) trigger value, especially in Bitterang and Nip Nip. However, reactive phosphorus only exceeded the trigger value in Nip Nip and Boich and concentrations were noticeably higher in the former of these.

There was large variation in nutrient concentrations within the different water regimes. However, there is some suggestion of higher total nitrogen (due to total Kjeldahl and organic nitrogen) and reactive phosphorus in the temporary Nip Nip wetland.

Table 4 Nutrient and chlorophyll-a concentrations from each wetland. Bold values exceed relevant ANZECC (2000) trigger values. Underlined values exceed DRAFT SEPP Waters of Victoria guidelines

	Water regime class	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Nitrite + Nitrate (NOx – mg/L)	Total Kjeldahl Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Reactive Phosphorus (mg/L)	Total Phosphorus (mg/L)	Chlorophyll-a (mg/L)
Hattah	Semi-permanent	0.06	<0.01	0.02	**0.02**	3.4	3.3	**<u>3.4</u>**	<0.01	**<u>0.50</u>**	**0.092**
Mournpall		0.04	0.04	0.36	**0.40**	3.8	3.8	**<u>4.2</u>**	<0.01	**<u>0.47</u>**	**0.079**
Bitterang	Persistent temporary	0.29	0.01	0.03	**0.04**	3.0	2.7	**<u>3.0</u>**	<0.01	**<u>1.14</u>**	**0.025**
Boich		0.07	<0.01	<0.01	<0.01	4.4	4.3	**<u>4.4</u>**	**0.04**	**<u>0.41</u>**	0.004
Cantala		0.96	0.04	0.08	**0.12**	3.3	2.3	**<u>3.4</u>**	0.01	**<u>0.44</u>**	**0.008**
Nip Nip	Temporary	0.11	<0.01	0.04	**0.04**	8.3	8.2	**<u>8.3</u>**	**0.21**	**<u>0.95</u>**	**0.015**
Marramook		Dry									
Kramen	Episodic	Dry									
ANZECC trigger value[6]		-	-	-	0.01	-	-	0.35	0.01	0.005	0.005
SEPP (Waters) Guidelines[7]		-	-	-	-	-	-	1.5[7]	-	0.10[8]	-

5.2.2 Phytoplankton communities

Chlorophyll-a has been used as an indicator of algal community abundance in the wetlands and concentrations for each location are included in Table 4. Chlorophyll-a ranged from 0.004 mg/L in Boich to 0.092 mg/L in Hattah. All wetlands excluding Boich exceeded the ANZECC (2000) trigger value. There is some evidence that the semi-permanent Hattah and Mournpall wetlands had higher algal abundances.

[6] ANZECC (2000) trigger values are those relevant to lakes and reservoirs slightly disturbed ecosystems in south-eastern Australia
[7] SEPP guidelines for riverine floodplain wetlands
[8] Based on 75th percentile of monthly data collected over a minimum 11 month period

5.2.3 Zooplankton communities

Zooplankton densities for all wetlands are included in Table 5, while raw data are included in Appendix A. Cladocera were the most common zooplankton taxa recorded across all wetlands followed by Copepoda. Ostracoda and Rotifera were rare compared to the other taxa. However, there was variation in the occurrence of zooplankton taxa with Copepoda in higher abundances in Cantala and Mournpall, and Cladocera in the other wetlands. The semi-permanent and temporary wetlands had noticeably higher abundances of zooplankton than the persistent temporary wetlands.

Table 5 Mean and standard error zooplankton abundance (per litre) from each wetland. Total abundance for each taxa and each wetland are also presented. Values in parentheses are corrected values to account for 2 less samples at Boich and Nip Nip

	Water regime class	Copepoda	Cladocera	Ostracoda	Rotifera	**Total**
Hattah	Semi-permanent	5 +/- 2	307 +/- 226	1 +/- 0	2 +/- 1	**1888**
Mournpall		113 +/- 52	23 +/- 11	1 +/- 0	10 +/- 4	**877**
Bitterang	Persistent temporary	26 +/- 12	34 +/- 10	1 +/- 0	4 +/- 2.2	**389**
Boich		2 +/- 1	9 +/- 3	2 +/- 1	0 +/- 0	**51 (77)**
Cantala		20 +/- 14	2 +/- 1	7 +/- 6	14 +/- 10	**255**
Nip Nip	Temporary	130 +/- 22	236 +/- 72	11 +/- 2	1 +/- 1	**1415 (2123)**
Marramook		Dry				
Kramen	Episodic	Dry				
Total		**1927**	**2917**	**105**	**190**	**4875 (6147)**

5.2.4 Macroinvertebrate communities

The raw macroinvertebrate data for each sample collected are included in Appendix B. Across all wetlands, a total of 32 taxa were collected. Water boatmen (Hemiptera: Corixidae) and non-biting midges (Diptera: Chironominae) were the most common taxa and accounted for over 52% of total abundance followed by worms (Oligochaeta), non-biting midges (Diptera: Tanypodinae) and biting midges (Diptera: Ceratopogonidae).

The average site abundances and taxa richness for each wetland and each water regime are included in Table 6. Nip Nip was the most diverse wetland and Boich and Mournpall the least diverse. The lowest abundances were also found in Mournpall while Bitterang, Cantala and Hattah had higher abundances than the other wetlands.

There was no major differences in the number of taxa between the different water regimes that ranged from 22 to 26 taxa. However, the average abundance was noticeably lower in the temporary Nip Nip compared to the persistent temporary and semi-permanent wetlands.

Table 6 Total taxa richness and average abundance and standard errors from each wetland and wetland water regime

	Bitterang	Boich	Cantala	Hattah	Mournpall	Nip Nip	Marramook	Kramen
Water regime class	Persistent temporary			Semi-permanent		Temporary		Episodic
Taxa Richness	18	13	19	20	13	24	Dry	Dry
	26			22		24		
Ave. Abund. & S.E.	2955 ± 1143	1725 ± 623	2742 ± 610	3089 ± 764	964 ± 377	1516 ± 257		
	11394 ± 3259			12157 ± 6,376		1516 ± 257		

The nMDS ordination of each macroinvertebrate sample suggests there are some differences in community composition amongst the wetlands Figure 4. For example, samples from Nip Nip are clearly separated from all other wetlands. With the exception of Boich, samples from the same wetland are generally grouped together although there is some overlap. The stress value associated with the ordination suggests that it is a reasonable representation of similarity amongst samples. The patterns on the nMDS were generally confirmed by a pairwise comparisons of a one-way ANOSIM that detected significant differences between all wetlands ($P < 0.05$) with the exception of Bitterang and Hattah ($P = 0.30$).

The nMDS ordination of each macroinvertebrate sample also suggests there are some differences in community composition amongst the different water regime classes (Figure 4). Samples from the temporary Nip Nip are clearly separated from the other water regime classes. The semi-permanent wetlands generally intersect the persistent temporary wetlands suggesting that some of the latter wetlands are more similar to one another due to factors others than water regime class. These patterns were confirmed by pairwise comparisons from the one-way ANOSIM that detected significant differences between the temporary wetlands and all other water regime classes ($P < 0.05$). However, there were no significant differences between the persistent temporary and semi-permanent water regime classes ($P = 0.17$).

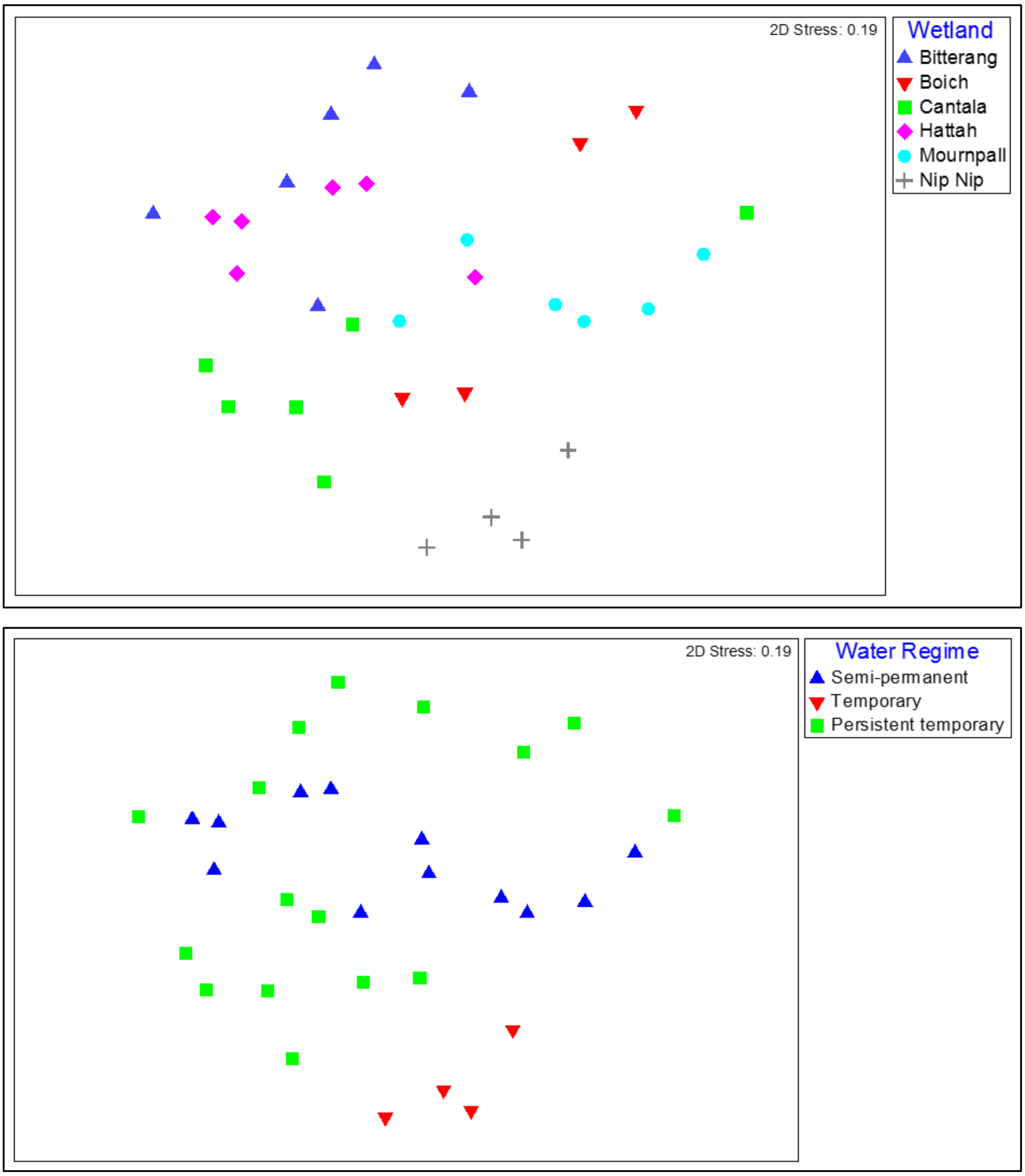

Figure 4 Non-metric multidimensional scaling (nMDS) ordinations with color-coding of macroinvertebrate samples based on wetland (top) and each water regime class (bottom)

A shade plot showing differences in abundances of taxa from each wetland are included in Figure 5. The shade plot suggests the major differences between the wetlands included much higher abundances of shrimp (Decapoda: Atyidae) and limpets (Mollusca: Ancylidae) at Cantala compared to other wetlands. Mayflies (Ephemeroptera: Caenidae) were rare at Boich, Mournpall and Nip Nip, while other mayflies (Ephemeroptera: Baetidae) were rare at Bitterang, Boich, Hattah and Mournpall. Shade plots for each water regime class highlight the higher abundance of non-biting midges (Diptera: Chironominae and Tanypodinae), water boatmen (Hemiptera: Corixidae), worms (Oligochaeta), biting midges (Diptera: Ceratopogonidae) and Caenid mayflies in the temporary persistent and semi-permanent wetlands compared to the temporary wetland (Figure 5). Furthermore, shrimp and limpets were more common in persistent temporary wetlands and Baetid mayflies in the temporary wetland.

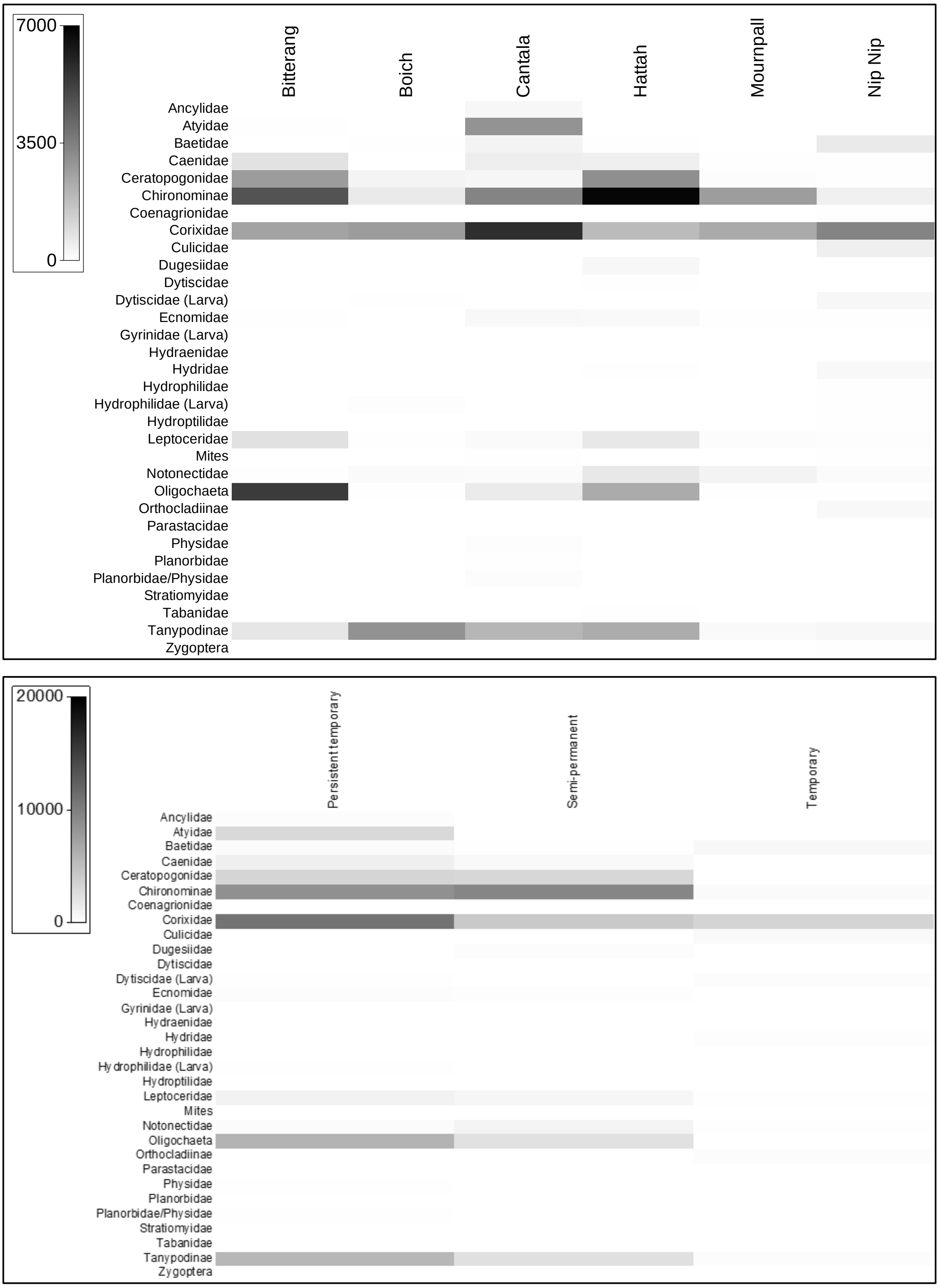

Figure 5 Shade plot indicating differences in total abundances of macroinvertebrate taxa from each wetland (top) and wetland water regime class (bottom)

5.3 Vegetation monitoring

5.3.1 Water level zone

As outlined in Section 3.2, approximately 24 1 x 1 m quadrats were surveyed in each water depth zone at each wetland. A summary of the characteristics of each depth zone at each wetland is outlined in Table 7. There was no bryophyte cover observed in any of the zones in all wetlands. All vegetation quadrat data are provided in Appendix C.

5.3.1.1 Lake Nip Nip

This small wetland was inundated at the time of the survey, with aquatic vegetation in the water and Lakebed Herbland vegetation around the damp and drying mud edges (Plate 1).

Plate 1 Lake Nip Nip

Lower

This zone was characterised by partially inundated and recently receded substrate, with a high cover of aquatic species *Myriophyllum verrucosum* (Red Water Milfoil). Mean water depth was 5.3 ± 1.3 cm and water cover was 48.8 ± 10.0%. On average, around one third of the ground was bare (30.4 ± 7.4%) and there was minimal litter cover (0.8 ± 0.2%). No coarse woody debris was observed in this zone and cryptogram cover was <1%.

Upper

This zone contained no water, with all quadrats in areas either dry or recently receded at the time of the survey. Mean bare ground cover was 22.2 ± 4.0%, while litter cover was 28.8 ± 5.1%. Coarse woody debris cover was below 1% and cryptogram cover was 12.8 ± 3.8%.

Table 7 Habitat characteristics (mean +/- SE) associated with each water depth zone for each wetland

Wetland	Water regime class	Water depth zone	Elevation Zone (m AHD)	Water Depth (cm)	Water cover (%)	Bare ground cover (%)	Litter cover (%)	CWD cover (%)	Cryptogram cover (%)	Bryophyte cover (%)
Hattah	Semi-permanent	Lower	41.0 – 41.5	11.6 +/- 1.2	84.2 +/- 6.5	6.3 +/- 4.4	25.6 +/- 4.5	0.4 +/- 0.4	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	57.5 +/- 5.6	40.5 +/- 5.4	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	45.2 +/- 5.3	53.8 +/- 5.3	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
Mournpall		Lower	41.0 – 41.5	19.5 +/- 1.6	96.0 +/- 1.2	0.0 +/- 0.0	23.8 +/- 2.6	0.8 +/- 0.8	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	56.2 +/- 5.8	43.0 +/- 6.0	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
Bitterang	Persistent temporary	Lower	41.0 – 41.5	25.0 +/- 1.1	97.5 +/- 2.3	0.0 +/- 0.0	20.0 +/- 2.5	2.5 +/- 1.8	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	41.5 – 42.0	0.2 +/- 0.2	4.2 +/- 4.2	58.8 +/- 6.0	27.9 +/- 5.1	0.8 +/- 0.7	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	48.6 +/- 5.2	44.3 +/- 5.6	0.3 +/- 0.2	0.0 +/- 0.0	0.0 +/- 0.0
Boich		Lower	41.0 – 41.5	21.8 +/- 1.2	95.8 +/- 4.2	0.0 +/- 0.0	1.5 +/- 0.9	0.4 +/- 0.4	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	80.2 +/- 3.4	9.5 +/- 2.3	0.0 +/- 0.0	4.4 +/- 2.9	0.0 +/- 0.0
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	59.1 +/- 6.4	28.3 +/- 5.3	0.0 +/- 0.0	6.5 +/- 2.9	0.0 +/- 0.0
Cantala		Lower	41.5 – 42.0	15.5 +/- 1.1	98.5 +/- 1.0	0.0 +/- 0.0	50.1 +/- 6.4	3.8 +/- 1.7	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	18.8 +/- 5.1	70.2 +/- 6.4	1.3 +/- 0.8	1.5 +/- 1.5	0.0 +/- 0.0
		Upper	>42.5	0.0 +/- 0.0	0.0 +/- 0.0	7.1 +/- 3.0	70.3 +/- 8.4	8.4 +/- 6.3	2.2 +/- 2.2	0.0 +/- 0.0
Nip Nip	Temporary	Lower	41.5 – 42.0	5.3 +/- 1.3	48.8 +/- 10.0	30.4 +/- 7.4	0.8 +/- 0.2	0.0 +/- 0.0	0.3 +/- 0.2	0.0 +/- 0.0
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	22.2 +/- 4.1	28.8 +/- 5.2	0.8 +/- 0.5	12.8 +/- 3.8	0.0 +/- 0.0
Marramook		Lower	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	48.3 +/- 2.9	2.0 +/- 0.6	0.6 +/- 0.6	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	65.9 +/- 4.4	25.3 +/- 3.8	1.1 +/- 1.0	0.0 +/- 0.0	0.0 +/- 0.0
Kramen	Episodic	Lower	41.0 – 41.5	0.0 +/- 0.0	0.0 +/- 0.0	23.0 +/- 2.8	41.5 +/- 2.8	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	35.8 +/- 3.2	48.1 +/- 3.4	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0

5.3.1.2 Lake Boich

This wetland was inundated at the time of the survey, with some aquatic vegetation in the water and Lakebed Herbland vegetation around the damp and drying mud edges. The wetland contained a high algae load, which was visibly affecting the health of the aquatic vegetation (Plate 2).

Plate 2 Lake Boich

Lower

At the time of the survey this zone was inundated with a mean water depth of 21.8 ± 1.2 cm and water covering most of the zone (95.8 ± 4.2%). There was no bare ground and minimal litter cover (<2.4%) or coarse woody debris cover (<0.8%). No cryptogram cover was observed during the survey.

Mid

This zone was characterised by recently exposed substrate with no quadrats inundated at the time of the survey. Mean bare ground cover was relatively high (80.2 ± 3.4%), with litter cover 9.5 ± 2.3%. There was no coarse woody debris cover observed while cryptogram cover was 4.4 ± 2.9%.

Upper

This zone was exposed, with all quadrats in areas either dry or recently receded at the time of the survey. Mean bare ground cover was 59.1 ± 6.4%, while litter cover was 28.3 ± 5.3%. Coarse woody debris cover was below 1% and cryptogram cover 6.5 ± 2.9%.

5.3.1.3 Lake Hattah

This wetland was inundated at the time of the survey, with minimal aquatic vegetation in the water and some Lakebed Herbland vegetation around the damp and drying mud edges (Plate 3).

Plate 3 Lake Hattah

Lower

At the time of the survey this zone was characterised by a mean water depth of 11.6 ± 1.2 cm and water cover of 84.2 ± 6.5%. Bare ground cover was relatively low (6.3 ± 4.4%) and although litter cover was 25.6 ± 4.5% coarse woody debris was low and <1%. There was no cryptogram cover observed during the survey.

Mid

This zone had a recently exposed substrate, with no quadrats inundated. More than half of the zone was bare ground (57.5 ± 5.6%) although there was a high degree of litter cover (40.5 ± 5.4%). Coarse woody debris and cryptogram cover was absent in this zone.

Upper

This zone contained no water, with all quadrats either dry or in areas recently exposed at the time of the survey. Mean bare ground cover was 45.2 ± 5.3% although there was a high degree of litter cover (53.8 ± 5.3%). Coarse woody debris and cryptogam cover were both zero in this zone.

5.3.1.4 Lake Mournpall

This wetland was inundated at the time of the survey, with the water level high (Plate 4). As such, only two water level zones were able to be surveyed. No aquatic vegetation was recorded in the water, but some Lakebed Herbland vegetation around the damp and drying mud edges was observed.

Plate 4 Lake Mournpall

Lower

At the time of the survey this zone was characterised by a mean water depth of 19.5 ± 1.6 cm and a water cover of 96.0 ± 1.2%. Although there was no bare ground, underwater leaf litter covered almost a quarter of the zone (23.8 ± 2.6%). Coarse woody debris was low and usually <1% while no cryptogram cover was observed.

Upper

This zone was characterised by recently receded water and exposed substrate. No quadrats were inundated during the survey. Mean bare ground cover was 56.2 ± 5.8%, with litter cover 43 ± 5.9%. There was no coarse woody debris or cryptogram cover within this zone.

5.3.1.5 Lake Bitterang

This wetland was inundated at the time of the survey, with minimal aquatic vegetation in the water and Lakebed Herbland vegetation around the damp and drying mud edges (Plate 5).

Lower

At the time of the survey this zone was inundated with a mean water depth of 25 ± 1.1 cm and water cover of 97.5 ± 2.3%. There was zero bare ground in this zone and litter cover was 20.0 ± 2.5% and coarse woody debris cover was 2.5 ± 1.8%. No cryptogram cover was observed in this zone.

Mid

This zone was characterised by a substrate that was recently exposed although there was some water cover (4.2 ± 4.2%) with a mean depth of <1 cm. On average, bare ground cover was 58.8 ± 6.0%, with litter cover 27.9 ± 5.1%. Coarse woody debris was low and usually less than 1% in all quadrats while no cryptogram cover was observed.

Upper

This zone contained no water, with all sites either dry or recently exposed at the time of the survey. Mean bare ground cover was 48.6 ± 5.2%, while litter cover was also relatively high at 44.3 ± 5.6%. Coarse woody debris cover and cryptogam cover were both under 1% in this zone.

Plate 5 Lake Bitterang

5.3.1.6 Lake Cantala

This wetland was inundated at the time of the survey, and the water level was quite high (Plate 6). Minimal aquatic vegetation was recorded in the water but Lakebed Herbland vegetation was recorded around the damp and drying mud edges.

Lower

At the time of the survey this zone was characterised by a water depth of 15.5 ± 1.1 cm with water covering almost all of the zone (98.5 ± 0.9%). There was zero bare ground cover and litter covered around half of the zone (50.1 ± 2.2%). There was some coarse woody debris cover (3.8 ± 1.7%) but no cryptogram cover in the zone.

Mid

This zone contained recently exposed substrate and no quadrats were inundated. Mean bare ground cover was 18.8 ± 5.1%, with litter cover high at 70.2 ± 6.4%. Coarse woody debris and cryptogram cover were relatively low and generally less than 2%.

Upper

This zone contained no water, with all sites either dry or in areas recently exposed at the time of the survey. Mean bare ground cover was 7.1 ± 3%, while litter cover was high at 70.3 ± 8.4%. Coarse woody debris cover was 8.44 ± 6.3% and cryptogam cover was 2.2 ± 2.2%.

Plate 6 Lake Cantala

5.3.1.7 Lake Marramook

This wetland was dry at the time of the survey, with only two LIDAR AHD elevation zones mapped, the upper and lower depth zones (Plate 7).

Plate 7 Lake Marramook

Upper and Lower

Both LIDAR AHD elevation zones were quite dry. Mean bare ground cover was 57.1 ± 2.9%, with litter cover 13.7 ± 2.6%. There was little coarse woody debris cover observed (<1.5%) and no cryptogram cover.

5.3.1.8 Lake Kramen

This wetland was dry at the time of the survey, with only two LIDAR AHD elevation zones mapped, both falling under the dry category.

Plate 2 Lake Kramen

Upper and Lower

Both mapped LIDAR AHD elevation zones were very dry, with low flora species richness recorded. Mean bare ground cover was 29.4 ± 2.3%, with litter cover 44.8 ± 2.2%. There was no coarse woody debris or cryptogram cover observed in this zone during the survey.

5.3.2 Eucalypt seedlings and saplings

Saplings of *Eucalyptus* sp. (either *E. camaldulensis* or *E. largiflorens*) were not recorded in any of the wetlands during the survey (Table 8). However, eucalypt seedlings were recorded in 179 of the 469 quadrats surveyed. No seedlings were observed in the lower depth zone in any of the wetlands. However, they were found in the upper depth zones in all wetlands excluding Kramen. They were also found in mid depth zone in all wetlands.

The proportion of seedlings in the different zones varied amongst the wetlands. For example, in Lake Hattah there were greater abundances in the mid depth zone (51.2 +/- 17.5) compared to the upper depth zone (2.7 +/- 1.1). A similar pattern in distribution was found in Cantala. In Bitterang, there were similar abundances in both of these zones.

Table 8 Sapling and seedling data in relation to water depth zones

Water regime class	Wetland	Water level zone	Elevation Zone (m AHD)	Saplings <2 m ht.	Saplings <2 m no.	Seedlings <0.25 m no.
Semi-permanent	Hattah	Lower	41.0 – 41.5	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	51.2 +/- 17.5
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	2.7 +/- 1.1
	Mournpall	Lower	41.0 – 41.5	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	38.0 +/- 14.3
Persistent temporary	Bitterang	Lower	41.0 – 41.5	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	52.2 +/- 12.5
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	52.3 +/- 13.5
	Boich	Lower	41.0 – 41.5	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	10.8 +/- 3.8
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	27.5 +/- 10.5
	Cantala	Lower	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Mid	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	101.1 +/- 28.5
		Upper	>42.5	0.0 +/- 0.0	0.0 +/- 0.0	7.6 +/- 4.5
Temporary	Nip Nip	Lower	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	16.2 +/- 3.6
	Marramook	Lower	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	0.2 +/- 0.1
		Upper	42.0 – 42.5	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
Episodic	Kramen	Lower	41.0 – 41.5	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0
		Upper	41.5 – 42.0	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0

5.3.3 Species composition

Species richness

A total of 61 taxa (51 native, 10 introduced) were observed within the 469 quadrats in the wetlands. Across all quadrats, total species richness varied considerably, ranging from 0-17. In all wetlands, the highest mean species richness was consistently found in the upper depth zone followed by the mid depth zone and finally, the lower zone, which was usually inundated (Figure 6). However, it should be noted that lakes Nip Nip, Mournpall, Marramook and Kramen did not contain a 'mid' depth zone at the time of the surveys.

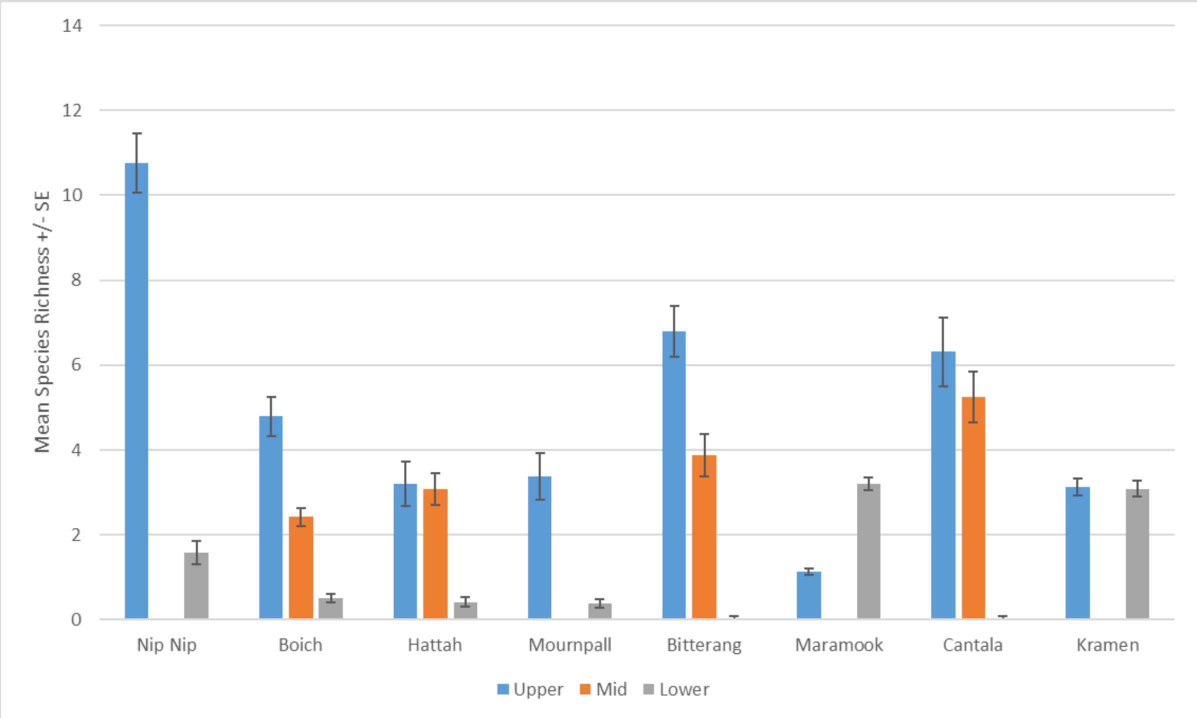

Figure 6 Mean species richness in relation to water level zones for all wetlands

Species cover

Approximately 99% of vegetative cover across all quadrats comprised native species. Mean native cover followed a similar pattern to mean species richness across the wetlands that were inundated, with cover generally lowest in the lower depth zone, intermediate in the mid depth zone, and highest in the upper depth zone (Figure 7), with the exception of Lake Nip Nip, which had a high cover of *Myriophyllum verrucosum* (Red Water-milfoil) in the lower depth zone. The dry lakes Marramook and Kramen also had high native species cover in the lower zone due to the lack of water cover and period since drying.

Mean cover of introduced species was low across all zones at all wetlands, with Lake Kramen, which has been dry longer than any other wetland, showing the highest mean weed cover (Figure 8).

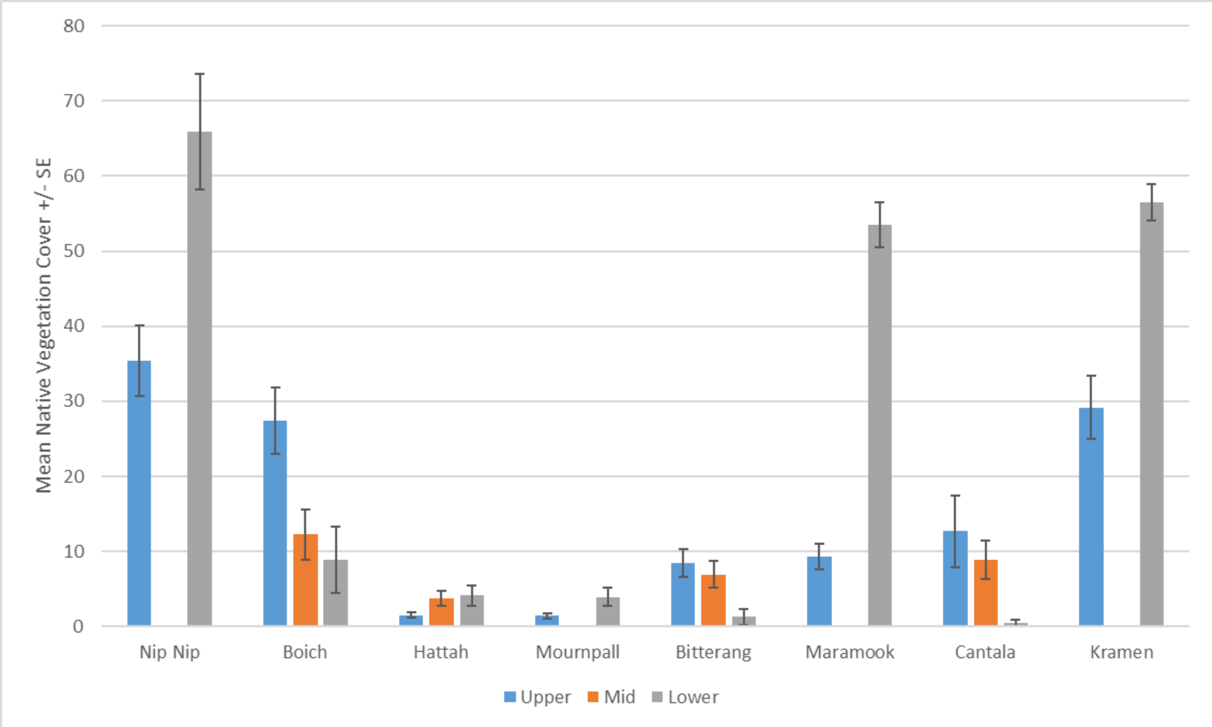

Figure 7 Mean native species cover in relation to water level zones for all wetlands

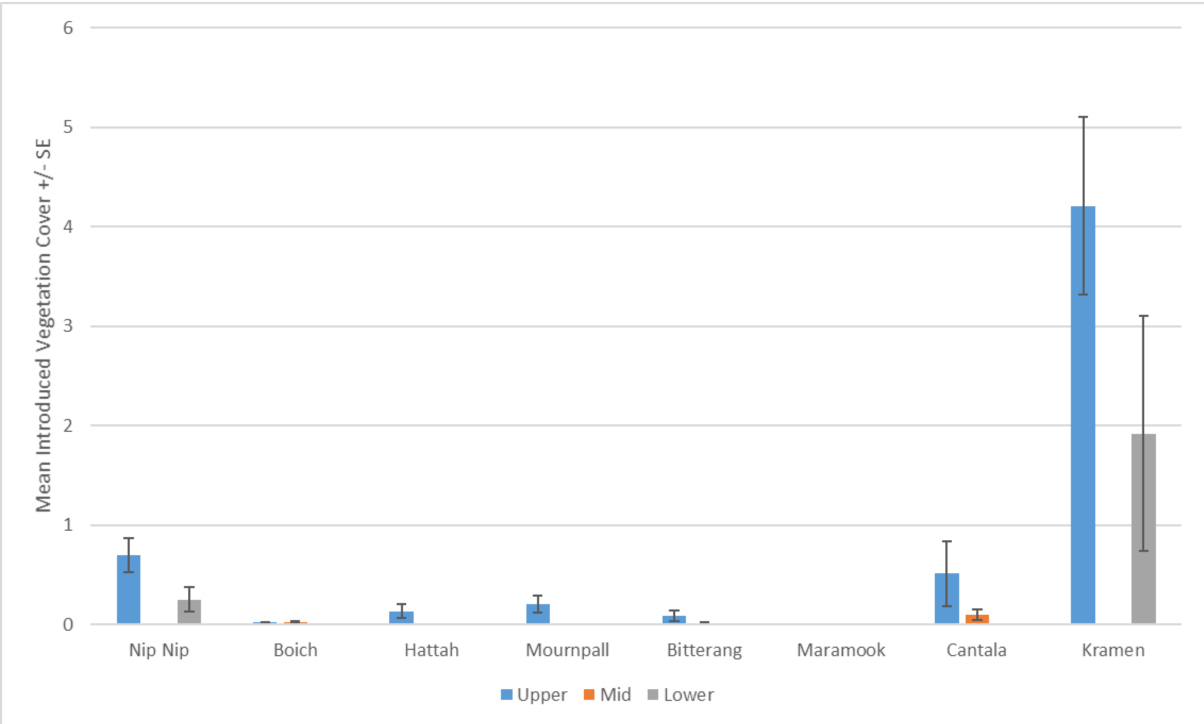

Figure 8 Mean introduced species cover in relation to water level zones for all wetlands

Data showing the mean individual species cover in relation to water level can be found in Appendix C.

Species proportional frequency

Flora species were analysed for their proportional frequency (Appendix D), which is a measure of how many times that species was recorded (presence/absence) out of all the quadrats in that water depth zone at that wetland. For example, if a species was present in 12 out of the 24 quadrats at a given water depth zone at a wetland, it would have a proportional frequency of 50%. The species showing high proportional frequencies across all depth zones included *Centipeda cunninghamii* (Common Sneezeweed), *Eucalyptus camaldulensis* (River Red-gum), *Glycyrrhiza acanthocarpa* (Southern Liquorice) and *Polygonum plebeium* (Small Knotweed).

Eucalyptus camaldulensis (River Red-gum) and *Glycyrrhiza acanthocarpa* (Southern Liquorice) were frequently found in the quadrats within all three depth zones although the degree of frequency varied as they were more regularly observed in the upper and mid zones. *Polygonum plebeium (*Small Knotweed*)* was also more frequent in the upper and mid zones while *Myriophyllum verrucosum* (Red Water Milfoil) was more frequent in the lower zone.

The species that were frequently found in the upper depth zone (across all wetlands) were *Eucalyptus camaldulensis* (57% of all quadrats), *Glycyrrhiza acanthocarpa* (51%), *Centipeda cunninghamii* (46%) and *Polygonum plebeium* (44%). In the mid depth zone the species were *Eucalyptus camaldulensis* (84%), *Glycyrrhiza acanthocarpa* (55%) and *Polygonum plebeium* (38%). In the lower depth zone the frequent species were *Glycyrrhiza acanthocarpa* (23%), *Myriophyllum verrucosum* (18%) and *Eucalyptus camaldulensis* (13%).

5.3.4 Rare or threatened species

A total of three species listed as rare in Victoria under the *Advisory List of Rare or Threatened Plants in Victoria – 2014* (DEPI 2014) were recorded during the monitoring. These species are described below, with information sourced from VicFlora[9]. Of particular note is *Centipeda nidiformis* (Cotton Sneezeweed), which has only been recorded twice within 10 km of the Hattah Lakes, the last time being in 1982, as identified in the VBA search.

Austrobryonia micrantha (Mallee Cucumber) – Rare (DEPI 2014)

Prostrate annual from a perennial rootstock. Flowers November to April. Occurs on drying or dried clay soils (e.g. lake-beds, ephemeral watercourses and lagoons) on the floodplain of the Murray River in the far north-west, with southerly occurrences at e.g. Lake Tyrrell and Wyperfeld National Park.

Centipeda nidiformis (Cotton Sneezeweed) – Rare (DEPI 2014)

Decumbent to ascending cottony annual, spreading to c. 15 cm diameter and/or 15 cm high. Flowers mostly January to April. Scattered throughout the Murray Basin and around the Grampians along the margins of watercourses on clay or clay-loam soils. Only two previous records of this species within 10 km of the Hattah Lakes.

Calotis cuneifolia (Blue Burr-daisy) – Rare (DEPI 2014)

Erect, ascending or procumbent, freely branching perennial; stems glabrescent to pubescent. Leaves spathulate to cuneate. Flowers August–February. Scattered along the Murray River and

[9] https://vicflora.rbg.vic.gov.au/

its floodplain. 14 records within a 10 km radius of the Hattah Lakes. Monitoring indicated that this species had a strong preference for upper depth zone sites.

***Eleocharis acuta* (Common Spike-rush) – not listed**

There is a form of this species chiefly found in the far north-west of the State, on sandy or silty soils of lake and stream margins. These plants are smaller than in typical *E. acuta*, and have the bristles reduced. However, there are no obvious qualitative characters to separate this form from the common form of *E. acuta*. Further study is needed to establish the status of this form.

6. Discussion

Effective management of floodplain lakes and wetlands is often limited by a lack of hydrological and ecological knowledge (Davis & Froend, 1999). To address this, this study has established baseline aquatic ecosystem and vegetation conditions in eight wetlands that are part of the Hattah Lakes Icon Site.

The monitoring program has been designed to be repeatable and allow statistical comparisons to be made between depth zones and wetlands following intervention monitoring in future years at different water levels. This would increase the knowledge regarding the response of the aquatic environment and vegetation communities to variable water levels and aid in the management of the lakes. This is important given The Living Murray program has attempted to replicate the natural hydrograph through environmental watering and Kennard (2005) found that aquatic fauna can demonstrate resilience to variable flow regimes provided that changes in flow and habitat resemble natural pre-disturbance conditions. Bird communities in Australian wetlands and floodplain lakes have also suffered due to alterations of natural flow regimes (Kingsford & Thomas, 2004) so water level manipulation has the potential to provide multiple ecosystem benefits. The wetlands and their associated water regime classes monitored were:

- Semi-permanent – Lakes Mournpall and Hattah
- Persistent temporary – Lakes Cantala, Boich and Bitterang
- Temporary – Lakes Nip Nip and Marramook
- Episodic – Lake Kramen

Generally, the monitoring occurred following a period of decreasing water levels in all wetlands. The study assessed the current condition of the aquatic environment and vegetation in the littoral zone, and provides information on productivity, food sources and habitat available for fauna that utilise the lakes following the water level decreases. Due to Lake Marramook and Kramen both being dry during November 2018, the aquatic environment in these wetlands was not assessed.

6.1 Aquatic monitoring

6.1.1 Water quality and phytoplankton communities

As threats to aquatic biota may include high nutrient and salinity levels, extreme dissolved oxygen and pH levels, as well as algal blooms, an assessment of water quality is important as it is a driver of aquatic communities such as zooplankton, macroinvertebrates, vegetation and fish. It should be noted that the assessment of water quality in each wetland during this study was made at a single location on one occasion only. As such, the results represent a snapshot only and spatial, diurnal and seasonal variation would be expected in some parameters.

Water temperature, dissolved oxygen (DO), pH, turbidity and chlorophyll-a during November 2018 were within the range observed in previous studies of the Hattah Lakes (McCarthy et al., 2009). There was variation in electrical conductivity (EC) amongst the wetlands during November 2018 that ranged from 343 to 1120 µS/cm. These levels were higher than the 2018 average monthly EC in the Murray River at Colignan as recorded at Gauging Station 414207 that ranged from 62 to 137 µS/cm. However, they were within the EC range expected for Hattah Lakes based on McCarthy et al. (2009) who found levels ranging from around 250 to 1,450 µS/cm, depending on water level.

Under ambient conditions DO in water is typically around 6 to 10 mg/L, although daytime super-saturation (>100%) may occur due to photosynthesis by algae and submerged macrophytes

(McCarthy et al., 2009; DEHP, 2013). Furthermore, most freshwater has a pH in the range of 6.5 to 8.0, although in wetlands with high densities of algae and macrophytes, pH may be higher (ANZECC, 2000). This occurs because carbon dioxide (CO_2) is acidic and the sequestration of CO_2 during photosynthesis increases the pH of water. The high turbidity levels are likely due to a combination of wind disturbance, which is not uncommon for shallow lakes, and high algal biomass (ANZECC, 2000). EC variation is also expected as salts become concentrated or diluted in association with changes in water levels (McCarthy et al., 2009).

Nutrient concentrations were also high in the wetlands with oxides of nitrogen (NOx), total nitrogen (TN), reactive phosphorus (RP) and total phosphorus (TP) regularly exceeding recommended values for the protection of aquatic ecosystems. The major contributor to TN was organic nitrogen (ON) that can originate from both dead and living organisms (Jorgensen, 2009) and aquatic and terrestrial flora (Kingsford, 2000). Large amounts of ON can also accumulate on the beds and sediments of the wetlands during low water levels or dry (terrestrial) phases (McCarthy et al., 2009). Phosphorus can be delivered to waterways from the catchment either in dissolved forms or bound to sediments, or directly from source water inputs from the Murray River (Davis et al., 1998). Nutrient enrichment is a common issue for floodplain wetlands and lakes in Australia, as water levels decrease (Davis & Froend, 1999).

The high nutrient concentrations of the wetlands are likely contributing to high algal abundances and risk of bloom formations (Downing & McCauley, 1992). In some ways this was not surprising, as nutrient rich waters of floodplain wetlands support higher primary and secondary productivity than associated river channels. However, it may be a concern given McCarthy et al. (2009) detected a total of 20 blue-green algae (Cyanobacteria) taxa in some of the wetlands, including four potentially toxic species; *Microcystis aeruginosa*, *Anabaena spiroides f. spiroides*, *Cylindrospermopsis raciborskii* and *Anabaena circinalis*.

6.1.2 Zooplankton communities

Although there was some variation, Cladocera were the most common zooplankton taxa recorded across all wetlands followed by Copepoda, while Ostracoda and Rotifera were relatively rare. Cladocera have previously been reported as the dominant taxa in the Hattah Lakes (Ecological Associates, 2007).

The characteristics of zooplankton communities are driven by factors including surface area, depth, trophic level, water colour and interactions with other biological communities (Ismail & Mohd Adnan, 2016). Furthermore, Medeiros & Arthington (2008) found that seasonal variation in zooplankton of floodplain habitats was influenced by changes in water availability. This includes flooding following a drying phase as the re-wetting of sediments can stimulate communities and new habitat is created when terrestrial vegetation is inundated (Reid & Brooks, 2000; MDBC, 2006). In fact, in a study of the Chowilla floodplain, Boulton & Lloyd (1992) found that frequent flooding increased the abundance and diversity of zooplankton assemblages compared to wetlands that were rarely flooded. This was also found in this study with the semi-permanent and temporary wetlands having noticeably higher abundances than the persistent temporary wetlands.

6.1.3 Macroinvertebrate communities

Water boatmen (Hemiptera: Corixidae) and non-biting midges (Diptera: Chironominae) were the most common taxa in the wetlands followed by worms (Oligochaeta), non-biting midges (Diptera: Tanypodinae) and biting midges (Diptera: Ceratopogonidae). Similar taxa have been found in other floodplain habitats in eastern Australia (Medeiros & Arthington, 2008). With the exception of worms, these taxa are winged insects and their presence may be related to their dispersal abilities. Davis & Froend (1999) suggest that winged insects are able to persist in wetlands whose hydrology has been altered and have lost connection due to absence of large-scale flooding.

Spatial and temporal patterns in macroinvertebrate assemblages are influenced by a range of factors including the hydrological regime (Reid & Brooks, 2000). The temporary Nip Nip was found to be the most diverse wetland with the more permanent Boich and Mournpall the least diverse. This agrees with Balla & Davis (1995), who found that temporary wetlands generally have more diverse macroinvertebrate communities than nearby permanent waterbodies. This was attributed to variable water levels facilitating a decrease in the abundance of dominant taxa that would otherwise outcompete more inferior taxa during stable conditions (Balla & Davis, 1995).

However, the diversity and abundance of macroinvertebrate communities are also dependent on other factors such as physico-chemical conditions and habitat conditions including macrophyte communities (Davis & Froend, 1999). Abundance of macroinvertebrates varied amongst the water regime classes and were lowest in Mournpall (semi-permanent), but highest in Hattah (Semi-permanent) and Bitterang and Cantala (persistent temporary) than the other wetlands.

6.2 Vegetation monitoring

This baseline vegetation monitoring at the Hattah Lakes revealed distinct patterns in relation to species composition, richness and frequency across a narrow elevation gradient comprising two or three water depth zones at each wetland.

Recruitment of canopy species (i.e. eucalypts) was patchy and highly localised, as observed in other studies on the River Murray floodplain (e.g. George *et al.* 2005). The patchy nature of eucalypt recruitment is most likely due to prevailing westerly winds pushing eucalypt seeds to aggregate in high densities near previous high water marks.

Total species richness, mean species richness and mean native cover all displayed similar trends – lowest in lower depth zone (usually inundated) and highest in the upper depth zone (usually dry or recently receded) on the outer fringe of the lake bed. This is a commonly observed phenomenon in floodplain wetlands of the Murray-Darling Basin (e.g. GHD 2018), with species diversity maximised once the disturbance event (i.e. watering) has finished. This observation was verified by the fact that the two wetlands that were dry at the time of assessment, Marramook and Kramen, had higher richness and native cover in the lower depth zone. While quadrats were not sampled in water deeper than 0.3 m, anecdotal evidence indicated that aquatic vegetation was concentrated in the littoral zone and exposed outer margins of the lake bed.

As expected, in this monitoring event, most flora were specialists confined to a particular water depth zone (usually the upper depth zone), while only a few were generalists. This concurs with the PFG approach, whereby Tda (terrestrial moisture dependent species with rootstocks intolerant of more than superficial inundation) were dominant on the outer margins of the lake, which had been exposed over the preceding months, and amphibious species (e.g. Ate, ARp) were dominant in the shallow littoral zone. These results largely concurred with those of GHD (2014), which indicated a substantial increase in Tda and amphibious species following flooding.

Species richness was highly variable at the time of monitoring, with up to 17 species recorded in one 1 x 1 m quadrat. This is a baseline survey for the Hattah Lakes, and it was undertaken in a drawing down phase for six of the lakes, with the other two already dry. This provides a solid dataset for comparison with potential future productivity monitoring of the Hattah lakes under different environmental watering regimes.

Introduced species were a very minor component of the flora at the time of monitoring, with weed cover generally low across all lakes.

The littoral zones of the inundated lakes were subject to moderate waterbird use, with moderate numbers of birds sighted during the monitoring, and evidence of bird activity (droppings, footprints) in several quadrats that were not inundated at the time of assessment. Evidence of colonial breeding (nests) was also observed in some large River Red gums on the fringes of the lakes.

6.3 Water level variation and wetland management

The results from this study suggest that water level variation may be a major driver influencing the health of the aquatic ecosystem in the wetlands. Changes in water level can have a direct and indirect influence on water quality, zooplankton and macroinvertebrate communities, as well as interactions between these factors. This an important management consideration given that zooplankton are also recognised as an important trophic link between primary production and higher order consumers (Medeiros & Arthington, 2008) and along with macroinvertebrates can provide a food source for many bird (Loyn et al., 2014) and fish species (Kuiter, 2013).

Changes in water level have also shown to influence the vegetation community. During periods of high water level, the highest vegetation cover is in the upper depth zone. However, when water levels are reduced, this creates an opportunity for vegetation cover to increase in the lower, recently exposed, depth zone. Given that organic nitrogen has been shown to be a major contributor to nutrient levels in the wetlands, as discussed by rewetting of the wetlands and inundation of the vegetation in the lower depth zone would likely lead to a marked increase in the total nitrogen load (e.g. see McCarthy et al., 2009).

Manipulation of water levels alone are only one management tool in the protection of the wetlands and additional landscape-scale management actions, such as reducing the inputs of nutrients, would also aid in improving health. The high nutrient, chlorophyll-a concentrations and turbidity suggest that wetlands in the Lake Hattah Icon Site are eutrophic or even hyper-eutrophic (see Carlson, 1977). Without appropriate management, continued eutrophication has the potential to cause the wetlands to become more productive via nutrient enrichment, thereby stimulating primary producers, causing algal blooms, water quality deterioration and potentially fish kills and other impacts (Wang & Wang, 2009).

Management of nutrient inputs to the wetlands may require consideration of the ratio between nitrogen (N) and phosphorus (P). There is debate over the optimum ratio for uptake by algae and vegetation (see discussion by Wang & Wang, 2009) although many limnologists use 7:1 (N:P by mass) proposed by Redfield et al. (1963). In general, if the ratio exceeds 7 there is an excess of N and growth is limited by available P. Alternatively, if the ratio is less than 7 the water is considered N-limited. When N is limiting nutrient, there is potential for Cyanobacteria blooms to form due to their ability to fix atmospheric nitrogen (Bulgakov & Levich, 1999). The results of this project found that Bitterang was N-limiting (ratio 2.6) while all other wetlands were P-limiting. So although all wetlands had high N and P levels, it may be that the organic-N inputs are reducing the chance of nitrogen becoming limiting and therefore, reducing the risk of Cyanobacteria blooms.

Reducing organic matter into waterways is seen as a way to manage ‘black water’ events in the region. However, the high organic nitrogen loads identified in this study suggest that this should be done in parallel with phosphorus management. As discussed by Wang & Wang (2009), a reduction in nitrogen may not decrease the biomass of total phytoplankton as it can stimulate blooms of nitrogen-fixing Cyanobacteria and to mitigate eutrophication focus should be placed on limiting phosphorus.

7. Conclusions

This study has established baseline aquatic and vegetation conditions at the Hattah Lakes based on monitoring undertaken during November and December 2018. In general, the results represent conditions during falling water levels in Lakes Mournpall, Hattah, Cantala, Boich, Bitterang and Nip Nip. While Lakes Marramook and Kramen were dry during monitoring. The following key points were determined:

Aquatic Ecosystem

- *In situ* water quality of the lakes was similar to previous studies of the Hattah Lakes. This included high dissolved oxygen and pH which was likely driven by the high algal biomass in the wetlands.
- High nutrient concentrations in the wetlands are likely to be contributing to increased algal abundances and the risk of Cyanobacteria (Blue-green algal) blooms.
- The composition of the zooplankton and macroinvertebrate communities are similar to other floodplain wetlands.
- Based on the results of the monitoring, it appears wetlands associated with the Lake Hattah Icon Site are highly productive eutrophic or even hyper-eutrophic ecosystems characterised by high nutrients, turbidity and high primary productivity.
- Interactions between algal and vegetation communities, and variation in the hydrology of the wetlands is a major driver in water quality conditions and the composition of biotic communities.

Vegetation

- When lakes are drawing down, highest mean species richness and cover of native flora occurs in upper water depth zone where water has receded in recent months. As water level recedes, moisture-dependent terrestrial vegetation is expected to colonise the exposed substrate. When lakes are dry, highest species richness and cover of native flora occurs in the lower water depth zone, where water has recently most recently been present.
- Anecdotal evidence suggests that vegetation in the littoral zone is being actively utilised by waterbirds during foraging activities, with evidence (i.e. nests) of colonial breeding.

Water level variation and wetland management

- Manipulation of water levels in the Hattah Lake wetlands has the potential to influence the aquatic ecosystem and vegetation communities.
- Further intervention monitoring at difference water levels would add knowledge on the dynamics of the wetlands and how water level changes can best be used to manage ecological health.
- In addition to the management of water levels, catchment wide land and water management (e.g. nutrients controls) would also be required for maximum benefits of the lake.

8. Recommendations

Following this baseline survey, we make the following recommendations.

8.1 Aquatic monitoring

- Repeat monitoring at different water levels to increase knowledge on the dynamics of the wetlands and any differences associated with the water regime classes.
- Use of univariate (e.g. ANOVA) and multivariate statistics (e.g. ANOSIM) to compare results generated in this study to intervention monitoring at different water levels and seasons.
- Dissolved oxygen loggers could be deployed to investigate if there are dramatic decreases in oxygen at night, especially during warmer months.
- Organic matter and sediment sampling in dry/exposed areas of the wetlands in an attempt to identify the sources of nutrients that drive productivity. Or other specific study to identify sources of nutrients to the wetlands. If this is already known, then implementation of management strategies to attempt to decrease nutrient inputs.
- Decreasing the inputs of organic matter, and hence nitrogen, to the wetlands is a current management focus in the region to prevent ‘blackwater’ events. However, this study has shown that phosphorus concentrations are also high and the limiting nutrients in the majority of the wetlands. Reducing nitrogen inputs through the reduction of organic matter may result in the wetlands become nitrogen limiting, thereby potentially increasing the chance of conditions favouring Cyanobacteria (see Schindler et al., 2008). Some consideration should be given to this to determine if it is a potential issue for the region.

8.2 Vegetation monitoring

- Additional aquatic and vegetation intervention monitoring at different water levels and during different seasons/years would contribute to the overall knowledge of ecosystem dynamics at the Hattah Lakes.
- Future analysis of vegetation data should focus on determining whether there is a link between nutrient levels, vegetation cover and overall productivity of the wetlands. This may include approaches such as correlation analyses between these components of the ecosystem.
- Avoid reducing replicate quadrat numbers (i.e. below 24) in each water level zone if possible.

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Appendices

Appendix A – Raw zooplankton results (per litre) for each location

Wetland	Bitterang						Boich				Cantala					
Water Regime Class	Persistent temporary						Persistent temporary				Persistent temporary					
Replicate	1	2	3	4	5	6	2	1	4	3	1	2	3	4	5	6
Copepoda	2.0	46.5	74.0	4.8	26.4	3.0	5.7	0.6	0.4	0.0	3.2	4.6	88.5	15.6	6.0	3.0
Cladocera	4.2	47.6	68.1	13.2	41.7	28.8	16.2	6.9	5.2	6.0	0.3	0.7	2.5	0.6	3.6	2.7
Ostracoda	0.0	1.1	2.6	0.9	0.6	0.0	3.0	0.6	0.4	5.5	0.0	0.3	35.5	1.5	0.6	2.4
Rotifera	0.3	14.6	4.2	0.6	2.4	1.2	0.0	0.0	0.0	0.0	0.6	0.7	61.0	12.0	6.6	2.4

Wetland	Hattah						Mournpall					Nip Nip		
Water Regime Class	Semi-permanent						Semi-permanent					Temporary		
Replicate	1	2	3	4	5	6	1	2	4	5	6	1	4	3
Copepoda	6.0	2.8	0.0	15.9	2.8	5.2	66.0	310.2	82.5	3.9	100.8	135.8	163.4	89.5
Cladocera	54.3	184.9	19.5	1429.4	31.7	122.2	3.6	6.6	14.4	65.4	25.5	359.3	237.3	111.1
Ostracoda	0.0	0.1	0.8	0.5	0.0	1.0	0.1	1.8	0.1	1.5	0.3	10.3	7.8	13.6
Rotifera	1.1	3.1	0.4	5.0	0.2	1.2	21.6	8.1	11.4	0.6	6.9	3.3	0.3	0.4

Appendix B – Raw macroinvertebrate results for each location

Wetland	Bitterang						Boich				Cantala					
Water Regime Class	Persistent temporary						Persistent temporary				Persistent temporary					
Replicate	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6
Ancylidae	0	0	0	0	0	0	0	0	0	0	8	10	0	170	10	20
Atyidae	10	0	1	2	1	1	0	0	0	0	1517	980	0	50	15	380
Baetidae	0	0	0	0	0	0	0	20	0	0	50	50	0	40	10	170
Caenidae	340	92	280	19	33	35	0	0	0	0	133	20	0	60	235	30
Ceratopogonidae	820	125	1090	43	587	50	20	120	60	100	58	0	90	10	30	70
Chironominae	2040	700	1460	305	107	100	30	280	40	230	75	1770	20	700	390	400
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	590	1350	280	12	227	70	90	1320	170	1130	892	580	150	2060	565	1460
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dugesiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	8	0	0	0	0	0	10	0	0	0	0	0	0	5	0
Dytiscidae (Larva)	10	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0
Ecnomidae	0	0	10	5	0	15	0	0	0	0	0	20	0	100	45	30
Gyrinidae (Larva)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydraenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Hydridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	1	0	0	0	0	0	0	0	0	0	10	0	0	0
Hydrophilidae (Larva)	0	0	0	0	0	0	0	20	20	10	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Leptoceridae	440	142	30	5	20	180	10	20	0	0	25	40	0	0	55	20
Mites	0	0	0	0	0	5	0	0	0	0	0	20	0	0	0	10
Notonectidae	0	0	10	0	7	10	0	50	0	100	0	0	100	10	0	10
Oligochaeta	3560	183	30	326	1200	50	0	20	20	0	8	170	0	260	0	100

Wetland	Bitterang						Boich				Cantala					
Water Regime Class	Persistent temporary						Persistent temporary				Persistent temporary					
Replicate	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6
Orthocladiinae	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Parastacidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	0	0	0	0	10	0	0	0	0	0	0	0	20	5	30
Planorbidae	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
Planorbidae/Physidae	0	0	0	0	0	0	0	0	0	0	0	20	0	40	10	0
Stratiomyidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Tanypodinae	430	167	20	62	13	0	310	1190	580	890	100	360	0	430	155	940
Zygoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wetland	Hattah						Mournpall						Nip Nip			
Water Regime Class	Semi-permanent						Semi-permanent						Temporary			
Replicate	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4
Ancylidae	0	0	0	0	10	0	0	0	0	0	0	0	0	0	7	0
Atyidae	0	0	0	0	1	0	0	8	1	0	3	1	0	0	0	0
Baetidae	0	10	10	0	20	0	0	0	0	0	0	0	140	133	180	125
Caenidae	110	80	20	40	150	35	0	2	1	0	8	7	20	7	0	5
Ceratopogonidae	830	730	830	620	10	45	33	4	3	18	18	13	10	0	0	5
Chironominae	3030	140	930	1920	360	435	1942	92	53	148	298	143	140	73	127	80
Coenagrionidae	0	0	0	0	10	0	0	0	0	0	0	0	0	7	27	0
Corixidae	520	210	390	200	130	415	775	296	170	504	143	430	1140	1033	813	385
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	370	0	60	20
Dugesiidae	40	70	80	10	0	15	0	0	0	0	0	0	10	0	0	0
Dytiscidae	0	0	0	0	20	0	0	0	1	2	0	0	0	0	0	10
Dytiscidae (Larva)	0	10	0	0	0	0	0	0	0	0	0	0	90	0	87	40

Wetland	Hattah						Mournpall						Nip Nip			
Water Regime Class	Semi-permanent						Semi-permanent						Temporary			
Replicate	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4
Ecnomidae	40	20	10	0	90	5	0	0	4	2	15	7	0	20	0	0
Gyrinidae (Larva)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hydraenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydridae	10	0	0	0	0	10	0	0	0	0	0	0	0	180	0	5
Hydrophilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	27	7	0
Hydrophilidae (Larva)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	13	25
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	10	13	0	0
Leptoceridae	350	50	130	80	30	0	33	2	4	4	30	3	20	13	7	15
Mites	0	0	0	0	0	0	0	4	0	0	5	0	0	13	0	5
Notonectidae	240	30	10	90	10	255	8	24	30	82	45	143	30	7	20	40
Oligochaeta	520	150	780	0	830	15	8	0	0	0	28	0	0	13	0	5
Orthocladiinae	0	0	0	0	0	0	0	0	0	0	5	3	110	0	33	55
Parastacidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
Planorbidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planorbidae/Physidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stratiomyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tabanidae	0	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0
Tanypodinae	440	10	1170	70	570	10	0	2	0	2	158	13	40	47	73	50
Zygoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	10

Appendix C – Mean flora cover in relation to water depth zones

	Status	Hattah			Mournpall			Bitterang			Boich			Cantala			Nip Nip			Maramook			Kramen		
		Semi-permanent						Persistent temporary									Temporary						Episodic		
		Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower
Austrobryonia micrantha	r											0.1 +/- 0.0			0.1 +/- 0.0		0.3 +/- 0.2								
Centipeda nidiformis	r							0.1 +/- 0.0						0.1 +/- 0.0											
Eleocharis acuta													1.0 +/- 0.0												
Eucalyptus camaldulensis		0.4 +/- 0.2	1.9 +/- 0.6	9.9 +/- 2.1	0.8 +/- 0.2		10.6 +/- 1.8	2.2 +/- 0.7	2.5 +/- 1.6	5.0 +/- 0.0	2.0 +/- 0.7	0.7 +/- 0.1		0.4 +/- 0.2	2.0 +/- 0.5		1.5 +/- 0.3			15.0 +/- 10.0		1.7 +/- 1.0			
Haloragis aspera								0.1 +/- 0.0						6.0 +/- 4.0	2.0 +/- 0.0										
Limosella australis														0.1 +/- 0.0	3.0 +/- 2.0				0.1 +/- 0.0						
Medicago sp.	*				1.0 +/- 0.0				0.1 +/- 0.0			0.1 +/- 0.0					0.6 +/- 0.5						5.3 +/- 1.0		
Stemodia florulenta		0.3 +/- 0.2	0.7 +/- 0.6					1.1 +/- 0.5	1.0 +/- 0.5		1.1 +/- 1.0			0.3 +/- 0.2	0.1 +/- 0.0		0.1 +/- 0.0								
Centipeda cunninghamii		0.6 +/- 0.2	0.6 +/- 0.5		1.0 +/- 0.4			2.9 +/- 1.1	0.1 +/- 0.0		0.7 +/- 0.2	0.1 +/- 0.0		5.5 +/- 2.8	7.7 +/- 4.6		19.4 +/- 3.4			0.1 +/- 0.0		33.7 +/- 2.4			
Polygonum plebium		0.3 +/- 0.1	0.7 +/- 0.1		0.4 +/- 0.1			0.9 +/- 0.1	0.2 +/- 0.1		0.5 +/- 0.1	1.0 +/- 0.0		0.7 +/- 0.2	0.4 +/- 0.1		1.6 +/- 0.2					1.3 +/- 0.2			
Helichrysum luteoalbum		0.6 +/- 0.2	0.1 +/- 0.0					0.6 +/- 0.1			0.5 +/- 0.2			2.4 +/- 0.8	2.7 +/- 1.1		0.5 +/- 0.3								
Persicaria prostrata		0.9 +/- 0.2	0.3 +/- 0.2		0.8 +/- 0.1			0.3 +/- 0.2	0.1 +/- 0.0					0.1 +/- 0.0			4.9 +/- 1.7						2.0 +/- 1.0		2.0 +/- 0.0
Sphaeromorphea littoralis		0.7 +/- 0.3	0.8 +/- 0.2		0.1 +/- 0.0			0.5 +/- 0.2	0.1 +/- 0.0		1.0 +/- 0.5			2.5 +/- 0.9	2.9 +/- 1.3		2.3 +/- 1.2								
Poaceae																	0.1 +/- 0.0								
Eclipta platyglossa subsp. *platyglossa*	#																0.6 +/- 0.5								
Schenkia australis		0.6 +/- 0.2	1.0 +/- 0.0					0.8 +/- 0.4			0.1 +/- 0.0			0.4 +/- 0.3	2.0 +/- 0.0		0.4 +/- 0.3								
Heliotropium curassavicum	*																0.3 +/- 0.1								
Eragrostis dielsii		0.1 +/- 0.0	0.1 +/- 0.0		0.1 +/- 0.0			0.4 +/- 0.3			0.1 +/- 0.0			2.0 +/- 0.0			0.8 +/- 0.1		0.1 +/- 0.0				1.4 +/- 0.4		
Isolepis sp.		1.0 +/- 0.0	0.1 +/- 0.0		0.1 +/- 0.0			0.3 +/- 0.2	0.3 +/- 0.2		0.3 +/- 0.2			14.0 +/- 10.5	5.1 +/- 5.0		7.1 +/- 1.9								

	Status	Hattah			Mournpall			Bitterang			Boich			Cantala			Nip Nip			Maramook			Kramen		
		Semi-permanent						Persistent temporary									Temporary						Episodic		
		Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower
Dysphania pumilio	#	0.1 +/- 0.0	0.1 +/- 0.0		0.1 +/- 0.0			0.1 +/- 0.0	0.6 +/- 0.2		0.1 +/- 0.0	0.1 +/- 0.0		1.0 +/- 0.0	0.7 +/- 0.2		0.9 +/- 0.2		0.7 +/- 0.3						
Heliotropium supinum	*								0.1 +/- 0.0		0.1 +/- 0.0	0.1 +/- 0.0			0.1 +/- 0.0		1.2 +/- 0.2		1.5 +/- 0.3						
Scleroblitum atriplicinum																	0.2 +/- 0.1								
Juncus sp.																	0.1 +/- 0.0								
Glossostigma sp.								1.0 +/- 0.0									0.1 +/- 0.0								
Atriplex suberecta																	0.3 +/- 0.1						6.5 +/- 4.3		16.6 +/- 3.3
Verbena officinalis	#	0.6 +/- 0.5						0.6 +/- 0.5			0.1 +/- 0.0			2.0 +/- 0.0			0.1 +/- 0.0								
Erigeron sp.	*	0.7 +/- 0.2						0.6 +/- 0.5			0.1 +/- 0.0			2.0 +/- 1.5	0.1 +/- 0.0		0.1 +/- 0.0								
Lachnagrostis filiformis		0.1 +/- 0.0						0.5 +/- 0.2	0.1 +/- 0.0		0.1 +/- 0.0			1.6 +/- 1.0	0.8 +/- 0.5		0.1 +/- 0.0								2.0 +/- 0.0
Rorippa sp.																	0.1 +/- 0.0								
Alternanthera denticulata															0.1 +/- 0.0		0.1 +/- 0.0								
Rumex sp.								0.3 +/- 0.2	0.7 +/- 0.6					0.1 +/- 0.0	0.1 +/- 0.0		0.1 +/- 0.0								0.1 +/- 0.0
Myriophyllum verrucosum					0.1 +/- 0.0			1.0 +/- 0.0	5.7 +/- 2.1		0.1 +/- 0.0	0.8 +/- 0.2	19.1 +/- 8.8		1.4 +/- 0.9		0.1 +/- 0.0		65.9 +/- 7.8						
Callitriche sonderi																	0.1 +/- 0.0		0.1 +/- 0.0						
Glycyrrhiza acanthocarpa		1.3 +/- 0.5	6.0 +/- 3.7		0.7 +/- 0.2			3.5 +/- 1.9	1.8 +/- 0.5		28.8 +/- 4.5	13.5 +/- 3.7		0.6 +/- 0.5	0.6 +/- 0.4		0.1 +/- 0.0			9.9 +/- 3.3		17.4 +/- 1.6	29.4 +/- 3.9		41.6 +/- 3.6
Glinus lotoides			0.1 +/- 0.0					0.1 +/- 0.0			0.1 +/- 0.0						0.1 +/- 0.0					1.0 +/- 0.0			
Wahlenbergia fluminalis		0.1 +/- 0.0						0.6 +/- 0.5			0.1 +/- 0.0			1.3 +/- 1.0	0.1 +/- 0.0										
Emergent seedling									0.6 +/- 0.5		0.1 +/- 0.0	1.0 +/- 0.0							0.4 +/- 0.3			1.0 +/- 0.0			
Spergularia sp.											0.1 +/- 0.0														
Einadia nutans											0.1 +/- 0.0														
Dodonaea viscosa subsp. *angustissima*		0.1 +/- 0.0																							
Acacia stenophylla			0.1 +/- 0.0					0.1 +/- 0.0						1.0 +/- 0.0	1.1 +/- 1.0	1									

	Status	Hattah			Mournpall			Bitterang			Boich			Cantala			Nip Nip			Maramook			Kramen		
		Semi-permanent						Persistent temporary									Temporary						Episodic		
		Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower
Enchylaena tomentosa var. *tomentosa*		0.1 +/- 0.0						0.1 +/- 0.0														0.6 +/- 0.5			
Cyperus gymnocarlus		1.0 +/- 0.0	0.1 +/- 0.0		1.0 +/- 0.0																				
Senecio quadridentatus					0.1 +/- 0.0			0.1 +/- 0.0																	
Brassica tournefortii	*				0.1 +/- 0.0																				
Sonchus oleraceus	*				0.1 +/- 0.0				0.1 +/- 0.0						0.1 +/- 0.0										
Senecio runcinifolius								0.1 +/- 0.0						2.0 +/- 0.0											
Verbena supina	*							0.1 +/- 0.0																	
Solanum nigrum	*							0.1 +/- 0.0						0.1 +/- 0.0	0.6 +/- 0.5										
Nicotiana sp.								0.1 +/- 0.0																	
Vulpia sp.	*																						1.6 +/- 0.9		1.4 +/- 0.6
Austrosipa scabra subsp. *falcata*																							1.0 +/- 0.0		
Cynodon dactylon var. *pulchellus*	k													1.0 +/- 0.0	2.0 +/- 0.0										
Calotis cuniefolia	r													0.6 +/- 0.5	0.1 +/- 0.0								1.0 +/- 0.0		
Hypericum gramineum														0.1 +/- 0.0	0.1 +/- 0.0										
Ranunculus pentandrus var. *platycarpus*															0.1 +/- 0.0										
Duma florulenta								0.1 +/- 0.0						0.3 +/- 0.2	1.0 +/- 0.0										
Euphorbia dallachyana	#													0.1 +/- 0.0	1.0 +/- 0.0										
Malva sp	*																						1.1 +/- 0.5		1.0 +/- 0.0
Polygonum aviculare	*																						1		8.6 +/- 1.9
Maireana sp																									1.0 +/- 0.0

r – rare; k – data deficient, * - introduced; # - Native but some stands may be alien

Appendix D – Vegetation species proportional frequency in relation to water depth zones

	Status	Hattah			Mournpall		Bitterang			Boich			Cantala			Nip Nip		Maramook		Kramen	
		Semi-permanent					Persistent temporary									Temporary				Episodic	
		Upper	Mid	Lower	Upper	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Austrobryonia micrantha	r	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	8%	0%	17%	0%	0%	0%	0%	0%
Centipeda nidiformis	r	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%
Eleocharis acuta		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Eucalyptus camaldulensis		38%	83%	42%	92%	38%	92%	92%	4%	79%	67%	0%	54%	96%	0%	88%	0%	13%	21%	0%	0%
Haloragis aspera		0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	8%	4%	0%	0%	0%	0%	0%	0%	0%
Limosella australis		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	8%	0%	0%	4%	0%	0%	0%	0%
*Medicago sp.**	*	0%	0%	0%	4%	0%	0%	4%	0%	0%	8%	0%	0%	0%	0%	8%	0%	0%	0%	63%	8%
Stemodia florulenta		21%	13%	0%	13%	0%	58%	13%	0%	8%	0%	0%	17%	8%	0%	25%	0%	0%	0%	0%	0%
Centipeda cunninghamii		25%	8%	0%	17%	0%	83%	17%	0%	92%	8%	0%	46%	38%	0%	100%	0%	8%	96%	0%	0%
Polygonum plebium		33%	67%	0%	33%	0%	92%	33%	0%	67%	8%	0%	25%	42%	0%	100%	0%	0%	92%	0%	0%
Helichrysum luteoalbum		21%	4%	0%	0%	0%	46%	0%	0%	29%	0%	0%	50%	42%	0%	79%	0%	0%	0%	0%	0%
Persicaria prostrata		25%	21%	0%	13%	0%	21%	13%	0%	0%	0%	0%	4%	0%	0%	67%	0%	0%	0%	13%	8%
Sphaeromorphea littoralis		38%	46%	0%	17%	0%	38%	17%	0%	13%	0%	0%	17%	29%	0%	67%	0%	0%	0%	0%	0%
Poaceae		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%
Eclipta platyglossa subsp. platyglossa	#	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%
Schenkia australis		29%	4%	0%	0%	0%	21%	0%	0%	17%	0%	0%	13%	4%	0%	25%	0%	0%	0%	0%	0%
*Heliotropium curassavicum**	*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%
Eragrostis dielsii		4%	8%	0%	0%	0%	13%	0%	0%	13%	0%	0%	4%	0%	0%	63%	4%	0%	0%	38%	0%
Isolepis sp.		4%	8%	0%	17%	0%	21%	17%	0%	17%	0%	0%	13%	8%	0%	92%	0%	0%	0%	0%	0%
Dysphania pumilio	#	4%	8%	0%	25%	0%	8%	25%	0%	4%	4%	0%	4%	42%	0%	33%	13%	0%	0%	0%	0%
*Heliotropium supinum**	*	0%	0%	0%	8%	0%	0%	8%	0%	8%	17%	0%	0%	13%	0%	50%	17%	0%	0%	0%	0%
Scleroblitum atriplicinum		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%

	Status	Hattah			Mournpall		Bitterang			Boich			Cantala			Nip Nip		Maramook		Kramen	
		Semi-permanent					Persistent temporary									Temporary				Episodic	
		Upper	Mid	Lower	Upper	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Juncus sp.		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%
Glossostigma sp.		0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%
Atriplex suberecta		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%	29%	92%
Verbena officinalis	#	8%	0%	0%	0%	0%	8%	0%	0%	4%	0%	0%	4%	0%	0%	17%	0%	0%	0%	0%	0%
*Erigeron sp.**	*	25%	0%	0%	0%	0%	8%	0%	0%	8%	0%	0%	13%	8%	0%	8%	0%	0%	0%	0%	0%
Lachnagrostis filiformis		4%	0%	0%	4%	0%	21%	4%	0%	4%	0%	0%	42%	17%	0%	4%	0%	0%	0%	0%	4%
Rorippa sp.		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%
Alternanthera denticulata		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	21%	0%	0%	0%	0%	0%
Rumex sp.		0%	0%	0%	13%	0%	25%	13%	0%	0%	0%	0%	8%	8%	0%	13%	0%	0%	0%	0%	13%
Myriophyllum verrucosum		0%	0%	0%	63%	0%	4%	63%	0%	4%	33%	46%	0%	21%	0%	8%	100%	0%	0%	0%	0%
Callitriche sonderi		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	8%	0%	0%	0%	0%
Glycyrrhiza acanthocarpa		17%	21%	0%	58%	0%	46%	58%	0%	88%	88%	0%	8%	54%	0%	4%	0%	88%	96%	100%	88%
Glinus lotoides		0%	4%	0%	0%	0%	4%	0%	0%	8%	0%	0%	0%	0%	0%	4%	0%	0%	8%	0%	0%
Wahlenbergia fluminalis		8%	0%	0%	0%	0%	8%	0%	0%	4%	0%	0%	21%	8%	0%	0%	0%	0%	0%	0%	0%
Emergent seedling		0%	0%	0%	8%	0%	0%	8%	0%	4%	4%	0%	0%	0%	0%	0%	13%	0%	4%	0%	0%
Spergularia sp.		0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Einadia nutans		0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dodonaea viscosa subsp. angustissima		4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Acacia stenophylla		0%	4%	0%	0%	0%	4%	0%	0%	0%	0%	0%	4%	8%	4%	0%	0%	0%	0%	0%	0%
Enchylaena tomentosa var. tomentosa		8%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	4%	0%	0%
Cyperus gymnocarlus		4%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Senecio quadridentatus		0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
*Brassica tournefortii**	*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
*Sonchus oleraceus**	*	0%	0%	0%	4%	0%	0%	4%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	0%	0%
Senecio runcinifolius		0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%

	Status	Hattah			Mournpall		Bitterang			Boich			Cantala			Nip Nip		Maramook		Kramen	
		Semi-permanent					Persistent temporary									Temporary				Episodic	
		Upper	Mid	Lower	Upper	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	Upper	Lower	Upper	Lower	Upper	Lower
*Verbena supina**	*	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
*Solanum nigrum**	*	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	4%	8%	0%	0%	0%	0%	0%	0%	0%
Nicotiana sp.		0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
*Vulpia sp.**	*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	21%	13%
Austrosipa scabra subsp. falcata		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%
Cynodon dactylon var. pulchellus	k	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	4%	0%	0%	0%	0%	0%	0%	0%
Calotis cuniefolia	r	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	4%	0%	0%	0%	0%	0%	4%	0%
Hypericum gramineum		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	17%	4%	0%	0%	0%	0%	0%	0%	0%
Ranunculus pentandrus var. platycarpus		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%
Duma florulenta		0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	17%	4%	0%	0%	0%	0%	0%	0%	0%
Euphorbia dallachyana	#	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	4%	0%	0%	0%	0%	0%	0%	0%
Malva sp	*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	42%	8%
*Polygonum aviculare**	*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	71%
Maireana sp		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%

r – rare; k – data deficient, * - introduced; # - Native but some stands may be alien

GHD

Level 18 180 Lonsdale Street
Melbourne VIC 3000
T: 61 3 8687 8000   F: 61 3 8687 8522   E: melmail@ghd.com

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