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The Living Murray Condition Monitoring: Hattah Lakes 2018–19, Part A

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Summary

Ecology Australia was commissioned by the Mallee Catchment Management Authority (CMA) to undertake the 2018-19 condition monitoring of the Hattah Lakes Icon Site, as part of The Living Murray Condition Monitoring Program. Monitoring encompassed the assessment of five vegetation components (River Red Gum, Black Box, wetland vegetation communities, floodplain vegetation communities and Lignum) as well as waterbirds and fish communities.

The Living Murray is a joint initiative of the Australian Government and the governments of New South Wales, Victoria, South Australia and the Australian Capital Territory, and was initiated in response to the demonstrable long-term decline in the health of the Murray River system (MDBA 2011). The primary goal of the program is to achieve a healthy, working river through the accrual and release of environmental flows to benefit the ecology of the system (MDBA 2011).

Monitoring for The Living Murray Condition Monitoring Program began in 2006-07, and has been undertaken annually since, with the exception of 2014-15 due to a lack of program funding. A summary of the 2018–19 results is provided in **Table** 1.

Table 1 Summary of whether ecological objectives have been met for each project component for 2018–19

Component	Objective	Achieved	Partially achieved	Not achieved
River Red Gum	Sustainable populations of River Red Gum	✓		
Black Box	Sustainable populations of Black Box	✓		
Wetland vegetation	Restore diversity, extent and abundance of wetland and floodplain vegetation		✓	
Floodplain vegetation	Restore diversity, extent and abundance of wetland and floodplain vegetation		✓	
Lignum	Restore a mosaic of healthy wetland and floodplain communities to maintain the ecological character of the Ramsar site		✓	
Waterbirds	Provide habitat for a range of waterbirds, including migratory species and colonial nesters.		✓	
Fish communities	Maintain native fish populations, their relative abundance and diversity		✓	

River Red Gum

For the eighth consecutive year the condition of River Red Gum has remained above the target of 85% of trees achieving a crown extent score of ≥4.

A mean River Red Gum population status index of 0.90 was recorded for the current three-year period at Hattah Lakes, exceeding the minimum threshold of 0.8

The health of the River Red Gum communities at the Hattah Lakes icon site continues to be sustained above established targets, therefore the specific adopted objective of 'sustainable populations of River Red Gum' is being achieved.

Black Box

For the eighth consecutive year the condition of Black Box has remained above the target of 80% of trees achieving a crown extent score of ≥4.

A mean Black Box population status index of 0.92 was recorded for the current three-year period at Hattah Lakes, exceeding the minimum threshold of 0.85; this is the highest score for all three-year periods.

The health of the Black Box communities at the Hattah Lakes icon site continues to be sustained above established targets, therefore the specific adopted objective of 'sustainable populations of Black Box is being achieved.

Wetland vegetation communities

As has been the case throughout the program, many of the wetlands during the current monitoring period were in different states of inundation and drying, providing a mosaic of habitats in the Hattah Lakes icon site. While some encroachment of drought tolerant species into wetlands has occurred since 2017–18, this is taken to be a natural response to drying within ephemeral wetlands.

The whole-of-icon-site score for native species richness at wetlands appears to be significantly higher than the score recorded in 2017–18 and similar to the score recorded in 2015–16. The icon site score for native species abundance was higher than the 2016–17 and 2017–18 scores. As noted in previous years, the indices are not sensitive to vegetation condition when a wetland is inundated.

The objective of 'restore diversity, extent and abundance of wetland vegetation' is being partially achieved at the Hattah Lakes icon site.

Floodplain vegetation communities

Floodplain inundation from natural flooding in 2016 and large-scale environmental watering in 2017–18 has benefited vegetation within often and sometimes-flooded Floodplain Return Frequency (FRF) sites, with drought-tolerant species much reduced since monitoring began in 2007–08. Despite the positive trend toward water-responsive functional groups, water-responsive species richness and abundance for all three FRF categories have declined since 2017–18.

Whole-of-icon-site scores for both richness and abundance of native water-responsive species have declined from 2017–18. The scores indicate that this decline is not significantly different due to large confidence intervals. However, in 2017–18 seven and nine sites were compliant with the richness and abundance targets, respectively, compared to one each in 2018–19, suggesting that levels of native water-responsive species abundance and richness were generally lower in 2018–19.

Despite the low number of targets achieved, data collected over the twelve-year duration of the monitoring program highlight the benefit—with regard to species richness and abundance—to floodplain vegetation from large-scale watering events.

Lignum

The 2018–19 monitoring results indicate a minor decline in Lignum condition since 2017–18, and that this occurred across Lignum Shrubland, Lignum Swamp, and Lignum Woodlands. This decline is reflected at the icon site scale, with the Icon Site index—i.e. the proportion of sites that exceed the established target—reducing from 0.56 in 2017–18 to 0.44 in 2018–19.; however this reduction does not indicate a significant change in condition.

Data collected for the current round of monitoring comprises the third year of data collection under the new method, and only the second year where the full complement of sites were assessed (only three of 16 sites were able to be assessed in 2016–17). As flooding is the major driver of Lignum growth, the decline of Lignum condition since 2017–18 is most likely a reflection of the time interval since last flood.

Waterbirds

Ten of the 13 surveyed wetlands were found to provide feeding habitat during the survey periods for a range of waterbirds, including species considered threatened on the Victorian Advisory List. No migratory species were recorded in the current season. Waterbird breeding was observed for cormorants at Lake Cantala and Australian Pelicans at Lake Hattah. Nests were also observed at Lake Bulla, but were unoccupied at the time of survey. Freckled Ducks were again observed during the surveys; Lake Bulla and Lake Hattah can be confirmed to provide habitat for the species. Grey Falcon and White-bellied Sea-Eagle were not recorded in the 2018/19 surveys. Colonial waterbirds were observed to be breeding during the current season, although breeding of spoonbills, egrets, night herons or bitterns was not confirmed. No migratory bird species were recorded at the Hattah Lakes icon site for the 2018–19 monitoring.

Fish communities

The fish species 'Expected' index scores for the riverine macrohabitat are identical to those recorded over most of the monitoring program, while the wetland results are marginally lower than recorded in 2018. All riverine sites and two wetland sites (one at Lake Bulla and one at Lake Mournpall) exceeded the (Robinson 2015) point of reference targets of 4.95 and 5.05 for riverine and wetland macrohabitats respectively. The Nativeness Index scores for the riverine macrohabitat are comparable to 2018, 2010–11 and 2013, but lower than 2014 and 2016, while the wetland score is relatively low. Only four sites (two Lake Bulla sites, one Lake Mournpall site and one Murray River site) met the Brown et al. (2016) point of reference score of ≥0.5. The Recruitment Index scores for all for the riverine macrohabitats are comparable to 2010, 2012, 2016–17 but lower than 2018. The scores for the wetland macrohabitat are marginally lower than the 2018 scores but still relatively high, despite being limited by only four of the seven wetlands being sampled in 2019. The Brown et al. (2016) point of reference score of ≥ 0.5 for the Recruitment Index was met for almost every wetland site but was not met at any riverine site.

1 Introduction

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Monitoring for The Living Murray Condition Monitoring Program began in 2006–07, and has been undertaken annually since, with the exception of 2014–15 due to a lack of program funding.

Reporting for the 2018–19 condition monitoring has been split into two documents. Part A (this report) provides the ecological objectives, methods, results and discussion for each of the monitoring components, while Part B provides supporting information such as site data, photographs and species lists.

1.1 Study area

The Hattah Lakes Icon Site is located in north-west Victoria and covers approximately 13,000 ha of lakes and floodplain set within the 48,000 ha Hattah–Kulkyne National Park and the Murray–Kulkyne Park (MDBA 2012a; Figure 1). It is situated within Mildura Rural City local government area and the Mallee Catchment Management Authority region, and straddles three bioregions: Robinvale Plains Bioregion, Lowan Mallee and Murray Mallee.

Hattah Lakes is one of six icon sites that are the focus of the TLM program . These sites were chosen because of their high ecological and economic value and their cultural and heritage significance to Aboriginal people and the broader community (MDBA 2011). The Hattah Lakes was selected as a TLM Icon Site on the basis of the extent, condition, diversity and habitat value of the lake and floodplain communities, as well as the social and cultural importance of the lakes (MDBA 2012a).

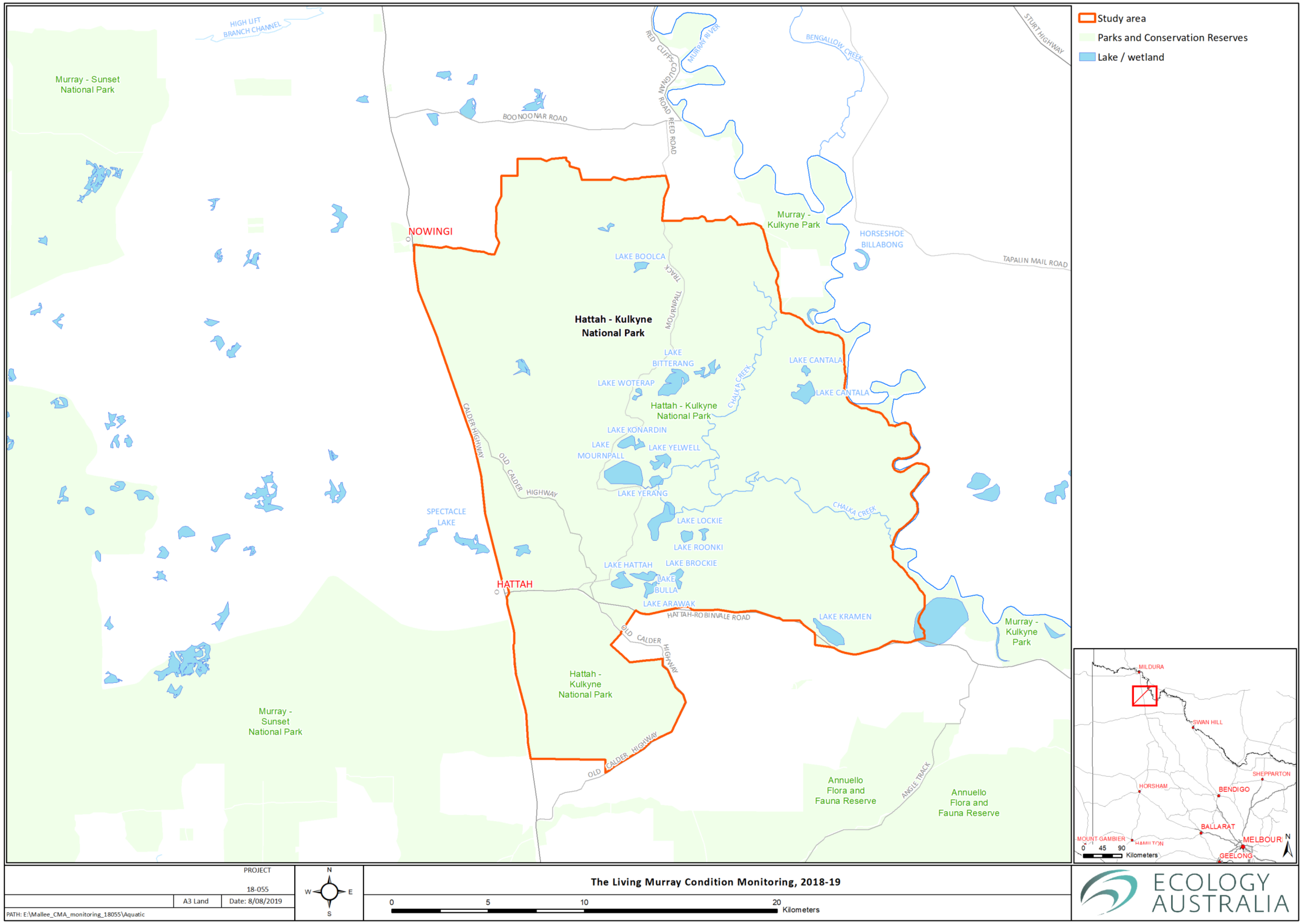

Figure 1 The location of the Hattah Lakes icon site

1.2 Hydrology

1.2.1 Murray River

Over the course of the monitoring program (2007–2019), the highest Murray River flow events (as detected at the Colignan gauge) were the flood events that occurred in February 2011 (mean discharge >65,000 ML/day) and November 2016 (>112,000 ML/day), both of which caused overbank flooding (Figure 2, Figure 3). These two events dwarf other flow events over the monitoring period, although the 2016 flood was an isolated and much larger event whereas the 2011 flood formed part of a relatively sustained period of higher flows including three sub-peaks in September 2011 (>40,000 ML/day), April 2012 (>38,000 ML/day), and August/September 2012 (>45,000 ML/day). The frequency of high flow/flood events during the last 20 years is notably lower than it was during the preceding 25 years (Figure 3).

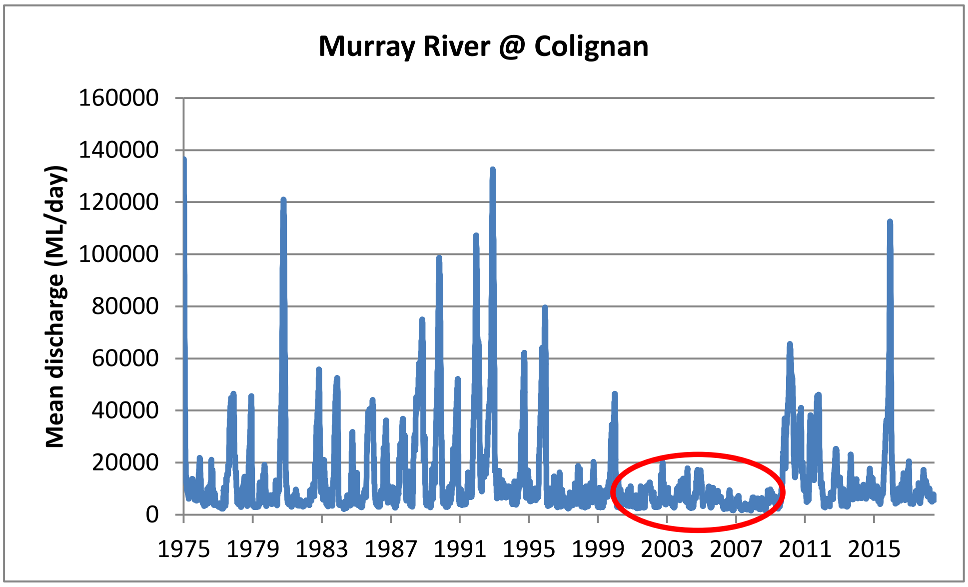

Figure 2 **Average daily discharge (ML/day) hydrograph for the Murray River at Colignan 1975–2019 (source: http://data.water.vic.gov.au/monitoring.htm), with the Millennium Drought circled in red.**

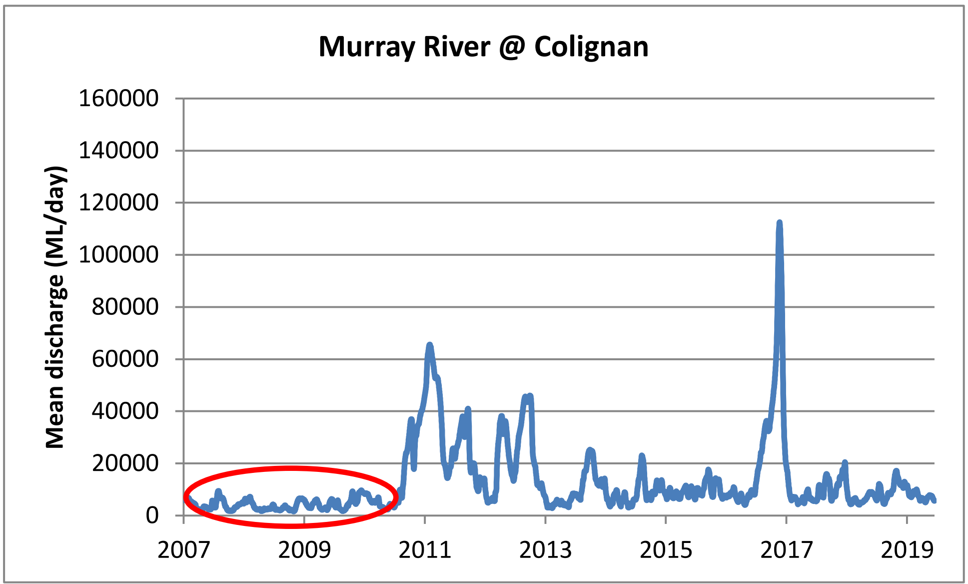

Figure 3 Average daily discharge (ML/day) hydrograph for the Murray River at Colignan over the course of the monitoring program 2007–2019 (source: http://data.water.vic.gov.au/monitoring.htm) with the Millennium Drought circled in red.

Since September 2013, average flows (discharge) in the Murray River at Colignan have remained below 25,000 ML/day (with the exception of the 2016 flow event), and for the most part have remained well below 15,000 ML/day. However, since August 2010 the minimum base-flows have generally remained above 5,000 ML/day, in contrast to the peak of the Millennium drought (February 2007 – July 2010), where sustained periods of flows below 5,000 ML/day were common.

During the current monitoring year (2018/19) there were no flooding events or flow events exceeding 20,000 ML/day.

1.2.2 Chalka Creek

According to Messengers regulator gauge there has been no flow in Chalka Creek since December 2017. It should be noted that this is the longest cease to flow period in the dataset; however, the dataset is limited to 2013 onwards (i.e. when the regulator was installed)(Figure 4). Longer periods of cease to flow may have occurred during the course of the monitoring period, especially during the Millennium drought.

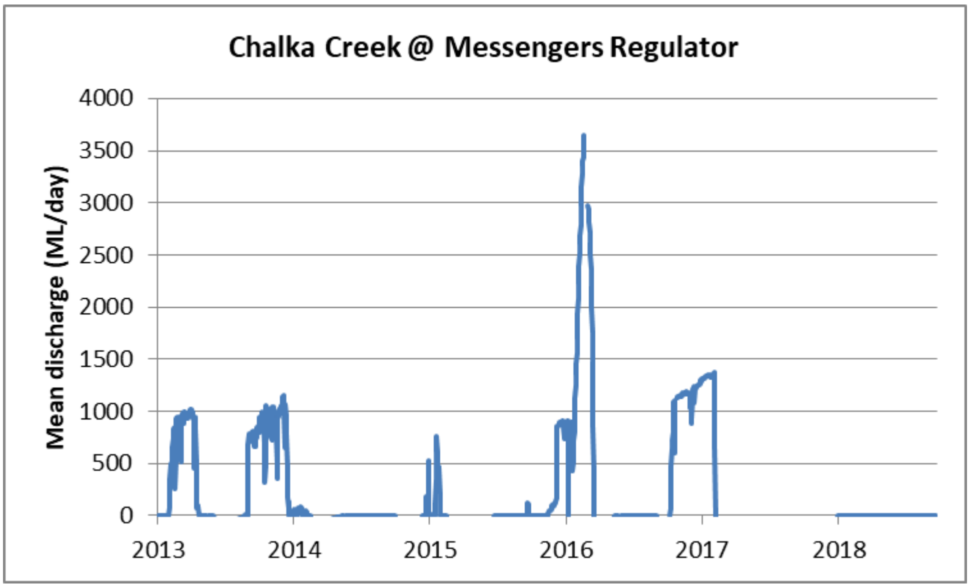

Figure 4 Average daily discharge (ML/day) hydrograph for Chalka Creek at Messengers Regulator 2013–2019 (source: http://data.water.vic.gov.au/monitoring.htm).

1.2.3 Environmental water

A detailed account of the alteration to natural flow regimes, and the use of supplementary pumping of environmental water over the course of the monitoring program, is provided in Wood et al. (2018). This includes associated works such as the installation of a pump station and regulator in 2013 to deliver environmental water to the floodplain and wetlands via Chalka Creek, and the return of floodplain water to the Murray River in spring 2014. During the current survey year there was no environmental water delivered to the Hattah Lakes (J. Munro pers. comm. 2019).

2 River Red Gum

2.1 Introduction

River Red Gum *Eucalyptus camaldulensis* is a large native tree growing to 40 m high (VicFlora 2018). River Red Gums are a dominant tree of Red Gum forests and woodlands and naturally require frequent flooding (MDBA 2012a). These vegetation communities provide hollows which are valuable habitat to a range of fauna including EPBC Act and FFG Act listed threatened species (MDBA 2012a). The Hattah Lakes has been severely degraded over the past two decades due to the use of water for anthropogenic processes, which has led to reductions of the overall health of these ecosystems (MDBA 2012a). In recent times plans have been made to increase the frequency of flooding to the lakes of Hattah and the surrounding River Red Gum vegetation (MDBA 2012a). Tree condition monitoring for River Red Gum communities are conducted to assess the long-term health of these areas (MDBA 2012a).

This report section will:

- Assess the crown extent of River Red Gum against an established target to estimate tree condition
- Assess the population structure of River Red Gum against an established index to estimate population status

2.2 Ecological objectives

Ecological objectives for the Hattah Lakes icon site are set out in the Environmental Water Management Plan for the site (MDBA 2012a). As part of a TLM condition monitoring refinement project, Robinson (2015) established ‘adopted objectives’ to evaluate specific monitoring components and improve reporting against the overarching ecological objectives of the program.

The ecological objective for River Red Gum is:

- “Maintain and, where practical, restore the ecological character of the Ramsar site with respect to the Strategic Management Plan (2003)” (MDBA 2012a)

The adopted objective for River Red Gum is:

- “Sustainable populations of River Red Gum” (Robinson 2015)

2.3 Methods

Three methods were used to assess the condition of River Red Gum:

- Tree condition assessments;
- Population status; and
- Stand condition.

A summary of each sampling method is provided below. Refer to the Condition Monitoring Program design for Hattah Lakes (Huntley et al. 2016a) for detailed account of tree condition assessment and population structure, and to Cunningham et al. (2018) for stand condition.

Population status/structure data was collected in October–December 2018, and tree condition assessment and stand condition data in February–early May 2019.

2.3.1 Tree condition assessments

The tree condition assessments for River Red Gum and Black Box are determined by ground survey alone, on the basis of a determination of the condition of a representative 30 trees from within a particular assessment site. The condition of trees at each site is determined by combining an assessment of crown extent and crown density. Additional indicators include new tip growth, epicormic growth, extent of bark cracking and leaf die-off, with the latter considered to indicate the future direction of tree condition. Additionally, the tree condition assessment collects contextual information at both the scale of the individual tree and the assessment site to aid interpretation (MDBA 2012b).

All 27 tree condition assessment sites were surveyed.

2.3.2 Population status

Population structure of River Red Gum is assessed on a rolling three-year cycle so that each year approximately one third of sites are sampled; transects were established in 2006–07, 2007–08 and 2008–09 (Brown et al. 2017). This method seeks to capture data on the spatial arrangement and age (using trunk diameter as a surrogate) of River Red Gum along transects set perpendicular to key environmental gradients, such as water bodies and elevation (Huntley et al. 2016). River Red Gums occurring within 20 m wide established belt transects are mapped using handheld GPS units, and their diameter recorded as well as whether they are alive or dead.

All but two of the 24 sites allocated for this year’s monitoring were assessed in their entirety; due to flooding only a small portion of HR-S5 was completed and half of HR-S4.

2.3.3 Stand condition

River Red Gum and Black Box stand condition of is determined using the TLM stand condition model (MDBA 2012b). The TLM stand condition model uses the relationship between ground survey condition monitoring data from permanent monitoring sites and remotely sensed data (covering the whole Murray River floodplain), to predict the condition of river red gum and black box stands (MDBA 2012b). The model estimates stand condition across all icon sites supporting River Red Gum and Black Box populations. This enables stand condition to be mapped across the distribution of these vegetation types and categorised into the stand condition classes (good, moderate, poor, degraded and severe)(MDBA 2012b).

Within stand condition sites, every tree with a Diameter at Breast Height (DBH) larger than 10 cm, within the defined sampling plot, must be assessed as live or dead and have its DBH recorded. In addition, thirty marked trees at the site must also be assessed for crown extent (Cunningham et al. 2018).

Field data was collected at 25 stand condition sites. Analysis of these data is not undertaken as part of this condition monitoring report.

2.4 Indices and points of reference

As per preceding condition reports, indices and associated points of reference developed by Brown et al. (2015) and Robinson (2015) are incorporated into the evaluation of River Red Gum condition at Hattah Lakes.

2.4.1 Tree condition

The target developed for River Red Gum condition at Hattah (Huntley et al. 2016) is:

- 85% of trees with crown extent score ≥ 4

A crown extent score of equal to or greater than four is associated with a tree crown that is more than 40% foliated (Brown et al. 2018).

As per Brown et al. (2017), the percentage of sampled trees with a crown extent score ≥ 4 was calculated per site and averaged across all sites. Data are presented as the mean proportion of trees (± standard error) at each site within the Hattah Lakes icon site, with a crown extent score ≥ 4.

2.4.2 Population status

The change in population structure of River Red Gum trees over time was visualised by plotting the square-rooted frequency of DBH, in 15 cm size classes, of all trees surveyed in Hattah Lakes population status sites, for each rolling three-year period. This process was repeated for trees with DBH >15 cm, with 1 cm size classes.

Analysis of population structure over time followed the methods outlined in Huntley et al. (2016). Diameter at Breast Height (DBH) data was collected for all trees within each population structure site, with all sites sampled over a three-year schedule (i.e. the 2016–2019 period contains surveys in 2016–17, 2017–18 and 2018–19). Sites are sampled from different Water Regime Class (WRC) strata as follows:

- For River Red Gum condition:
  - Red Gum Forest (RGF);
  - Red Gum with Flood-Tolerant Understorey (RGFTU); and
  - Fringing Red Gum Woodland (FRGW); and
- For Black Box condition:
  - Black Box Swampy Woodland (BBSW); and
  - Riverine Chenopod Woodland (RCW).

DBH data for each site were plotted as a histogram, in 15 cm bins, and compared to an ideal reference population structure, i.e. an inverse J curve (George et al. 2005). The distance between the observed data and the reference data for each site was assessed using Spearman's rho coefficient (ρ), and a J curve index, with a value between 0 and 1, was calculated from rho as follows:

$$\rho = \frac{\sum_i (x_i - \bar{x})\,(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

$$Index = (\rho + 1)/2$$

Following Robinson (2014), a linear mixed effects model with repeated measures was fitted, to assess how the index varied over time, with WRC strata as a fixed effect and site as a random effect nested within strata. All calculations were made in R (R Development Core Team 2018). The *lme4* package

(Bates et al. 2015) was used to estimate fitted values for each time period within each stratum and standard deviation (SD) was estimated using bootstrapping. The Student's t-distribution was used to calculate 95% confidence intervals from the SD. Differences in the index between time periods were examined using the *lmerTest* package (Kuznetsova et al. 2017), which calculates *P*-values for the *F*-test using a Satterthwaite approximation for the numerator degrees of freedom. The mean index (± 95% confidence intervals) across time periods was plotted to track the state of the River Red Gum population structure at the Hattah Lakes icon site over time, in relation to the minimum threshold of a mean J curve index of 0.8, which is based on previous data and aligns with records at the end of the Millennium Drought (Brown et al. 2017).

2.5 Results

2.5.1 Tree condition

The proportion of trees with a crown extent score of 4 or more was calculated for each of the 24 River Red Gum Tree Condition sites within the Hattah study area. The target of 85% for River Red Gums was reached, with 94.9% of sampled trees having a crown extent score of 4 or more (Figure 5). This represents the eighth year of consecutive monitoring in which the target for River Red Gum tree condition at Hattah Lakes was reached, excluding 2014–15.

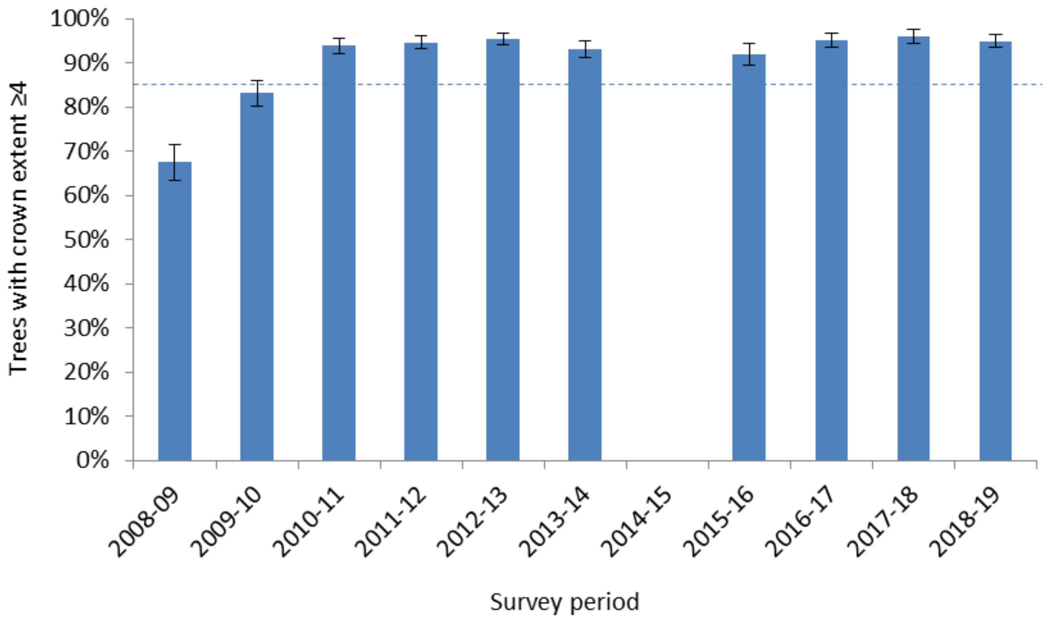

Figure 5 Mean percentage (±SE) of River Red Gum trees with crown extent scores ≥ 4 for each survey period across the River Red Gum Tree Condition sites. An overall target of 85% was used to determine if the Hattah Lakes icon site tree population was healthy and sustainable.

2.5.2 Population status

A mean River Red Gum population status index of 0.90 (pooling indices between WRCs) was recorded for the current three-year period at Hattah Lakes, exceeding the minimum threshold of 0.8 (Figure 6). A linear mixed effect model did not detect a significant effect of year on population status index across any rolling survey period, with relatively wide confidence intervals for the amount of change between periods (Table 2).

A significant effect of WRC was detected, with population status indices significantly higher in Red Gum Forest (RFG) compared to Red Gum with a flood-tolerant understorey (RGFTU; *P* = 0.04; Table 2).

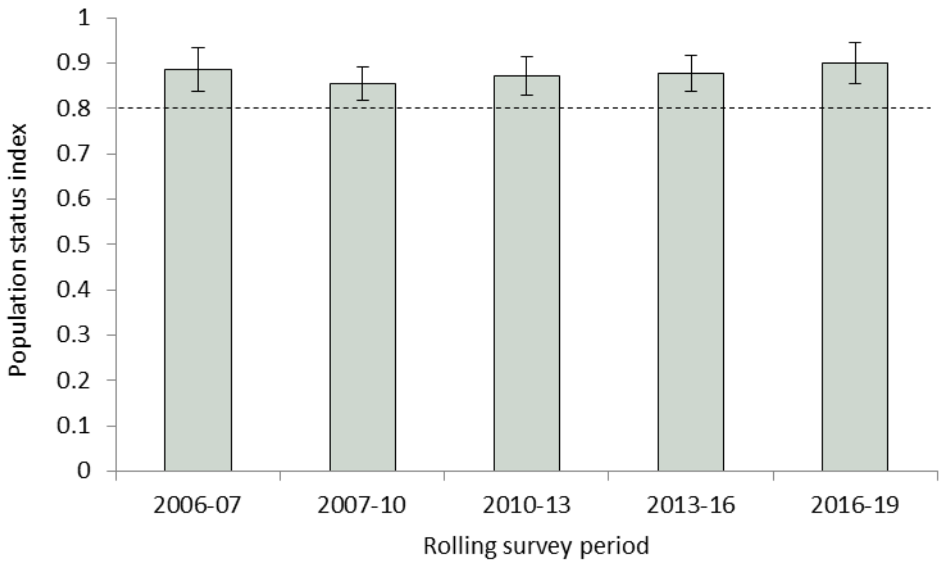

Figure 6 Mean population status index (± 95% CI) for River Red Gum at the Hattah Lakes icon site, based on correlation with an ideal population structure, the 'inverse j-curve'. A minimum threshold of 0.8 is set for River Red Gum at Hattah Lakes. Population status indices are pooled between WRCs in each survey period.

Table 2 Outputs from a linear mixed effect model exploring the effect of WRC on the River Red Gum population status index at the Hattah Lakes icon site, over time, with site as a random effect.

Parameter	Estimate	Standard error	Lower 95% CI	Upper 95% CI
FRGW	0.8731	0.02139	0.8301	0.9160
RFG	0.9437	0.03746	0.8684	1.0189
RGFTU	0.8203	0.02729	0.7655	0.8751
2006–07	0.8651	0.02650	0.8126	0.9176
2007–10	0.8665	0.02134	0.8243	0.9088
2010–13	0.8775	0.02126	0.8354	0.9195
2013–16	0.8962	0.02122	0.8543	0.9382
2016–19	0.8897	0.02236	0.8454	0.9339

A flatter distribution was observed when examining the DBH of juvenile River Red Gums (<15 cm) in 2016–19, when compared to the sharper J curve distribution observed in 2010–2013, when in excess of 300,000 trees with a DBH of 0–1 cm were recorded (Figure 7). Higher numbers of juvenile River Red Gums with DBH of 1–2 cm were observed in the current three-year period compared to previous years; however, the frequency of juveniles with DBHs greater than 2 cm were similar across periods (Figure 8).

Figure 7 Frequency of River Red Gum trees (square-root transformed) for each DBH size-class (0–300+ cm) for each three year period, pooled within the Hattah Lakes icon site.

Figure 8 Frequency of River Red Gum trees (square-root transformed) for each DBH size-class (0–15 cm) for each three year period, pooled within the Hattah Lakes icon site.

2.6 Discussion

For the eighth consecutive year the condition of River Red Gum has remained above the target of 85% of trees achieving a crown extent score of ≥4. Data collected in 2018–19 show a slight decrease in condition from the preceding two monitoring events, possibly reflecting the diminishing influence of inundation in 2016 and 2017; a similarly minor decline in River Red Gum condition was observed in 2013–14 following extensive inundation in 2010. Additionally, substantially reduced rainfall since 2016—2016 = 413 mm, 2017 = 374 mm, 2018 = 194 mm (as recorded for Ouyen Post Office (BOM 2019)), is likely to be a contributing factor. This likelihood is strengthened by a study by George et al. (2005) which found that the favourable response of River Red Gum to high levels of water availability generally lasts no longer than a year.

While the data indicate that the frequency of inundation experienced by River Red Gum since 2010 provides for near-optimal River Red Gum condition (at least in relation to crown extent), flooding at too closer intervals (such as occurred in 2016 then 2017) may be at the expense of establishing future cohorts, as young seedlings are highly sensitive to drowning (Kube and Price 1986). This is reflected in the data with no increase, or a relatively small increase, in the number of plants recorded in the smaller size classes, following significant seedling germination within the 2013–2016 monitoring period. The issue is addressed by Wood et al. (2018), who recommend that the period between large-scale inundations be increased (e.g. in the case of environmental releases) to allow for the establishment of new cohorts.

The health of the River Red Gum communities at the Hattah Lakes icon site continues to be sustained above established targets (85% of trees achieving a crown extent score of ≥4 and population status index exceeding 0.8), therefore the specific adopted objective of 'sustainable populations of River Red Gum' is being achieved.

2.7 Recommendations

Some discrepancies were noted with regard to photo-point imagery, relating to changing photo-points, differing numbers of photo-points for sites between years and lack of information for accurately replicating photographs (i.e. there are no documented bearings for photo-points). It is recommended that the number, location and bearing of photo-points are clearly documented for future monitoring events. This could be undertaken by The CMA prior to next year's monitoring, or written into the scope of works to be undertaken by the successful contractor.

3 Black Box

3.1 Introduction

Black Box *Eucalyptus largiflorens* is a large native tree growing to 20 m high and occurs on seasonally inundated riverine floodplains (VicFlora 2018). Black Box form dominant woodlands which naturally require periodic inundation (MDBA 2012a). The Hattah Lakes has been severely degraded over the past two decades due to the use of water for anthropogenic processes, which has led to reductions of the overall health of these ecosystems (MDBA 2012a). In recent times plans have been made to increase the frequency of flooding to the lakes of Hattah and the surrounding Black Box woodland (MDBA 2012a). Tree condition monitoring for this vegetation community is conducted to assess the long-term health of these areas (MDBA 2012a).

This report section will:

- Assess the crown extent of Black Box against an established target to estimate tree condition
- Assess the population structure of Black Box against an established index to estimate population status

3.2 Ecological objectives

Ecological objectives for the Hattah Lakes Icon Site are set out in the Environmental Water Management Plan for the site (MDBA 2012a). As part of a TLM condition monitoring refinement project, Robinson (2015) established 'adopted objectives' to evaluate specific monitoring components and improve reporting against the overarching ecological objectives of the program.

The ecological objective for Black Box is:

- "Maintain and, where practical, restore the ecological character of the Ramsar site with respect to the Strategic Management Plan (2003)" (MDBA 2012a)

The adopted objective for Black Box is:

- "Sustainable populations of Black Box" (Robinson 2015)

3.3 Methods

Three methods were used to assess the condition of Black Box:

- tree condition assessments;
- population status; and
- stand condition.

A summary of each sampling method is provided below. Refer to the Condition Monitoring Program design for Hattah Lakes (Huntley et al. 2016a) for detailed account of tree condition assessment and population structure, and to Cunningham et al. (2018) for stand condition.

Population status/structure data was collected in October–December 2018, and tree condition assessment and stand condition data in February–early May 2019.

3.3.1 Tree condition assessments

All 18 assessment sites were surveyed this year. As detailed in Brown et al. (2017), these sites were established in 2007–08 and have been sampled annually since, except for some sites in 2010–11 due to flooding and all sites in 2014–15 when the program was not funded.

Refer Section 2.3.1 for further details on the tree condition assessment methodology.

3.3.2 Population status

All nine sites allocated for this year's monitoring were assessed. Refer Section 2.3.2 for further details on the population status methodology.

3.3.3 Stand condition

Refer Section 2.3.3 for further details on the stand condition methodology.

3.4 Indices and points of reference

As per preceding condition reports, indices and associated points of reference developed by Brown et al. (2016) and Robinson (2015) are incorporated into the evaluation of Black Box condition at Hattah Lakes.

3.4.1 Tree condition

The target developed for Black Box condition at Hattah Lakes (Huntley et al. 2016) is:

- 80% of trees with crown extent score ≥ 4

Refer Section 2.4.1 for further details.

3.4.2 Population status

A linear mixed effect model was used to determine whether the population status index changed over time. The mean index (± 95% confidence intervals) across time periods was plotted to visualise the state of the Black Box population structure at the Hattah Lakes icon site over time, in relation to the minimum threshold of a mean J curve index of 0.85, which is based on previous data and aligns with records at the end of the Millennium Drought (Brown et al. 2017).

All methods used to assess change in population structure over time are outlined in Section 2.4.2.

3.5 Results

3.5.1 Tree condition

The proportion of trees with a crown extent score of 4 or more was calculated for each of the 18 Black Box Tree Condition sites within the Hattah study area. The target of 80% for Black Box was reached, with 86.9% of sampled trees having a crown extent score of 4 or more (Figure 9). This represents the eighth consecutive year of monitoring in which the target for Black Box condition at Hattah Lakes was reached, excluding 2014–15.

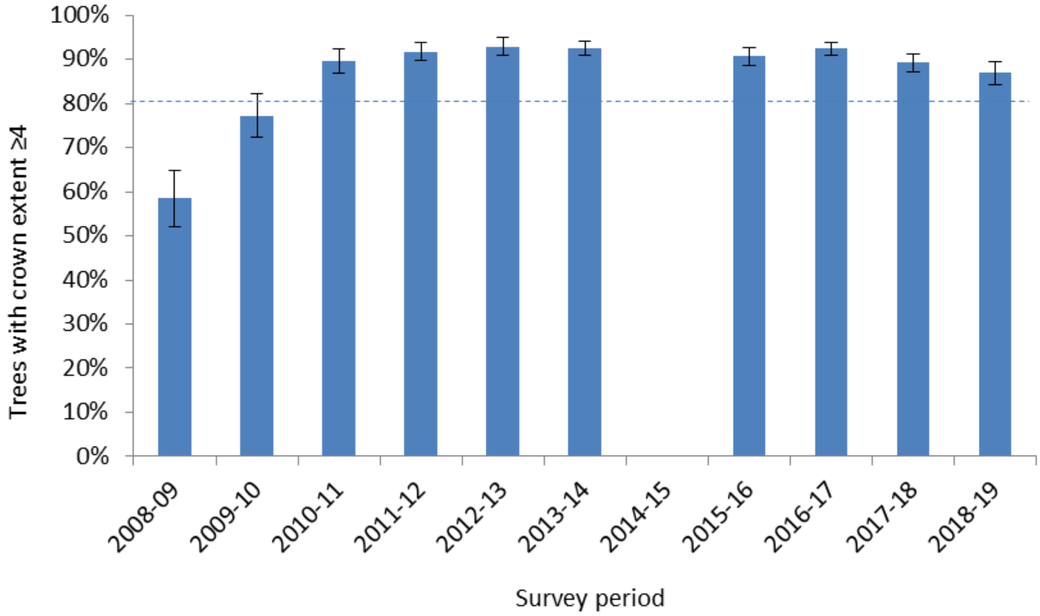

Figure 9 Mean percentage (±SE) of Black Box trees with crown extent scores ≥ 4 for each survey period across the 18 Black Box Tree Condition sites. An overall target of 80% was used to determine if the Hattah icon site tree population was healthy and sustainable.

3.5.2 Population status

A mean Black Box population status index of 0.92 (pooling indices between WRCs) was recorded for the current three-year period at Hattah Lakes, exceeding the minimum threshold of 0.85 (Figure 10). A linear mixed effect model did not detect a significant effect of year on population status index across any rolling survey period, with relatively wide confidence intervals for the amount of change between periods (Table 3).

Water Regime Class did not have a significant effect on the degree to which Black Box at each site approximated an ideal population structure (P = 0.52; Table 3).

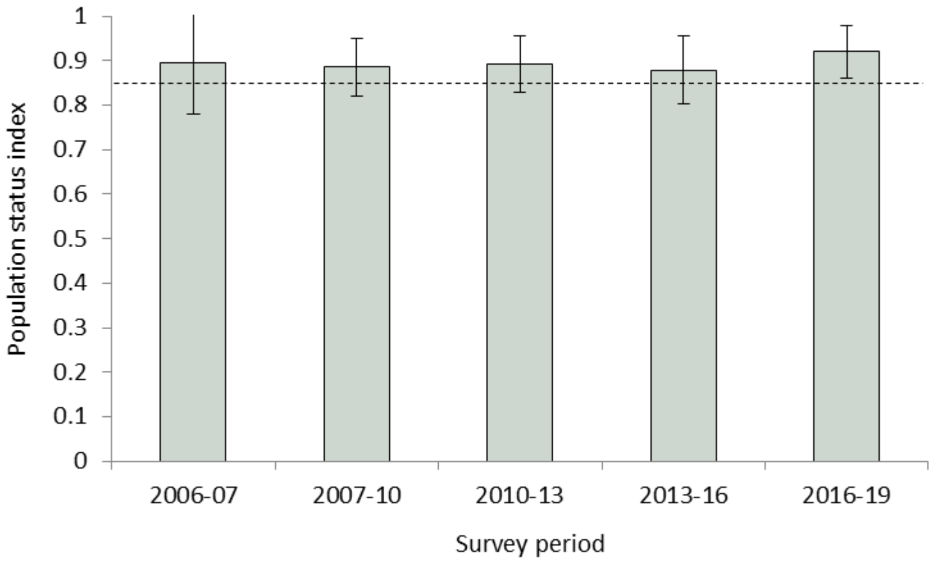

Figure 10 Mean population status index (± 95% CI) for Black Box at the Hattah Lakes icon site, based on correlation with an ideal population structure, the 'inverse j-curve'. A minimum threshold of 0.85 is set for Black Box at Hattah Lakes. Population status indices are pooled between WRCs in each survey period.

Table 3 Outputs from a linear mixed effect model exploring the effect of WRC on the Black Box population status index at the Hattah Lakes icon site, over time, with site as a random effect.

Parameter	Estimate	Standard error	Lower 95% CI	Upper 95% CI
BBSW	0.8601	0.04822	0.7595	0.9606
RCW	0.9016	0.04029	0.8176	0.9856
2006–07	0.8581	0.03779	0.7825	0.9337
2007–10	0.8645	0.03402	0.7965	0.9326
2010–13	0.8953	0.03333	0.8286	0.9620
2013–16	0.8748	0.03333	0.8082	0.9415
2016–19	0.9114	0.03339	0.8446	0.9782

The population structure of Black Box recorded at Hattah Lakes in the current three-year period is similar to the distribution recorded in the previous two three-year periods, albeit with fewer juvenile records (<15 cm BDH; Figure 11).

A much flatter distribution was observed when examining the DBH of juvenile Black Box (<15 cm) in 2016–19, when compared to the sharper J curve distributions observed in 2010–2013 and 2013–16, when in excess of 1,000 trees with a DBH of 0–1 cm were recorded (Figure 12). The current monitoring period recorded the greatest number of trees between 2 cm and 15 cm DBH. The population structure of juvenile Black Box in the current year approximates the structure recorded in 2006–07, but with more trees recorded with DBHs greater than 6 cm, corresponding to the growth of the 0–1 cm cohort recorded in 2010–13 and 2013–16.

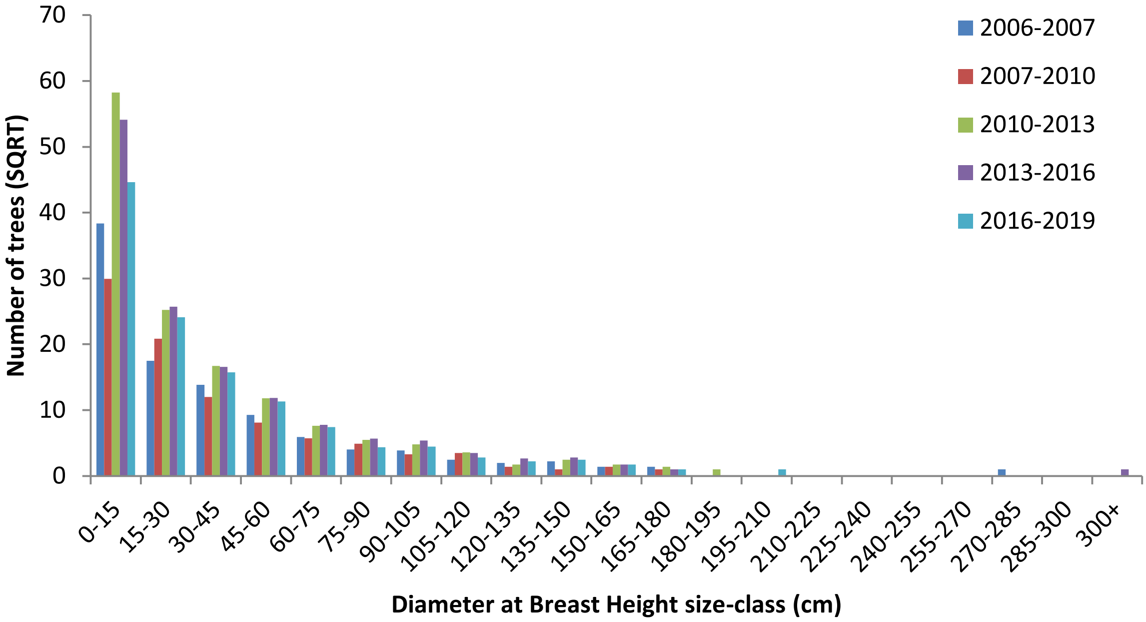

Figure 11 Frequency of Black Box trees (square-root transformed) for each DBH size-class (0–300+) for each three year period.

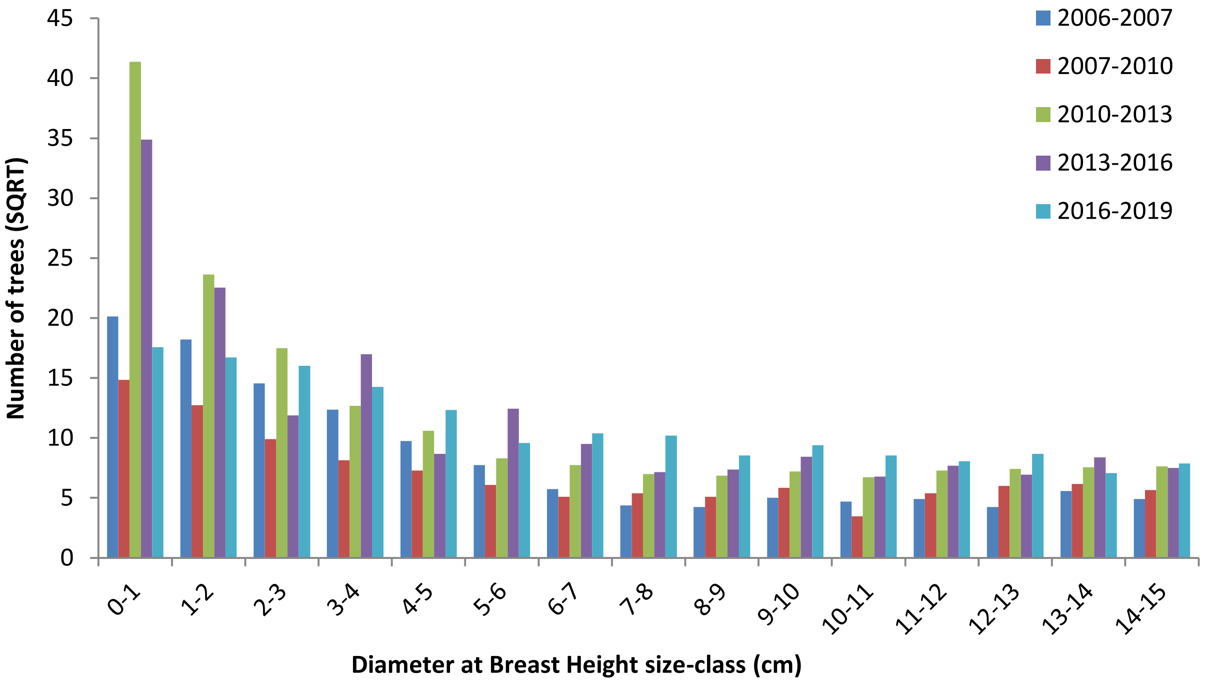

Figure 12 Frequency of Black Box trees (square-root transformed) for each DBH size-class (0–15 cm) for each three year period.

3.6 Discussion

For the eighth consecutive year the condition of Black Box has remained above the target of 80% of trees achieving a crown extent score of ≥4. Data collected in 2018–19 show a slight decrease in condition from the preceding two monitoring events, potentially reflecting a combination of decreasing rainfall—2016 = 413mm, 2017 = 374mm, 2018 = 194 mm (as recorded for Ouyen Post Office (BOM 2019))—and the diminishing influence of the inundation that some sites received in 2016. In a study undertaken by George et al. (2005) variations in tree ring width showed the positive effect of flooding on tree growth for the next two years. It is also worth noting that a comparable decline in condition was recorded for River Red Gum condition during this period.

A mean Black Box population status index of 0.92 was recorded for the current three-year period at Hattah Lakes, exceeding the minimum threshold of 0.85; this is the highest score for all three-year periods. While reduced recruitment of Black Box was recorded in the current period, the general size-class distribution of trees within Hattah Lakes follows the inverse j-curve shape required to reflect an ideal population structure. As the primary source of moisture for seedling establishment is from flooding (George et al. 2005), the absence of such events (natural or facilitated) is likely to negatively affect the population structure of Black Box within Hattah Lakes.

It is understood that artificial inundation of much of the Black Box community at Hattah Lakes is largely unachievable. Recommendations put forward by Wood et al. (2018) relating to the monitoring and potential manipulation of ground-water seem appropriate given the importance of this resource in sustaining Black Box and other floodplain species. Consideration should also be given to the benefits of facilitating recruitment of Black Box in priority areas through the focused application of water.

The health of the Black Box communities at the Hattah Lakes icon site continues to be sustained above established targets (80% of trees achieving a crown extent score of ≥4 and population status index exceeding 0.85), therefore the specific adopted objective of ‘sustainable populations of Black Box is being achieved.

3.7 Recommendations

Some discrepancies were noted with regard to photo-point imagery, relating to changing photo-points, differing numbers of photo-points for sites between years and lack of information for accurately replicating photographs (i.e. there are no documented bearings for photo-points). It is recommended that the number, location and bearing of photo-points are clearly documented for future monitoring events. This could be undertaken by The CMA prior to next year’s monitoring, or written into the scope of works to be undertaken by the successful contractor.

4 Wetland Vegetation Communities

4.1 Introduction

Water regime is a major factor influencing plant community development and patterns of plant zonation in wetlands (Casanova and Brock 2000). In a natural (undisturbed) system, the frequency and duration of floodplain wetland inundation is affected by the location of the wetland in the landscape and/or capacity to retain water. Anthropogenic changes to the quantity of water (e.g. changes to natural frequency, duration and extent) in waterways and wetlands, impacts wetland vegetation communities through changes in plant community composition and zonation, and increases the potential for invasions of introduced species (Brook 2003). In particular, increased drying of wetlands shows a decline in water responsive species (diversity and cover), and an increase in dryland terrestrial species, including exotic plant species (Brook 2003). Environmental water is used to assist in protecting and restoring the environmental values of waterways, floodplains and wetlands that have had their natural flow cycle adversely disrupted.

The Hattah Lakes icon site comprises the Hattah Lakes wetland complex and the adjoining floodplain area — the floodplain is defined by the largest flood on record (in 1956) (MDBA 2012a). The hydrology of the Hattah wetlands has changed substantially as a result of the regulation and diversion of River Murray flows, resulting in a reduction in the frequency and duration of flooding. This has had flow-on effects on the associated vegetation, including tree deaths, transitioning to an increasingly terrestrial understorey, reduction in habitat for a range of fauna, and changes to the diversity and abundance of wetland flora (MDBA 2012a). Part of The Living Murray program is to deliver environmental water to Hattah Lakes icon site to ameliorate the effects of reduced frequency of natural flooding (MDBA 2012a). Vegetation condition monitoring of 12 wetlands within the icon site has been undertaken to determine change over time and inform ongoing management of the watering program. The twelve sites have been divided into three water regime classes — semi-permanent wetlands (3 sites); persistent temporary wetlands (8 sites); and episodic wetlands (1 site).

The following section presents the finding of the vegetation condition monitoring of the 12 wetlands. It:

- assesses native water-responsive species richness and abundance in wetlands against a point of reference;
- assesses the condition of wetlands across the whole icon site using native water-responsive species richness and abundance scores; and
- examines the presence or absence of drought tolerant vegetation in wetlands.

4.2 Ecological objectives

Ecological objectives for the Hattah Lakes icon site are set out in the Environmental Water Management Plan (MDBA 2012a). As part of a TLM condition monitoring refinement project, Robinson (2015) established 'adopted objectives' to evaluate specific monitoring components and improve reporting against the overarching ecological objectives of the program.

The overarching ecological objective for wetland vegetation at Hattah Lakes is:

- "Restore a mosaic of healthy wetland and floodplain communities to maintain the ecological character of the Ramsar site" (MDBA 2012a).

The adopted objective for wetland vegetation at Hattah Lakes is:

- "Restore diversity, extent and abundance of wetland vegetation"

4.3 Methods

There are 12 sites established for monitoring wetland vegetation communities within the Hattah Lakes icon site, of which nine were established in 2007–08, and one each were established in 2010–11, 2011–12 and 2012–13 (Huntley et al. 2016). Each wetland site was assigned to one of three water regime classes. All sites have been surveyed annually since their establishment with the exception of 2014–15 (Brown et al. 2018).

Data collection for this round of monitoring was undertaken in January–February 2019. An overview of methods followed for data collection and statistical analysis are provided below; for further details on the project methodology see Huntley et al. (2016).

4.3.1 Data collection

Four established transects (three at Lakes Brockie and Boich) were surveyed at each site. Perpendicular to the transect line, between three and six 15 x 1 m quadrats were sampled (as 15 x 1 m x 1 m cells); these quadrats had been previously established to reflect differing elevation within the wetland (Figure 13). For the specific number of transects, quadrats and elevations at each individual wetland, refer to Brown et al. (2016).

Survey methods use the presence/absence of vegetation species within quadrats located along transects to produce a frequency score for each species. Species abundance in each quadrat is determined by recording the presence of each species that have live plants rooted within each cell. This provides a frequency score for each species in each quadrat of between 0 and 15. Dead or completely defoliated plants are recorded providing identification can be made. Bare earth and coarse woody debris are included as taxa (e.g. cells containing no live plants are given a bare ground score of 1).

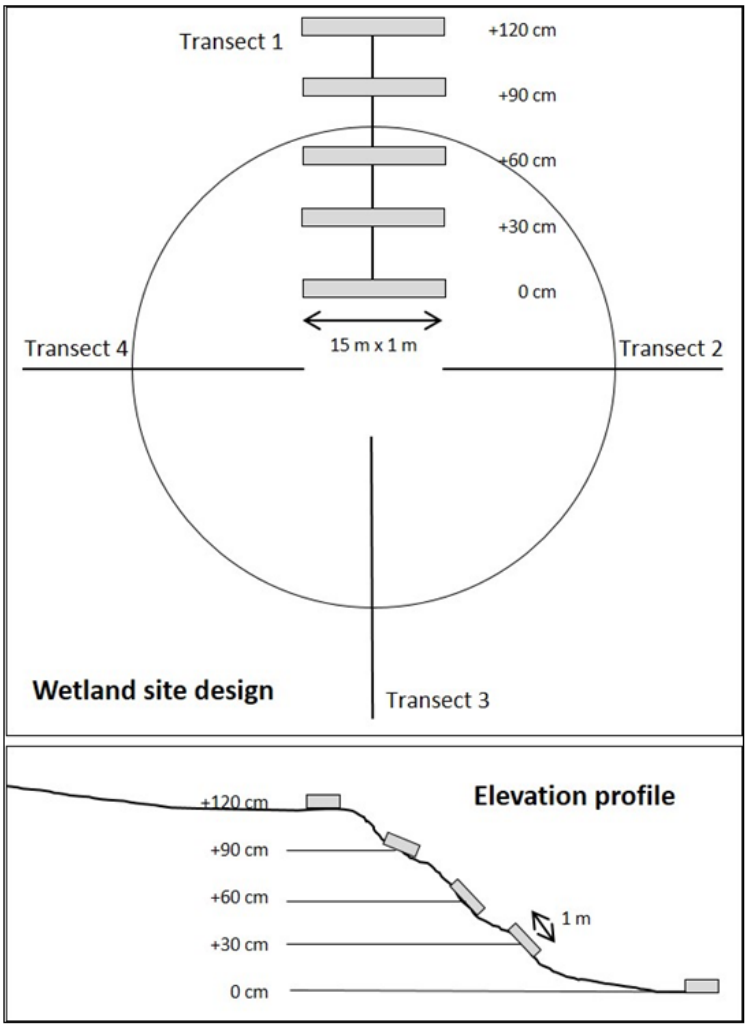

Figure 13 Schematic of the survey design used to assess wetland vegetation communities under The Living Murray program at the Hattah Lakes icon site (adapted from Wallace [2009] in Huntley et al. [2016]).

4.3.2 Plant species classification

Species identification

Plant taxonomy and the use of common names follow the Victorian online plant census (VicFlora 2019), the Victorian Biodiversity Atlas database (DELWP 2019) and for taxa not acknowledged in Victoria the NSW online flora (PlantNET 2019). Species of State and/or National conservation significance were determined by reference to the state advisory list (DEPI 2014), and listings under the Victorian *Flora and Fauna Guarantee Act 1988* and the Federal *Environment Protection and Biodiversity Conservation Act 1999*.

Where an asterisk (*) precedes a plant name, it is used to signify a non-indigenous taxon, those species which have been introduced to Victoria or Australia. A hash (#) is used to denote Victorian native plants that are not indigenous to the relevant vegetation type.

The seasonality of some plant species may prove to be a limitation to the survey. Some species may have been overlooked because they were inconspicuous in summer when the surveys were conducted, or have been identified to genus level only due to the absence of fertile material. While these limitations may affect comparison of species level data from year to year, as Huntley et al. (2016) points out, the use of plant functional groups (see below) ameliorates this issue to a large extent.

Plant functional groups

Plant species recorded in surveys at Hattah Lakes are classified into functional groups (Table 4). As specified in Huntley et al. (2016), the classification of plant species into these groups is based largely on Brock & Casanova (1997) and Reid & Quinn (2004), and species that are not classified in either of these studies are assigned to functional groups based on field observations and information in VicFlora (2019) and Cunningham et al. (1992). An additional floating (F) functional group is added to identify species not attached to the substrate. Functional group T (instead of Tdr or Tda) and A (instead of Ate, Atl, Arf or Arp) are assigned where species are identified to genus or family level only (Huntley et al. 2016).

Table 4 Plant functional groups used to classify species recorded during surveys of Hattah wetlands.

FG	Description
S	Aquatic submerged species (established plants do not tolerate drying).
F	Aquatic floating, unattached species (established plants do not tolerate drying).
Arf	Amphibious, fluctuation-responder, floating species which have floating leaves in their aquatic phases and also grow stranded on damp ground.
Arp	Amphibious, fluctuation-responder, floating species, with various growth characteristics, that feature morphological plasticity in response to water level fluctuations.
Atl	Amphibious, fluctuation-tolerant, emergent species which are dicotyledons and require damp conditions (low growing plants that tolerate wetting and drying).
Ate	Amphibious, fluctuation-tolerant, emergent species which are mostly monocotyledons (emergent plants that tolerate wetting and drying).
Atw	Amphibious, fluctuation-tolerant, emergent plants which are woody (trees and shrubs that tolerate wetting and drying).
A	Amphibious species (plants that tolerate both flooding and drying).
T	Terrestrial species (plants that do not tolerate flooding).
Tda	Terrestrial species that typically occur in damp habitats.
Tdr	Terrestrial species that typically occur in dry habitats.

4.3.3 Data analysis

Point of reference assessment

Wetlands are classified into three Water Regime Classes (WRC)(semi-permanent wetlands, persistent temporary wetlands and episodic wetlands), and for each WRC a point of reference index has been developed for species richness and species abundance (Huntley et al. 2016). To maintain consistency with the preceding monitoring report (Wood et al. 2018), indices have been updated in this report to reflect the 80th percentile, rather than the 90th percentile. The point of reference includes native plant species that are considered water-responsive and excludes drought-tolerant species (Huntley et al. 2016).

Table 5 Point of reference indices for wetland vegetation communities at the Hattah Lakes Icon Site (adapted from Huntley (2016)

Water Regime Class	Index 1: water responsive species richness (80th percentile)	Index 2: water responsive species abundance (80th percentile)
Semi-permanent wetlands	3.86	23.86
Persistent temporary wetlands	3.07	20.28
Episodic wetlands	3.84	27.48

As outlined in Wood et al (2018), using the indices in Table 5, wetland vegetation is considered to be in good condition when:

- native water-responsive species richness in a WRC is at or above the 80th percentile (adapted from Huntley et al. (2016)); and
- native water-responsive species abundance in a WRC is at or above the 80th percentile (adapted from Huntley et al. (2016)).

To calculate if water-responsive species richness was in good condition for wetlands (adapted from Huntley et al. (2016):

- all years of data were used, including only native water responsive plant species (e.g. species associated with the following functional groups; S, F, Arf, Arp, Atl, Ate, Atw, A and Tda) and excluding records classified only to genus level;
- the total number of species were averaged across all quadrats for each transect for each year;
- for each WRC in each year, transects with water responsive species richness at or above the 80th percentile (Index 1 in Table 5) score = 1 (compliant), and transects with water responsive species richness below the point of reference score = 0 (non-compliant); and
- the proportion of compliant transects across all wetlands within each WRC was plotted over time.

The same steps (above) were applied to determine if water responsive species abundance was in good condition for each WRC. Abundance measures for each species in each quadrat (i.e. maximum of 15 per species) were summed and then a transect abundance measure was estimated by averaging the quadrat abundance measures within each transect.

Whole-of-icon-site wetland scores were calculated by weighting the strata scores for both the richness and abundance of native water-responsive species, considering the total number of wetlands in each water regime class (WRC) in the Hattah Lakes icon site, and the number of transects sampled within each WRC. Scores were weighted using the example shown in Brown et al. (2016), informed by methods to estimate an overall mean from a stratified sample (Sutherland 2006). The number of wetlands in each of the WRCs at the Hattah Lakes icon site was converted to total number of possible transects, to ensure that the number of surveyed transects represents a sub-sample (Table 6). The total number of possible transects assumes that each wetland has four potential transects, except for the Lake Boich and Lake Brockie wetlands, where three transects have been surveyed. To determine 95% confidence intervals, t-values were calculated in R (R Core Team 2018) for $P = 0.05$ (two-sided) using the degrees of freedom method shown in Sutherland (2006). The Whole-of-icon site scores were calculated for each survey year since 2007–08 (excluding 2014–15) and presented with 95% confidence intervals. These values were plotted as a time series to examine the effect environmental watering has had on the richness and abundance of water responsive species at an icon site scale.

Drought-tolerant vegetation in wetlands

One of the original ecological objectives 'non-macrophyte vegetation in lakes' was intended to identify if there was an encroachment of drought tolerant plant species (i.e. species from the Tdr functional group) into wetlands (Huntley et al. 2016). Analysing the presence/absence of plant species through functional group representation in each WRC in each survey year was used to make this determination (Wood et al. 2018). This will be considered with respect to whether or not the presence of drought tolerant species is a natural occurrence (e.g. the presence of a drought tolerant community may be a reflection of the natural dry phase of an ephemeral wetland) (Wood et al. 2018). Therefore, this objective may only be relevant to some wetlands in some years (Huntley et al. 2016).

Charts were produced to display the proportion of functional group abundance data for each survey year, in each WRC. For display purposes, functional groups A, Arf, Arp, Ate, Atl (for definitions see Table 3) were combined into one amphibious group 'A'. Functional group 'T' was excluded from these graphs as it was not possible to determine if these species were drought tolerant (Tdr) or terrestrial damp (Tda) species.

Both indigenous and introduced species were included in the analysis, as both groups will respond to changes in hydrology across the wetlands.

4.4 Results

4.4.1 Data summary

A total of 63 vascular plant species was recorded from the 12 Hattah Lakes wetland sites during the 2018–19 monitoring. Of these, 48 (76.2%) were indigenous and 15 (23.8%) were exotic; six species are listed as rare or threatened in Victoria by DEPI (2014) (one vulnerable, two rare and three poorly known). For further details on plant species recorded please refer to Part B of this report.

4.4.2 Point of reference assessment

Water-responsive species richness

Almost a third of wetland transects in the Persistent Temporary Wetland WRC were considered compliant with the native water-responsive species richness index (Table 6, Figure 14), or 20.5% of all wetland transects. No wetland transects in the Semi-permanent or Episodic WRCs were considered compliant with the species richness index. This result represents an increase on the species richness index from the previous year, when only two transects were considered compliant. No transects in the semi-permanent WRC have been recorded as compliant since 2012–13; the transects at the episodic WRC were last considered compliant in 2016–17 (Figure 14).

Table 6 Number of transects compliant with ecological targets relating to species richness and abundance of native water-responsive species, in each water regime class (WRC) at the Hattah Lakes icon site, as surveyed in the 2018–19 season. Also shown are stratum scores for each WRC, a weighted icon site wetland score (with 95% confidence intervals for two sampled comparisons with normally distributed error variance) and the surveyed and total number of wetlands in each category. Stratum scores were weighted by the total number of possible transects in each WRC (in parentheses), to reflect the number of wetlands.

Water regime class (WRC)	No. wetlands (and transects) at icon site	No. surveyed wetlands	Species richness			Species abundance		
			No. compliant transects	Strata score	Icon Site score	No. compliant transects	Strata score	Icon Site score
Semi-permanent	5 (20)	3	0 of 12	0	0.183 (±0.060)	0 of 12	0	0.224 (±0.063)
Persistent temporary	13 (44)	8	9 of 30	0.30		11 of 30	0.37	
Episodic	2 (8)	1	0 of 4	0		0 of 4	0	

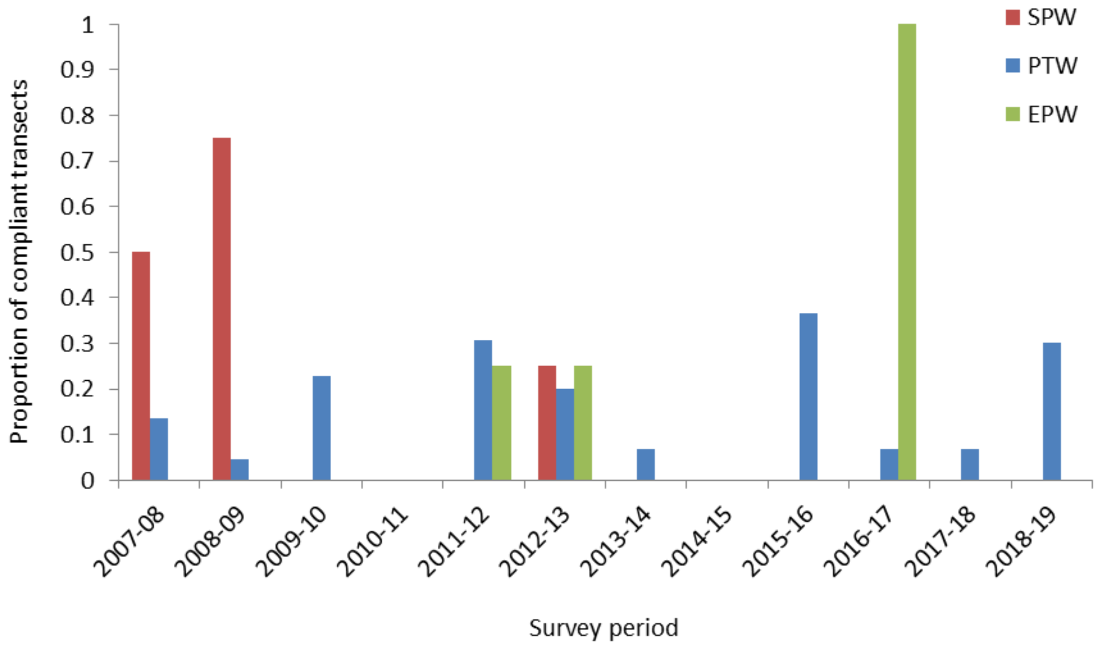

Figure 14 Proportion of transects from wetlands in WRCs at the Hattah Lakes icon site, considered compliant with the native water-responsive species richness index (transects with a mean species richness score above the 80th percentile).

Water responsive species abundance

As for species richness, only transects at wetlands in the Persistent Temporary WRC (PTW) were considered compliant with the native water-responsive species abundance index (Table 6, Figure 15); of these 11 transects were compliant, or 25% of all wetland transects, leading to a stratum score for PTW of 0.37 (Table 6). This result represents a considerable increase on the PTW species abundance index from the previous year, when two transects were considered compliant. No EPW transects were compliant in the current year, compared to half of the transects in 2017–18. No transects in the semi-permanent WRC have been recorded as compliant since 2012–13 (Figure 15).

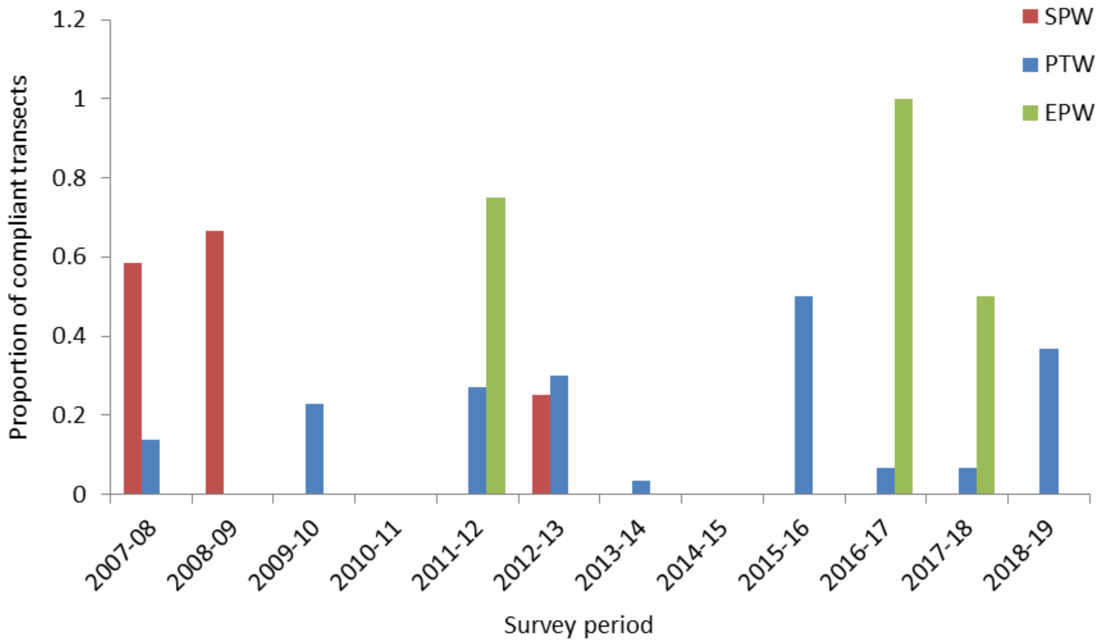

Figure 15 Species abundance proportion of compliant transects (transects with a species abundance score above the 80th percentile) for each WRC.

Whole-of-icon site score

The proportion of transects compliant with native water-responsive species richness indices at Hattah Lakes differed across WRCs (Table 6). No transects were compliant in semi-permanent or episodic wetlands, while almost a third of transects were compliant at persistent temporary wetlands. The icon site score for native species richness at wetlands appears to be significantly higher than the score recorded in 2017–18, and similar to the score recorded in 2015–16 (Figure 16). Icon site species richness scores in wetlands appear to be significantly higher in seasons without flooding, compared to seasons with e-water events (Figure 17). This may be due to the lower variation in icon site scores in seasons without flooding (min to max: 0.156–0.266); scores in seasons receiving e-water vary from 0.041 to 0.224. Icon site scores for wetland species richness in seasons with natural flooding were intermediate and do not appear significantly different from seasons with either no flooding or e-water flows.

Similarly for native water-responsive species abundance indices, no transects were recorded as compliant at semi-permanent or episodic wetlands at the Hattah Lakes icon site; just over a third of transects in persistent temporary wetlands were compliant with the species abundance index (Table 6). The icon site score for native species abundance was higher than the 2016–17 and 2017–18 scores (Figure 18). Native water-responsive species abundance icon site scores for wetlands at Hattah Lakes are generally (although not significantly) higher in seasons without flooding, compared to seasons where wetlands received water, either naturally or through e-water events (Figure 19). However there is considerable variation in the icon score when inundation occurs (Figure 18, Figure 19).

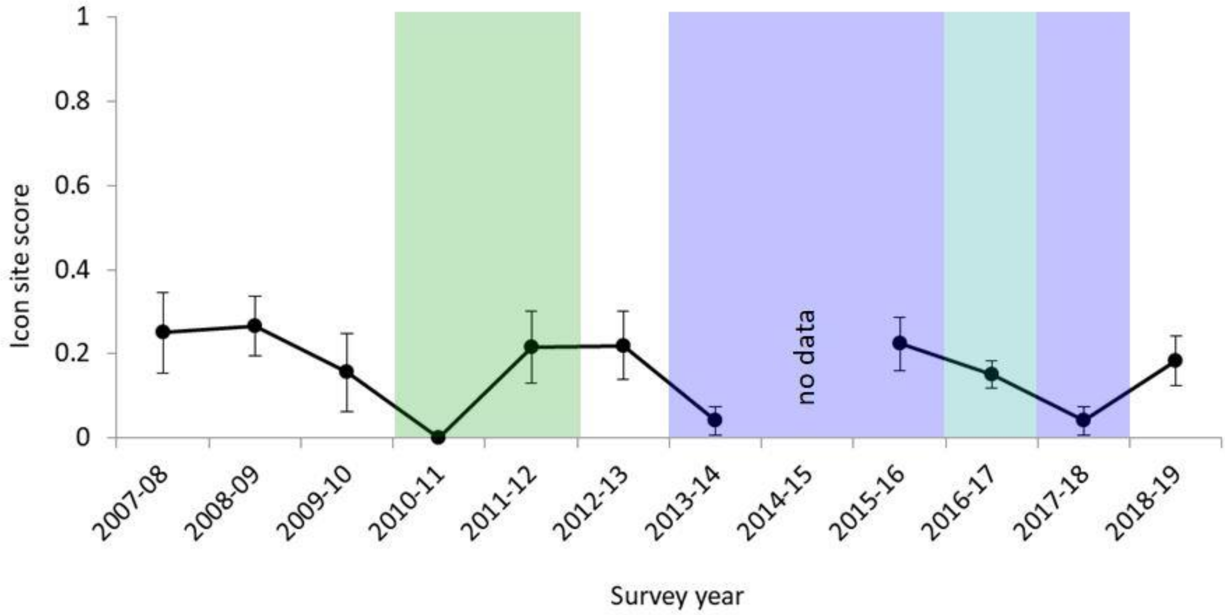

Figure 16 Icon site scores for the Hattah Lakes icon site wetlands based upon native water-responsive species richness indices and weighted across each WRC (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water).

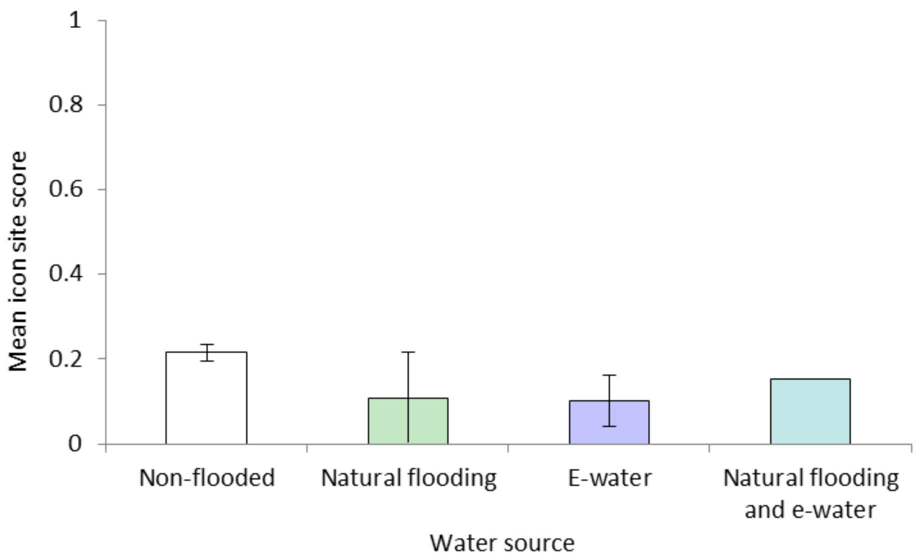

Figure 17 Mean icon site wetland scores based upon native water-responsive species richness indices, for the Hattah Lakes icon site (± standard error), for each water event type. Non-flooded years *n* = 5, natural flooding *n* = 2, e-water *n* = 3, natural flooding and e-water *n* = 1.

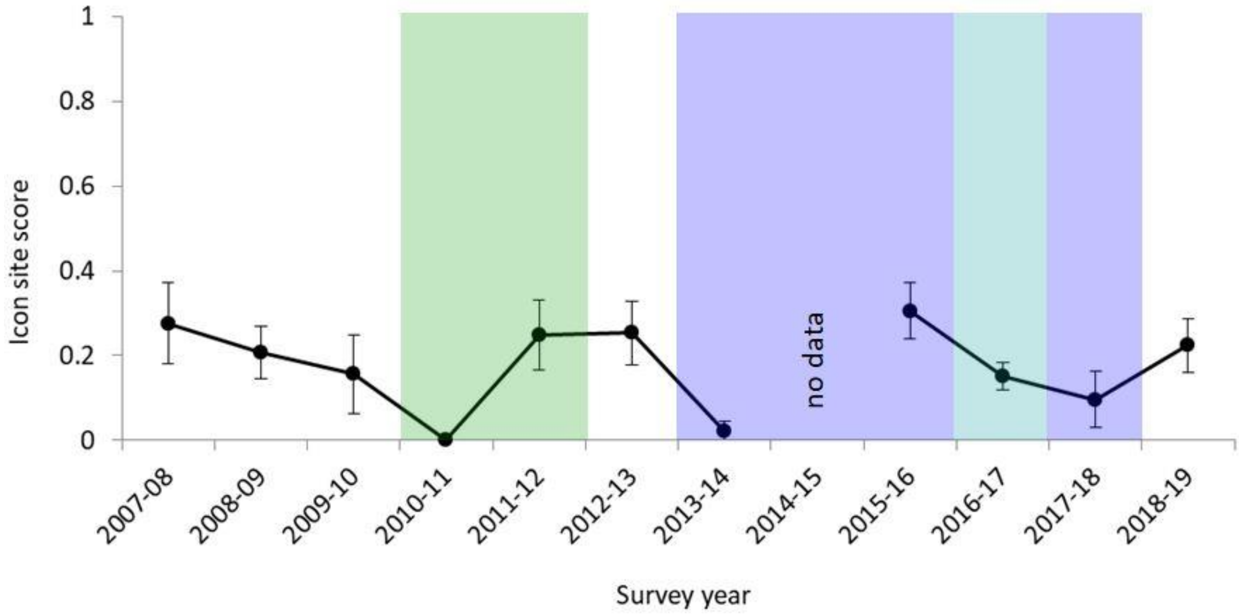

Figure 18 Icon site scores for the Hattah Lakes icon site wetlands based upon native water-responsive species abundance indices and weighted across each WRC (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water).

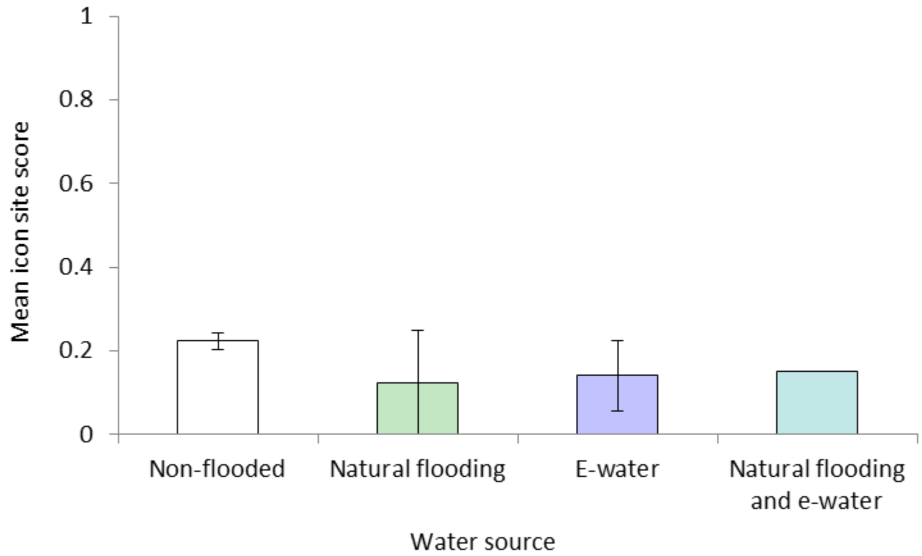

Figure 19 Mean icon site wetland scores based upon native water-responsive species abundance indices, for the Hattah Lakes icon site (± se), for each water event type. Non-flooded years *n* = 5, natural flooding *n* = 2, e-water *n* = 3, natural flooding and e-water *n* = 1.

4.4.3 Drought-tolerant vegetation in wetlands

Drought-tolerant species (Tdr) make up the greatest proportion of records at episodic wetlands (42%), with lower levels at persistent temporary (11.4%) and semi-permanent (11.1%) wetlands (Figure 21,

Figure 22, Figure 23). Woody species tolerating inundation (Atw) and amphibious species (A) were observed in greater proportions in semi-permanent wetlands, where they comprise over a third of records; they were recorded at the lowest levels in episodic wetlands, where they make up only 13.9% of records.

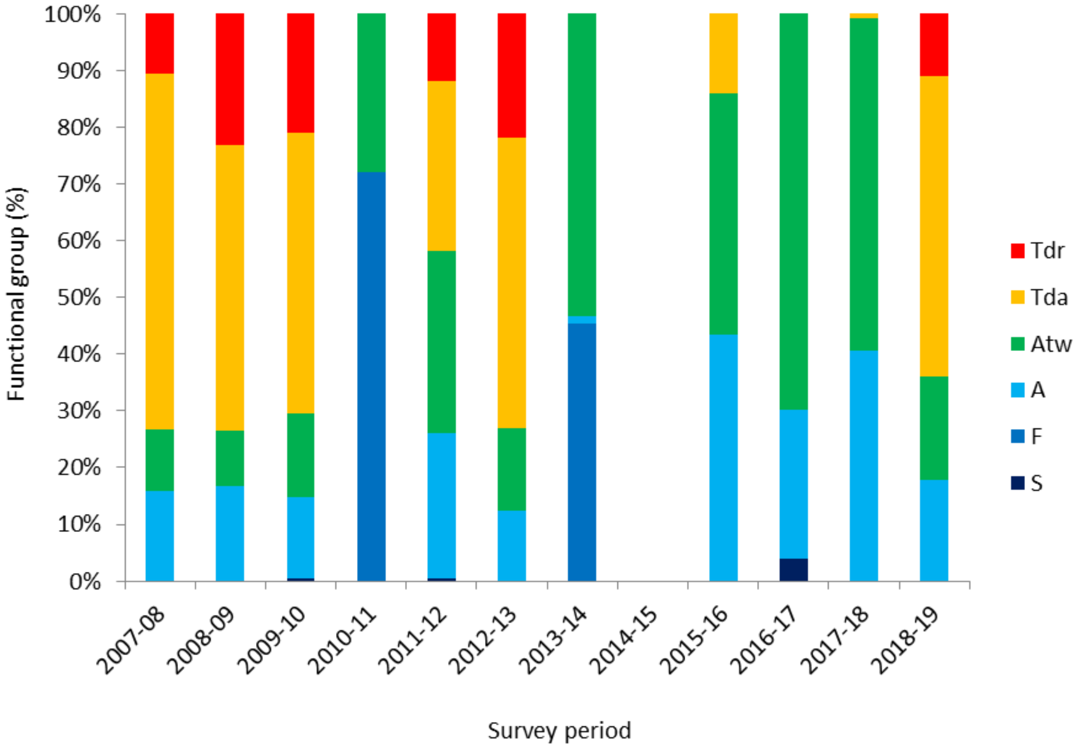

Figure 20 Percentage of plant functional groups recorded across survey periods in wetlands within the semi-permanent wetland WRC (SPW) in the Hattah Lakes icon site.

In 2018–19, over half the plant records obtained in semi-permanent wetlands at the Hattah Lakes icon site were terrestrial damp species (Tda), a considerable increase since the previous year, when less than 1% of records were of this functional group (Figure 20). Smaller proportions of woody species tolerating inundation (Atw) and amphibious species (A) were recorded, at lower levels than in the previous year (Figure 20). Over 10% of records comprised drought-tolerant species (Tdr), which have not been recorded in this WRC since 2012–13 (Figure 20).

A greater proportion of terrestrial damp species were recorded in persistent temporary wetlands compared to previous seasons, with this functional group making up almost two thirds of records (Figure 21). Records of plants in the Atw and A functional groups had declined from 2017–18; the proportion of drought-tolerant species also declined slightly between 2017–18 and 2018–19 (Figure 21).

Proportions of all functional groups remained similar between the previous season and 2018–19 at episodic wetlands (Figure 22). Over 85% of plants were either drought-tolerant or terrestrial damp species; a trend which has remained relatively consistent since 2015–16, when almost all plants recorded were amphibious (Figure 22).

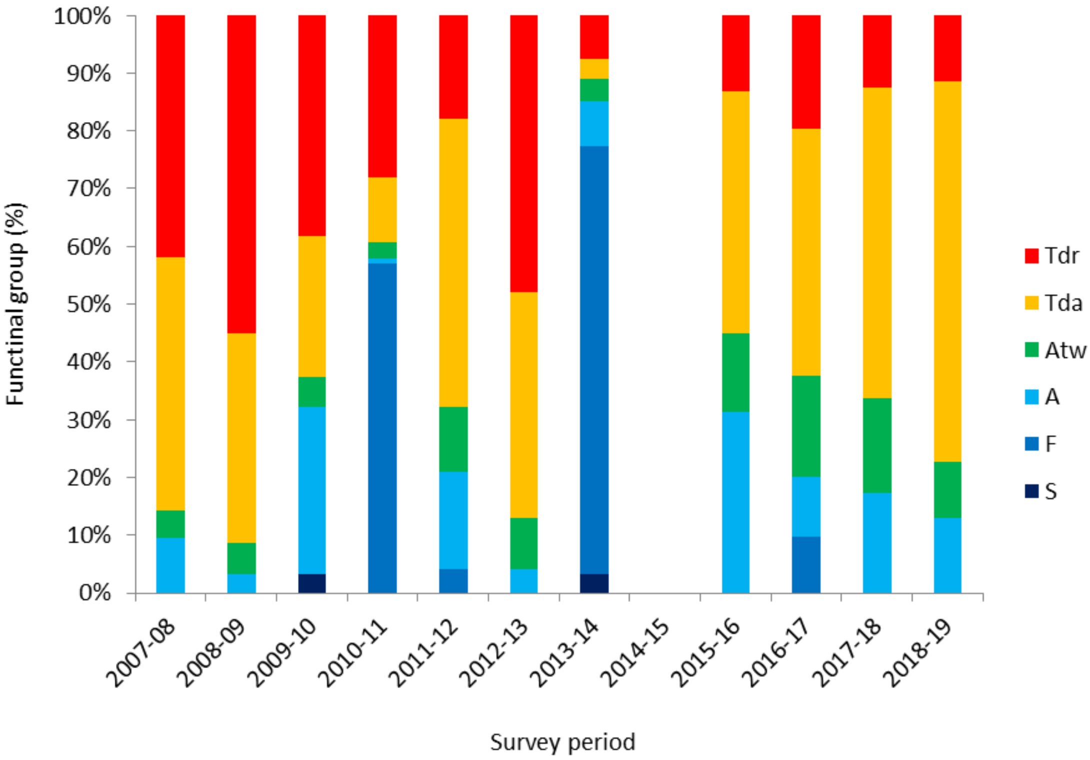

Figure 21 **Percentage of plant functional groups recorded across survey periods in wetlands within the persistent temporary wetland WRC (PTW) in the Hattah Lakes icon site.**

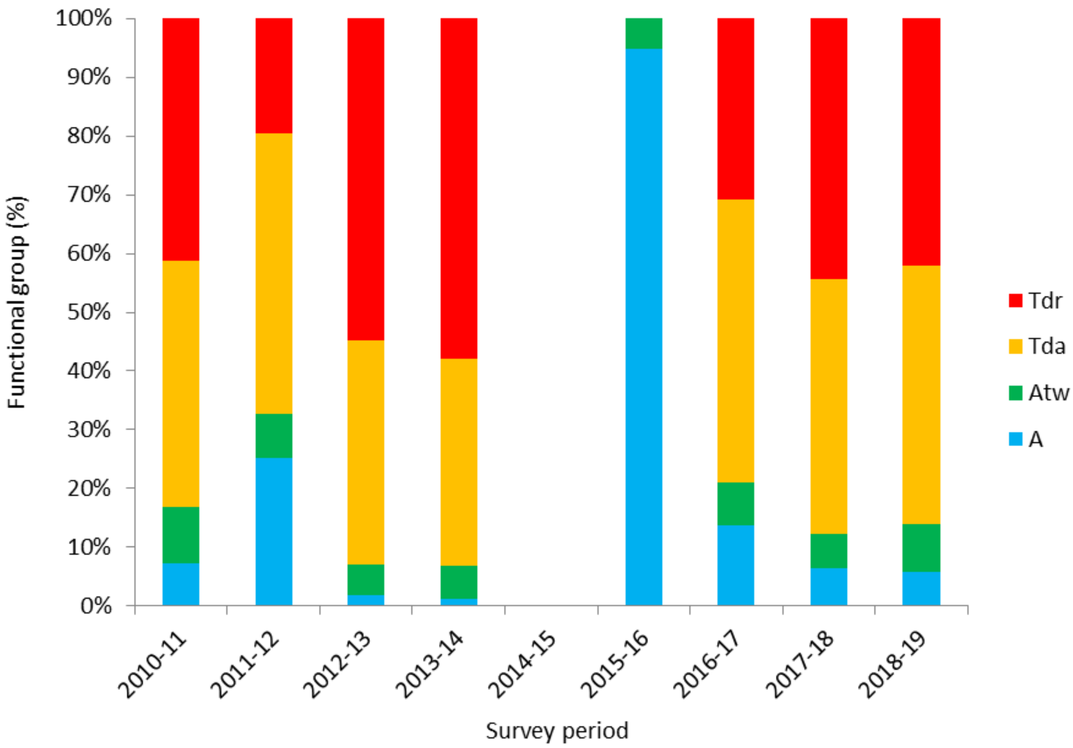

Figure 22 **Percentage of plant functional groups recorded across survey periods in wetlands within the episodic wetland WRC (EPW) in the Hattah Lakes icon site.**

4.5 Discussion

4.5.1 Persistent Temporary Wetlands

All Persistent Temporary Wetlands (PTWs), with the exception of Chalka Creek North, recorded higher water-responsive species richness and abundance during the current monitoring period, compared to the last two monitoring periods. All these sites were inundated last year, where Chalka Creek North was in a drawdown phase. This year Chalka Creek North supported the lowest water-responsive species richness and abundance of all the PTWs (and all monitoring periods) – half of the quadrats consisted predominately to bare ground and leaf litter.

Typically water-responsive species richness and abundance is highest the years following inundation (drawdown phase) (Casonova and Brock 2000, Huntley et al. 2016), and this results in a higher diversity of Tdr (terrestrial damp species) and A (all amphibious species groups). Despite having the greatest water responsive species richness and abundance in the last two monitoring periods, compliance has not been reached in the majority of transects. A total of nine transects were compliant for water-responsive species richness and eleven for abundance. Lake Nip Nip was the only site to achieve compliance across all four transects (Table 6).

Two sites had transects that were still partially inundated – Lake Bitterang and Lake Brockie – these sites achieved compliance in some of the transects (Table 6). Quadrats that were inundated supported no vascular plant taxa, which reduced the (average) species richness and abundance for the transects. Diversity and abundance of water-responsive species outside of the inundated quadrats was typically moderate to high.

For Chalka Creek, Chalka Creek North, Lake Boich, Lake Little Hattah, and Lake Yerrang, non-compliant transects had a number of factors in common - there were many quadrats where bare ground and leaf litter dominated or quadrats were occupied by one species, most typically *Glycyrrhiza acanthocarpa* Southern Liquorice. The diversity and abundance of dryland or exotic species was also not notably higher at these sites. This is suggests a low colonisation of these sites by any vascular plant taxa following the recession of water. Potentially the low species diversity at these sites could be due to a low seed bank and/or limited colonisation by propagules that have dispersed from other areas. Casonova and Brock (2000) have noted that in many temporary wetlands such as those on the Northern Tablelands of New South Wales Australia, the development of plant communities is largely the result of germination and establishment from a long-lived, dormant seed bank, and vegetative propagules that survive drought. If largely relying on an established seed bank, a species-poor site can result in one species dominating or large areas of bare ground. The sites may not have supported a diverse seed bank (prior to program commencing) or the seed bank has been depleted due to the extended period of inundation over recent years, where germination of terrestrial damp species may have occurred but plants may have not survived long enough to reproduce due to more inundation (to replenish the seed bank). Long-dry phases (short flooding durations) give an opportunity for terrestrial species to establish and reproduce (Casonova and Brock 2000). With the exception of Chalka Creek, full compliance for species richness across all transects has not been achieved during any of the monitoring periods. Chalka Creek last reached its full compliance of water responsive species richness during the 2011/2012 monitoring period.

Lake Nip Nip, which had full compliance of water-responsive species richness and abundance, had much fewer quadrats where bare ground and/or leaf litter was recorded and supported a diversity of species –

predominately from the Tda functional group. It also had the greatest diversity of all of the PTW sites of exotic species. In addition, no quadrats were inundated. It previously reached full compliance across all transects during the 2015/2016 monitoring period.

Overall, since the monitoring program began (prior to watering events) there has been a shift from dominance of dry terrestrial species (Tdr), to dominance of aquatic and amphibious species (S, F and A functional groups) during flooding and watering events, to predominately Tda (damp terrestrial) and amphibious species during the drawdown phase. This is consistent with other findings (e.g. Casonova and Brock, Moxham and Kenny 2016). It is expected that as the wetlands dry further, the diversity and abundance of dry terrestrial species will increase; similarly amphibious and damp terrestrial species (diversity and abundance) will decrease.

Table 7 Hattah Lakes Icon Site – summary of compliant transects

Wetland	No. of compliant transects		Potential Factors affecting compliance
	Richness	Abundance	
Persistent Temporary Wetlands			
Chalka Creek	1 (/4)	2 (/4)	Many quadrats with bare ground – including all of transect 2 and outer quadrats of other transects
Chalka Creek North	0 (/4)	0 (/4)	Many quadrats with bare ground and leaf litter (across all depths/elevations)
Lake Bitterang	2 (/4)	1 (/4)	Quadrats at 0 cm and 50 cm elevation were inundated with no vascular plant taxa recorded in these quadrats. Leaf litter common in outer quadrats. Pig disturbance noted along some transects.
Lake Boich	1 (/3)	1 (/3)	Majority of quadrats with low species diversity - high occurrence of *Glycyrrhiza acanthocarpa*
Lake Brockie	1 (/3)	2 (/3)	Quadrats at 0 cm elevation inundated. Leaf litter common within outer (120 cm elevation) quadrats. Compliance (for richness) almost reached in a second transect.
Little Lake Hattah	0 (/4)	1 (/4)	Majority of quadrats with low species diversity - high occurrence of *Glycyrrhiza acanthocarpa.* Compliance (for richness) almost reached in a second transect. Pig disturbance noted along some transects.
Nip Nip	4 (/4)	4 (/4)	-
Lake Yerrang	1 (/4)	2 (/4)	Low species diversity. High occurrence of bare ground, leaf litter and *Glycyrrhiza acanthocarpa*

Wetland	No. of compliant transects		Potential Factors affecting compliance
	Richness	Abundance	
Semi-permanent Wetlands			
Lake Hattah	0 (/4)	0 (/4)	Quadrats at -100 cm to 0 cm or 50 cm elevation were inundated with no species recorded. Leaf litter common in outer quadrats. Pig disturbance noted along some transects.
Lake Mournpall	0 (/4)	0 (/4)	Quadrats at -100 cm to 0/50 cm elevation were inundated with no species recorded. Compliance almost reached in one transect.
Lake Bulla	0 (/4)	0 (/4)	Quadrats at -100 cm to 0/50 cm elevation were inundated with no species recorded.
Episodic Wetlands			
Lake Kramen	0 (/4)	0 (/4)	Greatest number of dry terrestrial species (Tdr) *cf* other wetlands. Only three water sensitive species recorded – high occurrence of *Glycyrrhiza acanthocarpa*

4.5.2 Semi-permanent Wetlands

Three wetlands comprise the Semi-permanent Wetland Group – Lake Hattah, Lake Mournpall and Lake Bulla. Water responsive species richness and abundance was highest this monitoring period, compared to the last five monitoring periods, however compliance was not reached at any of the sites/transects. All three wetlands were still partially inundated – typically between -100 cm and 0 cm or 50 cm elevation, and no vascular plant taxa were recorded in the inundated quadrats. Similar to Lake Brockie and Lake Bitterang (which were also partially inundated), reasonable species diversity and abundance across the amphibious (A) functional groups and terrestrial damp (Tda) functional group was recorded in quadrats that were not inundated.

The drying of the wetlands has seen a shift in the species composition of the site – a likely reflection of the habitats along a wet – dry gradient. Since the last monitoring period, a significant increase in the proportion of terrestrial damp species has occurred, as well as terrestrial dry species, which have re-colonised the drier portions of the sites.

4.5.3 Episodic Wetlands

Lake Kramen is the only wetland within the Episodic Wetland group and therefore is more limited in sample size compared to the other wetland groups. This wetland did not achieve compliance in water-responsive species richness or abundance, and which were lower than the previous monitoring period. These results may be attributed to the continued drying of the Lake. This site recorded the highest diversity and abundance of terrestrial dryland (Tdr) species, compared to all wetlands. Other contributing factors in limiting compliance being achieved are the high incidence of leaf litter and

Glycyrrhiza acanthocarpa across all elevations (50 cm – 250 cm). Only three native species were recorded in the Tdr (terrestrial damp species) group, of which *G. acanthocarpa* was the most abundant - typically in all 15 quadrats between 50 cm and 200 cm.

Lake Kramen last achieved full compliance across all transects during the 2015/16 monitoring period – this was following the 2014 watering event. Full compliance could potentially be achieved again following another watering or natural flooding event.

4.5.4 Whole of Icon Site

Twenty percent (20%) of the transects were compliant for water-sensitive species richness and 25% for abundance. Despite this, there has at least been an improvement in the overall number of compliant transects since the last monitoring period.

The potential reasons for not achieving compliance varies between the sites and wetland groups (as indicated by the relatively large variation in site scores), and viewing the overall outcome for Hattah as one result is not reflective of the improvements to some wetlands since the program commenced. Each wetland is best to be reviewed separately, with a comparison of the results over time.

4.6 Progress towards ecological objectives

The diversity of wetland habitats is reflected in time and space along a wetness gradient. Wetlands change naturally over time due to wetting and drying events (Moxham and Kenny 2016, Huntely et al. 2016), and this is reflected in a change in vegetation communities and associated plant species (vegetation community composition), as well as a shift in the boundaries of the vegetation communities as wetlands fill or as water retreats (space). The change over time depends on the water regime of a wetland, where some wetlands fill more regularly than others. However, in all cases, extended dry periods beyond historical patterns, results in a decline in the quality of the wetland and associated vegetation, through the encroachment of dry terrestrial species, including exotic species (Casonova and Brock 2000).

During the current monitoring period, many of the wetlands were in different states of inundation and drying, providing a mosaic of habitats in the Hattah Lakes icon site. Viewing the results of water-sensitive species richness and abundance over time shows the benefit of the large-scale watering events. There has been a shift from the dominance of terrestrial species to a range of aquatic, amphibious and terrestrial species over a wetness gradient. This shift in plant functional groups and changes in water-sensitive species richness and abundance, as a result of the wet, drawdown and dry phases, is similar to what is expected naturally.

The overarching objective of ‘restoring a mosaic of healthy wetland communities’ is being achieved at the Hattah Lakes icon site.

4.7 Recommendations

The ability to achieve targets for each monitoring period is affected by a number of factors including the wetland status in relation to wetting and drying. It can’t be expected that during flooding and dry phases, which have been proven to support lower water-sensitive species richness and abundance, that the sites will always achieve the point of reference indices. Tailoring the indices to these wetland phases (i.e. separate indices for flooded/wet, drawdown and dry phases) may provide more meaningful and achievable targets. Development of the targets/point of reference indices (based on previously collected data) also need to ensure that exotic species are excluded.

If the wetland indices are not reviewed, it is recommended that the indices at least should be updated in The Living Murray: Condition Monitoring Program design for the Hattah Lakes (Huntley et al. 2016) to reflect the 80th percentile, rather than the 90th percentile, as recommended in the preceding condition monitoring report (Brown et al. 2018).

In addition, the transects at each wetland vary in length/elevation. There is uncertainty as to whether the data that determined the point of reference for Hattah included the range of elevations used in the current monitoring program. Robinson 2014 only addresses data used to determine indices at the LMW site (0 – 90 m elevation); Huntley et al. 2016 and Brown et al. 2016 state that the transects go from the bottom of the wetland (e.g. 0 cm) to the wetland. The range of elevations used to determine the point of reference will potentially affect the results – fewer water-sensitive species would be expected below 0 cm (e.g. the SPW sites transects start at -100 cm elevation), and also within higher elevations (currently varies between 60 cm and 250 cm elevation). It is hoped that the data from the full range of elevations in the current monitoring program have been used when determining the current point of reference.

5 Floodplain Vegetation Communities

5.1 Introduction

Floodplains are dynamic features of the riverine landscape. Floodplains include both aquatic and terrestrial habitats, making them highly productive and diverse ecosystems, often supporting large and diverse populations of plants and animals . In temperate and tropical regions, flow has been found to be the primary determinant of floodplain plant community composition and structure, and crucial to the maintenance of the floodplain ecosystem (Capon 2004). Frequency and duration of flooding across a floodplain affects the distribution of vegetation communities and their composition – which changes both temporally and spatially. Anthropogenic changes to the frequency of flooding can result in significant changes to plant community and composition, including loss of native species and increased invasion of exotic species (Capon 2004). For example, many plant species are adapted to regular disturbance by floods and will be replaced by more drought tolerant (including invasive) species if flooding frequencies are reduced. Changes to floodplain hydrology can also lead to a decline in the condition of the dominant riparian tree species (Holland et al 2013).

The Hattah Lakes floodplain's hydrology has changed substantially as a result of the regulation and diversion of River Murray flows, resulting in a reduction in the frequency and duration of flooding, which has caused a decline in the condition of floodplain vegetation communities (MDBA 2012a). With the delivery of environmental water to the Hattah Lakes icon site it is hoped that the condition of the floodplain vegetation will improve. Monitoring at six locations within the Hattah Icon Site has been established to determine the efficacy of the watering program.

The following section presents the findings of the 2018-2019 monitoring program. It:

- assesses native water-responsive species richness and abundance on Hattah Lakes floodplains against a point of reference;
- assesses the condition of the whole Icon Site using native water-responsive species richness and abundance scores; and
- analyses changes in vegetation community composition over time.

5.2 Ecological objectives

Ecological objectives for floodplain vegetation communities are consistent with those used for wetland vegetation communities (refer Section 4.2).

5.3 Methods

There are six locations (H1–H6) for monitoring floodplain vegetation communities within the Hattah Lakes Icon Site. As specified by Wood et al. (2018), these locations were established to represent three different flood return frequencies—often, sometimes and rarely—which relate to floodplain elevations as outlined in Table 8. A total of 17 sites have been established within these 6 locations (Table 8).

Since the establishment of sites in 2007–08, surveys have been undertaken annually with the exception of 2014–15. In 2010–11, only 14 sites were surveyed as flooding prevented access to some sites (Brown et al. 2018). Data collection for this round of monitoring was undertaken in January–February 2019 and all sites were surveyed.

An overview of methods followed for data collection and statistical analysis are provided below; for further details on the project methodology see Huntley et al. (2016).

Table 8 Flood return frequencies (FRFs), floodplain elevation, commence-to-flow (CTF) level and associated floodplain site names for TLM Program at the Hattah Lakes icon site. The FRFs were determined using CTF data (source: Brown et al. 2018)

Flood return frequency	Floodplain elevation	Commence to flow	Site names
Often	Lower floodplain	35 000–60 000 $ML.day^{-1}$	H1A; H2A; H3A; H4A; H5A; H6A
Sometimes	Mid floodplain	60 000–100 000 $ML.day^{-1}$	H1B; H2B; H3B; H4B; H5B; H6B
Rarely	Higher floodplain	> 100 000 $ML.day^{-1}$	H1C; H2C; H3C; H5C; H6C

5.3.1 Data collection

Each of the 17 sites contains four permanently established quadrats, spaced 50 m apart and each consisting of 15 x 1 m x 1 m cells (Figure 23). Floodplain vegetation surveys follow the methods described in Section 4.4.1. The methods to identify plant species and the use of plant functional group are described in Section 4.3.2.

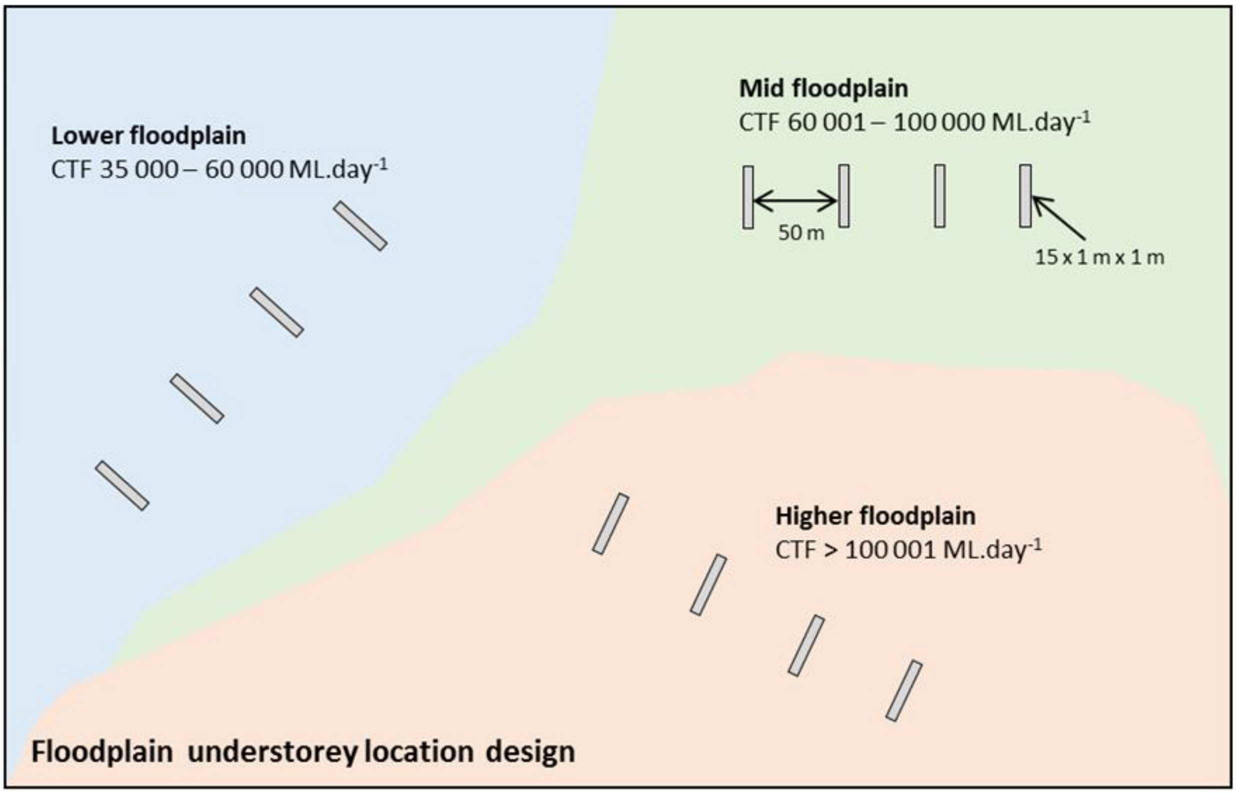

Figure 23 Schematic of the survey design used to assess floodplain understorey vegetation communities under The Living Murray program at the Hattah Lakes Icon Site (Huntley et al. 2016).

5.3.2 Data analysis

Point of reference assessment

There are three flood return frequency (FRF) classifications for the Hattah Lakes Icon Site: lower, mid and higher floodplain (Huntley et al. 2016). For each FRF, a point of reference index was developed by Brown et al. (2016) for species richness and species abundance using TLM condition monitoring data for floodplain understorey communities (Table 9). The point of reference includes plant species that are considered water responsive and excludes drought-tolerant species.

As detailed in Wood et al. (2018), floodplain vegetation is deemed to be in good condition when:

- Native water-responsive species richness in a FRF is at or above the 80th percentile (adapted from Huntley et al. (2016)
- Native water-responsive species abundance in a FRF is at or above the 80th percentile (adapted from Huntley et al. (2016).

Table 9 Ecological targets for floodplain understorey vegetation at the Hattah Lakes icon site (Brown et al. 2018).

Flood return frequency	Floodplain elevation	Index 1: water responsive species richness (80th percentile)	Index 2: water responsive species abundance (80th percentile)
Often	Lower floodplain	6.15	37.35
Sometimes	Mid floodplain	5.95	22.9
Rarely	Higher floodplain	1.6	7.15

The following is taken from Wood et al. (2018).

To calculate if water responsive species richness was in 'good' condition for floodplains (adapted from Huntley et al. (2016):

- all years of data were used, including only native water-responsive plant species (see Section 4.3.3) and excluding records only classified to genus level
- the total number of species were averaged across all quadrats for each site in each year
- for each FRF, sites with water responsive species richness at or above the 80th percentile (Index 1 in Table 5.2) score = 1 (i.e. compliant), and sites with water responsive species richness below the point of reference score = 0 (i.e. non-compliant)
- the proportion of compliant sites within each FRF were plotted over time.

The same steps (above) were applied to determine if water responsive species abundance was in 'good' condition for each FRF using the sum of abundance of water responsive plant species.

Whole of icon site floodplain scores were calculated by weighting the strata scores for both the richness and abundance of native water-responsive species, considering the total area of each FRF in the Hattah Lakes icon site, and the number of sites sampled within each FRF. Scores were weighted using the example shown in Brown et al (2014), informed by methods to estimate an overall mean from a stratified sample (Sutherland 2006). To determine 95% confidence intervals, t-values were calculated in R (R Core Team 2018) for *P* = 0.05 (two-sided) using the degrees of freedom method shown in Sutherland (2006). These whole-of-icon site scores were calculated for each survey year since 2007–08 (excluding 2014–15). Scores were plotted as a time series to examine the effect watering events have had on the richness and abundance of water responsive species at an icon site scale. The source and categories of watering events at Hattah Lakes were taken from MDBA (2018).

Plant functional groups

As outlined by Wood et al. (2018), the use of plant functional groups is a widely accepted method of interpreting disturbance related changes in plant communities, while minimising the effects of changes in species composition or inconsistencies in taxonomic classification (Brock & Casanova 1997; Campbell et al. 2014). Functional groups assist in demonstrating the influence of flood inundation on community composition (Wood et al. 2018). Consistent with the previous approach (Wood et al. 2018), charts were produced to display the proportion of functional group abundance data for each survey year, in each FRF. For display purposes, functional groups A, Arf, Arp, Ate, Atl were combined into one amphibious functional group ‘A’. Functional group ‘T’ was excluded from these charts because it was not possible to determine if these species were drought tolerant (Tdr) or terrestrial damp species (Tda) (Wood et al. 2018). Both indigenous and introduced species were included in the analysis because both groups are expected to respond to changes in hydrology across the wetlands.

5.4 Results

5.4.1 Data summary

A total of 94 vascular plant species was recorded from the six Hattah Lakes floodplain sites during the 2018–19 monitoring. Of these, 79 (84%) were indigenous and 15 (16%) were exotic. Ten species recorded are listed as rare or threatened in Victoria by DEPI (2014) (one endangered, two vulnerable, five rare and two poorly known); the species listed as endangered—Woolly Scurf-pea *Cullen pallidum*—is also listed as threatened under the Victorian *Flora and Fauna Guarantee Act 1988*. For further details on plant species recorded please refer to the 2018–2019 Part B.

5.4.2 Point of reference assessment

Water responsive species richness

The mean richness of native water-responsive species on floodplains was calculated for each of the 17 sites in the Hattah Lakes study area. Of the sites that are often-flooded FRF, none were compliant with the floodplain species richness index; one site was compliant in each of the sometimes- and rarely-flooded FRF strata, leading to strata scores for species richness of 0.17 and 0.2, respectively (Table 10). The current season’s results represent a decline in species richness strata scores for each FRF since 2017–18, when three of five sites were compliant in the rarely-flooded FRF, as well as two of six sites in the often and sometimes FRFs (Figure 24).

Table 10 Number of sites compliant with ecological targets relating to the species richness and abundance of native water-responsive species, in each floodplain return frequency

category (FRF) at the Hattah Lakes icon site, as surveyed in the 2018–19 season. Also shown are the stratum scores for each FRF, a weighted icon site floodplain score (with 95% confidence intervals for two sampled comparisons with normally distributed error variance) and the surveyed and total areas for each FRF.

FRF	FRF area (ha)	Surveyed area of FRF (ha)	Species richness			Species abundance		
			No. compliant sites	Stratum score	Icon Site score	No. compliant sites	Stratum score	Icon Site score
Lower floodplain (often)	1229.04	0.036	0 of 6	0	0.184 (±0.432)	0 of 6	0	0.157 (±0.435)
Mid floodplain (sometimes)	3969.81	0.036	1 of 6	0.17		0 of 6	0	
Higher floodplain (rarely)	18870.03	0.00016	1 of 5	0.2		1 of 5	0.2	

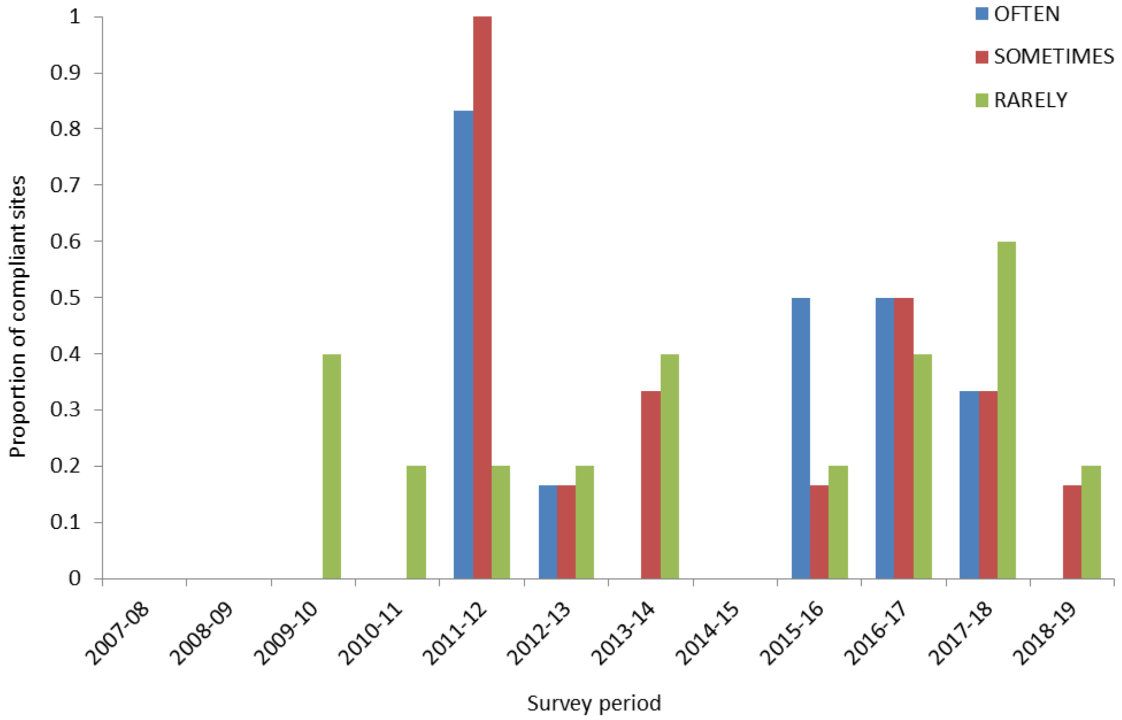

Figure 24 Proportion of compliant sites with species richness equal to or higher than the 80th percentile, within each FRF, across years.

Water-responsive species abundance

Only one site in the rarely flooded FRF was compliant with the index assessing native water-responsive species abundance in 2018–19; no sites were compliant in the often- and sometimes-flooded FRFs (Table 10). This represents a considerable decline from 2017–18, when three of five sites in the rarely-flooded FRF were compliant, as well as two often-flooded sites, and four sometimes-flooded sites (Figure 25).

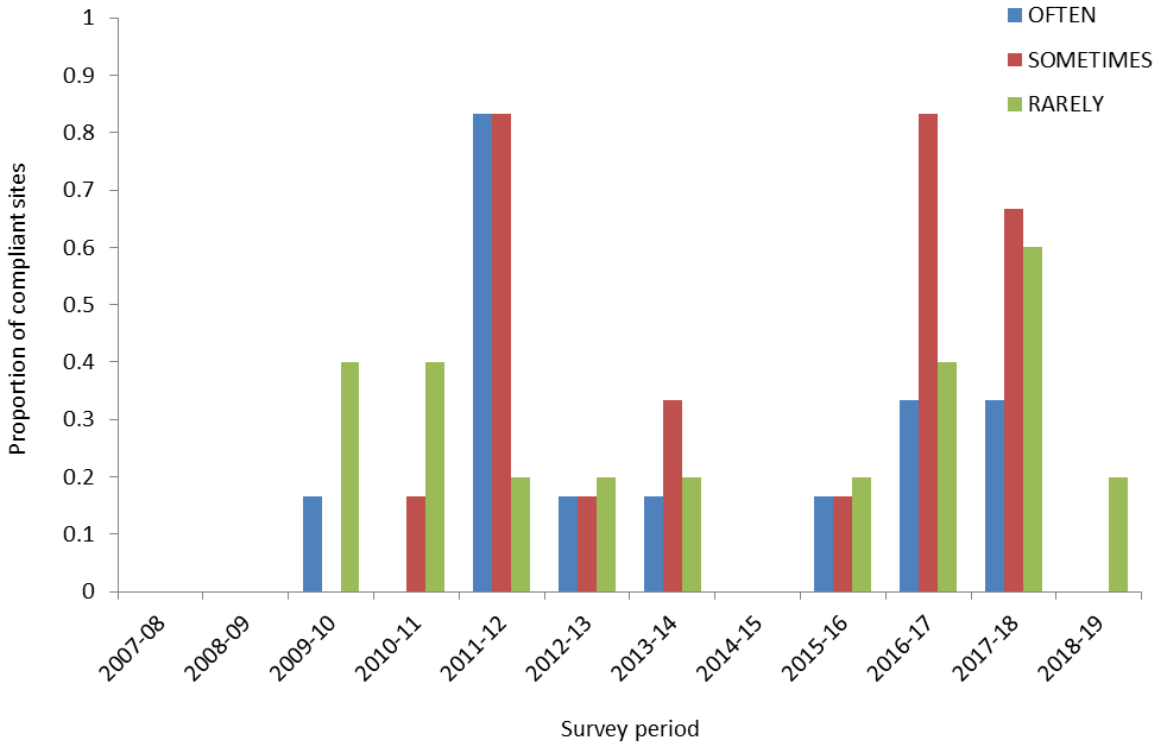

Figure 25 Proportion of compliant sites with species abundance equal to or higher than the 80th percentile, within each FRF, across years.

Whole-of-icon site score

Of the 17 floodplain sites surveyed across Hattah Lakes, only two were compliant in terms of native water-responsive species richness, one in the mid floodplain and one in the higher floodplain (Table 10). The icon site score for native species richness on floodplains was relatively low (Table 10), having declined (not significantly) from higher levels in 2017–18, and at similar levels to those observed in 2015–16 (Figure 26). The species richness of native water-responsive species on Hattah Lakes floodplains is significantly higher in seasons receiving environmental water, compared to seasons without flooding; no significant difference has been recorded in species richness between seasons with natural flooding and either seasons with environmental water, or without flooding (Figure 27). Compliant levels of native water-responsive species abundance were recorded at only one of the 17 Hattah Lakes floodplain sites in 2018–19 (Table 10). Native water-responsive species abundance across Hattah Lakes floodplains, as assessed using the icon site score, followed a similar trend to species richness — the icon site score was lower (not significantly) than in 2017–18, similar to the score recorded in 2015–16 (Figure 28). Icon site floodplain scores for native water-responsive species abundance are significantly lower in non-flooded seasons, compared to seasons with natural flooding, largely due to consistent scores recorded in 2010–2012 during natural flooding events. Abundance scores in seasons where Hattah Lakes floodplains receive environmental water do not appear significantly different from non-flooded or natural flooding seasons (Figure 29).

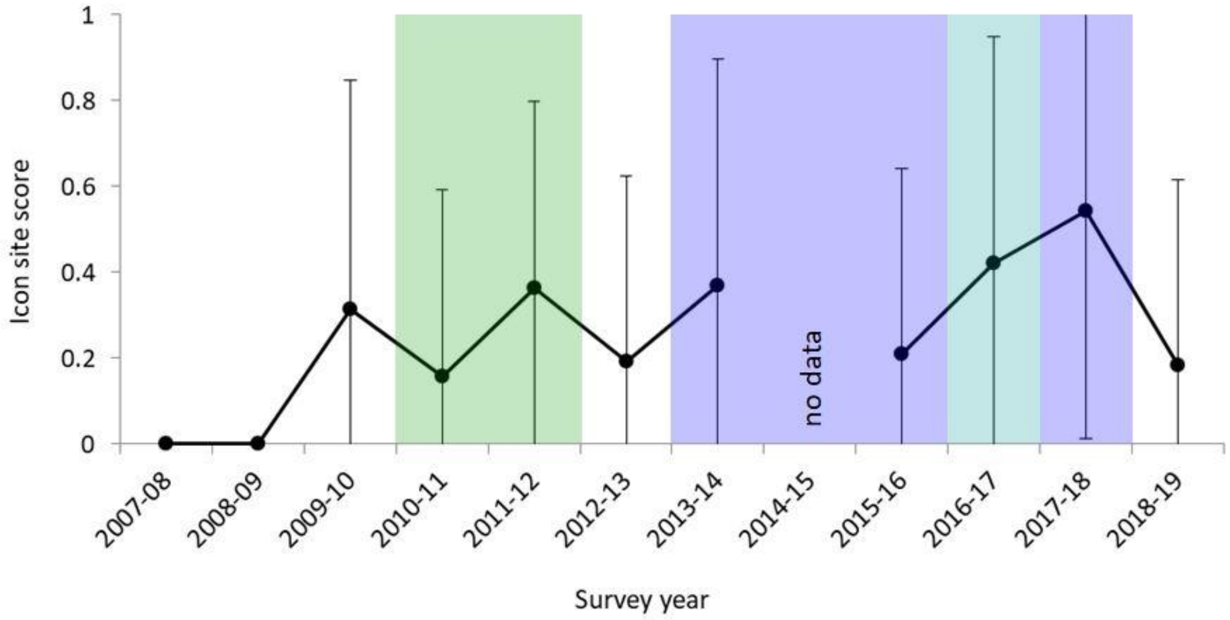

Figure 26 Icon site scores for the Hattah Lakes icon site floodplains based upon native water-responsive species richness indices and weighted across each FRF (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. No data were collected in 2014–15. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water).

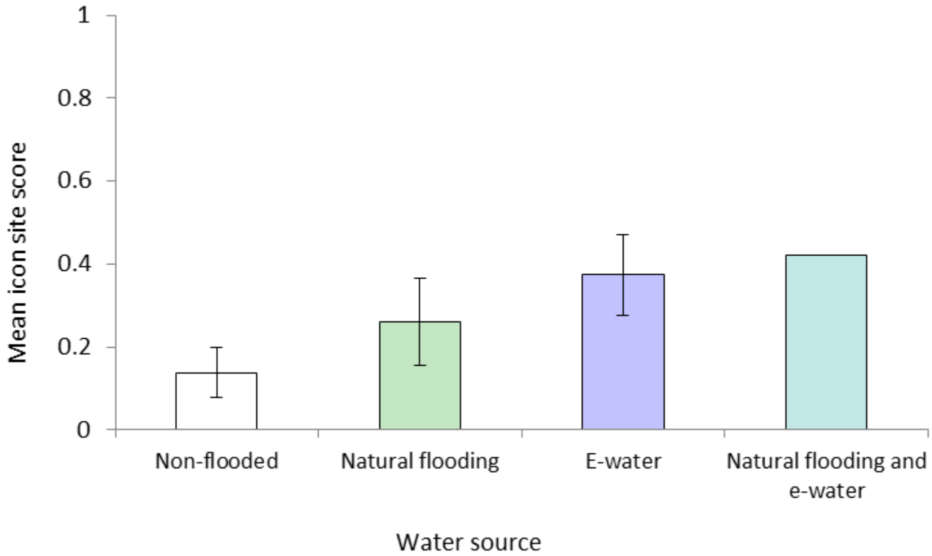

Figure 27 Mean icon site floodplain scores based upon native water-responsive species richness indices, for the Hattah Lakes icon site (± standard error), for each water event type. Non-flooded years *n* = 5, natural flooding *n* = 2, e-water *n* = 3, natural flooding and e-water *n* = 1.

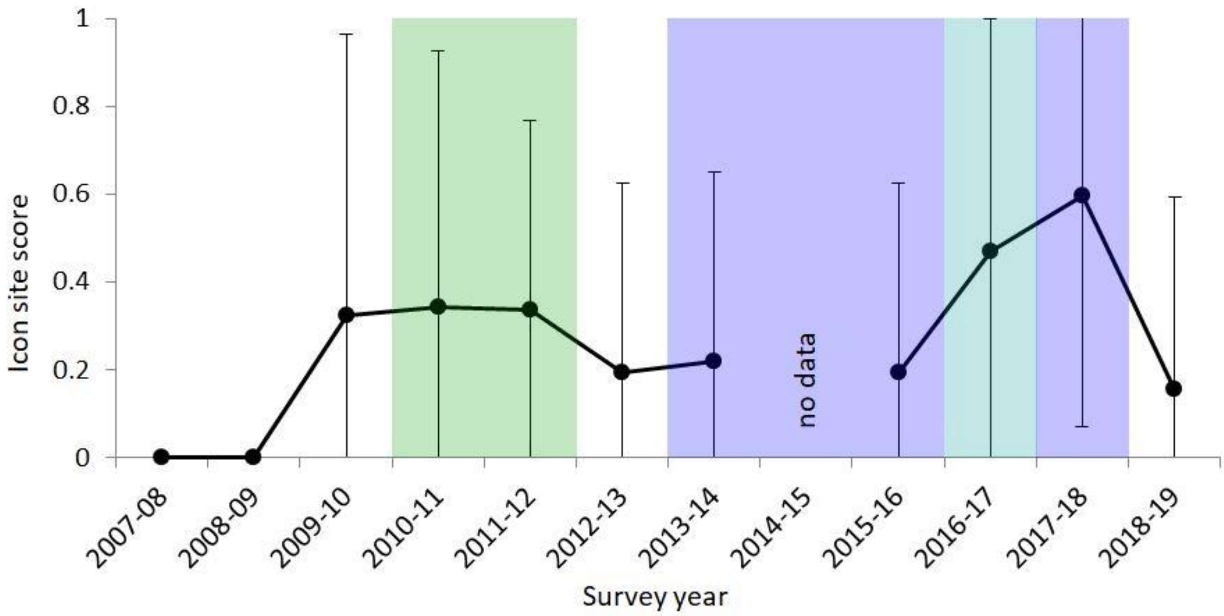

Figure 28 **Icon site scores for the Hattah Lakes icon site floodplains based upon native water-responsive species abundance indices and weighted across each FRF (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. No data were collected in 2014–15. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water).**

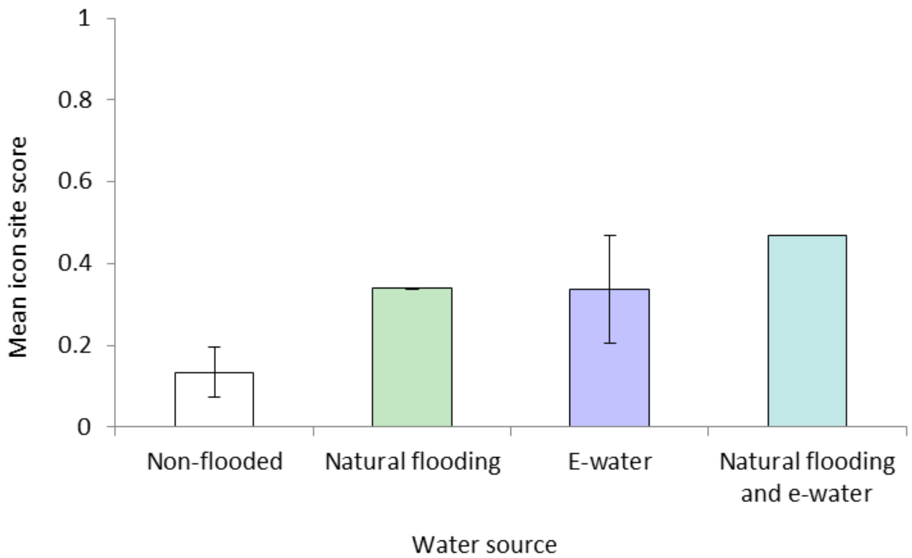

Figure 29 **Mean icon site floodplain scores based upon native water-responsive species abundance indices, for the Hattah Lakes icon site (± standard error), for each water event type. Non-flooded years *n* = 5, natural flooding *n* = 2, e-water *n* = 3, natural flooding and e-water *n* = 1.**

5.4.3 Plant functional groups

The proportion of drought-tolerant species (Tdr) recorded on Hattah floodplains increased as the frequency of flooding declined, from 15% at often-flooded sites, to 82% at rarely-flooded sites (Figure 28, Figure 29, Figure 30). Terrestrial damp species (Tda) comprised almost half of records at often-flooded sites, declining to only 10% of records at rarely-flooded sites. Amphibious species (A) represented 29% of records at often-flooded sites, but comprised only 2% of records at rarely-flooded sites. The remainder of plants recorded in the current season were woody species that tolerate flooding (Atw), with more records at sites with increased flooding frequencies.

The proportion of different functional groups at sites in the often-flooded FRF were similar to those recorded in the previous season, though small increases in amphibious species and woody species tolerant of flooding were noted, with a comparable decline in terrestrial damp species (Figure 28). A similar pattern was evident for sometimes-flooded sites (Figure 29).

A 16% increase in drought-tolerant species was recorded at rarely-flooded sites, with reductions in both terrestrial damp and amphibious species (Figure 30).

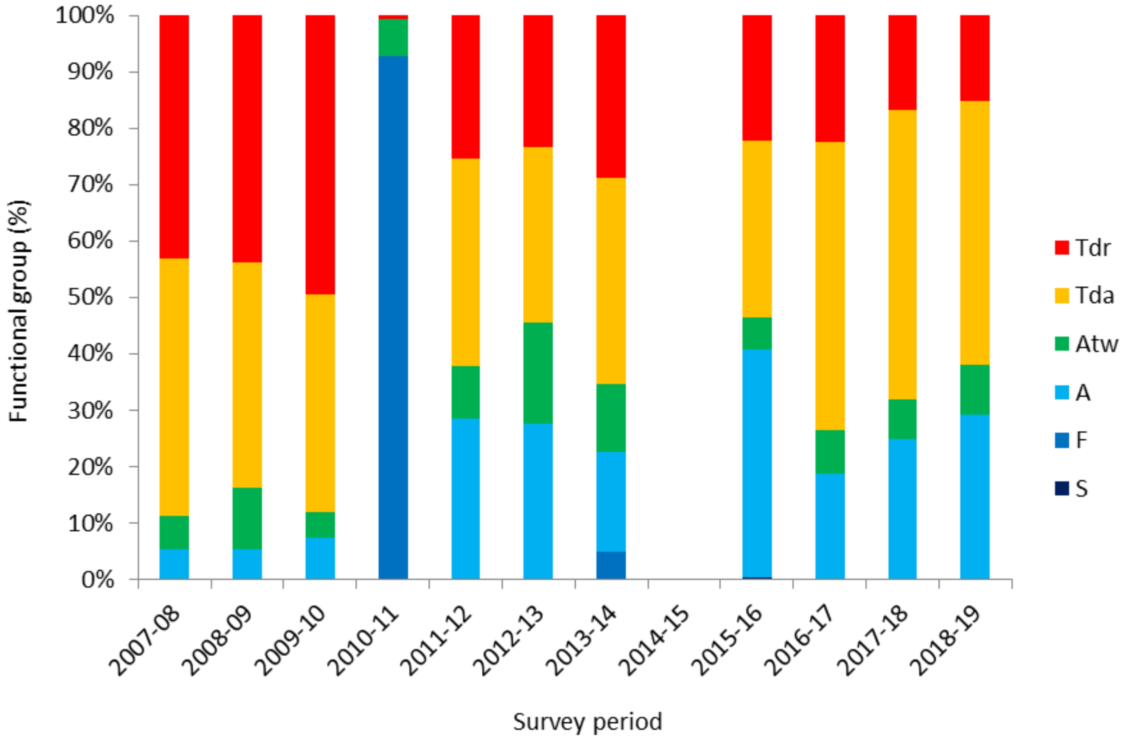

Figure 30 Percentage of plant functional groups recorded across survey periods at floodplain sites in the often-flooded FRF, across the Hattah Lakes icon site.

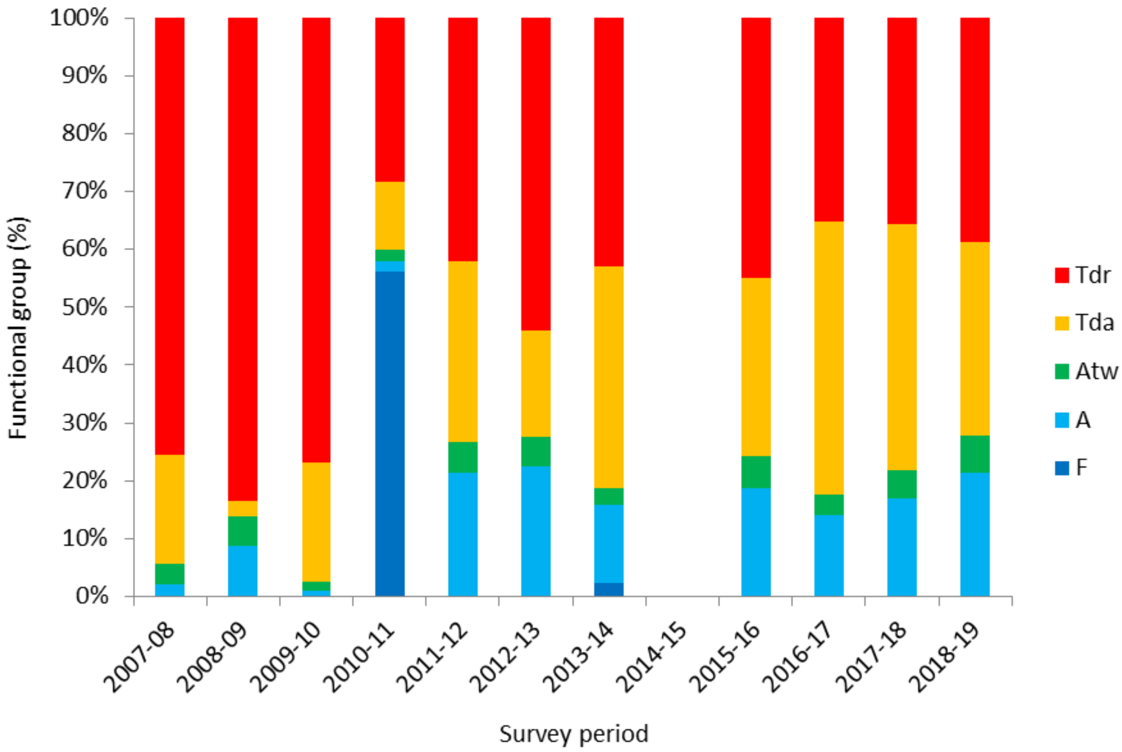

Figure 31 Percentage of plant functional groups recorded across survey periods at floodplain sites in the sometimes-flooded FRF, across the Hattah Lakes icon site.

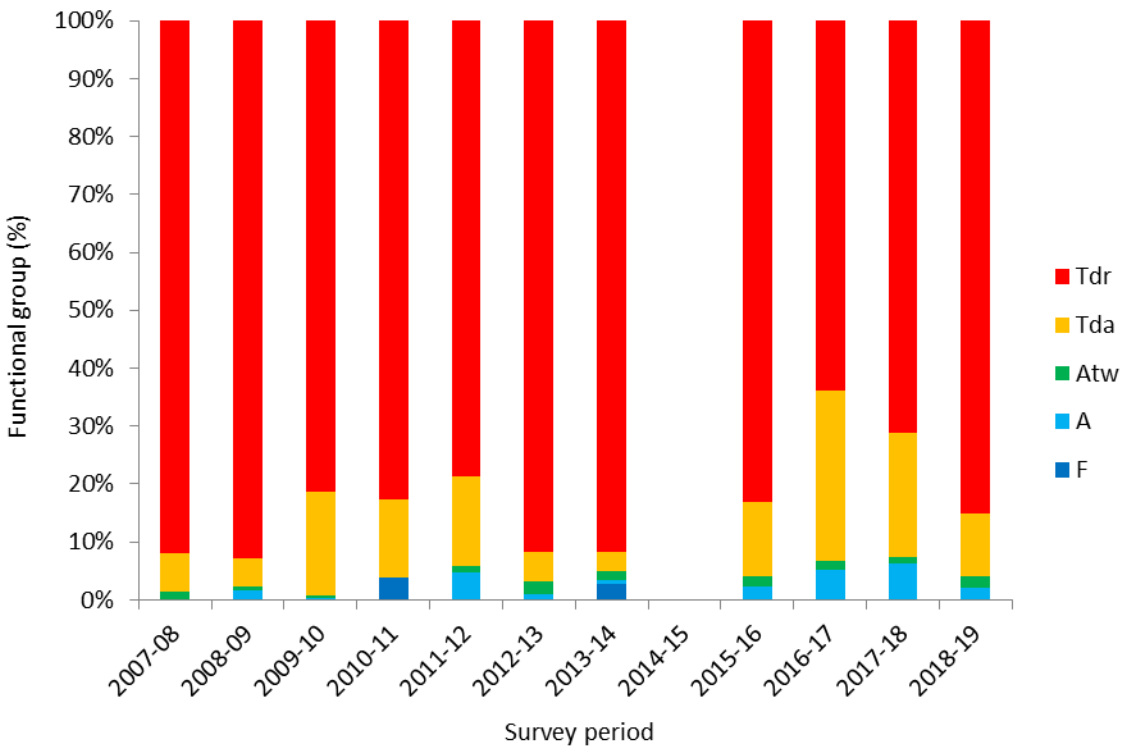

Figure 32 Percentage of plant functional groups recorded across survey periods at floodplain sites in the rarely-flooded FRF, across the Hattah Lakes icon site.

5.5 Discussion

5.5.1 Often-flooded

Floodplain inundation from natural flooding in 2016 and large-scale environmental watering in 2017–18 has resulted in a steady increase in water-responsive plant species over this period, while drought-tolerant species are now at the lowest level since monitoring began in 2007–08 (with the exception of 2010–11 when the majority of sites were submerged). Despite the positive trend toward water-responsive functional groups, water-responsive species richness and abundance have both declined in often-flooded sites since 2017–18, with no sites achieving compliance in 2018–19. Reductions in both the richness and abundance of water-responsive species are to be expected as floodplain habitats dry, and this process may have been hastened by below average rainfall in 2018 (194 mm as recorded for Ouyen Post Office compared to an annual average of 330 mm (BOM 2019)), which included exceedingly low rainfall for January through April.

5.5.2 Sometimes-flooded

Sometimes-flooded sites share a similar trajectory to often-flooded sites in relation to plant functional group composition, displaying a steady increase in water-responsive plant species since 2016–17, though terrestrial species of dry habitats have remained largely similar over this period. Similarly, water-responsive species richness and abundance have both declined in sometimes-flooded sites since 2017–18, the reasons for which are the same as for often-flooded sites above.

5.5.3 Rarely-flooded

Due to being situated at higher elevations that the other two FRF categories, rarely-flooded sites have been dominated by drought tolerant species for the duration of the monitoring program. While the occurrence of terrestrial damp species, and to a lesser degree amphibious species, can be seen to increase in response to inundation events, these fluctuations can be seen to reduce over the proceeding few years.

As for the other two FRF categories, water-responsive species richness and abundance have both declined in rarely-flooded sites since 2017–18.

5.5.4 Whole-of-icon-site score

No lower floodplain sites at the Hattah Lakes icon site the met compliance targets for either richness or abundance of native water-responsive species. Only one site in the mid and higher floodplain met the richness targets, and one site, in the higher floodplain, met the abundance target. The icon site scores indicate that the decline from 2017–18 is not significantly different, due to the large confidence intervals. However, seven and nine sites were compliant with the richness and abundance targets, respectively, in the previous year, suggesting that levels of native water-responsive species abundance and richness were generally lower in 2018–19.

Higher species richness indices are generally recorded in years when the Hattah Lakes floodplains are inundated; although the difference does not appear significant and natural flooding and environmental water provide similar improvements (Figure 28).While it appears that native water-responsive species abundance is generally higher when the Hattah Lakes floodplains receive inundation, the difference is more noticeable and consistent when this occurs as a result of natural flooding compared to environmental water (Figure 29).

5.6 Progress towards ecological objectives

Both the ecological objective and the adopted objective for floodplain vegetation in Hattah Lakes specifically address the 'diversity, extent and abundance' of wetland vegetation. Targets established for richness and abundance were only met at a rate of 12% and 6% respectively. However, when determining the progress towards these objectives, an assessment of vegetation dynamics over time is required. Despite the low number of targets achieved, data collected over the twelve-year duration of the monitoring program highlight the benefit—with regard to species richness and abundance—to floodplain vegetation from large-scale watering events.

6 Lignum

6.1 Introduction

Tangled Lignum *Duma florulenta* is a native branching shrub growing to around 2 m high and 2 m wide (VicFlora 2018). Tangled Lignum forms dominant 'Lignum' vegetation communities (such as Lignum Shrubland and Lignum Swamp), which naturally require periodic inundation (MDBA 2012a). The hydrology of Hattah Lakes has changed due to the impacts of the diversion and extraction of water from the Murray River for agricultural use (MDBA 2012a). This change has seen a decline in Lignum communities, and therefore habitat for flora and fauna, which rely on the periodic flooding of the natural lake system within the icon site (MDBA 2012a).

Monitoring of Lignum at Hattah Lakes as part of the TLM program has been undertaken since 2007, although a new methodology—applying to survey design, data collection and analyses—was implemented in 2016–17. Adoption of the new methodology followed recommendations put forward in Brown et al. (2016), Huntley et al. (2016) and Robinson (2014). As a result of widespread flooding during the 2016–17 survey period, most sites were unable to be assessed (Brown et al. 2017), therefore analyses in this report will be limited to the comparison of data collected in 2017–18 and 2018–19.

This report section will:

- Assess Lignum condition against an established target at site and Icon Site levels.

6.2 Ecological objective

Ecological objectives for the Hattah Lakes icon site are set out in the Environmental Water Management Plan (MDBA 2012a). There were no 'adopted objectives' established by Robinson (2015).

The ecological objective for Lignum at Hattah Lakes is to:

- "Restore a mosaic of healthy wetland and floodplain communities to maintain the ecological character of the Ramsar site" (MDBA 2012a).

6.3 Methods

Condition monitoring of Lignum comprised assessment of 16 quadrats, with each quadrat measuring 20 m x 20 ms. Data collected for each quadrat included:

- condition of every mature Lignum plant within the quadrat, using the Lignum Condition Index (LCI; Table 11);
- gender of each mature Lignum plant that is flowering, by examining the flowers and estimating the amount of flowering (e.g. absent; scarce; common; abundant);
- total number of emergent Lignum plants (e.g. seedlings or clones) that are present within the quadrat; and
- total percentage cover of Lignum over the whole quadrat.

Data collection was undertaken between October–December 2018.

The allocation of sites per stratum is as follows:

- Lignum Shrubland: H4, H12, H13, H14, H15

- Lignum Swamp: H17, H18, H19, H20, H21
- Lignum Woodland: H1, H3, H7, H9, H11, H16

Table 11 The Lignum Condition Index (LCI) used to assess Lignum plant condition (adapted from Huntley et al. 2016).

% Viable	Score
> 95	6
75 ≤ 95	5
50 ≤ 75	4
25 ≤ 50	3
5 ≤ 25	2
0 ≤ 5	1
0	0

Colour	Score
All green	5
Mainly green	4
Half green, half yellow/brown	3
Mainly yellow/brown	2
All yellow/brown	1
No viable stems	0

6.3.1 Indices and points of reference

The target developed for Lignum condition at Hattah Lakes is:

- more than 85% of Lignum plants at Hattah Lakes have a LCI score of ≥4 (e.g. ≥ 2 for viability and ≥ 2 for colour (Huntley et al. 2016).

As per Wood et al. (2018), the percentage of Lignum plants with an LCI ≥4 was calculated for each site. The mean proportion of plants within each site with an LCI ≥4 was then compared across survey periods to assess the average condition of Lignum within sites, over time.

As per Wood et al (2018), tTo report on Lignum condition at an icon site level, each site was assessed as being either compliant or non-compliant. Compliant sites, i.e. those where more than 85% of plants had LCI scores ≥4, were considered to be in good condition and to have attained the site-specific target.

The proportion of compliant sites was then used as an icon site index to document variation in Lignum condition over time, whereby a change of 0.3 between years will indicate significant changes (Robinson 2014).

6.4 Results

The 2018–19 monitoring results indicate a decline in Lignum condition since 2017–18, based on the number of plants with a LCI score of ≥4 (Figure 33). The results for each WRC showed that there was a decline in the condition of Lignum Shrubland, Lignum Swamp, and Lignum Woodlands (Figure 35–37). This overall decline is reflected at the icon site scale, with the Icon Site index—i.e. the proportion of sites that exceed the target of 85%—reducing from 0.56 in 2017–18 to 0.44 in 2018–19. However this reduction does not indicate a statistically significant change in condition.

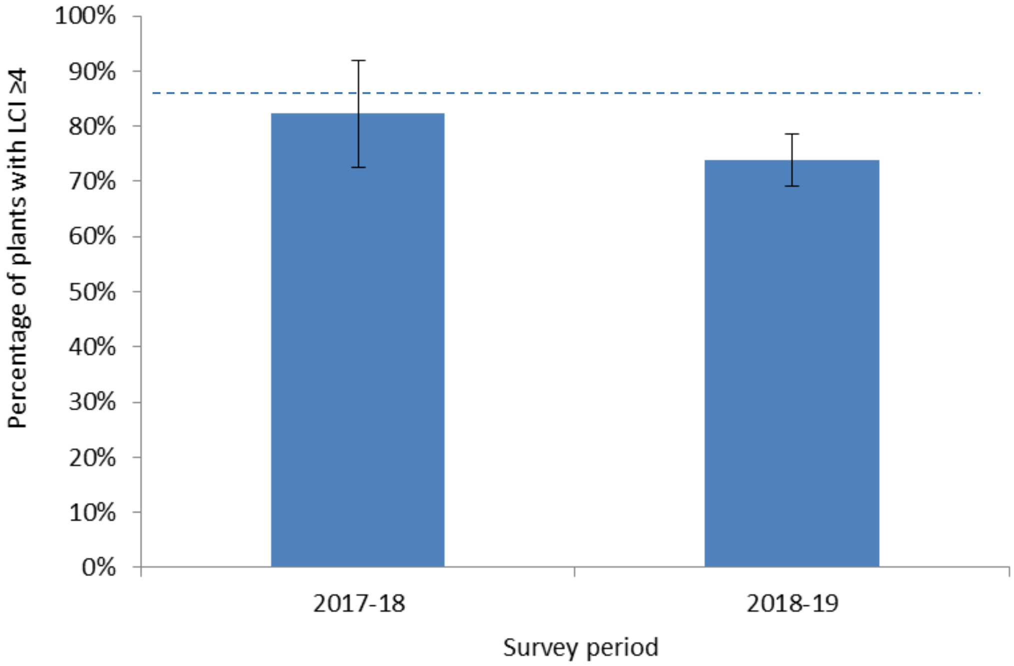

Figure 33 **Mean percentage (±SE) of Lignum plants with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon site target of 85% is shown for comparison.**

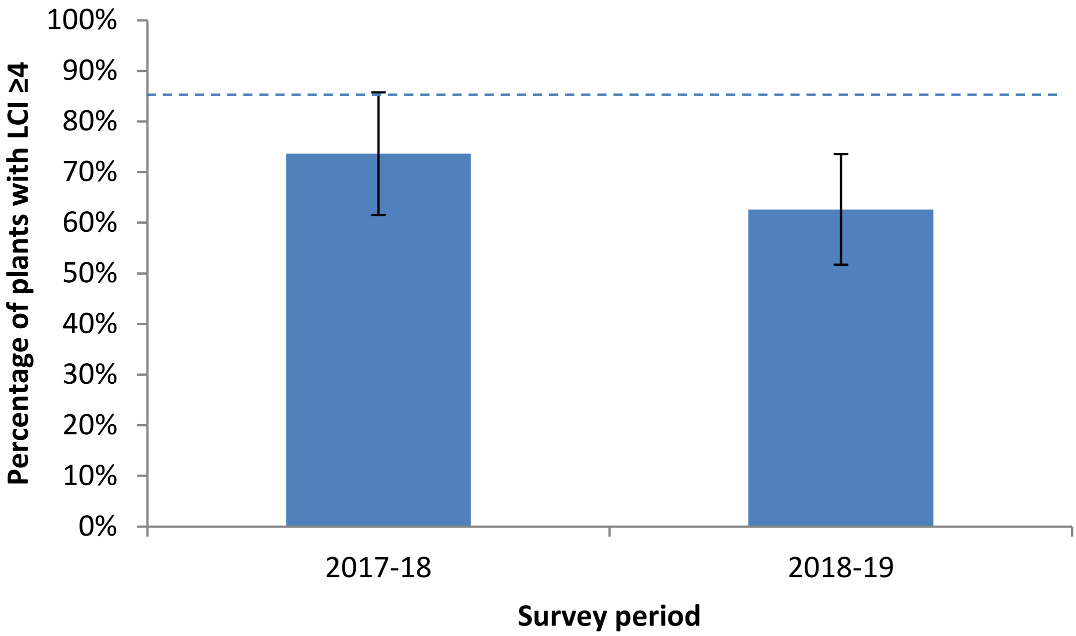

Figure 34 **Mean percentage (±SE) of Lignum plants within Lignum Shrubland with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon target of 85% is shown for comparison.**

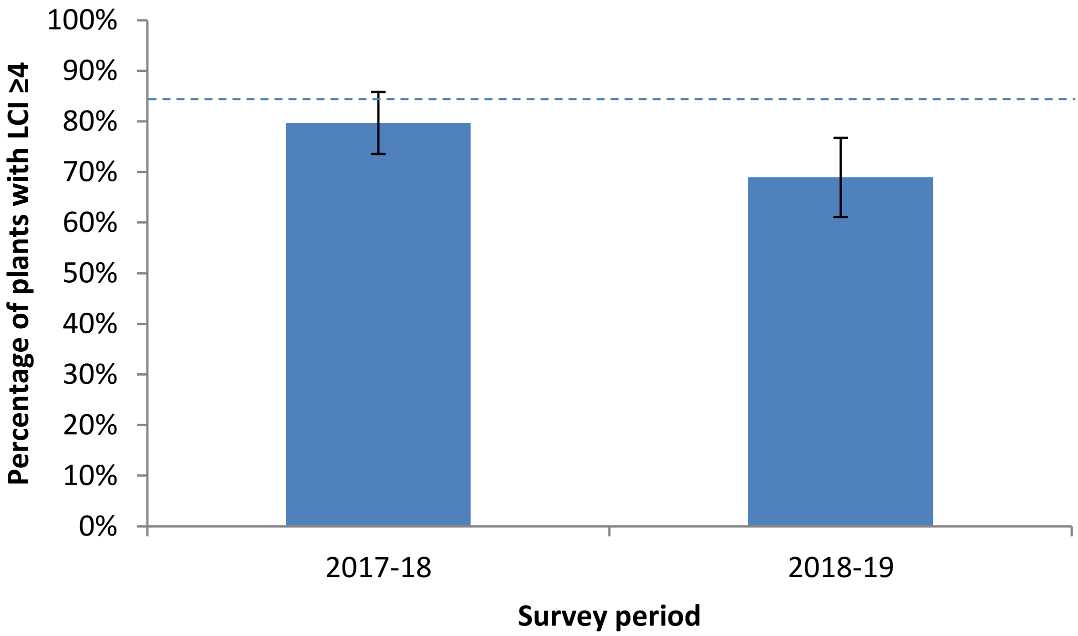

Figure 35 **Mean percentage (±SE) of Lignum plants within Lignum Swamp with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon target of 85% is shown for comparison.**

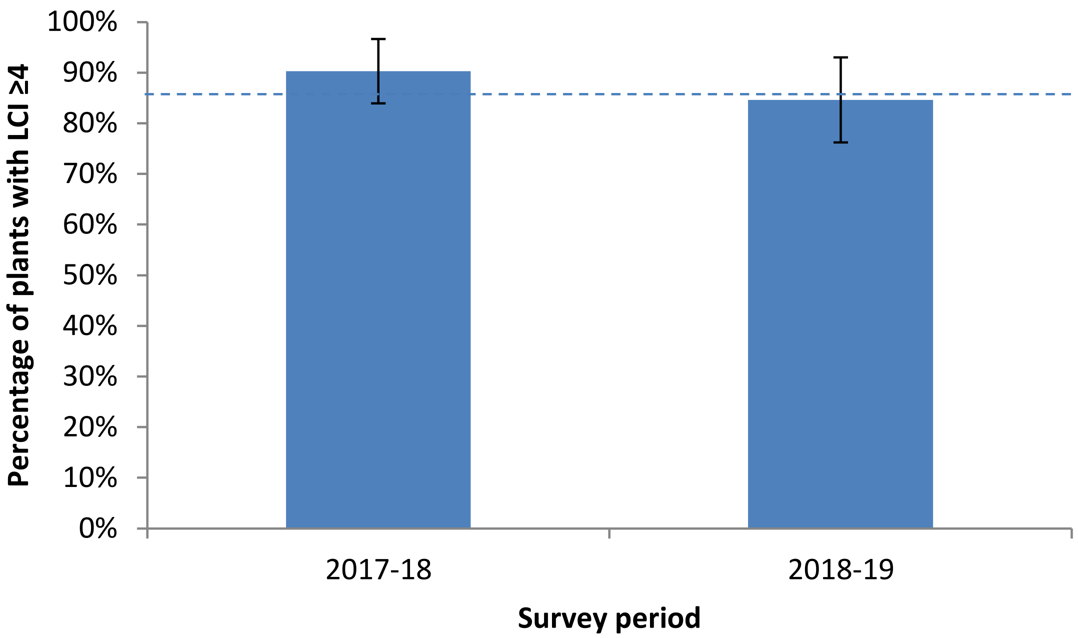

Figure 36 **Mean percentage (±SE) of Lignum plants within Lignum Woodlands with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon target of 85% is shown for comparison.**

6.5 Discussion

Data collected for the current round of monitoring makes for the third year of data collection under the new method, and only the second year where the full complement of sites were assessed (only three of 16 sites were able to be assessed in 2016–17). As flooding is the major driver of Lignum growth (Roberts and Marston 2011) the decline of Lignum condition since 2017–18 is most likely a reflection of time since last flood (the last flood having occurred in late 2016, with additional inundation occurring in winter/spring 2017 as a result of environmental watering). Leaves developed in response to watering are short-lived, and green stems dry out over time, eventually breaking off (Capon et al. 2009, Roberts and Marston 2011). Given the natural response of Lignum to wetting/drying cycles, such year-to-year fluctuations in condition are to be expected.

As discussed in Wood et al. (2018), variance in Lignum condition between each of the three strata/communities is possibly explained by differing spatial distributions and hence flooding frequency. As such, Lignum Woodland received greater exposure to artificial flooding in 2017 than did either of the other communities, which are reliant on rainfall and natural flooding.

Annual variability between counts of plants highlights potential deficiencies in the data collection method. While a tally of plants is not used in the data analyses for Lignum within Hattah Lakes, it would be beneficial to have an understanding of the extent of mortality occurring within Lignum populations. It is foreseeable that targets may be met for Lignum condition even while significant mortality of plants is occurring.

The site level target for Lignum condition states that more than 85% of Lignum plants at Hattah Lakes have a LCI score of ≥4; this target has not been met for any stratum. At an icon site level there was a decrease in the icon site Condition Index from 0.56 in 2017–18 to 0.44 in 2018–19; however this does not constitute a statistically significant change between years.

7 Waterbirds

7.1 Introduction

Wetlands of the Hattah Lakes icon site contain habitat for a range of waterbirds, including large wading birds such as the Yellow-billed Spoonbill *Platalea flavipes* and threatened Eastern Great Egret *Ardea modesta*, ducks including the vulnerable Musk Duck *Biziura lobata* and Australasian Shoveler *Anas rhynchotis* and shorebirds such as the Red-necked Avocet *Recurvirostra novaehollandiae*. Waterbird condition monitoring is undertaken at the Hattah Lakes icon site on a bi-annual basis, at a series of wetlands supporting potential waterbird habitat, as part of The Living Murray condition monitoring program.

7.2 Ecological objective

From the Hattah Lakes Environmental Water Management Plan (MDBA 2012a), the overarching objectives for waterbirds are to:

- Provide feeding and breeding habitat for a range of waterbird species, including threatened and migratory species; and
- Provide conditions for successful breeding of colonial nesters at least twice every ten years.

Three detailed objectives for waterbird values were also developed:

- Maintain habitat for the Freckled Duck, Grey Falcon and White-bellied Sea-Eagle in accordance with action statements;
- Increase successful breeding events for colonial waterbirds to at least two years in ten (including spoonbills, egrets, night herons and bitterns); and
- Provide suitable habitat for a range of migratory bird species (including Latham's Snipe, Red-necked Stint and Sharp-tailed Sandpiper.

7.3 Indices and points of reference

No indices, targets or points of reference have yet been developed for waterbirds at the Hattah Lakes icon site. Waterbird habitat is not assessed *per se*, but is inferred to occur if species are observed to occur at a site.

7.4 Methods

Waterbird survey methods were consistent with those deployed in previous years (Mallee CMA 2016, Wood et al. 2018), and were in accordance with the Birdlife Australia suggested methods for wetland birds as per the bird atlas methods. A fixed-point count was used, where all birds visible from a set viewing point (or two viewing points for large wetlands) were counted and the number of each species noted. Each point count was undertaken by two experienced observers, with a spotting scope and binoculars, for at least 30 minutes (longer when large numbers of waterbirds were present). Maximum species counts were agreed upon by the two observers. Evidence of breeding events and recruitment (i.e. nests, juveniles) were recorded incidentally, and water levels (as % cover of surface water) were estimated visually at each wetland. Surveys were repeated twice, with each site visited in both spring 2018 and autumn 2019.

In 2018–19, the following thirteen wetlands were surveyed (Figure 7 in the 2018–19 Part B report):

- Lake Arawak (not sampled in 2017/18);
- Lake Bitterang;
- Lake Brockie (not sampled in 2017/18);
- Lake Bulla;
- Lake Cantala (not sampled in 2017/18);
- Lake Hattah;
- Lake Konardin (not sampled in 2017/18);
- Lake Kramen;
- Little Hattah;
- Lake Lockie;
- Lake Mournpall;
- Lake Yelwell (not sampled in 2017/18); and
- Lake Yerang.

7.5 Results

The thirteen wetlands in the Hattah Lakes icon site were visited between 29 October and 1 November 2018 and again between 2 and 4 April 2019. Seven wetlands held water during both of these survey periods (Figure 6 in the 2018–19 Part B report); the three largest lakes — Lakes Bitterang, Cantala and Mournpall — were estimated to be at 80–100% capacity in spring 2018 and remained at least 70% full through summer to autumn 2019 (see Part B; Table 11). Lakes Konardin, Yelwell and Yerang held water during the spring 2018 survey, but dried over summer, while the remaining three wetlands — Lake Kramen, Lake Lockie and Little Hattah — were dry during both the spring 2018 and autumn 2019 surveys (Part B; Table 11). None of the wetlands at Hattah Lakes received environmental water allocations this year. The surface area and estimated water levels at each wetland are provided in Table 11 of the 2018–19 Part B report.

Table 12 Waterbird counts during the spring 2018 and autumn 2019 surveys at the Hattah Lakes icon site.

Waterbird species			Abundance estimate		
Common name	**Scientific name**	**Feeding guild**	**Spring**	**Autumn**	**Total**
Australasian Darter	*Anhinga novaehollandiae*	Fish-eaters	12	10	22
Australasian Grebe	*Tachybaptus novaehollandiae*	Grebes	26	96	122
Australasian Shoveler	*Anas rhynchotis*	Filter-feeding ducks	0	4	4
Australian Pelican	*Pelecanus conspicillatus*	Fish-eaters	269	1065	1334
Australian Shelduck	*Tadorna tadornoides*	Grazing duck	0	7	7
Australian White Ibis	*Threskiornis molucca*	Large wading birds	3	6	9
Australian Wood Duck	*Chenonetta jubata*	Grazing duck	89	3	92
Black Swan	*Cygnus atratus*	Swans	15	0	15
Black-fronted Dotterel	*Elseyornis melanops*	Shorebird	3	0	3
Black-tailed Native-hen	*Gallinula ventralis*	Waterhens	21	44	65
Black-winged Stilt	*Himantopus himantopus*	Shorebird	3	81	84
Cormorants	*Phalacrocoracidae* (fam)	Fish-eaters	15	0	15
Eastern Great Egret	*Ardea modesta*	Large wading birds	3	4	7
Eurasian Coot	*Fulica atra*	Coots	34	9	43
Freckled Duck	*Stictonetta naevosa*	Filter-feeding ducks	0	5	5
Great Cormorant	*Phalacrocorax carbo*	Fish-eaters	5	27	32
Great Crested Grebe	*Podiceps cristatus*	Grebes	4	0	4
Grey Teal	*Anas gracilis*	Dabbling Ducks	352	1848	2200
Hardhead	*Aythya australis*	Diving Duck	26	15	41
Hoary-headed Grebe	*Poliocephalus poliocephalus*	Grebes	292	209	501
Little Black Cormorant	*Phalacrocorax sulcirostris*	Fish-eaters	23	15	38
Little Pied Cormorant	*Microcarbo melanoleucos*	Fish-eaters	14	16	30
Masked Lapwing	*Vanellus miles*	Shorebird	15	42	57
Musk Duck	*Biziura lobata*	Diving Duck	4	2	6
Pacific Black Duck	*Anas superciliosa*	Dabbling Ducks	19	232	251
Pied Cormorant	*Phalacrocorax varius*	Fish-eaters	5	18	23
Pink-eared Duck	*Malacorhynchus membranaceus*	Filter-feeding ducks	0	928	928
Red-kneed Dotterel	*Erythrogonys cinctus*	Shorebird	0	10	10
Red-necked Avocet	*Recurvirostra novaehollandiae*	Shorebird	30	69	99
Whiskered Tern	*Chlidonias hybridus javanicus*	Terns	8	0	8
White-faced Heron	*Egretta novaehollandiae*	Large wading birds	3	7	10
White-necked Heron	*Ardea pacifica*	Large wading birds	0	1	1
Yellow-billed Spoonbill	*Platalea flavipes*	Large wading birds	48	51	99
		Total	**1341**	**4824**	**6165**

Waterbirds were generally only recorded at those wetlands that held water at the time of survey. Only one waterbird, a White-faced Heron *Egretta novaeholladiae*, was recorded at a dry wetland — Lake Konardin (Part B; Table 11). Waterbird species, and the total numbers of each species, recorded across all monitored wetlands at the Hattah Lakes icon site is provided in. The results of surveys at individual wetlands is provided in Table 11 of the 2018–19 Part B report; which shows numbers of waterbirds recorded at each wetland by guild, as well as the density of waterbirds and species richness recorded during each survey.

A number of non-waterbird species were also observed incidentally during the surveys, including six EPBC Act-listed Regent Parrots *Polytelis anthopeplus monarchoides* at Lake Lockie during the autumn survey. A full species list is provided in Part B; Table 12.

Table 13 Mean level of flooding and mean number of waterbirds observed during spring and autumn surveys of waterbirds at wetlands in the Hattah Lakes icon site during the 2018/19 monitoring season. Water levels and number of observed waterbirds are averaged within wetlands.

Flooding levels	No. sites	Mean no. waterbirds	Standard error
Mean dry	3	0	0
Mean 1–50% flooded	4	348	192.8
Mean 50–100% flooded	6	795.5	272.2

7.5.1 Numbers of waterbirds at selected wetlands

A total of 1,341 waterbirds, comprising 26 species, were observed during the spring 2018 surveys across the Hattah Lakes icon site (Table 12). A similar number of species was recorded in the autumn 2019 surveys (28 species), but estimated abundance increased, with more than three times as many waterbirds (4,828) recorded in total across the surveyed wetlands in autumn 2019 than spring 2018; a result which is consistent with the previous year. Of the wetlands that held water during both surveys, numbers of waterbirds increased at all sites except for Lake Mournpall, with the greatest increase recorded at Lake Bulla (Part B; Table 11). In particular, Australian Pelicans *Pelecanus conspicillatus*, Grey Teal *Anas gracilis* and Pink-eared Ducks *Malacorhynchus membranaceus* were observed in much greater numbers during the autumn 2019 surveys.

More than twice the mean number of waterbirds was recorded at wetlands that were at least 50% flooded on average across the two surveys (Table 13). Overall, the highest abundances were recorded at Lakes Bitterang, Brockie and Hattah (Part B; Table 11). Although Lake Brockie was only 10% full at the time of the autumn 2019 survey, it supported an especially high density of waterbirds (177.9 waterbirds per hectare), comprising mainly Grey Teal and shorebirds (Part B; Table 11).

Compared with the spring 2017 surveys, higher bird counts were observed in spring 2018 at Lake Bitterang (including 142 Hoary-headed Grebes *Poliocephalus poliocephalus*), Lake Konardin (including 100 Hoary-headed Grebes), Lake Mournpall (including 213 Australian Pelicans) and Lake Yelwell (including 162 Grey Teal). Particularly high bird counts were recorded during the autumn survey at Lake Arawak (including 252 Grey Teal), Lake Bitterang (including 593 Grey Teal, 501 Pink-eared Ducks and 298 Australian Pelicans), Lake Bulla (including 204 Grey Teal and 210 Pink-eared Ducks) and Lake Hattah (including 615 Australian Pelicans).

7.5.2 Waterbird breeding

Evidence of past or recent breeding events was recorded at Lake Cantala, Lake Hattah and Lake Bulla:

- Several nests were observed at Lake Cantala during the spring 2018 survey, but appeared not to be in use. During the autumn 2019 survey, a cormorant nesting colony was recorded at Lake Cantala, and a juvenile Great Cormorant *Phalacrocorax carbo* observed.
- Over 300 juvenile Australian Pelicans (approximately 60% of recorded individuals) were observed at Lake Hattah during the autumn 2019 survey.
- At Lake Bulla, four waterbird nests were recorded during the autumn 2019 survey, but the nests did not appear to be occupied.

7.5.3 Guild and species composition

Waterbird communities at the Hattah Lakes were dominated by four functional guilds: dabbling ducks, fish-eaters, filter-feeding ducks and grebes (comprising 89.4% of waterbirds in total). All other guilds recorded accounted for less than 5% of the total waterbirds (Table 14). The composition of waterbird guilds across the Hattah Lakes icon site was similar to that recorded the previous year, with the exception of filter-feeding ducks, which were reportedly scarce during 2017–18 surveys (Wood et al. 2018).

Almost 40% of all waterbirds observed at surveys in the Hattah Lakes icon site wetlands were dabbling ducks, which were observed at all wetlands holding water (Table 14). The vast majority of dabbling ducks observed were Grey Teal (2,200 individuals), with smaller numbers of Pacific Black Ducks *Anas superciliosa* (251) recorded (Part B; Table 11). Eighty-five per cent of the dabbling ducks were recorded in autumn, with this pattern apparent for both species.

Fish-eaters were the second most numerous waterbird guild comprising 24.2% of all waterbird records. Six fish-eating species were observed (Part B; Table 11), although the vast majority (89%) of individuals were Australian Pelicans. Over 75% of fish-eating waterbirds were recorded in autumn 2019, which can be mostly attributed to the large numbers of pelicans observed at Lake Hattah and Lake Bitterang during those surveys. In contrast, approximately half the number of pelicans observed at Lake Mournpall in spring 2018, were recorded in autumn 2019, accounting for the overall reduction in numbers at this site.

Filter-feeding Ducks comprised 15.2% of all waterbird records, all observed during the autumn surveys. Observations of this guild were dominated by Pink-eared Ducks (928 of 937 records). Small numbers of Australasian Shovelers were recorded at Lakes Arawak and Bitterang (two ducks at each lake) and the threatened Freckled Duck *Stictonetta naevosa* was recorded at Lake Bulla (four ducks) and Lake Hattah (one duck).

Grebes were observed in similar numbers during the spring 2018 (322 birds) and autumn 2019 (305 birds) surveys, making up 10.2% of all waterbird records in 2018–19. Hoary-headed Grebes were the most numerous species, with 501 individuals observed; Australasian Grebes were recorded in smaller numbers (122). Single Great Crested Grebes were recorded at Lake Bitterang, Lake Bulla, Lake Cantala and Lake Hattah, during spring 2018 surveys.

Five Australian-breeding shorebird species were observed at the Hattah Lakes icon site during the 2018–19 surveys (Part B; Table 11), but in relatively small numbers, making up 4.1% of all records. Almost 80% of the records were obtained in autumn, mostly due to larger numbers of Black-winged Stilts *Himantopus himantopus*, Red-necked Avocets and Masked Lapwings *Vanellus miles* observed at Lake

Brockie during the second survey, when water levels had drawn-down significantly (from 70% to 10%), thus providing suitable foraging habitat for shorebirds.

Large wading birds (ibis, herons and spoonbills) were observed in similar numbers in the spring and autumn surveys, making up 2% of all records observed during 2018–19. Five species were observed (Part B; Table 11), mostly represented by Yellow-billed Spoonbill, which was recorded in relatively large numbers at Lake Yelwell in spring (48 individuals) and at Lake Bitterang in autumn (27 individuals).

Grazing ducks, which forage on the grassy margins of wetlands, comprised 1.6% of all waterbird records. Australian Wood Ducks *Chenonetta jubata* were mostly recorded in spring (89 of 92 observations), with the largest numbers at Lake Arawak, Lake Brockie and Lake Yelwell (Part B; Table 11). Seven Australian Shelducks were recorded during the autumn survey, at Lakes Arawak, Bitterang and Bulla.

Coots, Diving Ducks, Swans, Terns and Waterhens were all recorded in low numbers during the surveys at Hattah Lakes in the 2018/19 season, each guild making up no more than 1.1% of the total proportion of waterbirds observed (Table 14).

Table 14 Number of waterbirds by guild observed during the spring 2018 and autumn 2019 surveys at the Hattah Lakes icon site, also expressed as a percentage of all birds recorded during the surveys.

Waterbird feeding guild	Spring	Autumn	Total	Mean	Mean as % of all waterbirds
Coots	34	9	43	21.5	0.7%
Dabbling Ducks	371	2080	2451	1225.5	39.8%
Diving Duck	30	17	47	23.5	0.8%
Filter-feeding ducks	0	937	937	468.5	15.2%
Fish-eaters	343	1151	1494	747	24.2%
Grazing duck	89	10	99	49.5	1.6%
Grebes	322	305	627	313.5	10.2%
Large wading birds	57	69	126	63	2.0%
Shorebird	51	202	253	126.5	4.1%
Swans	15	0	15	7.5	0.2%
Terns	8	0	8	4	0.1%
Waterhens	21	44	65	32.5	1.1%
All grazers (coots, hens, swan, grazing ducks)	159	63	222	111	3.6%
Total abundance	**1341**	**4824**	**6165**	**3082.5**	**100%**
Species richness	**36**	**38**	**32**	**37**	
Area of surface water (ha)	**714**	**439**	**577**	**576.35**	
Waterbird density (waterbirds.ha^{-1})	**1.9**	**11.0**	**10.7**	**6.4**	

7.5.4 Species richness

A total of 32 waterbird species were observed from 12 guilds across both surveys at the wetlands of the Hattah Lakes icon site (Table 12). The most numerous species observed were Australian Pelican, Grey Teal, Pink-eared Duck and Hoary-headed Grebe, representing four guilds. Species richness was similar between surveys, with 26 and 28 species recorded in spring 2018 and autumn 209, respectively. The highest species richness was recorded at Lake Bitterang (25 species); 19 species were observed at Lake Hattah and 18 species were observed at Lakes Bulla and Cantala (Part B; Table 11). Overall, species richness across all monitored sites was the same in 2018–19 as in 2017–18 (Wood et al. 2018).

7.6 Discussion

The results of the 2018–19 monitoring are consistent with previous years, demonstrating that waterbird distribution and abundance is influenced by the availability of water both at the local scale, and in the broader landscape, while the species and guild composition of waterbirds at individual wetlands reflects site conditions and characteristics, such as size, depth and surrounding habitat.

Waterbirds at the Hattah Lakes icon site were almost exclusively observed at sites holding water; waterbirds were observed during each survey of flooded wetlands, and only one waterbird was observed at a dry wetland during the 2018–19 monitoring. Waterbird communities at the Hattah Lakes were characterised by dabbling ducks, fish-eaters, grebes and filter-feeders. The relatively proportion of fish-eating waterbirds, comprising cormorants, darters and pelicans, and the grebes, which forage by diving or reaching below the surface for fish, distinguishes the deeper and more permanent Hattah Lakes from the more intermittent/ephemeral wetlands of the Lindsay, Mulcra and Wallpolla icon sites.

7.6.1 Patterns of response

It has been long established that patterns of waterbird distribution and abundance are dynamic, fluctuating with rainfall patterns, local flooding events and the availability of water in the landscape (see Frith 1982, Chambers and Loyn 2006).

The 2018–19 monitoring recorded much higher waterbird numbers compared with 2017–18, representing an almost five-fold increase (Wood et al. 2018). A greater number of wetlands were surveyed as part of the current monitoring year (13 in 2018–19 compared with eight in 2017–18); however, there was also a disproportionate increase in waterbird density across all sites. A 2.5-fold increase in waterbird density was observed during the spring 2018 survey, with an almost five-fold increase recorded in the autumn 2019 survey, compared with the previous year.

In 2017–18, environmental watering filled all wetlands at the Hattah Lakes icon site except Lake Kramen; flooding was widespread across wetland sites in spring 2017, with floodwaters receding somewhat by autumn (Wood et al. 2018). As a result, it was reported that higher numbers of waterbirds were recorded in surrounding flooded Red Gum and Black Box Woodland than on open water within the wetlands. The wider distribution of waterbirds across the landscape resulted in lower waterbird densities overall (Wood et al. 2018).

No environmental water was delivered to the Hattah Lakes in 2018–19, and while at least half of the wetlands surveyed held water during at least one survey, the availability of water in the broader landscape, including at the Lindsay-Mulcra-Wallpolla icon sites, was significantly reduced compared with the previous year. The relatively dry conditions across the landscape are likely to have resulted in increased densities of waterbirds at wetlands that held water.

In accordance with previous years, significantly more waterbirds (and higher densities) were also recorded in autumn 2019 than spring 2018 (Table 14; see also McKillop et al. 2018, Wood et al. 2018). It is likely that as wetlands dry over summer and water levels recede, waterbirds become more concentrated on particular wetlands, resulting in higher densities. Changes in water levels may also result in changes to available habitats, and attract different waterbird species, such as those that forage in shallow waters.

In particular, the autumn 2019 survey recorded large increases in the numbers of dabbling ducks, filter-feeding ducks, shorebirds and fish-eaters. Both dabbling ducks and filter-feeding ducks were recorded in substantially higher numbers in 2018–19 compared with the previous year (McKillop et al. 2018), largely as a result of high numbers recorded during the autumn 2019 survey. Dabbling ducks, predominantly Grey Teal, increased more than five-fold between spring 2018 and autumn 2019, while filter-feeding ducks, comprising large flocks of Pink-eared Duck at Lakes Arawak Bitterang and Bulla, were recorded exclusively in autumn. Significantly more shorebirds were also recorded in autumn, supposedly attracted by an increase in suitable foraging habitat as water levels receded at some wetlands. A clear increase in Australian Pelican numbers led to higher abundances of fish-eating waterbirds; cormorant numbers did not increase to the same degree.

Species richness estimates were the same between seasons, albeit with some changes to the species recorded. Three rare or threatened waterbirds were recorded in 2018–19 surveys but not in the previous year: Whiskered Tern *Chlidonias hybridus javanicus*, Australasian Shoveler and Musk Duck. In contrast, Nankeen Night Heron *Nycticorax caledonicus*, Dusky Moorhen *Gallinula tenebrosa* and Little Egret *Egretta garzetta* were not recorded in the current surveys.

Last year, the Freckled Duck, listed under the *Flora and Fauna Guarantee Act 1988* was recorded for the first time in many years; Freckled Ducks were again recorded at the Hattah Lakes this year, at two wetlands where the species was not observed in 2017–18 (i.e. Lake Bulla and Lake Hattah). Three species classified as vulnerable in Victoria were also recorded: Musk Ducks were recorded at Lake Cantala in both surveys, during which water levels were at least 75%; Hardheads were recorded at six wetlands in the current survey, compared to two in the previous year; and Australasian Shovelers were recorded in low numbers at Lake Arawak and Lake Bitterang. Of species considered near threatened, Whiskered Terns were recorded at two wetlands and Pied Cormorants were observed at three wetlands.

7.6.2 Implications for management

Patterns of waterbird distribution and abundance are dynamic, fluctuating with continental rainfall patterns and the availability of water in the landscape (see Frith 1982, Chambers and Loyn 2006). The results from the current and previous seasons of waterbird monitoring, demonstrate these patterns of response, with changes in waterbird abundance and density related to flooding and drying of wetlands at a both a local and landscape scale.

In terms of meeting ecological objectives for the Hattah Lakes icon site:

- Ten of the 13 surveyed wetlands were found to provide feeding habitat during the survey periods for a range of waterbirds, including species considered threatened on the Victorian Advisory List (DSE 2013). No migratory species were recorded in the current season.
- Waterbird breeding was observed for cormorants at Lake Cantala and Australian Pelicans at Lake Hattah. Nests were also observed at Lake Bulla, but were unoccupied at the time of survey.

In addressing the detailed objectives:

- Freckled Ducks were again observed during the surveys; Lake Bulla and Lake Hattah can be confirmed to provide habitat for the species. Grey Falcon and White-bellied Sea-Eagle were not recorded in the 2018/19 surveys.
- Colonial waterbirds were observed to be breeding during the current season, although breeding of spoonbills, egrets, night herons or bitterns was not confirmed.
- No migratory bird species were recorded at the Hattah Lakes icon site for the 2018–19 monitoring. It has previously been reported that several wetlands within the Hattah Lakes icon site may support migratory shorebirds when conditions are suitable, although they are not expected to attract large numbers of shorebirds.

8 Fish Communities

8.1 Introduction

Fish sampling for the TLM Condition Monitoring program at Hattah Lakes commenced in January 2006 and has been undertaken annually with the exception of 2009 and 2015. The background and methods used is described in the most recent program design report (Huntley et al. 2016). A number of refinements have been made over the duration of the monitoring program. The fish related refinements include:

- Switching the timing of sampling from spring (2005–2008) to autumn (2010 onwards);
- The inclusion of seine netting and bait trapping (2010 onwards);
- The adoption of conceptual models (Souter 2009); and
- Improved objectives, indicators, indices and reference points (Robinson 2015).

8.2 Ecological objectives

As outlined in Robinson (2015), the environmental watering objective for fish is to:

- Promote use of inundated areas by local native wetland fish, including for recruitment.

The fish monitoring objective of the TLM Condition Monitoring Program is to undertake annual sampling of large-bodied and small-bodied fish species and to assess the condition of the fish community against relevant points of reference and indices targets that are deemed to be representative of ‘good’ condition (Robinson 2015).

8.3 Methods

8.3.1 Sampling design

As outlined in the program design (Huntley et al. 2016), the monitoring program includes a total of 27 sites located within and adjacent to the Hattah-Kulkyne national park, including seven wetlands (3 sites were sampled per wetland), Chalka Creek (3 sites) and the Murray River (3 sites).

The sites are established within a nested sampling design, consisting of multiple sites within location reaches that have been assigned to five different flow categories referred to as ‘macrohabitats’, including:

- Riverine (Murray River): 3 sites
- Ephemeral channel (Chalka Creek): 3 sites
- Floodplain wetlands: 21 sites

8.3.2 Sampling methods

Fish sampling was undertaken in accordance with the methods detailed in Huntly et al. (2016). Fish sampling was undertaken between 5 March and 18 April 2019. Sampling was undertaken at a reduced number of sites due to the fact that Chalka Creek and three wetlands (Lake Little Hattah, Lake Lockie and Lake Yerang) were dry during the sampling period (Table 15). The location of sites was consistent with previous years.

Table 15 TLM Condition Monitoring fish sites sampled in 2019

Location	Reach	Macrohabitat	Sites sampled (2019)	Site dry (2019)
Hattah Lakes	Lake Arawak	Wetland	Ara1, Ara2, Ara3	
	Lake Bulla	Wetland	Bul1, Bul2, Bul3	
	Chalka Creek	Anabranch		Cha1, Cha2, Cha3
	Lake Hattah	Wetland	Ha1, Ha2, Ha3	
	Lake Little Hattah	Wetland		LH1, LH2, LH3
	Lake Lockie	Wetland		Loc1, Loc2, Loc3
	Lake Mournpall	Wetland	Mour1, Mour2, Mour3	
	Lake Yerang	Wetland		Yer1, Yer2, Yer3
Murray River	Hattah	Riverine	Mur1, Mur2, Mur3	

As outlined in Wood et al. (2018), the number of waterbodies and sites sampled between years has differed between years due to water availability (Table 16Table 16).

Table 16 Summary of Hattah Lakes TLM condition monitoring sites sampled each year. Shaded rows indicate years where sampling occurred during a different season to the 2010-2019 program (i.e. spring/summer instead of autumn).

Year and month	Arawak	Bulla	Chalka Creek	Hattah	Little Hattah	Lockie	Mournpall	Murray River	Yerang
2006 (Jan)			✓		✓ (1,2)	✓ (1,2)			
2006 (Nov, Dec)	✓	✓	✓	✓	✓	✓ (2,3)	✓	✓	✓
2007 (Dec)	✓	✓		✓			✓	✓	
2008 (Nov)		✓		✓			✓	✓	
2010 (Mar-May)			✓	✓	✓	✓	✓	✓	✓
2011 (Feb-Mar)	✓	✓	✓		✓	✓		✓	✓
2012 (Mar)	✓	✓	✓	✓	✓	✓	✓	✓	✓
2013 (Mar, Apr)				✓			✓	✓	
2014 (Mar, Apr)	✓	✓	✓	✓	✓	✓	✓	✓	✓
2015	Not sampled								
2016 (Apr)	✓	✓	✓	✓			✓	✓	✓
2017 (Apr, May)	✓	✓	✓	✓	✓	✓	✓	✓	✓
2018 (Mar)	✓	✓	✓	✓	✓	✓	✓	✓	✓
2019 (Mar, Apr)	✓	✓		✓			✓	✓	

Consistent with previous sampling years, backpack electrofishing and fyke netting were the primary methods used for all sites except the Murray River sites, where boat electrofishing was the primary technique.

As per the monitoring design (Huntley et al. 2016), a range of survey methods were employed in addition to electrofishing to ensure that the full range of fish species (and size range within those species) were comprehensively sampled.

Backpack electrofishing and boat electrofishing were undertaken using Sustainable Rivers Audit protocols (e.g. 8 x 150 second shots for backpack and 12 x 90 second shots for boat) (MDBC 2007). Backpack electrofishing was undertaken using a Smith Root LR24 backpack electrofisher. Boat electrofishing was undertaken using a medium sized (4.1 m long) 7.5 GPP boat electrofisher. Boat electrofishing was supplemented by deploying ten bait traps during the electrofishing event.

Overnight deployment of a pair of small-meshed 'larval' fyke nets (dual wing) was undertaken at all sites. Overnight deployment of a pair of large-meshed fyke nets (single wing) was undertaken at all sites except those that were boat electrofished. Seine netting (1 x 180 degree haul) was undertaken at all sites.

We understand that two electrofishing 'netters' were previously used on the boat (Paul Brown pers.comm. 2019), however this was not documented in the monitoring design (Huntley et al. 2016) and is an atypical approach (i.e. typically only used for training purposes). Consequently, during the 2019 sampling event the use of one experienced electrofishing 'netter' was employed on the boat at all times.

8.3.3 Indices

The following three indices were calculated:

- Recruitment Index (P recruits):
    - The proportion of indigenous native fish in each site that are recruits (regardless of species). This follows the method of Wood et al. (2018). Recruits are determined using the length at Young Of Year (YOY)
- Nativeness Index (P nativeness):
    - This is simply the proportion of fish biomass within each site that is from native fish species,
    - Calculated at site level using length weight relationships to calculate the biomass for each fish species (Robinson 2012)
- Alpha Diversity (expectedness) Index:
    - The number of native indigenous species collected in each site is compared to the number expected, given the sampling protocols used as described in Robinson (2012). The score is the number of species collected divided by number expected per site. If more species than expected occur, the site score is 1, if none occur the site scores 0.

All indices are calculated for each site independently. Each site is given equal weighting in calculating a macrohabitat mean for each index (the recommended scale for reporting). An annual icon site score for each index is generated as a guide only, using least squares means after fitting a linear mixed model. This icon site score is only a guide because it gives each macrohabitat equal weight in the calculation. This is not particularly valid in instances when some habitats are not sampled in some years (e.g. wetlands), and therefore have unequal numbers of sites. Additionally, different macrohabitats represent varying spatial areas within the icon site.

8.4 Results

8.4.1 Overview summary

The 2019 survey recorded 10,461 fish from twelve species, ten of which were native (Table 17Table 3). Murray cod *Maccullochella peelii* and Golden perch *Macquaria ambigua* were captured in the second highest numbers recorded over the 2010–2019 monitoring period. No goldfish were recorded in 2019, the first time this species has not been detected over that period, however this species has been recorded in very low abundance on several occasions previously (2013, 2016–17).

The small-bodied carp gudgeon *Hypseleotris* spp. comprised over 82% of all fish recorded, followed by flat-headed gudgeon *Philypnodon grandiceps* (4.3% of all fish recorded), the large-bodied bony herring *Nematalosa erebi* (4.0% of all fish recorded), the noxious eastern gambusia *Gambusia holbrooki* (3.9%), and Australian smelt *Retropinna semoni* (2.5%). Carp *Cyprinus carpio* were much more abundant than Murray cod, golden perch and silver perch *Bidyanus bidyanus* combined. Although only one silver perch was recorded, it was a Young of Year (35 mm LCF), which represents the first Young of Year of this species recorded by the TLM monitoring since 2014.

Table 17 Summary of the 2010–2019 Hattah fish monitoring results including flow guild designations (Baumgartner et al. 2014).

		Year								
		2010	2011	2012	2013	2014	2016	2017	2018	2019
		# of sites sampled								
Common name	**Flow guild**	21	21	27	9	27	21	27	27	15
Native large-bodied										
Silver perch	Flow dependent specialists	11	1	1	1	3	2		5	1
Spangled perch	NA		1	1						
Golden perch	Flow dependent specialists	32	78	41	12	35	31	41	34	44
Murray cod	Long-lived apex predators	5		1	7	30	52		8	38
Bony herring	Foraging generalists	672	126	337	270	1190	494	449	513	418
Native small-bodied										
Unspecked hardyhead	Foraging generalists	214	1263	97	19	81	198	25	9	28
Carp gudgeon complex	Foraging generalists	213	46029	14700	323	641	11026	34765	24393	8628
Murray-Darling rainbowfish	Foraging generalists	23	39	10	11	32	98	77	4	31
Flat-headed gudgeon	Foraging generalists	8	191	170	1	1	666	1404	1312	451
Dwarf Flat-headed gudgeon	Foraging generalists		1				12	41	35	12
Australian smelt	Foraging generalists	401	203	37	27	133	1969	4838	7276	262
Exotic large-bodied										
Carp	NA	39	1126	604	81	6950	46	988	104	144
Goldfish	NA	32	36	151	1	56	8	5	19	
Exotic small-bodied										
Eastern gambusia	NA	170	4960	1283	444	2346	12437	6823	25375	404
Oriental weatherloach	NA		49	8		54	8		5	
Total		1820	54103	17441	1197	11552	27047	49456	59092	10461
Average fish per site		87	2,576	646	133	428	1,288	1,832	2,189	697

Murray cod were primarily captured from Riverine sites, however for the first time over the duration of the monitoring program the species was also captured at Lake Mournpall. Species that were exclusively captured from Riverine sites in 2019 include silver perch, Unspecked Hardyhead *Craterocephalus fulvus*, and Murray-Darling Rainbowfish *Melanotaenia fluviatilis*. Golden perch were more prevalent at Riverine sites than Wetland sites, as were Australian smelt, carp and bony herring (i.e. on a per site basis). The only species that was exclusively captured from Wetland sites in 2019 was dwarf flat-headed gudgeon *Philypnodon macrostomus*. Other species that were clearly more prevalent in Wetland sites than Riverine sites included carp gudgeon, flat-headed gudgeon, and eastern gambusia *Gambusia holbrooki* (Table 18).

Table 18 Summary of 2019 Hattah TLM fish monitoring results by macrohabitat including flow designations (Baumgartner et al. 2014).

Common name	Flow guild	Riverine 3 sites	Wetland 12 sites	Total
Silver perch	Flow dependent specialists	1		1
Golden perch	Flow dependent specialists	35	9	44
Unspecked hardyhead	Foraging generalists	28		28
Carp gudgeon complex	Foraging generalists	519	8109	8628
Murray-Darling rainbowfish	Foraging generalists	31		31
Bony herring	Foraging generalists	141	277	418
Flat-headed gudgeon	Foraging generalists	3	448	451
Dwarf flat-headed gudgeon	Foraging generalists		12	12
Australian smelt	Foraging generalists	214	48	262
Murray cod	Long-lived apex predators	26	12	38
Carp	NA	65	79	144
Eastern gambusia	NA	16	388	404
Total		1079	9382	10461

8.4.2 Wetland sites summary

Of the Wetland sites, Murray cod were only recorded from Lake Mournpall and dwarf flat-headed gudgeon were only recorded from Lake Bulla. Golden perch were recorded in low abundance from every wetland except Lake Arawak. Carp gudgeon, eastern gambusia and bony herring were recorded from every wetland and every site within each wetland. Carp, flat-headed gudgeon, and Australian smelt were recorded from every wetland, but not at every site within each wetland. Carp gudgeon were more abundant at site Ara1 and Hat1 than at other sites. Flat-headed gudgeon were more abundant at Lake Bulla sites and one Lake Arawak site (Ara1) than at other wetlands and sites. Eastern gambusia were more abundant at site Ara1, and carp were more abundant at site Hat3 than at other sites.

8.4.3 Iconic species: Murray cod

Murray cod abundance has fluctuated considerably over the course of the monitoring program. The highest abundances were recorded in 2016, 2019 and 2014 (where 52, 26 and 26 individuals were captured respectively) (Table 19). Conversely, this species was not detected in 2011 and 2017, while very low abundances were recorded in 2010, 2012, and 2013 (Table 19). Although typically only recorded from the Murray River, the species has previously been recorded in very low abundance (1–3 fish per waterbody) from Chalka Creek (2006, 2014), Lake Bulla (2014), and Lake Little Hattah (2010, 2014). Murray cod were recorded in Lake Mournpall for the first time in 2019, in higher abundance than they had previously been recorded from any other non-Riverine TLM site. All of the records of Murray Cod previously recorded from non-Riverine sites (63–112 mm TL) and from Lake Mournpall in 2019 (91–131) were juveniles and likely to be Young of Year based on their lengths (King et al. 2008).

Table 19 Murray cod results from macrohabitats and reaches over the course of the monitoring program. Shaded cells indicate years where sampling occurred during a different season (i.e. spring/summer instead of autumn). Underlined numbers indicate that all of the Murray Cod recorded were likely YoY (< 150 mm TL).

Macrohabitat	Waterbody	2006	2007	2008	2010	2012	2013	2014	2016	2018	2019
Riverine	Murray River	6	7	2	4	1	7	26	52	8	26
Anabranch	Chalka Creek	3						1			
Wetland	Lake Bulla							1			
	Little Hattah				1			2			
	Lake Mournpall										12
	Total	**9**	**7**	**2**	**5**	**1**	**7**	**30**	**52**	**8**	**38**

Adult Murray cod have not been captured during Hattah TLM monitoring since 2016, however prior to this they were recorded in most years. Fish of a size that are considered likely to be Young of Year (i.e. less than 150 mm TL based on King et al. 2008) have been recorded every year and in fairly consistent proportional abundances in years that Murray Cod have been recorded (Figure 38). Although the numbers are low, the unweighted histograms and abundance data provide an indication of a likely change in Murray cod population size and/or structure adjacent to Hattah Lakes between the 2013–2016 period and the 2017–18 period, coinciding with before and after the November 2016 flooding event. The 2019 results are indicative of some recovery based on a moderate increase in catch per unit effort and evidence of successive years of recruitment success. The source of Young of Year Murray cod at Lake Mournpall is unknown, however examination of available fish stocking data and correspondence from the Victorian Fisheries Authority has confirmed that Lake Mournpall has not been stocked by the department (J Douglas pers. comm. 2019)(Figure 37, Plate 1).

Plate 1 Young of Year Murray cod captured from Lake Mournpall during the 2019 TLM monitoring survey.

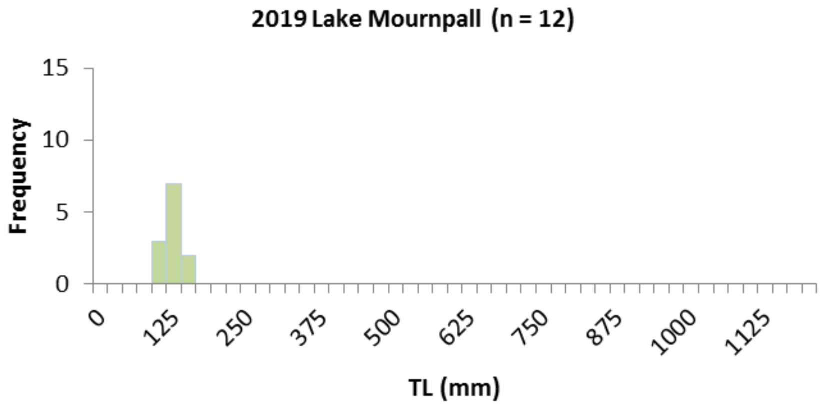

Figure 37 Length frequency histogram for Murray cod captured at Lake Mournpall in 2019. Green shading indicates Young of Year (YOY)

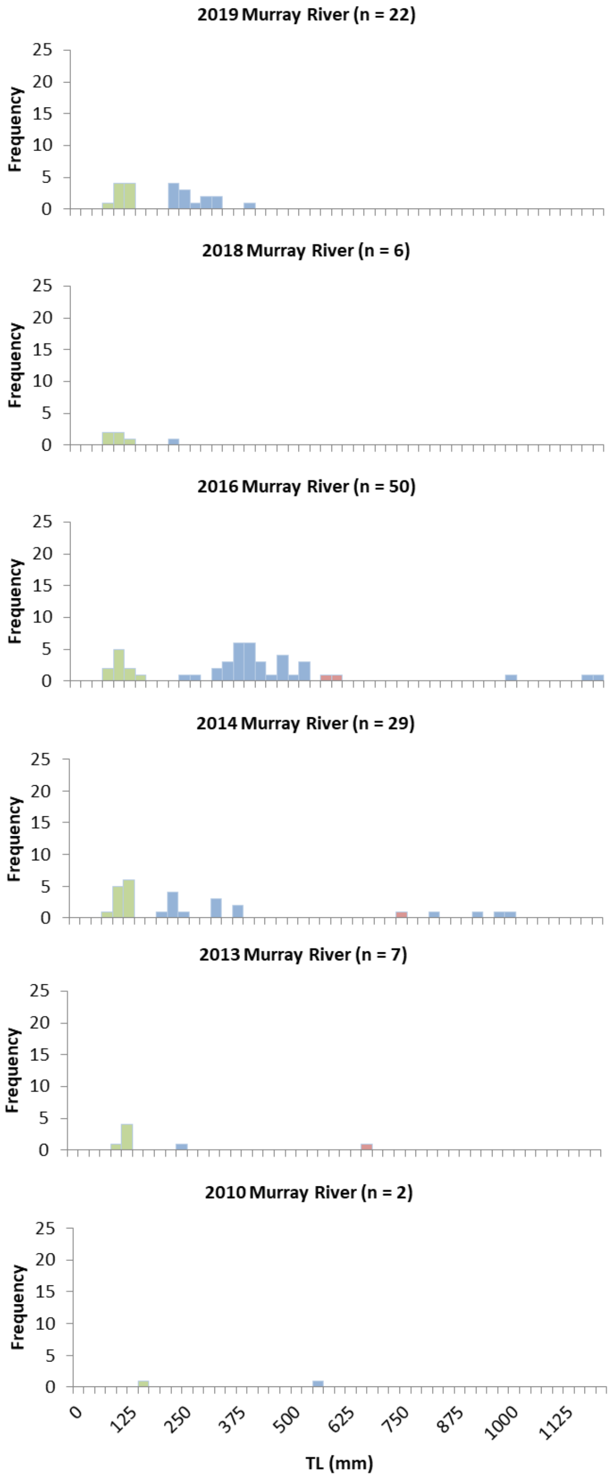

Figure 38 Unweighted length frequency histograms for Murray cod captured during 2010–2019 TLM monitoring. Green shading indicates Young of Year (YOY). Red shading indicates fish of 'legal size' 550–750 mm under Victorian recreational fishing regulations. Note that these unweighted histograms are provided to show the range of sizes captured across the icon site and not intended to provide an accurate representation of population structure.

8.4.4 Iconic species: golden perch

Over the course of the Hattah TLM monitoring program, golden perch have occurred in Wetland and Anabranch (i.e. Chalka Creek) sites more frequently and in higher abundances than Murray cod. Golden perch have occurred in all of the Wetlands previously, most frequently being detected in Lake Bulla (71% of surveys), Lake Mournpall (63%) and least frequently recorded from Lake Lockie (17% of surveys) (Table 20). Golden perch abundance in Wetlands has generally been low, with the exception of Lake Lockie (22 fish) and Lake Yerang (27 fish) in 2011 and Lake Mournpall (9 fish) in 2012. Similarly, Golden perch abundance in Chalka Creek has generally been low, with the exception of 2010 (12 fish) and 2011 (11 fish). Young of Year have only been detected in the Murray River on two occasions (2012 and 2019), in Lake Bulla on one occasion and in Lake Lockie and Lake Yerang on one occasion (2011).

Table 20 Golden perch results from macrohabitats and reaches over the course of the monitoring program. Grey shaded cells indicate years where sampling did not occur. Green shaded cells indicate the presence of Young of Year (YoY). Numbers in parentheses indicate the number of YoY recorded.

Macrohabitat	Waterbody	2010	2011	2012	2013	2014	2016	2017	2018	2019
Riverine	Murray River	20	10	23 (2)	12	20	31	28	30	35 (1)
Anabranch	Chalka Creek	12	11	1		5		2	1	
Wetland	Arawak			1		1		1		
	Bulla		3	3		1		4 (2)		1
	Hattah			4		3			1	4
	Little Hattah		5			2		4		
	Lockie		22 (10)							
	Mournpall			9		2		1	2	4
	Yerang		27 (4)			1		1		
	Total	**32**	**78**	**41**	**12**	**35**	**31**	**41**	**34**	**44**

In 2019, large golden perch (350–450 mm TL) appear to be the dominant cohort in the Riverine habitats (Figure 39). Although this is a similar result to 2017, this differs from 2016–2017, when a more even spread of sizes was evident.

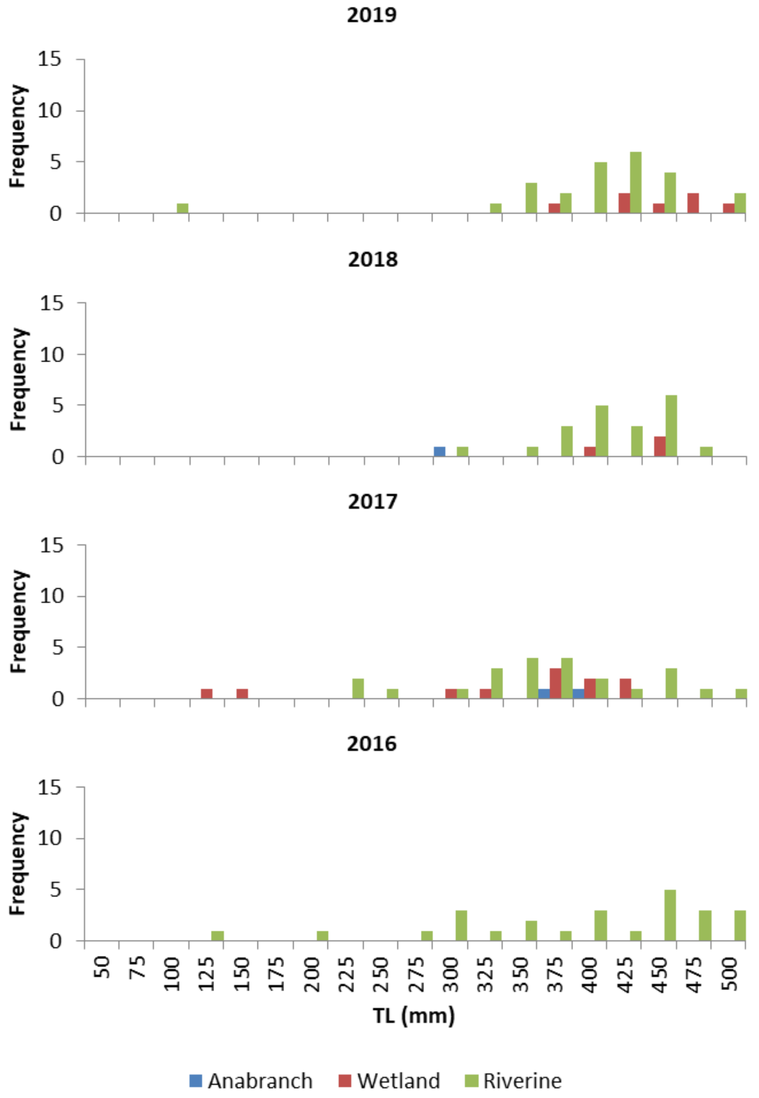

Figure 39 Unweighted length frequency histograms for golden perch captured during 2016–2019. Note that these unweighted histograms are provided to show the range of sizes captured across the macrohabitats but are not intended to provide an accurate representation of population(s) structure.

8.4.5 Index - P expected

The P expected scores for the riverine macrohabitat are identical to those recorded over most of the monitoring program (with the exception of 2012). The wetland results are marginally lower than recorded in 2018, but are limited to four of the seven wetlands. No anabranch sites were sampled in 2019 because Chalka Creek was dry. The last four years have been a period of high and relatively stable P expected scores for riverine and wetland macrohabitats, as well as at the icon site scale (Figure 40).

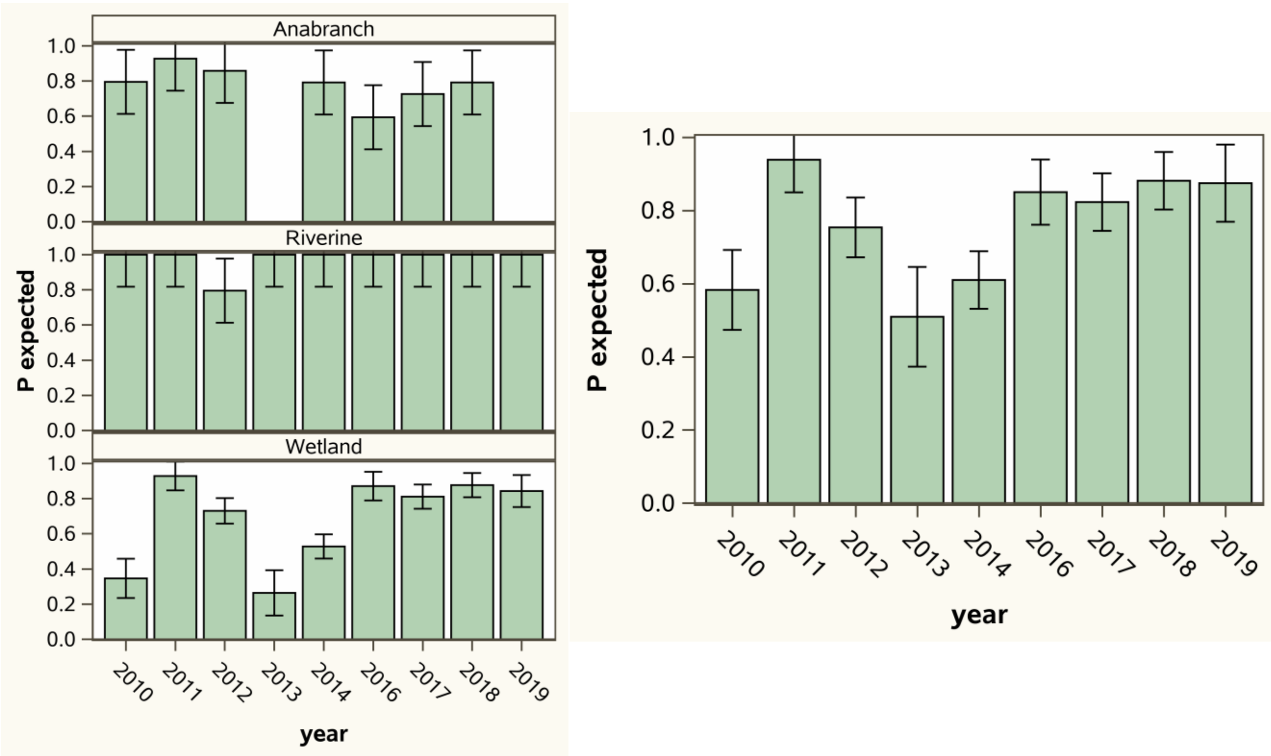

Figure 40 P expected scores at the macrohabitat scale (left) and icon site scale (right). Note that the icon site scale scores are provided as a guide only (refer to section 8.3.3).

8.4.6 Index – P nativeness

The P nativeness scores for the riverine macrohabitat are comparable to 2018, 2010–11 and 2013, but lower than 2014 and 2016. The lowest P nativeness scores for the riverine habitat were from 2012 and 2017. The 2019 wetland P nativeness score is relatively low, but limited by only four of the seven wetlands being sampled in 2019. No anabranch sites were sampled because Chalka Creek was dry. The overall icon site scale P nativeness scores are relatively low but are influenced by the limitations outlined above (Figure 41).

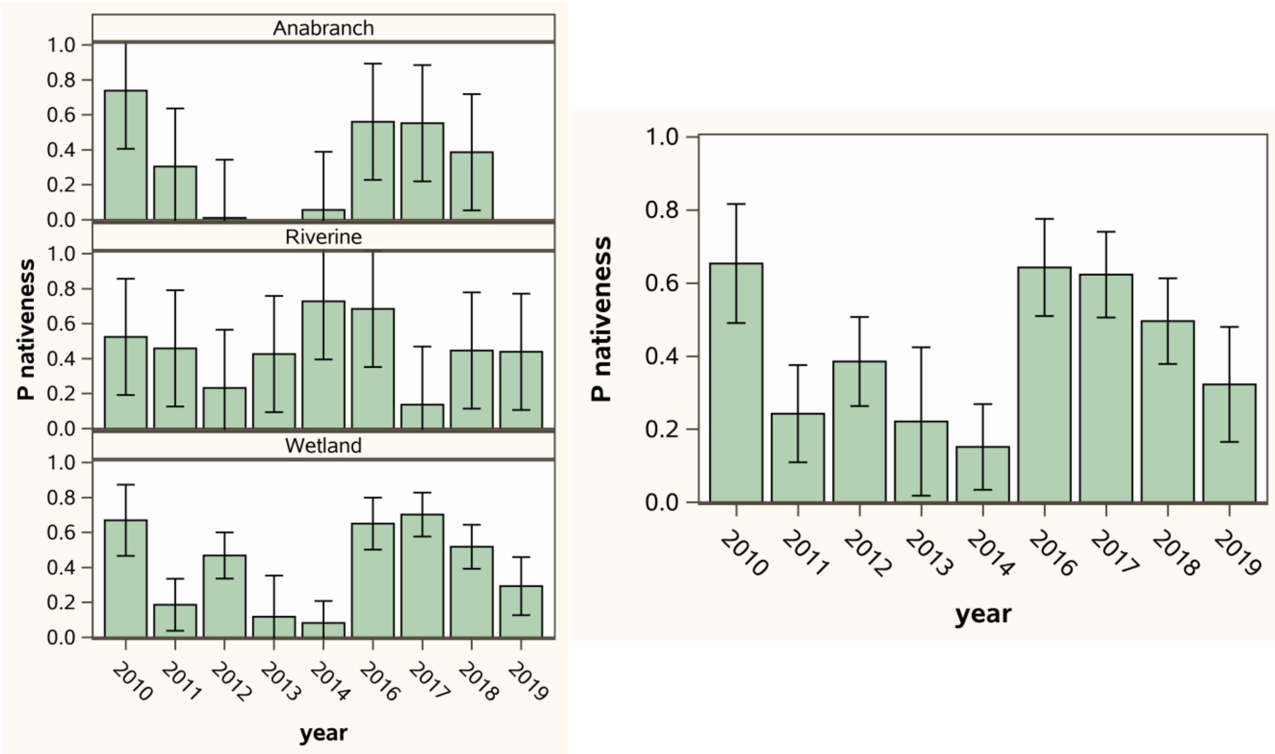

Figure 41 P nativeness scores at the macrohabitat scale (left) and icon site scale (right). Note that the icon site scale scores are provided as a guide only (refer to section 1.3.3).

8.4.7 Index - P recruits

The P recruits scores for the riverine macrohabitats are comparable to 2010, 2012, 2016–17 but lower than 2018. The P recruits scores for the wetland macrohabitat are marginally lower than the 2018 scores but still relatively high, despite being limited by only four of the seven wetlands being sampled in 2019. No anabranch scores were calculated because Chalka Creek was dry in 2019. The icon site scale scores are lower than 2018 but higher than 2010 and 2013–14, but should be interpreted with caution given the limitations outlined above (Figure 42).

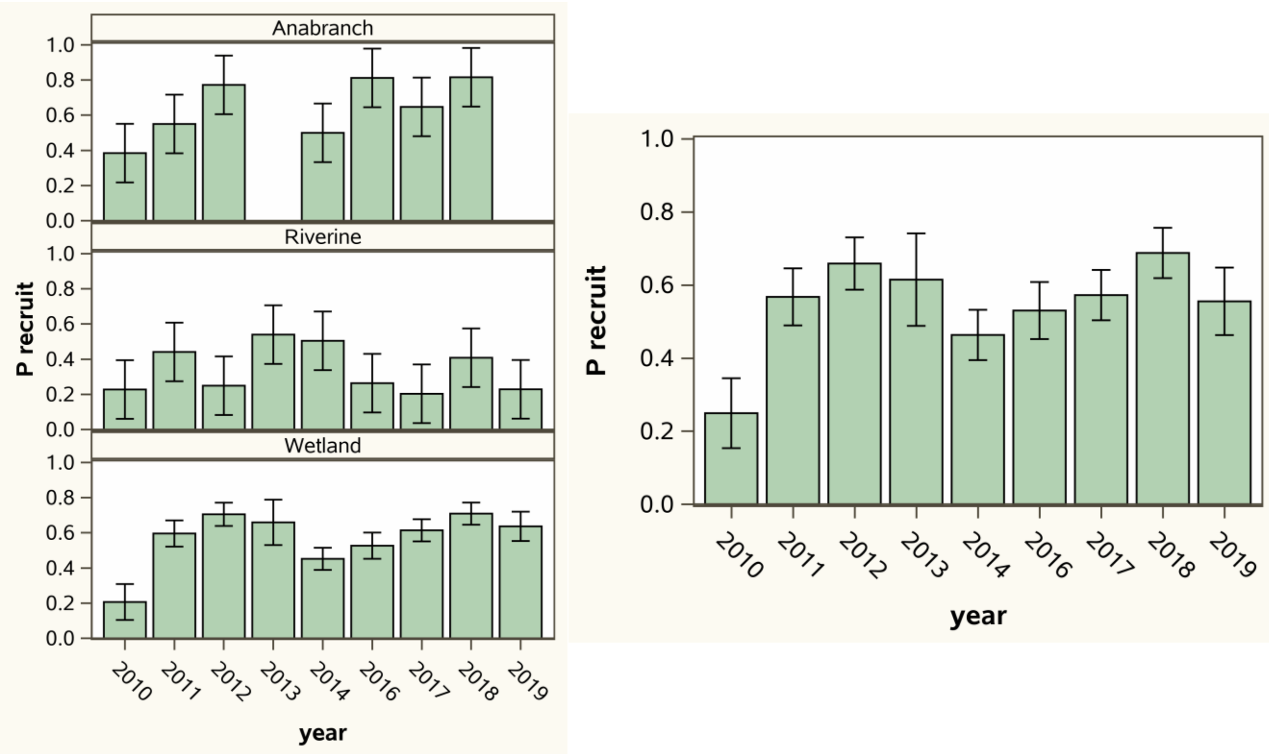

Figure 42 P recruits scores at the macrohabitat scale (left) and icon site scale (right). Note that the icon site scale scores are not particularly valid and are provided as a guide only (refer to section 8.3.3).

8.5 Discussion

Carp gudgeon dominated the fish community at the Hattah TLM Wetland sites, as has been the case in most previous years. This species is a 'foraging generalist', species that are generally thought to benefit from small watering releases that are focussed on habitat availability and enhancement of drought refuge connectivity and spawning conditions (Baumgartner et al. 2014). Carp gudgeon have been in very high abundance in all years except 2012–13. In previous years, other small-bodied 'foraging generalist' species have also been recorded in high abundance at the Wetland sites. These include Australian smelt and flat-headed gudgeon in 2016–18 and unspecked hardyhead in 2011. For the wetland macrohabitat, comparisons between years at a macrohabitat scale and whole of icon site scale are difficult to assess, not only due to population dynamics driven by variable natural and intervention (i.e. watering) based wetting and drying cycles and corresponding periods of connectivity (immigration and emigration opportunities) and isolation between years, but also by the variability in the number of wetlands which have been sampled. Over the course of the autumn based monitoring program (2010–19), there have only been four years where all wetland sites have been sampled. This temporal variability in wetland selection and sampling is likely to be partly responsible for the fluctuating wetland icon scale indices scores.

Unspecked hardyhead and Murray Darling rainbowfish were not recorded from any wetland site in 2019, the first time these species have not been detected at the TLM Wetland sites since 2013–14.It should be noted however, that rainbowfish have been in very low abundance throughout the monitoring program and hardyhead were in low abundance in 2017–18.

In 2019, dwarf flat-headed gudgeon were only recorded from Lake Bulla, a lake that also appeared to be a remaining stronghold for flat-headed gudgeon. For unspecked hardyhead and Murray-Darling rainbowfish, the Murray River provides a ready source of fish for Wetland site recolonization following disappearance due to desiccation or drawdown events. This is also the case for flat-headed gudgeon, although perhaps to a lesser extent considering the species has only been recorded in very low abundance at Murray River TLM sites in all years except 2011. For dwarf flat-headed gudgeon, the dataset suggests it may be important to maintain source populations within the Hattah Lakes wetlands, as the species has only been recorded once from the Murray River over the course of the monitoring period. Until their distribution is confirmed to be more widespread during subsequent years of monitoring, it is recommended that refuge habitat at Lake Bulla be maintained for dwarf flat-headed gudgeon and to a lesser extent flat-headed gudgeon.

Prior to 2014, Murray cod were only recorded in low abundance at the Hattah TLM monitoring sites. In 2014 and autumn 2016, Murray cod abundance was notably higher than the preceding years and included adult and large (> 900 mm TL) fish. Following the flood in November 2016, and the associated and widespread blackwater event, very few Murray cod were captured (none in 2017 and 8 fish in 2018). The 2019 results are indicative of a recruitment led recovery (i.e. a population dominated by juveniles including Young of Year), however adult fish remain absent or in low enough densities that they have not been detected by sampling for three successive years, suggesting the 2016 event caused mortality or emigration, or both. Genetic analyses of collected tissue (i.e. fin clips) from the Murray River is recommended to provide an indication of whether the recruitment and recovery evident in this section of the Murray River is being driven by spawning of wild Murray cod or stocking, or both.

The capture of twelve Young of Year Murray cod at Lake Mournpall was unexpected both in terms of the species presence and the catch per unit effort. Considering the tiny proportion of the wetland that was sampled using backpack electrofishing, the total abundance of Murray cod in Lake Mournpall is expected to be large. The species has not been recorded at Lake Mournpall previously and there are no records of the species being stocked at this location by the Victorian Fisheries Authority either historically or recently (J Douglas pers. comm. 2019). Murray cod are typically considered main channel specialists and are not typically known to actively leave the main channel to access floodplain habitats (Koehn and Crook 2013). Larval or juvenile drift during previous flooding events or the pumped transfer of larvae or juveniles during environmental watering are the likely explanation for previous very low abundance detections of this species in other Hattah Wetland macrohabitats. However the small size of the Murray Cod detected in Lake Mournpall (i.e. well within typical YoY size ranges), combined with the fact that there has been no flow in Chalka Creek since December 2017 and no flood connection between the Murray River and Lake Mournpall since November 2016, makes it unlikely that these YoY Murray cod are the result of active or passive juvenile/larval immigration during previous periods of natural connectivity. The likely high abundance of YoY Murray cod in Lake Mournpall suggests it is unlikely that pumped transfer during the winter/spring 2017 watering event (as detailed in Wood et al. 2018), was the source of these fish. Similarly, the high abundance detected reduces the likelihood that illegal stocking was the source. Collection of otoliths and/or genetic samples would provide greater certainty in this matter, however on the basis of currently available evidence, the most likely explanation for the sudden appearance of YoY Murray cod is that a resident population of Murray cod has established in Lake Mournpall, that a proportion of that population successfully spawned in spring 2018, and that the productivity of Lake Mournpall has been conducive to survival of larval and juvenile cod. It is plausible that the adult Murray cod population established in Lake Mournpall during the November 2016 flooding event, as a result of movements out of the Murray River channel to seek refuge from deoxygenated blackwater conditions.

The TLM methods used at Lake Mournpall to date (i.e. backpack electrofishing, seine netting and fyke netting) have not been appropriate for targeting adult Murray cod and therefore the potential presence of an adult Murray cod population is not expected to have been detected previously. Although we can confirm the Huntley et al. (2016) assertion that boat electrofishing is problematic in most of the wetland sites, especially in drying/drawdown years, we have identified a suitable launch site for Lake Mournpall and with the approval of Parks Victoria, it is recommend that this site be boat electrofished for all future years of the TLM monitoring, to ensure the sampling includes adequate representation of the fish community (i.e. including Murray cod and other large-bodied fish species).

The 2019 sampling at Lake Mournpall also captured broad-shelled turtle *Chelodina expansa* (in the large fyke nets). The presence of this threatened species further adds to the current conservation significance of Lake Mournpall. It is recommended that environmental watering decisions such as drawing down the lake to achieve vegetation benefits, take these values and the potential impacts to these aquatic fauna species into account. For example, all of the Murray cod captured were found closely associated with the dead River Red Gum saplings that have formed a ring around the Lake. Drawdown that reduces water depth in these areas of habitat could push juvenile Murray cod out of these areas of cover and into open water, areas where they are likely to be more vulnerable to predation by larger Murray Cod or golden perch. It is recommended that an additional survey of Lake Mournpall be undertaken as soon as possible to obtain a better understanding of the large bodied fish community. Tissue samples (i.e. fin clips) and some otolith samples should be collected from juvenile Murray cod for genetic and otolith analyses (e.g. accurate age determination).

Recruitment of golden perch has rarely been detected by the 2010–2019 Hattah TLM monitoring, with the most significant recruitment event appearing to be in 2011, when young of year were recorded in Lakes Lockie and Yerang. Similar to that observed for the LMW TLM monitoring, a dominant cohort of golden perch between 350–450 mm TL now seems to occur, rather than the more even spread of sizes that were evident in previous years. Only nine golden perch were found in wetlands and seven were captured and processed, with four of these fish being in poor physical condition, with lesions (3 individuals) or ulcers (1 individual). A smaller proportion of the golden perch captured in the Murray River were in poor physical condition, with almost all of these fish affected by fungus (‘fin rot’) rather than lesions or ulcers.

Exotic fish species abundance in 2019 differed from 2018, in that there were substantially fewer eastern gambusia recorded and no goldfish or oriental weatherloach detected, although both have only been recorded in very low abundance in 2016–18. With the exception of a couple of juvenile carp (236–247 mm LCF), all of the carp captured from the Wetland sites were very large, with the majority being over 600 mm LCF and the maximum being 830 mm LCF and weighing just under 11 kg. Although no Young of Year were captured from the Wetland sites (using the Robinson 2012 cut-off length of 200mm LCF), around 28% of the carp captured in the Murray River were YoY.

As outlined in Huntley et al. (2016), the relative efficacy of bait traps, fyke nets, and seine nets is intended to be assessed to determine the most appropriate technique to supplement electrofishing and ensure representative sampling of the fish community. To our knowledge this is yet to occur, however is clearly an aspect of the study design that is likely to benefit from review and refinement. We recommend that the dataset be analysed to determine the relative efficacy of these methods to date. Specifically, we recommend evaluation of efficacy and cost effectiveness of continuing the inclusion of the following aspects of the monitoring program, together with any implications associated from their removal:

- 2 hr diurnal bait trap sets;
- beach seine hauls, particularly at riverine sites;
- fine-meshed fyke nets at riverine sites;
- weighing of small-bodied fish; and
- measuring of eastern gambusia

The reference condition score (i.e. expected number of native species) used in the calculation of P expected scores for the Riverine macrohabitat appears to be too low, in that it returns a score of 1 if five or more native species are recorded for that site. It is recommended that the reference score for this macrohabitat be raised to a more appropriate level to ensure that annual variability in the scores are not masked.

8.6 Progress towards ecological objectives

The Expected index (i.e. number of species detected vs expected) scores for the riverine macrohabitat are identical to those recorded over most of the monitoring program (with the exception of 2012). The wetland results are marginally lower than recorded in 2018, but are limited to four of the seven wetlands. All riverine sites and two wetland sites (one at Lake Bulla and one at Lake Mournpall) exceeded the (Robinson 2015) point of reference targets of 4.95 for riverine macrohabitat and 5.05 for wetland habitat. The Nativeness Index scores for the riverine macrohabitat are comparable to 2018, 2010–11 and 2013, but lower than 2014 and 2016, while the wetland score is relatively low but limited by only four of the seven wetlands being sampled in 2019. Only four sites (two Lake Bulla sites, one Lake Mournpall site and one Murray River site) met the Brown et al. (2016) point of reference score of ≥0.5. The Recruitment Index (i.e. proportion of native fish in each site that are recruits) scores for all for the riverine macrohabitats are comparable to 2010, 2012, 2016–17 but lower than 2018. The scores for the wetland macrohabitat are marginally lower than the 2018 scores but still relatively high, despite being limited by only four of the seven wetlands being sampled in 2019. The Brown et al. (2016) point of reference score of ≥ 0.5 for the Recruitment Index was met for almost every wetland site but no riverine site.

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