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The Living Murray Condition Monitoring: Hattah Lakes 2019–20, Part A

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Summary

Ecology Australia was commissioned by the Mallee Catchment Management Authority (CMA) to undertake the 2019-20 condition monitoring of the Hattah Lakes Icon Site, as part of The Living Murray Condition Monitoring Program. This follows on from the previous condition monitoring carried out by Ecology Australia in 2018-19. 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 2019–20 results is provided in Table 1.

Table 1 Summary of whether ecological objectives have been met for each project component for 2019–20

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	Unknown – most macrohabitats were dry		

River Red Gum

For the ninth 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 0.89 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 (i.e. the targets are being met), therefore the specific adopted objective of 'sustainable populations of River Red Gum' is being achieved.

Black Box

For the ninth 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 0.88 was recorded for the current three-year period at Hattah Lakes, exceeding the minimum threshold of 0.85. This score has decreased from 0.92 in the previous monitoring period.

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

Wetland vegetation communities

Whole-of-icon-site scores for both species richness and abundance have increased since the last survey and were the highest recorded since surveying began in 2007-08. More transects were compliant in the current monitoring than in recent years.

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. Some encroachment of drought tolerant species had occurred in wetlands, however, this is taken to be a natural response to drying within ephemeral wetlands.

The objective of 'restoring a mosaic of healthy wetland communities' is being achieved at the Hattah Lakes icon site. This is emphasised by achieving the highest icon site scores for species richness and abundance since surveys began in 2007–08.

Floodplain vegetation communities

Whole-of-icon-site scores show there has been a marked increase in the species richness since the last survey. This species richness icon score is the highest recorded since surveying began in 2007–08. Interestly, this is coupled with a low icon site abundance score, suggesting that while there is a high diversity of plant species recorded across the transects, plants are in low abundance. The high species richness indices observed in this survey period are unusual as high species richness is generally recorded in years when the Hattah Lakes floodplains are inundated.

The proportion of terrestrial dry species has generally increased since the last survey, after having decreased steadily since monitoring began in 2007-08. The high proportion of terrestrial species observed in often- and sometimes-flooded sites suggest that following the flooding events from 2016–

18, the floodplains are beginning to dry and dryland species are encroaching. While it appears that native water-responsive species abundance is generally higher when the Hattah Lakes floodplains receive inundation, the difference is more consistent when this occurs as a result of natural flooding compared to environmental water.

Targets for the Hattah floodplain vegetation were partially met, with targets established for richness and abundance met at a rate of 58% and 18%, respectively. The objective of 'restoring a mosaic of healthy floodplains communities' is being partially achieved at the Hattah Lakes icon site.

Despite targets only being partially met, the data collected over the thirteen-year duration of the monitoring program highlight the benefit, with regard to species richness and abundance, to floodplain vegetation from the impacts of large-scale watering events, and the benefits of applying necessary management to an area over time.

Lignum

The 2019–20 monitoring results indicate a minor increase in Lignum condition since 2018–19 across all sites. This is after a decline in Lignum condition was noted in the in 2018–19 survey. 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 only been met for both Lignum Woodland and Lignum Swamp strata, but not Lignum Shrubland.

The Icon Site index (i.e. the proportion of sites that exceed the established target) was found to be the same in the current monitoring period as the previous (both 0.44). This is following a non-significant decrease was observed in the icon site index from 0.56 in 2017–18. Based on the results from the current period, the ecological objective is partially met with two, but not all, Lignum strata considered to be healthy and meeting the target condition.

Waterbirds

Seven of the 15 surveyed wetlands were found to provide foraging habitat during the survey periods for a range of waterbirds, including species considered threatened on the Victorian Advisory List (DEPI 2014). Two migratory species were recorded in the 2019–20 surveys: the Sharp-tailed Sandpiper (*Calidris acuminata)* and Common Greenshank (*Tringa nebularia)*.

There were no recordings of Freckled Duck (*Stictonetta naevosa)*, Grey Falcon (*Falco hypoleucos)* or White-bellied Sea-Eagle (*Haliaeetus leucogaster)*.

No waterbird breeding was observed during this year's monitoring.

The surveyed wetlands which were carrying water provided roosting habitat for colonial waterbirds but colonial nesting was not confirmed. Some disused nests of colony-breeding waterbird species were observed at some of the wetlands but none of these were less than a year old and had not been rebuilt or used in recent months. No other evidence of waterbird breeding was observed.

Fish communities

For the first time over the duration of the monitoring program, the only macrohabitat sampled was the Murray River. Chalka Creek and all of the wetland sites were dry. Lake Mournpall experienced a fish kill in February 2020, following fish and turtle relocation in November and January 2020. Progress towards ecological objectives cannot be assessed in 2020 due to the lack of sites available for assessment.

The diversity (P expected) scores for the riverine macrohabitat are identical to those recorded over most of the monitoring program (with the exception of 2012). The nativeness (P nativeness) scores for the riverine macrohabitat are marginally higher than 2018–19, 2010–11 and 2013, but lower than 2014 and 2016. The recruitment index (P recruits) scores for the riverine macrohabitats are marginally higher than 2010, 2012, 2016–17 and 2019, but lower than 2011, 2013–14 and 2018.

Prior to 2014, Murray Cod were only recorded in low abundance at the Hattah TLM Murray River monitoring sites. In 2014 and autumn 2016, Murray Cod abundance was notably higher than the preceding years and included adult and large fish. Following the flood in November 2016, and the associated and widespread blackwater event, very few Murray Cod were captured. The 2019–20 results are indicative of a recruitment led recovery (i.e. a population dominated by juveniles including Young of Year), however adult fish have likely been in low densities, with only one being recorded in 2020, the first in over three years.

Recruitment of Golden Perch has rarely been detected by the 2010–2020 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 in March 2011, following sustained elevated river flows from late winter 2010 through to a flood peak in February 2011. 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.

1 Introduction

Ecology Australia was commissioned by the Mallee Catchment Management Authority (CMA) to undertake the 2019–20 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.

Reporting for the 2019–20 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).

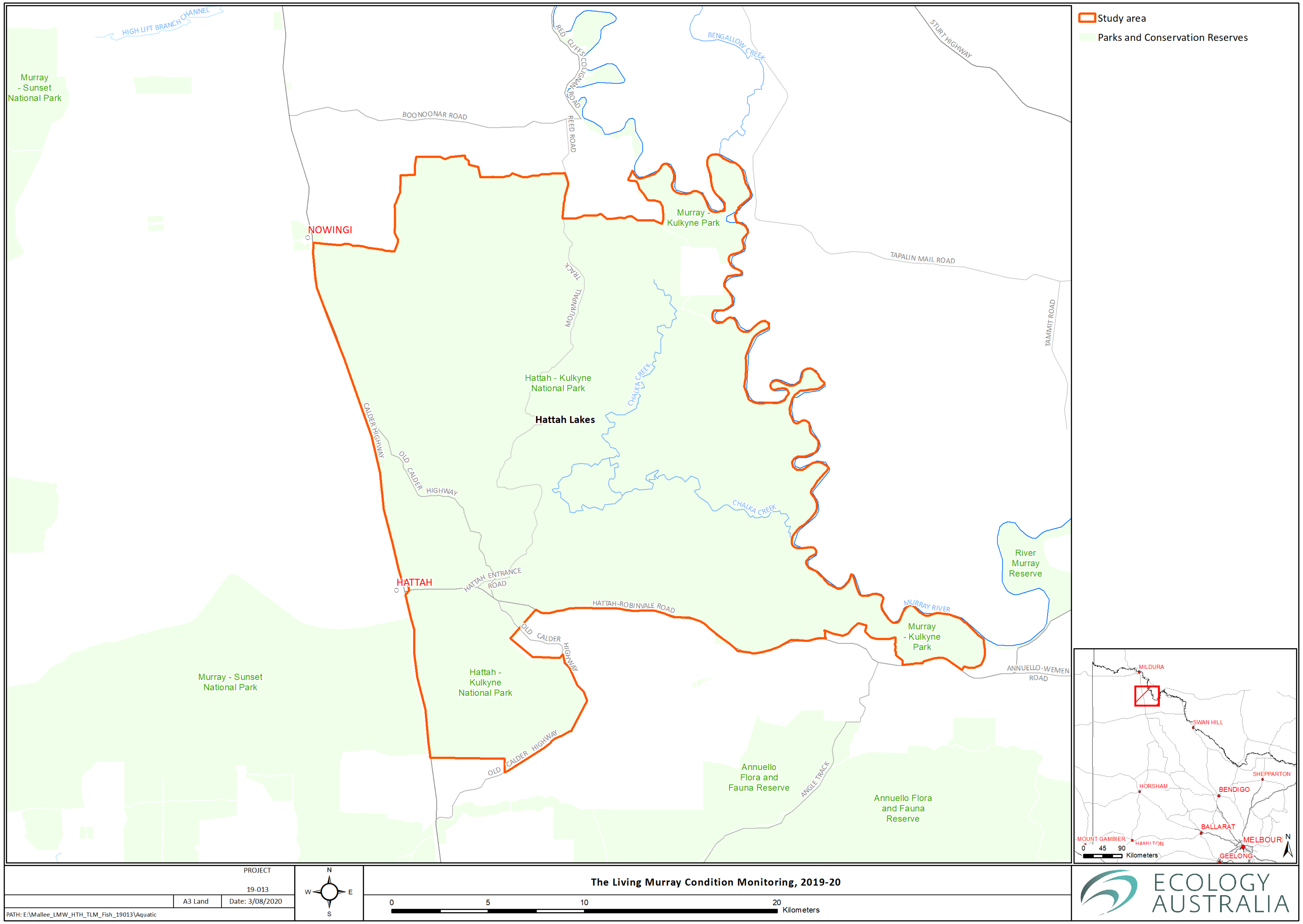

Figure 1 The location of the Hattah Lakes icon site.

1.2 Hydrology

1.2.1 Murray River

Over the course of the monitoring program (2007–2020), 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).

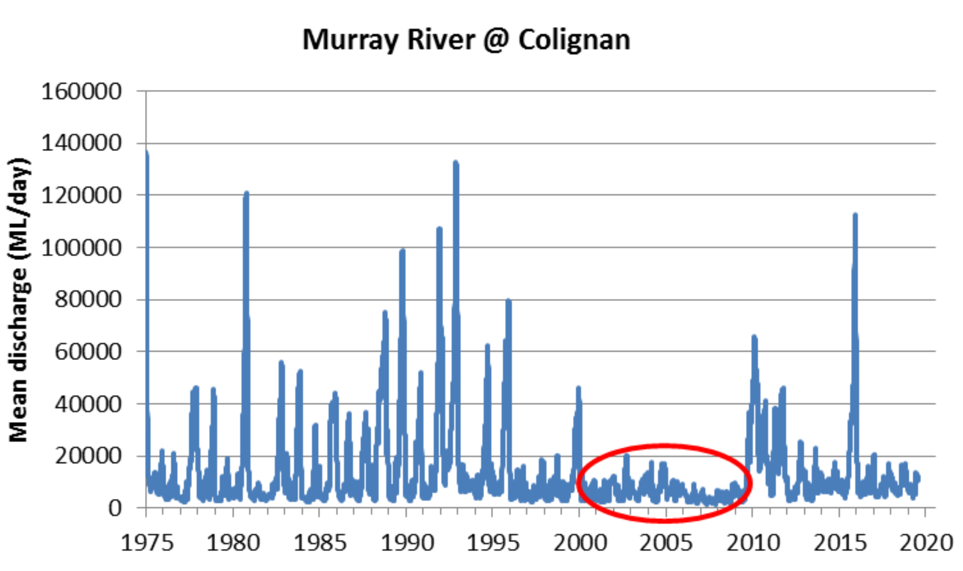

Figure 2 Average daily discharge (ML/day) hydrograph for the Murray River at Colignan 1975–2020 (source: http://data.water.vic.gov.au/monitoring.htm), with the Millennium Drought circled in red.

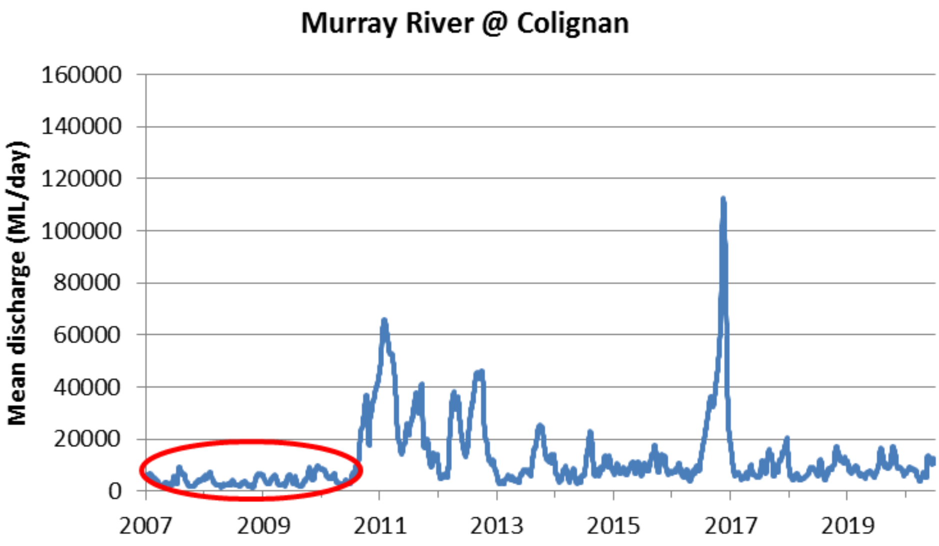

Figure 3 Average daily discharge (ML/day) hydrograph for the Murray River at Colignan over the course of the monitoring program 2007–2020 (source: http://data.water.vic.gov.au/monitoring.htm) with the Millennium Drought circled in red.

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 (2019–20) 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.

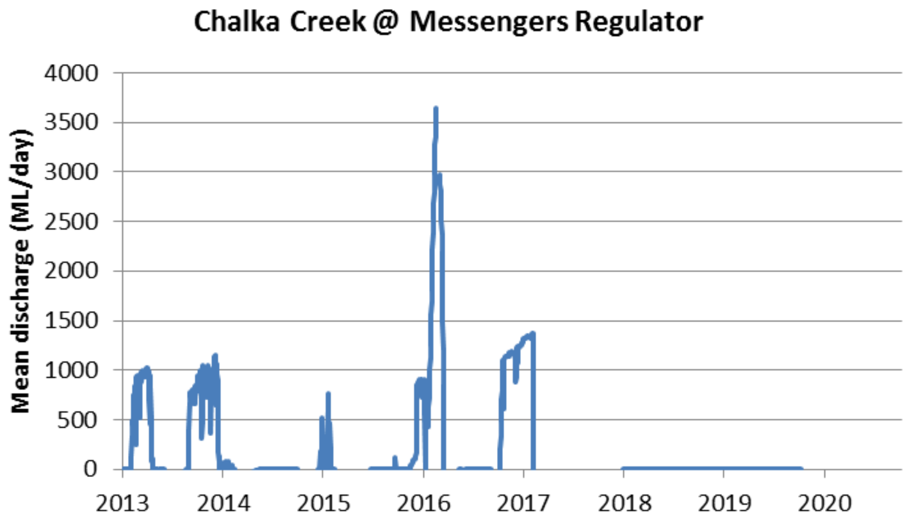

Figure 4 Average daily discharge (ML/day) hydrograph for Chalka Creek at Messengers Regulator 2013–2020 (source: http://data.water.vic.gov.au/monitoring.htm).

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 Lake Kramen was the only site to receive environmental water (in spring 2019)(D Wood pers. comm. 2020).

2 River Red Gum

2.1 Introduction

River Red Gum *Eucalyptus camaldulensis* is a large native tree growing to 40 m high (VicFlora 2020). 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

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

- tree condition assessments; and
- population status.

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.

Population status/structure data was collected in September–October 2019, and tree condition assessment in December 2019.

2.3.1 Tree condition assessments

The tree condition assessments for River Red Gum 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 nine sites allocated for this year's monitoring were assessed.

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 were sampled from the following Water Regime Class (WRC) strata: Red Gum Forest (RGF); Red Gum with Flood-Tolerant Understorey (RGFTU) and Fringing Red Gum Woodland (FRGW).

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:

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

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

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 27 River Red Gum Tree Condition sites within the Hattah study area. The target of 85% for River Red Gums was reached, with 93.7% of sampled trees having a crown extent score of 4 or more (Figure 5). This represents the ninth year of consecutive monitoring in which the target for River Red Gum tree condition at Hattah Lakes was reached, excluding 2014–15.

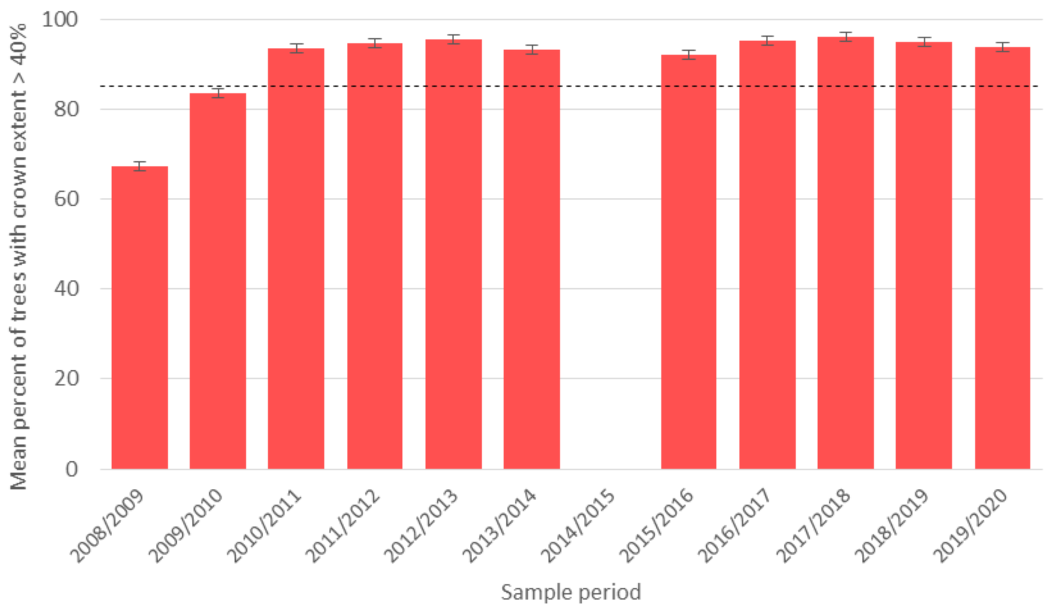

Figure 5 Mean percentage (±SE) of River Red Gum trees with crown extent scores ≥ 4 for each survey period across the River Red Gum Tree Condition sites. An overall target of 85% was used to determine if the Hattah Lakes icon site tree population was healthy and sustainable.

2.5.2 Population status

A mean River Red Gum population status index of 0.89 (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; $P = 0.03$; Table 2).

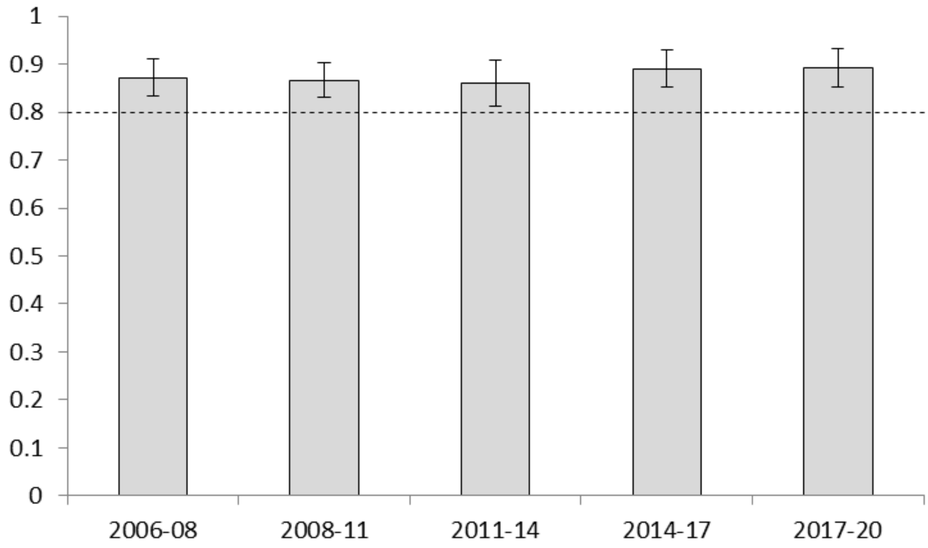

Figure 6 Mean population status index (± 95% CI) for River Red Gum at the Hattah Lakes icon site, based on correlation with an ideal population structure, the 'inverse j-curve'. A minimum threshold of 0.8 is set for River Red Gum at Hattah Lakes. Population status indices are pooled between WRCs in each 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	0.8724	0.02138	0.8295	0.9153
RFG	0.9491	0.03619	0.8764	1.0217
RGFTU	0.8224	0.02698	0.7683	0.8766
2006–08	0.8610	0.02239	0.8167	0.9053
2008–11	0.8783	0.02097	0.8368	0.9198
2011–14	0.8699	0.02089	0.8286	0.9113
2014–17	0.9055	0.02196	0.8621	0.9489
2017–20	0.8917	0.02055	0.8510	0.9323

A flatter distribution was observed when examining the DBH of juvenile River Red Gums (<15 cm) in 2017–20, when compared to the sharper J curve distribution observed in 2014–2017, 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).

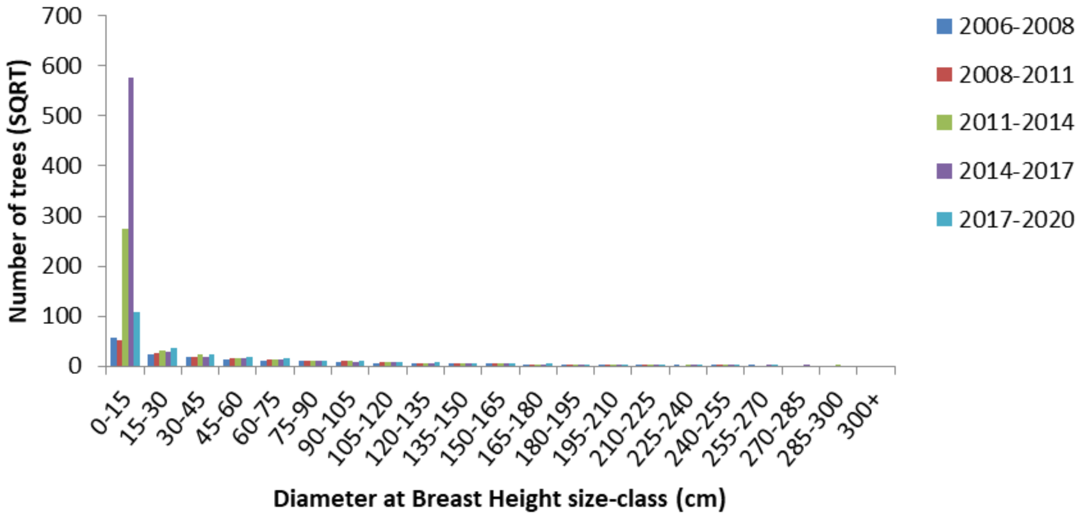

Figure 7 Frequency of River Red Gum trees (square-root transformed) for each DBH size-class (0–300+ cm) for each three year period, pooled within the Hattah Lakes icon site.

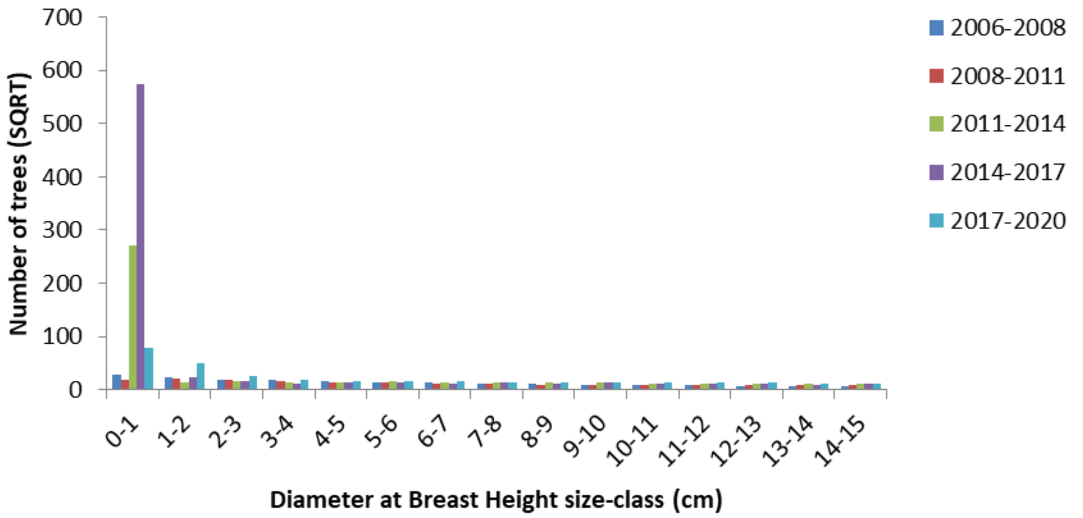

Figure 8 Frequency of River Red Gum trees (square-root transformed) for each DBH size-class (0–15 cm) for each three year period, pooled within the Hattah Lakes icon site.

2.6 Discussion

For the ninth 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 2019–20 show a potentially 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 = 197 mm, 2019 = 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 2020). 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 regulation of the Murray River and the extraction of water for agriculture, industry and urban use. This has impacted on the flow regime resulting in decline in overall the health of black box communities (MDBA 2012a). In recent times plans have been made to increase the frequency of flooding to the lakes of Hattah and to increase the duration of flooding to enable the surrounding Black Box woodland at higher elevations to receive the relevant amount of inundation (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

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

- tree condition assessments; and
- population status.

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.

Population status/structure data was collected in September–October 2019, and tree condition assessment in December 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 six sites allocated for this year's monitoring were assessed. Refer Section 2.3.2 for further details on the population status methodology. Sites were sampled from the Black Box Swampy Woodland (BBSW) and Riverine Chenopod Woodland (RCW) Water Regime Class (WRC) strata.

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 87.59% of sampled trees having a crown extent score of 4 or more (Figure 9). This represents the ninth consecutive year of monitoring in which the target for Black Box condition at Hattah Lakes was reached, excluding 2014–15.

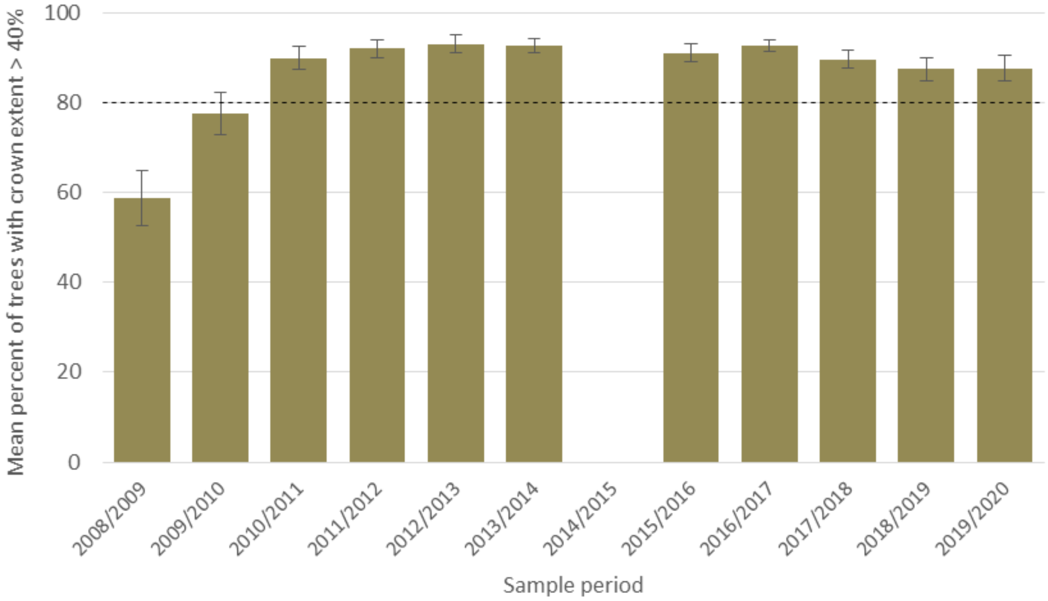

Figure 9 Mean percentage (±SE) of Black Box trees with crown extent scores ≥ 4 for each survey period across the 18 Black Box Tree Condition sites. An overall target of 80% was used to determine if the Hattah icon site tree population was healthy and sustainable.

3.5.2 Population status

A mean Black Box population status index of 0.88 (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 ($P = 0.3$; Table 3).

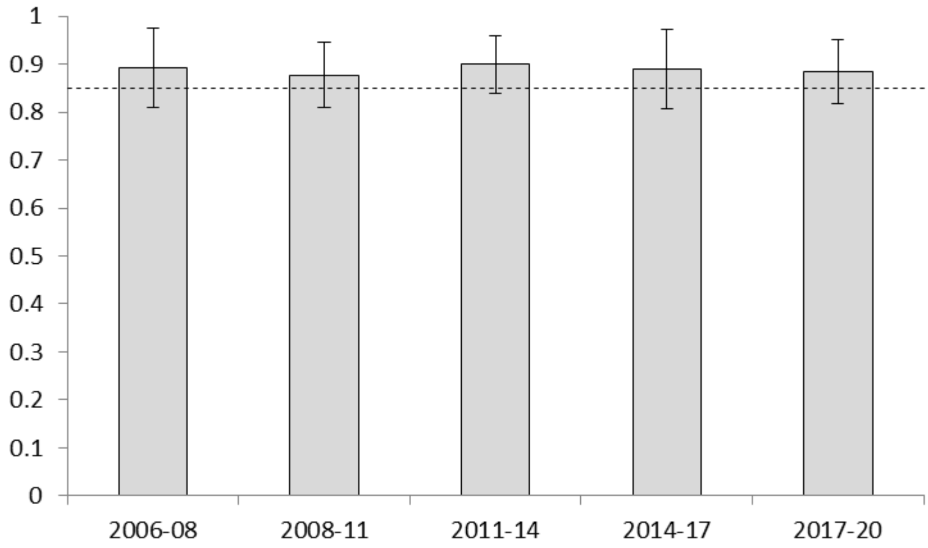

Figure 10 Mean population status index (± 95% CI) for Black Box at the Hattah Lakes icon site, based on correlation with an ideal population structure, the 'inverse j-curve'. A minimum threshold of 0.85 is set for Black Box at Hattah Lakes. Population status indices are pooled between WRCs in each survey 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	0.8292	0.05064	0.7239	0.9345
RCW	0.9005	0.04408	0.8089	0.9922
2006–08	0.8485	0.03698	0.7746	0.9224
2008–11	0.8428	0.03606	0.7707	0.9148
2011–14	0.8863	0.03544	0.8155	0.9572
2014–17	0.8613	0.03554	0.7902	0.9323
2017–20	0.8854	0.03506	0.8153	0.9555

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 2017–20, when compared to the sharper J curve distributions observed in 2011–2014 and 2014–17, 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 (1350 individuals). The population structure of juvenile Black Box in the current year approximates the structure recorded in

2006–08, but with more trees recorded with DBHs greater than 6 cm, corresponding to the growth of the 0–1 cm cohort recorded in 2011–14 and 2014–17.

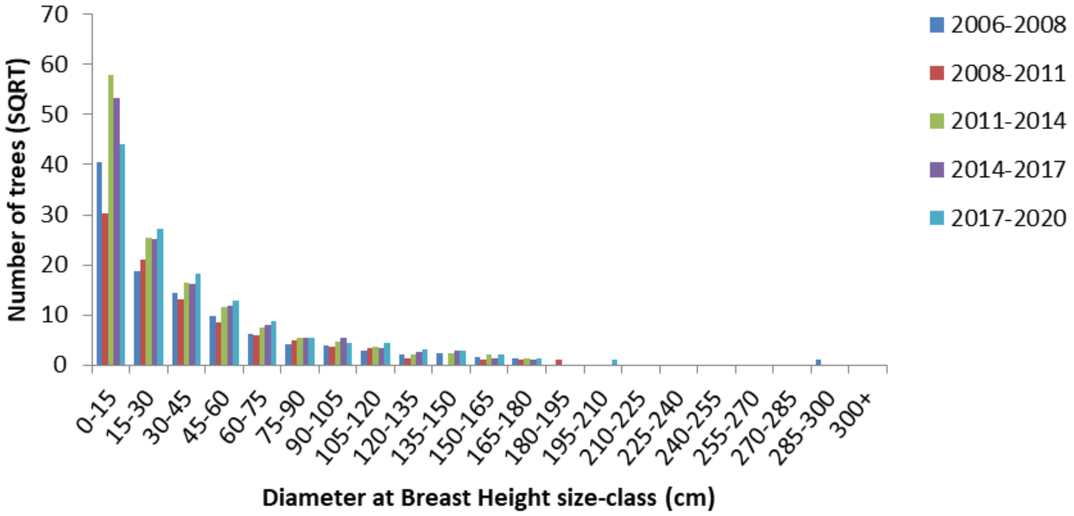

Figure 11 Frequency of Black Box trees (square-root transformed) for each DBH size-class (0–300+) for each three year period.

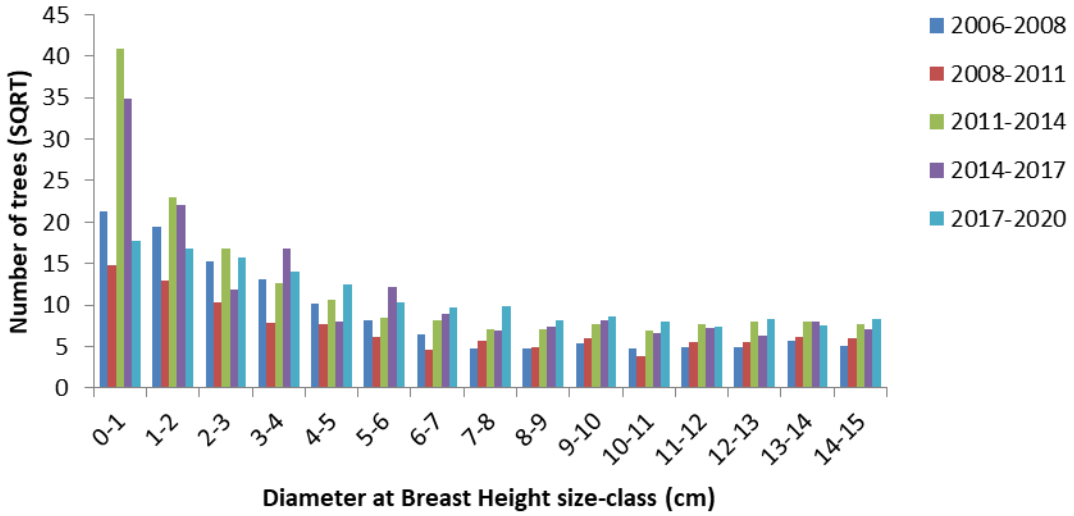

Figure 12 Frequency of Black Box trees (square-root transformed) for each DBH size-class (0–15 cm) for each three year period.

3.6 Discussion

For the ninth 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 2019–20 show a potentially slight decrease in condition from the preceding two monitoring events, potentially reflecting a combination of decreasing rainfall—2016 = 413mm, 2017 = 374mm, 2018 = 197 mm, 2019 = 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 two years following inundation.

A mean Black Box population status index of 0.88 was recorded for the current three-year period at Hattah Lakes, exceeding the minimum threshold of 0.85; a slight decline from 2014-17 (0.89) and a further decline from highest period of 2011-14 (0.9). 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.

Groundwater is an important source of moisture for Black Box woodlands and other floodplain species. The recommendations put forward by Wood et al. (2018) to monitor the quality and depth of groundwater are therefore appropriate and important, especially for monitoring trends in these communities.

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 extent 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 restore the floodplains to a condition prior to water regulation (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 vegetation at Hattah Lakes is:

- "Restore diversity, extent and abundance of wetland and floodplain vegetation" (Robinson 2015).

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 2020. 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^2 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 number of transects, quadrats and elevations at each individual wetland, see Table 4.

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.Recently dead annual plants (those from the current season) are identified, providing identification can be made, but are not included in analysis. 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).

Table 4 The number of transects, quadrats and elevations at each of the 12 wetlands in Hattah Lakes.

Site	No. of transects	No. of quadrats per transect	Elevations surveyed (cm)
Chalka Creek	4	4	0, 50, 100, 150
Chalka Creek North	4	4	0, 30, 60, 90
Lake Bitterang	4	6	0, 50, 100, 150, 200, 150
Lake Boich	4	3	0, 30, 60
Lake Brockie	4	5	0, 30, 60, 90, 120
Lake Bulla	4	6	-100, -50, 0, 50, 100, 150
Lake Hattah	4	6	-100, -50, 0, 50, 100, 150
Lake Kramen	4	5	50, 100, 150, 200, 250
Lake Little Hattah	4	3	0, 30, 60
Lake Mournpall	4	7	-100, -50, 0, 50, 100, 150, 200
Lake Nip Nip	4	3	0, 50, 100
Lake Yerang	4	3	0, 50, 100

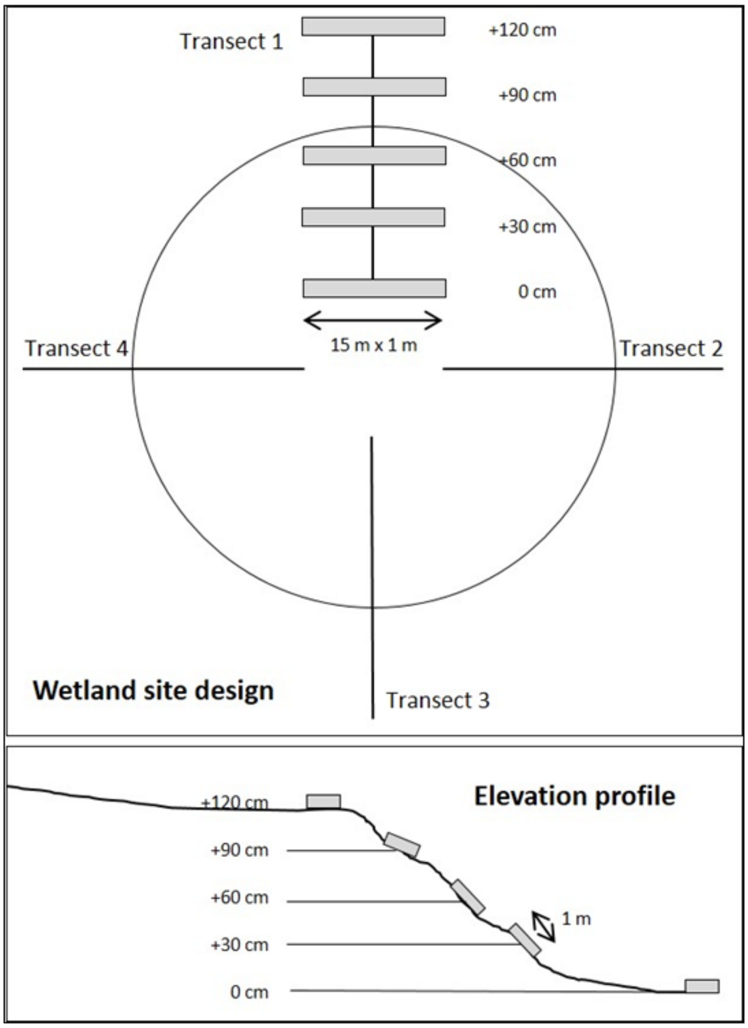

Figure 13 Schematic of the survey design used to assess wetland vegetation communities under The Living Murray program at the Hattah Lakes icon site (adapted from Wallace [2009] in Huntley et al. [2016]).

4.3.2 Plant species classification

Species identification

Plant taxonomy and the use of common names follow the Victorian online plant census (VicFlora 2020), the Victorian Biodiversity Atlas database (DELWP 2020) and for taxa not acknowledged in Victoria the NSW online flora (PlantNET 2020). 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 5). 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 (2020) 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 5 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 6 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 6, 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 6) 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 7). 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 39 vascular plant species was recorded from the 12 Hattah Lakes wetland sites during the 2019–20 monitoring. Of these, 33 (84.6%) were indigenous and 6 (15.4%) were exotic; two species are recorded on the advisory list of rare or threatened plants in Victoria by DELWP (formerly DEPI) (2014) (one vulnerable and one 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; the same as the previous survey period (Table 7, Figure 14). There were three quarters of wetland transects in the Semi-permanent WRC that were compliant. The Episodic WRC had no compliant transects with the species richness index. This was likely due to the wetland being unable to be sampled effectively due to being flooded at the time of survey. Across the icon site, compliance has doubled on the species richness index from the previous year, when only nine transects were considered compliant across all WRC's. Transects in the Semi-permanent WRC have been compliant in the current survey period, the first time since 2012–13. The last time any transects at the Episodic WRC considered compliant was in 2016–17 (Figure 14).

Table 7 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 2019–20 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 at icon site	No. transects at icon site	No. wetlands surveyed 2019/20	Species richness			Species abundance		
				No. compliant transects	Strata score	Icon Site score	No. compliant transects	Strata score	Icon Site score
Semi-permanent	5 (20)	20	3	9 of 12	0.75	0.516 (±0.119)	6 of 12	0.5	0.322 (±0.081)
Persistent Temporary	13 (44)	44	8	9 of 30	0.41		9 of 30	0.3	
Episodic	2 (8)	8	1	0 of 4	0		0 of 4	0	

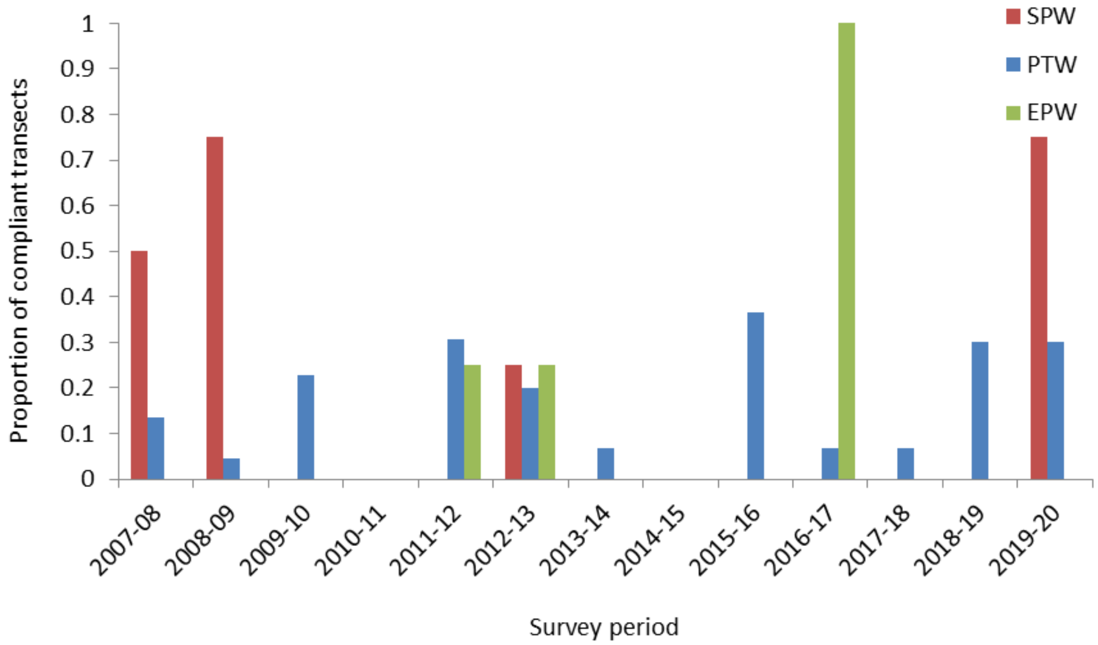

Figure 14 Proportion of transects from wetlands in WRCs at the Hattah Lakes icon site, considered compliant with the native water-responsive species richness index (transects with a mean species richness score above the 80th percentile).

Water responsive species abundance

As for species richness, transects at wetlands in the Persistent Temporary WRC (PTW) and Semi-permanent WRC (SPW) were considered compliant with the native water-responsive species abundance index (Table 7, Figure 15). There were 15 compliant transects (9 in PTW, 6 in SPW), or 33% of all wetland transects (Table 7). This result represents a slight decrease on the PTW species abundance index from the previous year, when eleven transects were considered compliant. This is the first time transects in the Semi-permanent WRC have been recorded as compliant since 2012-13. No EPW transects were compliant in the past two survey periods, compared to half of the transects in 2017–18 (Figure 15).

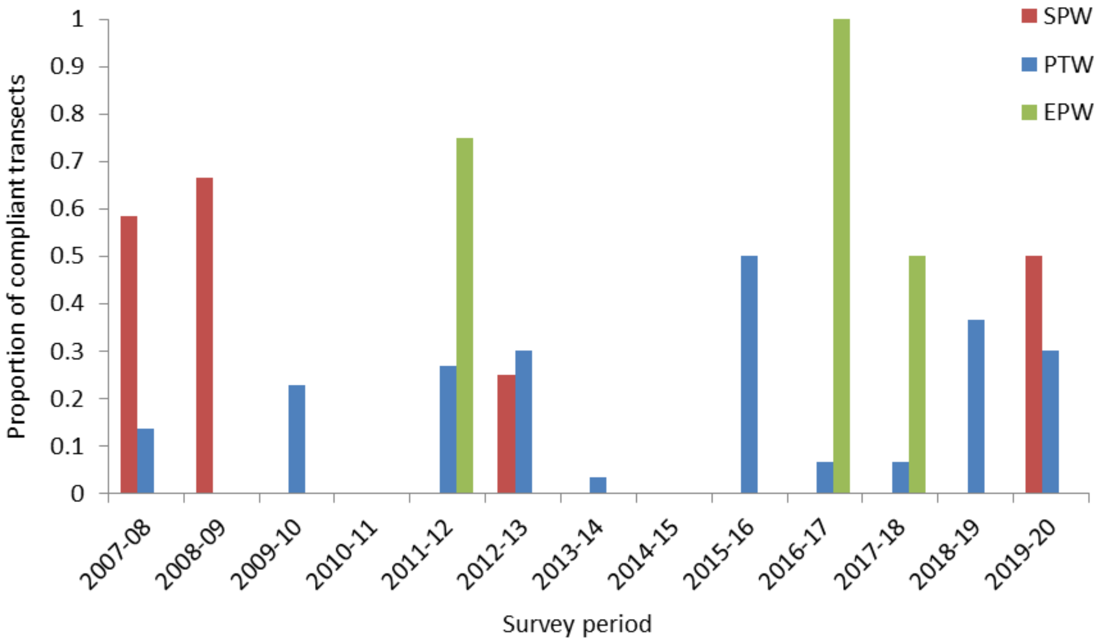

Figure 15 Species abundance proportion of compliant transects (transects with a species abundance score above the 80th percentile) for each WRC.

Whole-of-icon site score

The proportion of transects compliant with native water-responsive species richness indices at Hattah Lakes differed across WRCs (Table 7). Transects were compliant in Semi-permanent and Persistent Temporary Wetlands with no compliant transects in the Episodic Wetlands due to flooding. The icon site score for native species richness at wetlands is the highest on record since the beginning of the Living Murray initiative and is significantly higher than the score recorded in 2018–19, where the trajectory showed an increase for the first time since 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). 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 Episodic Wetlands at the Hattah Lakes icon site; just under a third of transects in Persistent Temporary Wetlands and half of Semi-permanent Wetlands were compliant with the species abundance index (Table 7). The icon site score for native species abundance was higher than the last three survey periods (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).

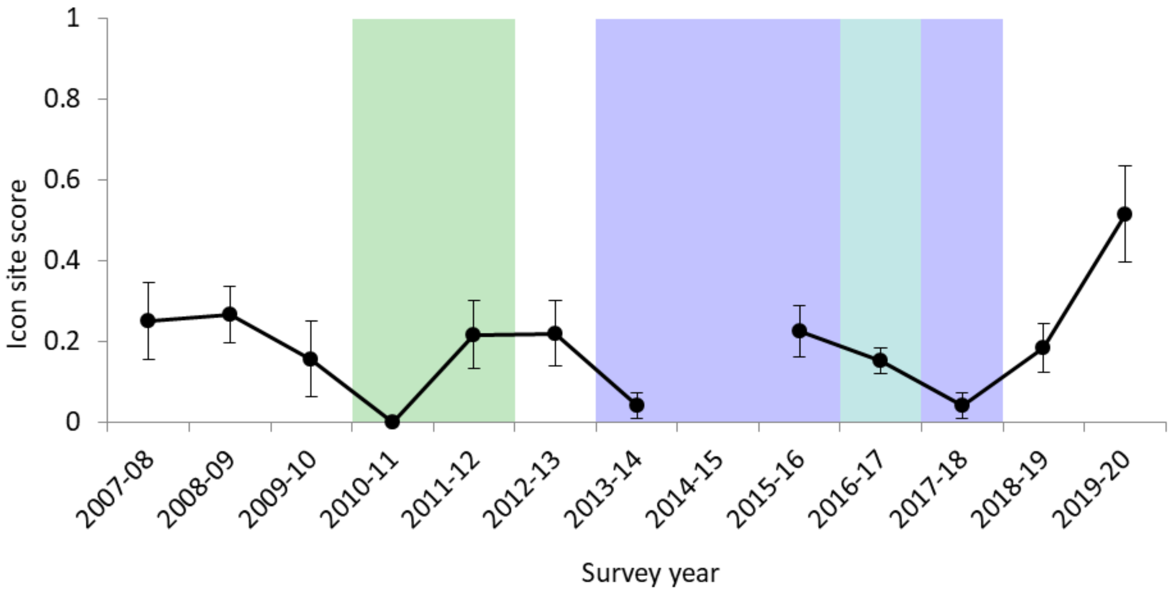

Figure 16 **Icon site scores for the Hattah Lakes icon site wetlands based upon native water-responsive species richness indices and weighted across each WRC (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. No data were collected in 2014–15. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water).**

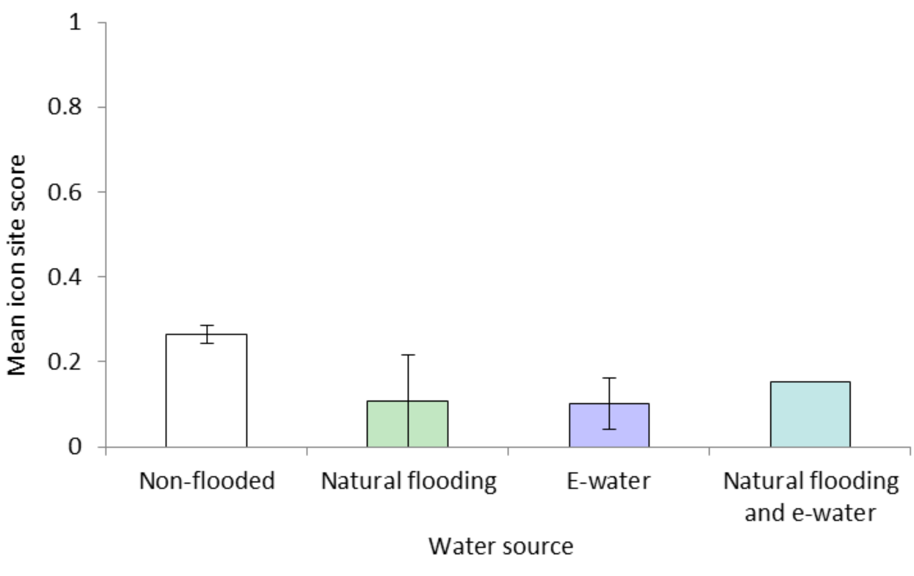

Figure 17 **Mean icon site wetland scores based upon native water-responsive species richness indices, for the Hattah Lakes icon site (± standard error), for each water event type. Non-flooded years *n* = 6, natural flooding *n* = 2, e-water *n* = 3, natural flooding and e-water *n* = 1.**

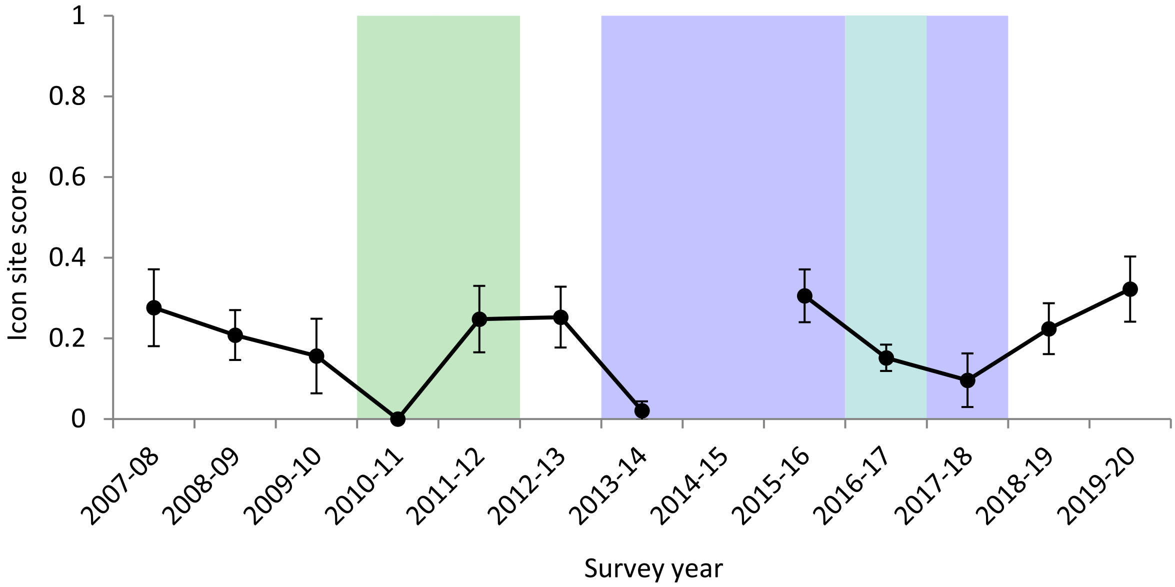

Figure 18 **Icon site scores for the Hattah Lakes icon site wetlands based upon native water-responsive species abundance indices and weighted across each WRC (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. No data were collected in 2014–15. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water).**

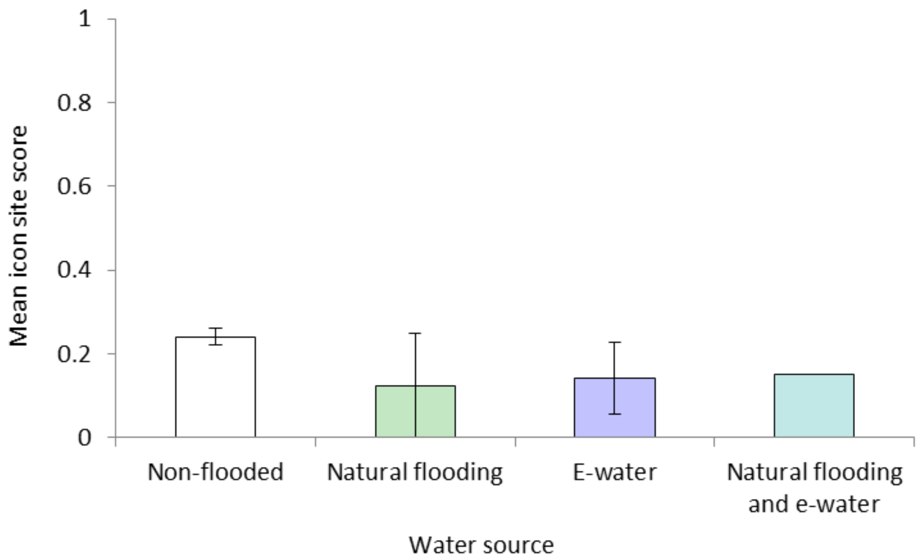

Figure 19 **Mean icon site wetland scores based upon native water-responsive species abundance indices, for the Hattah Lakes icon site (± se), for each water event type. Non-flooded years *n* = 6, natural flooding *n* = 2, e-water *n* = 3, natural flooding and e-water *n* = 1.**

4.4.3 Drought-tolerant vegetation in wetlands

There were no species recorded at Episodic Wetlands due to flooding for the current survey period. There was a slight increase in drought-tolerant species (Tdr) at Persistent Temporary (22.8%) and Semi-permanent (16.1%) wetlands (Figure 21, Figure 22 and Figure 23). There was little change in the proportion of terrestrial damp species compared to 2018-19. Woody species tolerating inundation (Atw) and amphibious species (A) remain unchanged in Semi-permanent Wetlands, where they comprise over a third of records; they were recorded at lower levels in Persistent Temporary Wetlands, where they make up only 15.9% of records.

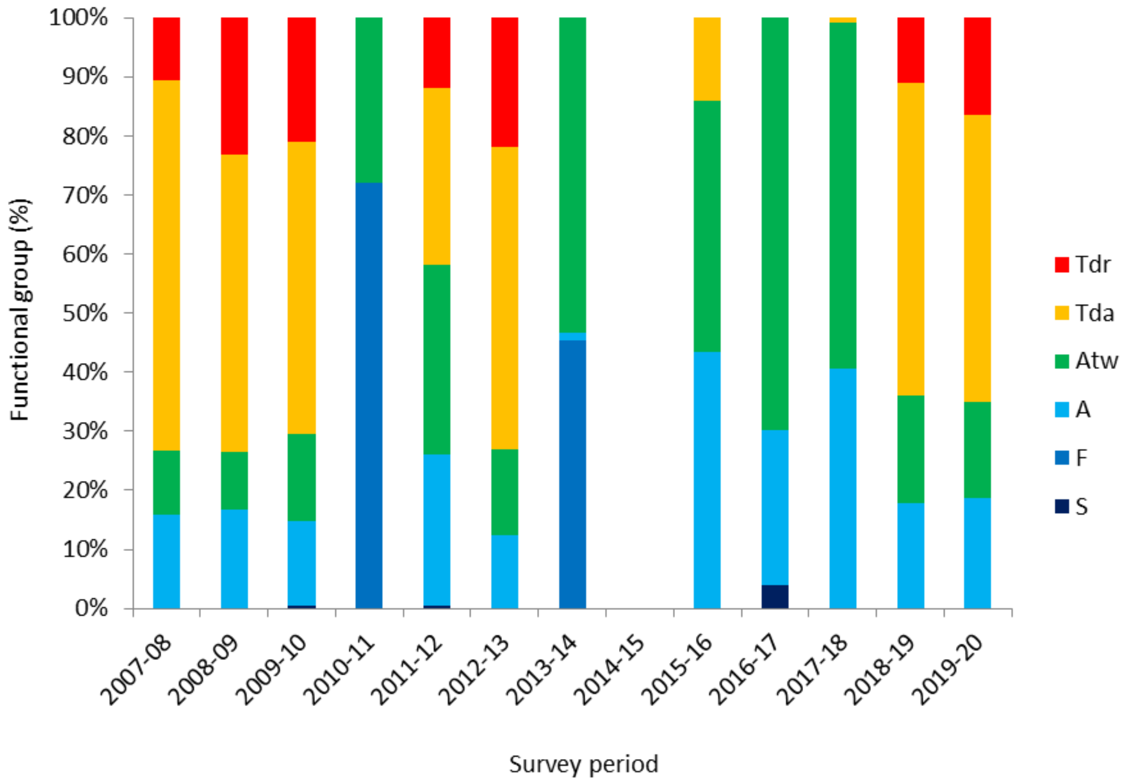

Figure 20 Proportion of sum of abundance for each functional group across the Semi-permanent Wetland WRC (SPW) at the Hattah Lakes icon site for each survey period. No data were collected in 2014-15.

In 2019–20, over half the plant records obtained in Semi-permanent Wetlands at the Hattah Lakes icon site were drought tolerant species (Tdr) and terrestrial damp species (Tda). This result is unchanged since 2018–19, but a considerable increase since the 2017–18 survey, when less than 1% of these functional groups were recorded (Figure 20). Drought-tolerant species (Tdr), which have not been recorded in this WRC since 2012–13, were recorded for the first time in 2018–19 and have increased in proportion in 2019–20. Similar proportions of woody species tolerating inundation (Atw) and amphibious species (A) were recorded compared to the previous year (Figure 20).

A greater proportion of drought-tolerant species were recorded in Persistent Temporary Wetlands compared to previous seasons, with this functional group making up almost a quarter of records (Figure 21). Records of plants in the Atw and A functional groups had declined from 2018–19, continuing a trend in decline since 2015–16 (Figure 21).

Episodic Wetlands were unable to be sampled effectively during the current survey period due to all transects being completely inundated (Figure 22).

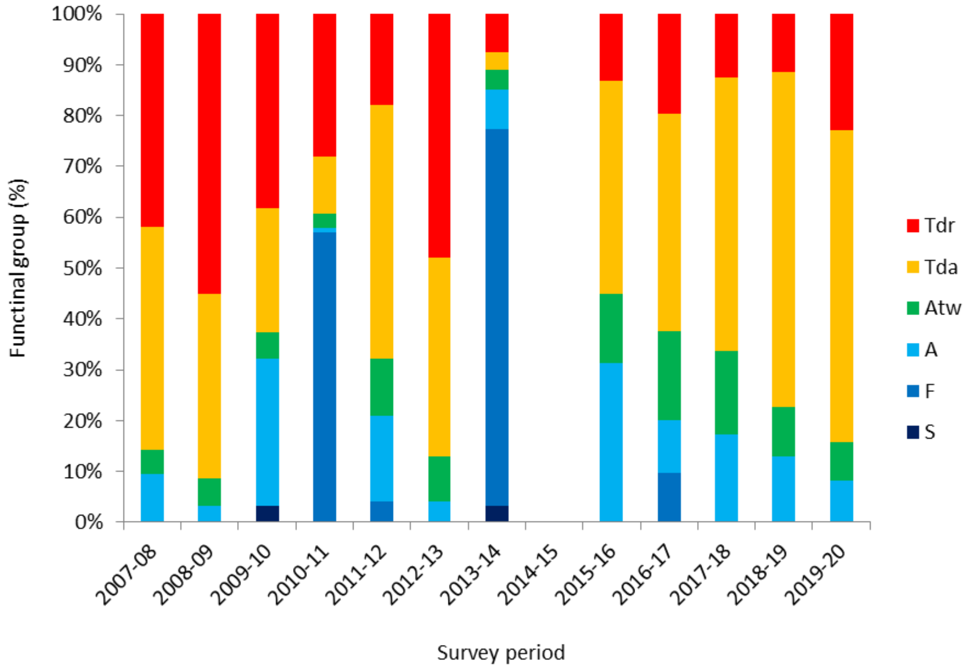

Figure 21 Proportion of sum of abundance for each functional group within the Persistent Temporary Wetland WRC (PTW) at the Hattah Lakes icon site for each survey period. No data were collected in 2014-15.

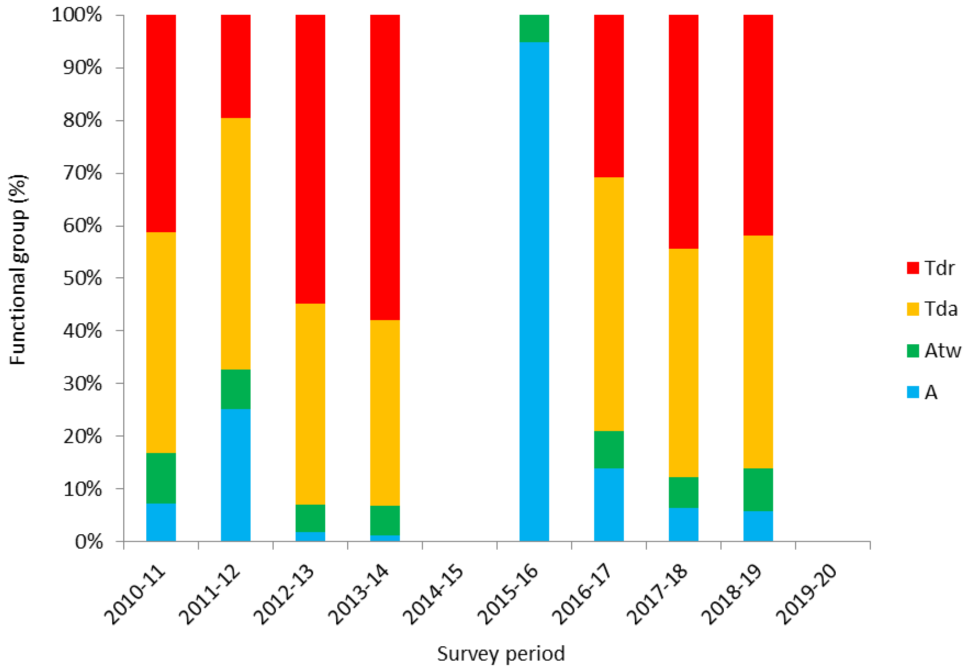

Figure 22 Proportion of sum of abundance for each functional group within the Persistent Episodic Wetland WRC (EPW) at the Hattah Lakes icon site for each survey period. No data were collected in 2014–15. EPW sites were were too deeply inundated to be effectively surveyed in 2019–20.

4.5 Discussion

4.5.1 Persistent Temporary Wetlands

Three of the Persistent Temporary Wetlands (PTWs), including Lake Bitterang, Brockie, and Yerang, recorded higher water-responsive species richness and abundance during the current monitoring period, when compared to the last monitoring period (Table 7). These sites still contained inundated areas in 2018–19 from flooding in 2017–18, with the exception of Lake Yerang which was dry in 2018–19, but all were dry in 2019–20. The remaining five wetlands supported low water-responsive species richness and abundance with no transects being compliant in Chalka Creek, Lake Boich, and Little Hattah.

Typically, water-responsive species richness and abundance is highest in the years following inundation (drawdown phase) (Casanova and Brock 2000, Huntley et al. 2016), and this results in a higher diversity of Tda (terrestrial damp species) and A (all amphibious species groups). This has led to the past two monitoring periods having the greatest water responsive species richness and abundance since 2015–16, although compliance has not been reached in the majority of transects. A total of nine transects were compliant for water-responsive species richness and abundance, a slight decline from the previous monitoring period with nine and eleven respectively. Lake Bitterang was the only site to achieve compliance across all four transects for species abundance (Table 6).

It should be noted that in 2018–19, most transects across a numer of sites (Chalka Creek, Chalka Creek North, Lake Boich, Lake Little Hattah, and Lake Yerang) had many quadrats that were dominated by either bare ground and leaf litter or were occupied by one species (typically *Glycyrrhiza acanthocarpa* Southern Liquorice). With the exception of Lake Yerang, all of these sites have remained low in diversity into summer 2020. This 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 is likely to be a combination of well below average rainfall (reduced water availability) and a depauperate seed bank and/or limited colonisation by propagules that have dispersed from other areas. The low rainfall has likely further limited both germination from the seed bank, and seed production in the surrounding landscape. Casanova and Brock (2000) have noted that in many temporary wetlands, such as those on the Northern Tablelands of New South Wales, 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. This occurs where germination of terrestrial damp species may have occurred but plants may have not survived long enough to reproduce (and replenish the seedbank) due to more inundation. Long-dry phases (short flooding durations) give an opportunity for terrestrial species to establish and reproduce (Casanova 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 in 2018–19, had very low compliance in 2019–20. This wetland had 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 which are now the dominant occurring species in the current 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. Casanova and Brock 2000, 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 8 Hattah Lakes Icon Site – summary of compliant transects

Wetland	No. of compliant transects		Potential Factors affecting compliance
	Richness	Abundance	
Persistent Temporary Wetlands			
Chalka Creek	0 (/4)	0 (/4)	Many quadrats with bare ground and a high proportion of drought-tolerant species (Tdr)
Chalka Creek North	1 (/4)	1 (/4)	Many quadrats with bare ground and leaf litter (across all depths/elevations)
Lake Bitterang	3 (/4)	4 (/4)	Quadrats at 0 cm and 50 cm elevation were inundated in 2018-19. Complete drawdown in 2019-20 with more area covered by vegetation
Lake Boich	0 (/3)	0 (/3)	Majority of quadrats with low species diversity - high occurrence of *Glycyrrhiza acanthocarpa*. High proportion drought-tolerant (Tdr) species.
Lake Brockie	2 (/3)	2 (/3)	Complete drawdown in 2019-20, with more area covered by vegetation than previous monitoring event
Little Lake Hattah	0 (/4)	0 (/4)	Majority of quadrats with low species diversity - high occurrence of *Glycyrrhiza acanthocarpa.* Also high proportion drought-tolerant (Tdr) species.
Nip Nip	1 (/4)	0 (/4)	Majority of quadrats with low species diversity and high proportion drought-tolerant (Tdr) species.
Lake Yerrang	2 (/4)	2 (/4)	High occurrence of bare ground, leaf litter and drought-tolerant (Tdr) species.
Semi-permanent Wetlands			
Lake Hattah	3 (/4)	2 (/4)	Complete drawdown in 2019-20 with more area covered by vegetation than in previous monitoring event
Lake Mournpall	4 (/4)	3 (/4)	Almost complete drawdown in 2019-20 with more area covered by vegetation

Wetland	No. of compliant transects		Potential Factors affecting compliance
	Richness	Abundance	
			than in previous monitoring event
Lake Bulla	2 (/4)	1 (/4)	Complete drawdown in 2019-20 with high amount of bare ground and leaf litter
Episodic Wetlands			
Lake Kramen	0 (/4)	0 (/4)	Too deeply inundated at the time of survey to sample effectively

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 and compliance was particularly high at Lake Hattah and Lake Mournpall. All three wetlands were still partially inundated in 2018–19 – typically between -100 cm and 0 cm or 50 cm elevation, and no vascular plant taxa were recorded in the inundated quadrats. No sites were inundated in 2019–20. Similar to Lake Brockie and Lake Bitterang (which were also partially inundated in 2018–19), reasonable species diversity and abundance across the amphibious (A) functional groups and terrestrial damp (Tda) functional group was recorded in quadrats in the current survey period.

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 due to flooding (inundation) during the current survey period. The flooding of Lake Kramen likely provides good habitat (as well as landscape variation) despite the low compliance score. It is expected that with draw down, compliance will increase as species germinate and emerge from propagules.

In past survey periods, Lake Kramen has had a higher proportion of compliant sites in the years following significant flooding by natural and environmental water. 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 therefore potentially be achieved again following the 2019–20 flooding event.

4.5.4 Whole of Icon Site

Thirty-nine percent (39%) of transects were compliant for water-sensitive species richness and 33% for abundance. Despite this, this survey period has had the highest icon site score for species richness and abundance since surveying began in 2007–08. This indicates an improvement in the overall number of compliant transects since the last monitoring period and that there is a shift towards vegetation more indicative of wetland habitat.

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. It is also important to highlight that these wetlands are cyclic in nature and the results indicate there is landscape variability, a mosaic of habitats, across the icon site. These wetlands go through different phases due to timing of flooding and the time it takes for complete drawdown to occur. 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). 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 (Casanova and Brock 2000).

During the current monitoring period, although all of the wetlands were not inundated, with the exception of Lake Kramen, there has been substantial differences in the rate of 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. This is emphasised by achieving the highest icon site scores for species richness and abundance since surveys began in 2007–08.

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.

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 80^{th} percentile, rather than the 90^{th} percentile, as recommended in the preceding condition monitoring report (Brown et al. 2018).

In addition, 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 cm 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 edge of 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 had been established in order to investigate the overall condition of the floodplain vegetation community at the icon site. The monitoring program has also provided the opportunity to examine the efficacy of the watering program.

The following section presents the findings of the 2019–2020 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 9. A total of 17 sites have been established within these 6 locations (Table 9).

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 2020 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 9 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 from modelled natural flows at Euston (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.

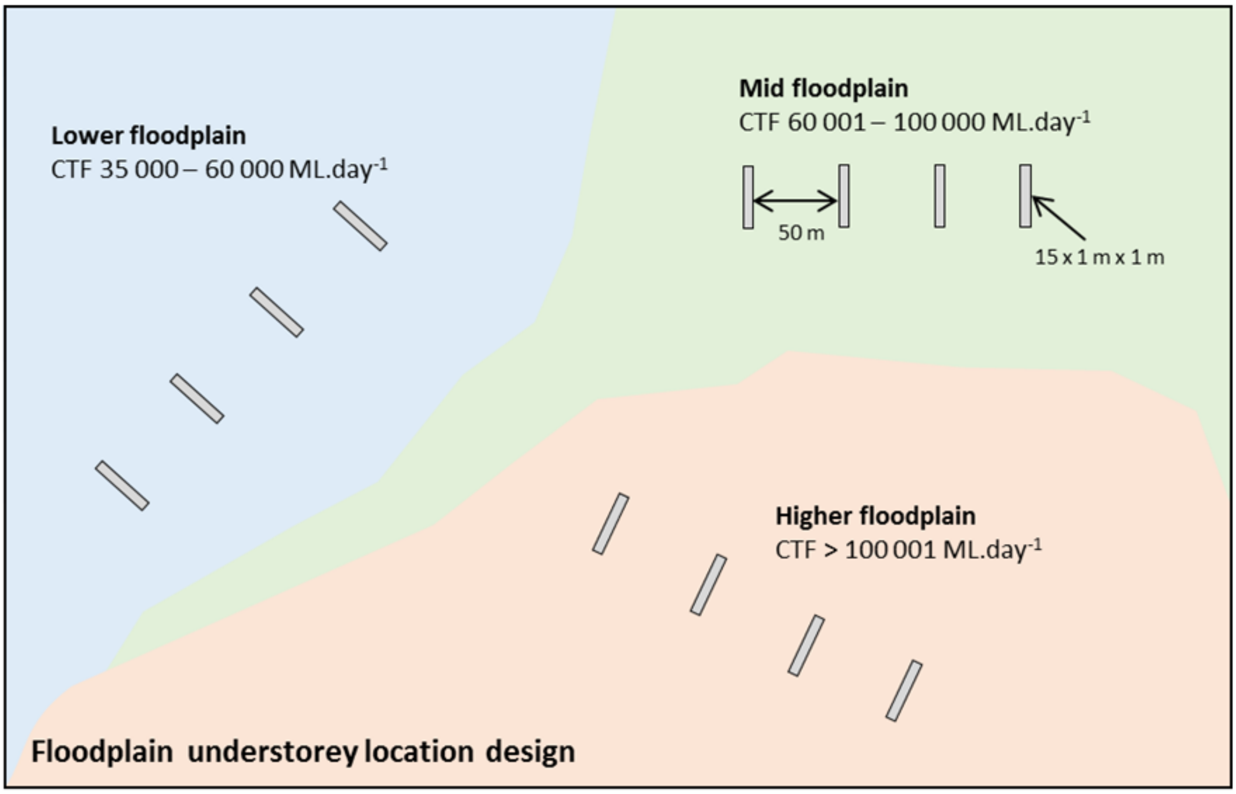

Figure 23 Schematic of the survey design used to assess floodplain understorey vegetation communities under The Living Murray program at the Hattah Lakes Icon Site (Huntley et al. 2016).

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 10). 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 10 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 and 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 129 vascular plant species was recorded from the six Hattah Lakes floodplain sites during the 2019–20 monitoring. Of these, 100 (77.5%) were indigenous and 29 (22.5%) were exotic. Ten species recorded are on the Victorian advisory list as rare or threatened plants in Victoria by DELWP (formerly DEPI) (2014) (two vulnerable, five rare and three poorly known). For further details on plant species recorded please refer to the 2019–2020 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, one was compliant (strata score of 0.17), with the floodplain species richness index. Four sites were compliant in the sometimes flooded FRF (strata score 0.67) and all sites in the rarely-flooded FRF strata (1.0) (Table 11). The current season’s results represent an increase in species richness strata scores for each FRF from 2018–19, when only one of five sites in both the rarely-flooded and sometimes-flooded FRF were compliant, and no sites in the often-flooded FRF being compliant (Figure 24).

Table 11 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 2019–20 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	1 of 6	0.17	0.902 (±0.097)	0 of 6	0	0.212 (±0.446)
Mid floodplain (sometimes)	3969.81	0.036	4 of 6	0.67		2 of 6	0.33	
Higher floodplain (rarely)	18870.03	0.00016	5 of 5	1.0		1 of 5	0.2	

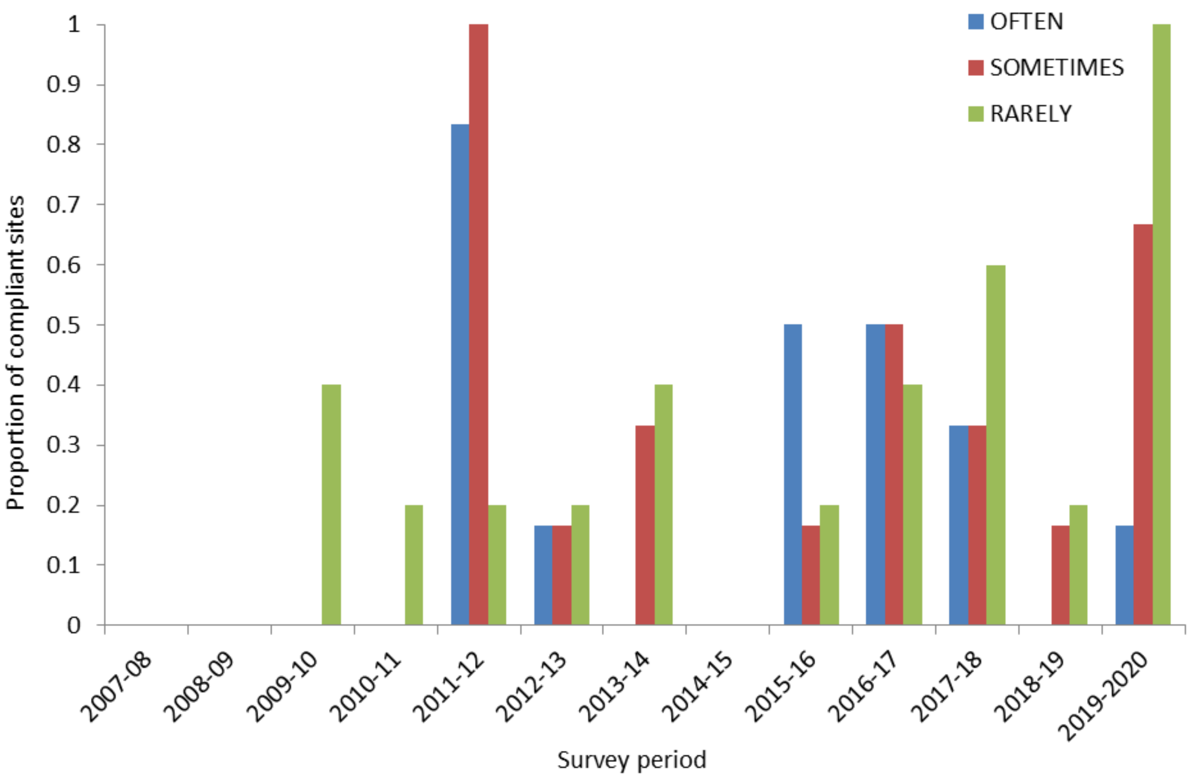

Figure 24 Proportion of compliant sites with species richness equal to or higher than the 80th percentile, within each FRF, across years.

Water-responsive species abundance

Only one site in the rarely flooded FRF was compliant with the index assessing native water-responsive species abundance in 2019–20; with two sites in the sometimes-flooded FRFs (Table 11). No sites were compliant in the often flooded FRF.

This represents a slight increase from 2018–19, when one site in the rarely- flooded FRF was compliant. This current increase in compliance is still significantly lower than recorded in 2016–17 and 2017–18 (Figure 25).

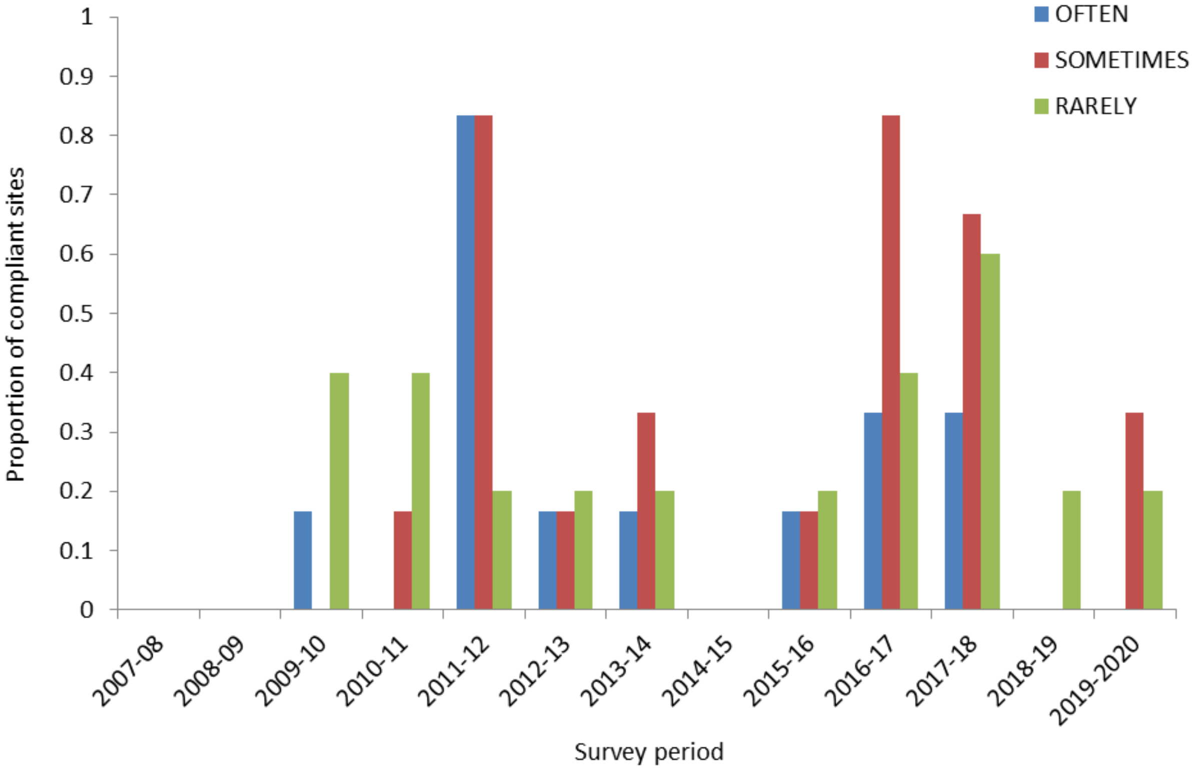

Figure 25 Proportion of compliant sites with species abundance equal to or higher than the 80th percentile, within each FRF, across years.

Whole-of-icon site score

Of the 17 floodplain sites surveyed across Hattah Lakes, ten were compliant in terms of native water-responsive species richness, one in the lower floodplain, four in the mid floodplain and five in the higher floodplain (Table 11). The icon site score for native species richness on floodplains was the highest that it has been since surveys began in 2007–08 (Table 11), having increased significantly from lower levels in 2018–19 (Figure 26). While the current season was a non-flood year, typically the species richness of native water-responsive species on Hattah Lakes floodplains is higher in seasons receiving environmental water, compared to seasons without flooding (Figure 26, Figure 27). The current survey period is an exception.

Compliant levels of native water-responsive species abundance were recorded at only three of the 17 Hattah Lakes floodplain sites in 2019–20 (Table 11). Native water-responsive species abundance across Hattah Lakes floodplains, as assessed using the icon site score, followed a different trend to species richness. The icon site score was only slightly higher (not significantly) than in 2018–19 and 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).

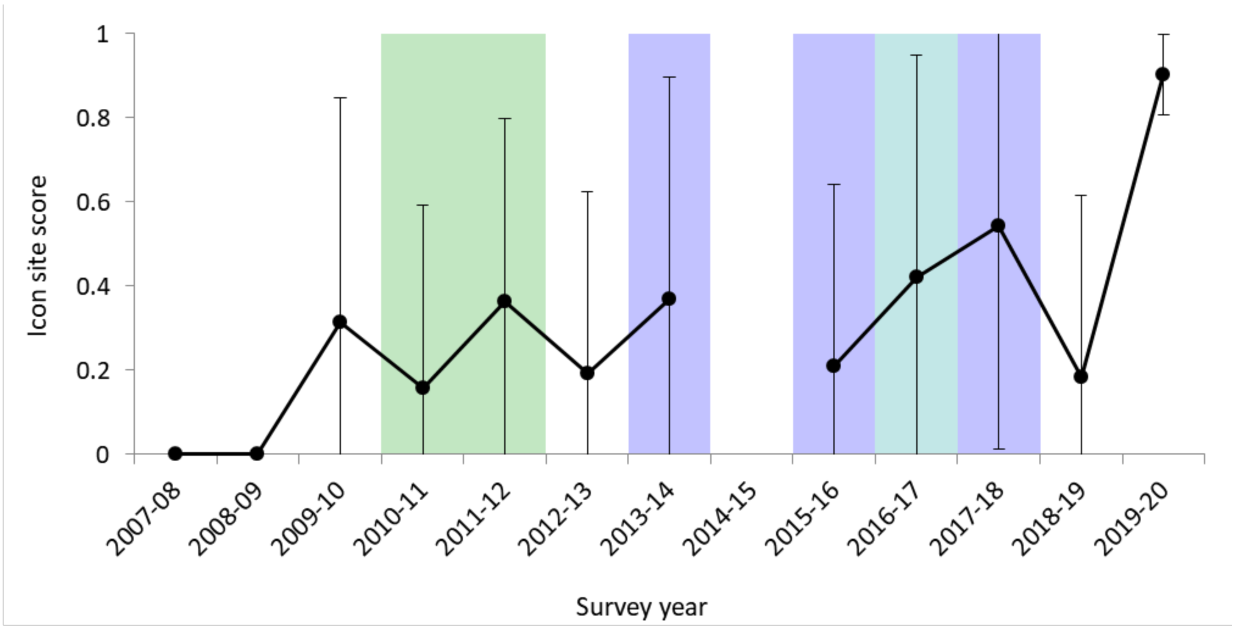

Figure 26 Icon site scores for the Hattah Lakes icon site floodplains based upon native water-responsive species richness indices and weighted across each FRF (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. No data were collected in 2014–15. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water). NB: While e-watering occurred at Hattah lakes in 2014–15, but this would not have reached the floodplain.

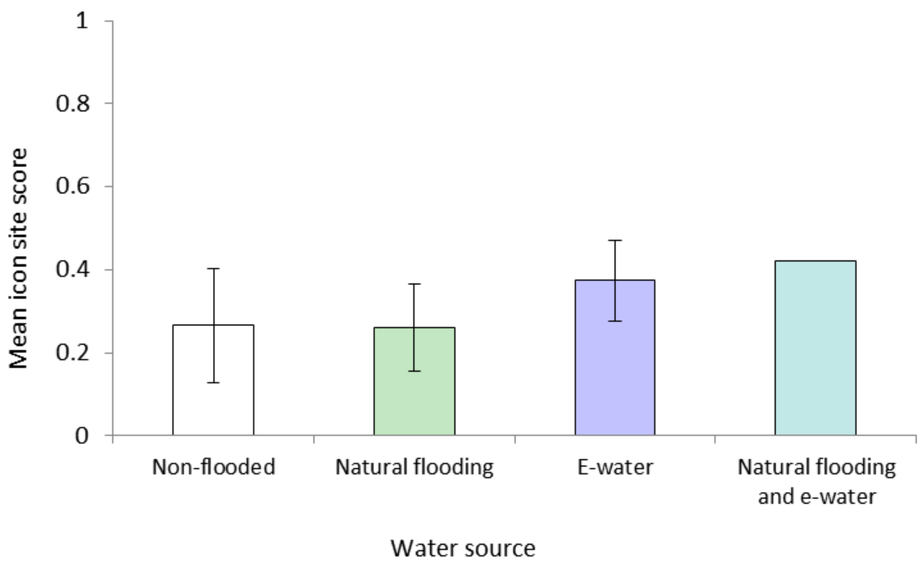

Figure 27 Mean icon site floodplain scores based upon native water-responsive species richness indices, for the Hattah Lakes icon site (± standard error), for each water event type.

Non-flooded years *n* = 6, natural flooding *n* = 2, e-water *n* = 3, natural flooding and e-water *n* = 1.

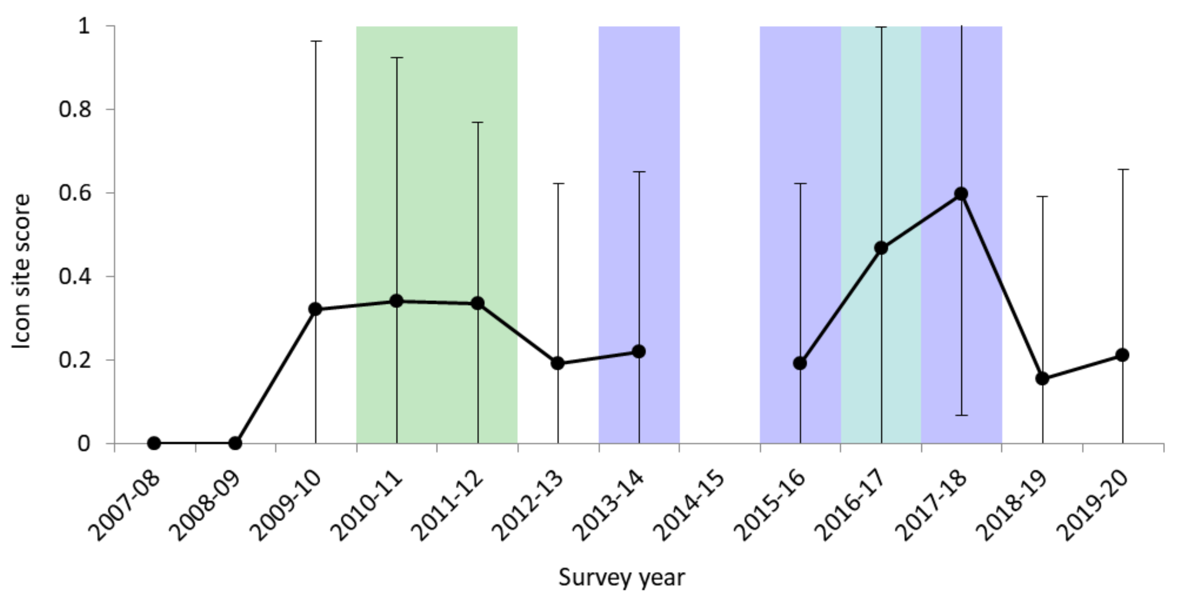

Figure 28 Icon site scores for the Hattah Lakes icon site floodplains based upon native water-responsive species abundance indices and weighted across each FRF (± 95% confidence intervals for two sampled comparisons with normally distributed error variance) across survey years. No data were collected in 2014–15. Water events are shaded (green: natural flooding; purple: e-water; teal: natural flooding and e-water). While e-watering occurred at Hattah lakes in 2014–15, but this would not have reached the floodplain.

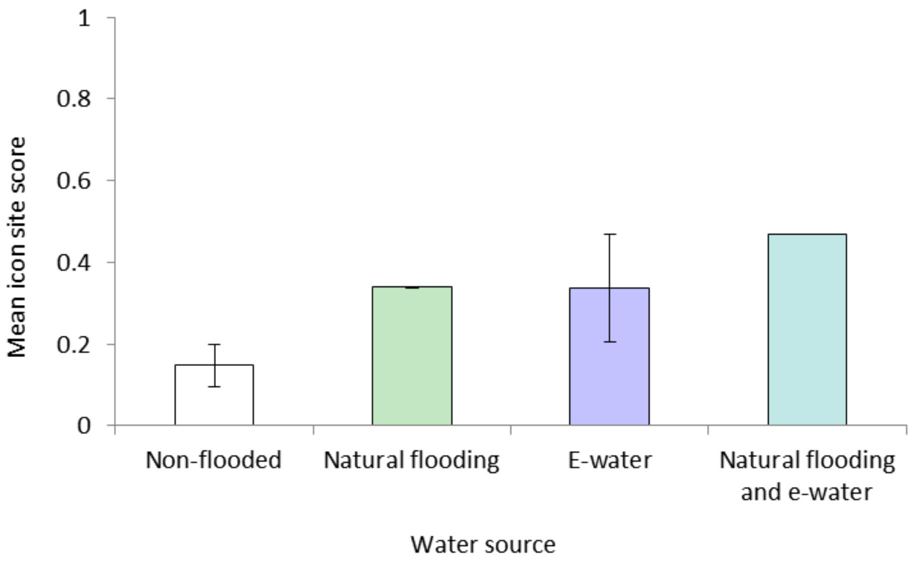

Figure 29 Mean icon site floodplain scores based upon native water-responsive species abundance indices, for the Hattah Lakes icon site (± standard error), for each water

event type. Non-flooded years *n* = 6, 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 43% at often-flooded sites, to 83% at rarely-flooded sites (Figure 28, Figure 29 and Figure 30). Terrestrial damp species (Tda) comprised over one quarter of records at often-flooded sites, declining to only 8% of records at rarely-flooded sites. Amphibious species (A) represented 23% of records at often-flooded sites, but comprised only 7% 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, although there were significant increases in drought-tolerant species and corresponding decreases in terrestrial-damp species. Small decreases in amphibious species and woody species tolerant of flooding were also noted (Figure 28). A similar pattern was evident for sometimes-flooded sites, although there was a slight increase in the proportion of amphibious species (Figure 29).

A slight decrease (not significant) in drought-tolerant and terrestrial damp species was recorded at rarely-flooded sites, with a 5% increase in amphibious species (Figure 30).

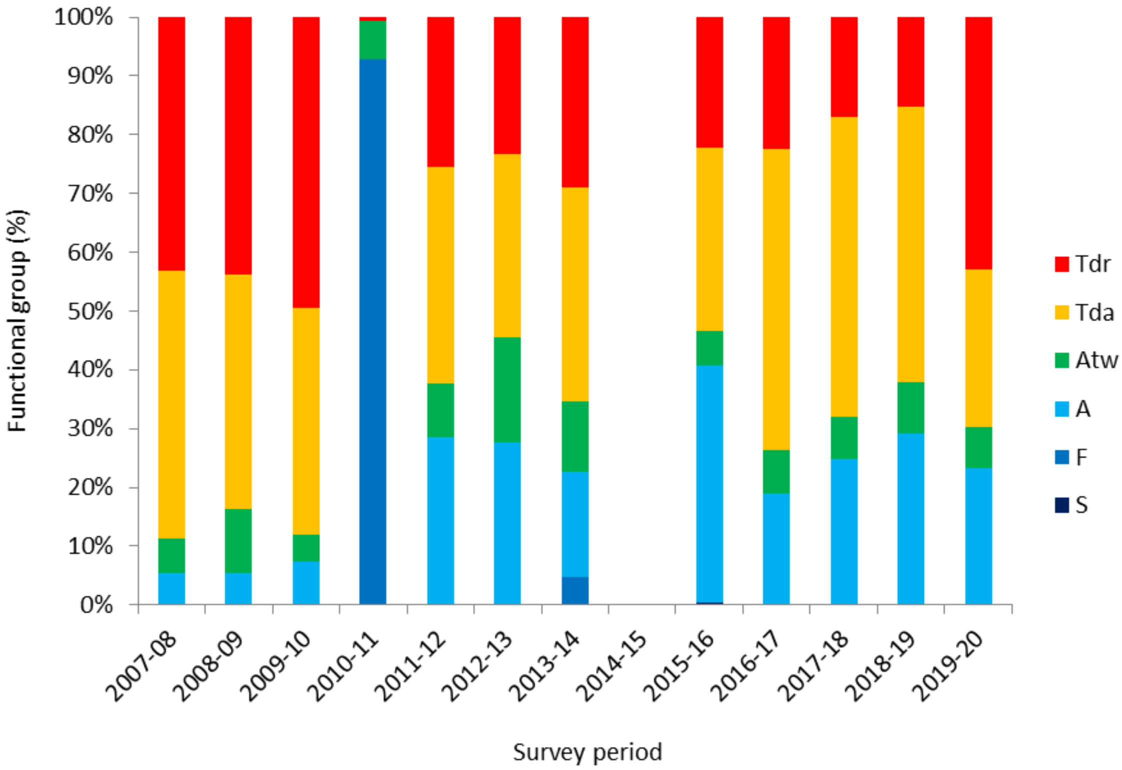

Figure 30 Proportion of sum of abundance for each functional group recorded for the Hattah Lakes often-flooded FRF sites, for each survey period. No data were collected in 2014–15.

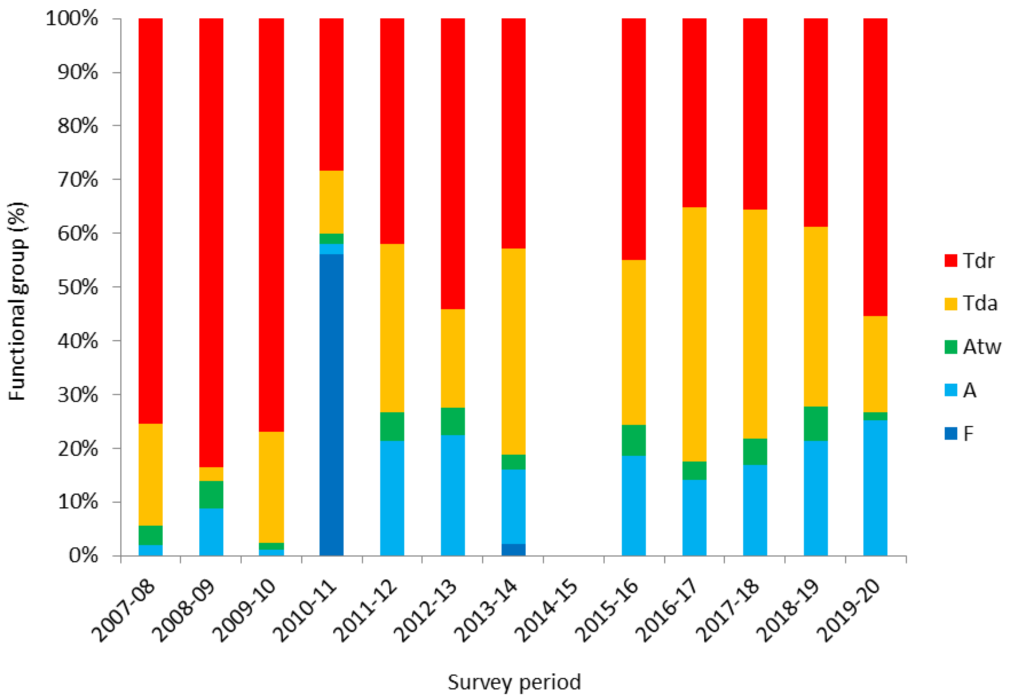

Figure 31 Proportion of sum of abundance for each functional group recorded for the Hattah Lakes sometimes-flooded FRF sites, for each survey period. No data were collected in 2014–15.

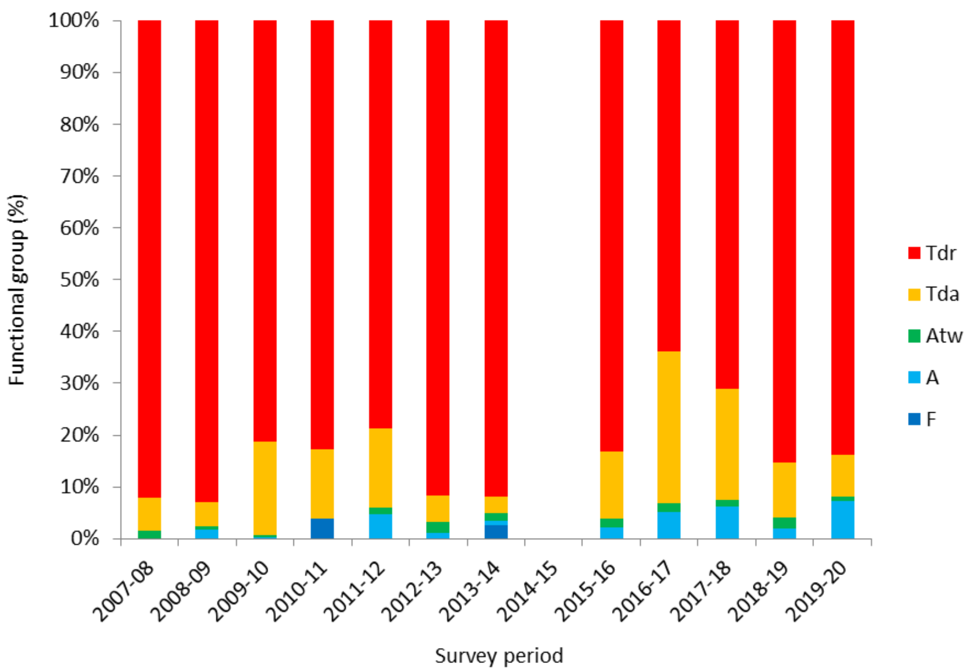

Figure 32 Proportion of sum of abundance for each functional group recorded for the Hattah Lakes rarely-flooded FRF sites, for each survey period. No data were collected in 2014–15.

5.5 Discussion

5.5.1 Whole-of-icon-site score

Whole-of-icon-site scores show there has been a marked increase in the species richness since the last survey. This species richness icon score is the highest recorded since surveying began in 2007–08. Interestingly, this is coupled with a low icon site abundance score, suggesting that while there is a high diversity of plant species recorded across the transects, they are either localised or in low abundance.

The high species richness indices observed in this survey period are unusual as they are generally recorded in years when the Hattah Lakes floodplains are inundated. Although the difference does not appear significant, natural flooding and environmental water provide similar improvements (Figure 28). The reason for this year's marginal increase is uncertain and may be due to multiple factors (e.g. slightly increased rainfall).

The proportion of terrestrial dry species has generally increased since the last survey, after having decreased over time since monitoring began in 2007–08. The high proportion of terrestrial species observed in often- and sometimes-flooded sites suggest that following the flooding events from 2016–18, the floodplains are beginning to dry and dryland species are encroaching. While it appears that native water-responsive species abundance is generally higher when the Hattah Lakes floodplains receive inundation, the difference is more consistent when this occurs as a result of natural flooding compared to environmental water (Figure 29).

5.5.2 Often-flooded

Floodplain inundation from natural flooding in 2016 and large-scale environmental watering in 2017–18 resulted in a steady increase in water-responsive plant species between 2016 and the 2018–19 survey period. The 2019–20 survey period has however shown that often-flooded sites have had a decline in the proportion of water-responsive species and a significant increase in the proportion of drought-tolerant species.

Despite the negative trend in abundance of water-responsive functional groups, water-responsive species richness has significantly increased across all FRFs with the highest record since surveying began in 2007–08. In contrast to this general trend, only one often-flooded site achieved compliance in 2019–20. Increases in both the richness and abundance of water-responsive species have been expected due to slow drawdown of the nearby wetlands since 2017–18 flooding using environmental water. While the latter has not been observed, increases in richness were. It should be noted that average rainfall was only 59% of the long-term average in 2019 (194 mm recorded at Ouyen Post Office, long-term average 328 mm; BOM 2020). It is therefore unlikely rainfall has had a major effect on the increase in species richness and abundance, with draw-down patterns expected to be a more significant contributing factor.

5.5.3 Sometimes-flooded

The plant functional group composition of water responsive species demonstrated a slight increase for the sometimes-flooded sites in 2019–20. In contrast, terrestrial species of dry habitats and often-flooded sites have increased significantly over this period. Similarly, water-responsive species richness and abundance have both increased in sometimes-flooded sites since 2018–19, the reasons for which are the same as for often-flooded sites above.

5.5.4 Rarely-flooded

Due to being situated at higher elevations than 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 has increased while species abundance has remained the same in rarely-flooded sites since 2018–19.

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 were partially met, with targets established for richness and abundance met at a rate of 58% and 18%, respectively. This was the highest for species richness since surveys began in 2007–08. However, when determining the progress towards these objectives, an assessment of vegetation dynamics over time is required. The data collected over the thirteen-year duration of the monitoring program highlight the benefit, with regard to species richness and abundance, to floodplain vegetation from the impacts of large-scale watering events, and the benefits of applying necessary management to an area over time.

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 2020). Tangled Lignum forms dominant 'Lignum' vegetation communities (such as Lignum Shrubland and Lignum Swamp), which require periodic inundation (MDBA 2012a). The hydrology of Hattah Lakes has changed due to the impacts of diverting and extracting water from the Murray River for agricultural and domestic 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, 2018–19 and 2019–20.

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) and represent the most current objective for Lignum at Hattah Lakes.

The ecological objective relating to 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 x 20 m. Data collected for each quadrat included:

- condition of every mature Lignum plant within the quadrat, using the Lignum Condition Index (LCI; Table 12);
- 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 for 2019–20 was undertaken in October–December 2019.

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 12 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), to 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 2019–20 monitoring results indicate a potential increase in Lignum condition since 2018–19, with 7% more plants obtaining an LCI score ≥4, on average across all sites (81% vs 74% respectively; Figure 33). This is after a decline in Lignum condition in 2018–19 when compared to 2017–18. The results for each Water Regime Class (WRC) show a slight positive trend in the condition of Lignum Shrubland, Lignum Swamp, and Lignum Woodlands since 2018–19 (Figure 34–36).

However, this overall increase is not reflected at the icon site scale, with the Icon Site index—i.e. the proportion of sites that exceed the target of 85%—remaining at 0.44, the same as in 2018–19. This is after a reduction from 0.57 in 2017–18 to 0.44 in 2018–19. However this reduction does not indicate a statistically significant change in condition.

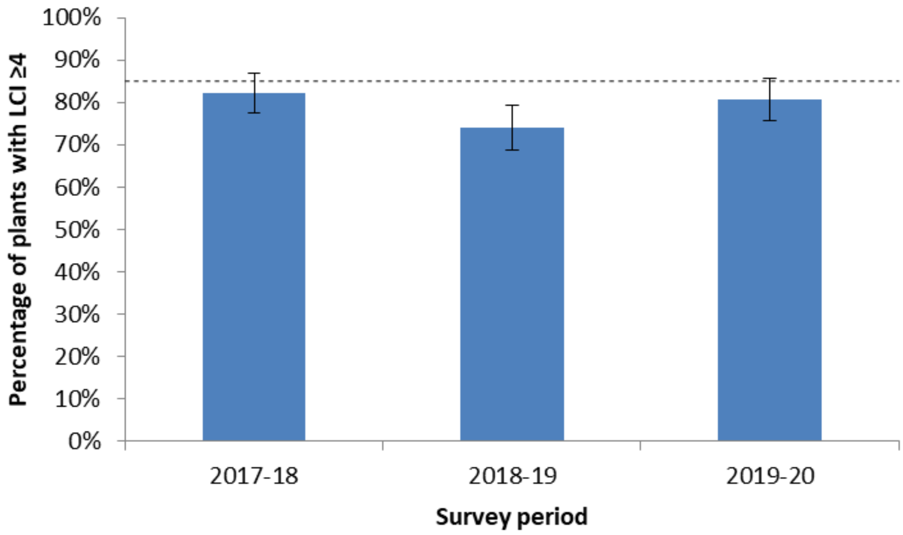

Figure 33 Mean percentage (±SE) of Lignum plants with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon site target of 85% is shown for comparison.

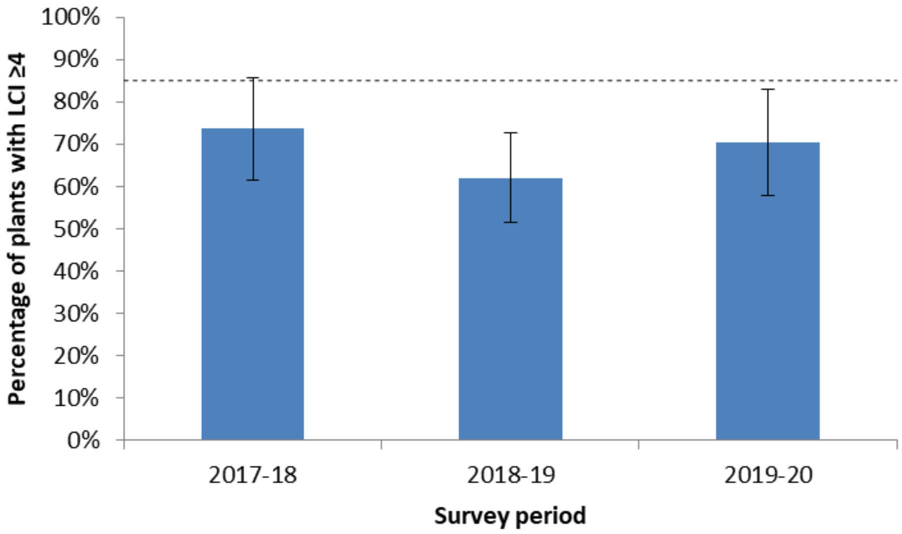

Figure 34 Mean percentage (±SE) of Lignum plants within Lignum Shrubland with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon target of 85% is shown for comparison.

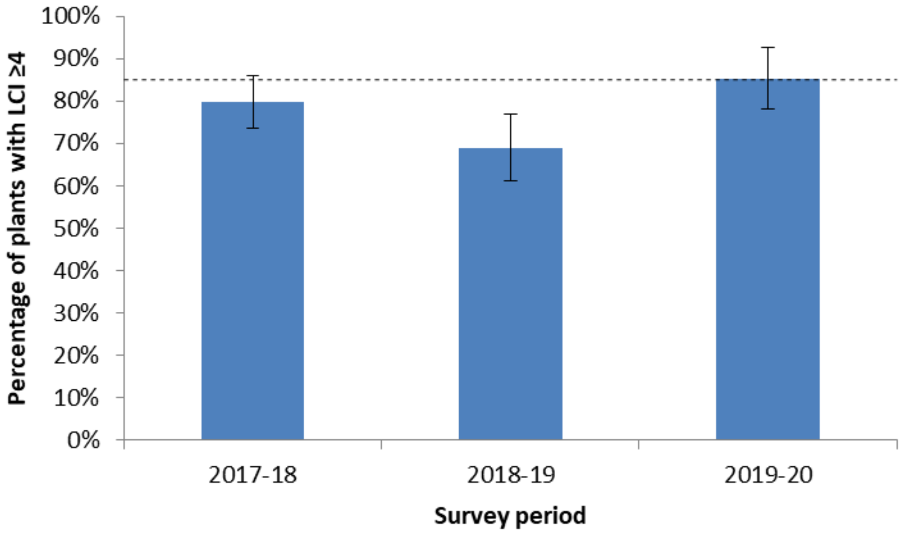

Figure 35 Mean percentage (±SE) of Lignum plants within Lignum Swamp with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon target of 85% is shown for comparison.

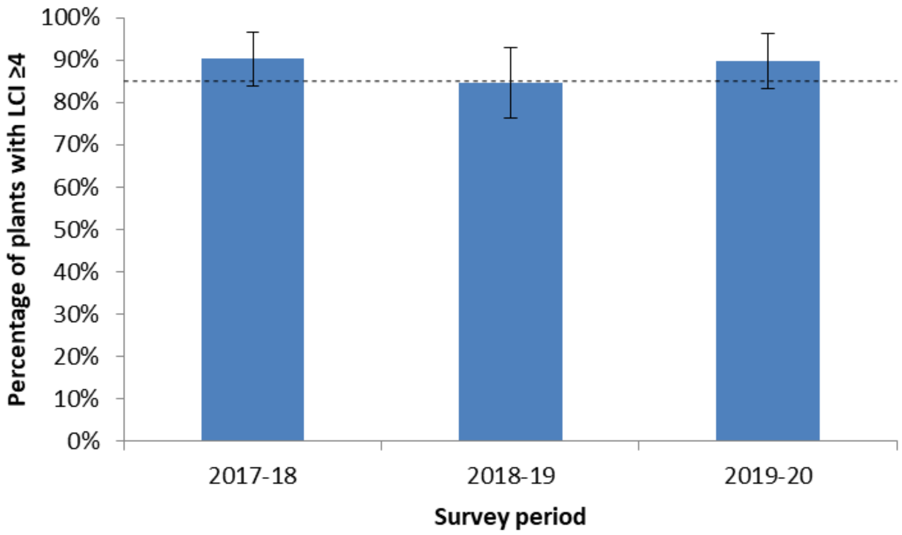

Figure 36 Mean percentage (±SE) of Lignum plants within Lignum Woodlands with LCI ≥4 at survey sites at the Hattah Lakes icon site. The icon target of 85% is shown for comparison.

6.5 Discussion

Data collected for the current round of monitoring represents the fourth year of data collection under the new method, and only the third 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 more reliant on rainfall and natural flooding.

The reliance on the compliance score may not always be an accurate indicator of site health. The compliance score does not necessarily indicate the size and condition of a Lignum stand, and only represents the proportion of healthy plants with a LCI ≥4 compared to the number of unhealthy or dead plants with a LCI <4.

This metric may misrepresent the 'health' of a Lignum stand, for example:

- compliant site H13 contained 1% Lignum cover and had 100% of plants with a LCI ≥4 (8 healthy Lignum plants)
- non-compliant site H15 had 50% Lignum cover and contained 63.64% of plants with a LCI ≥4 (58 healthy Lignum plants)

In this example the more robust—and arguably healthier—population with 58 healthy plants is non-compliant, whereas the site with only 8 plants is compliant. Both of these sites are classified within the Lignum Shrubland stratum and therefore would have similar flooding regimes. This shows the need for another index to measure the change in population size over time.

It may also be beneficial to clarify the relationship between the sites and their assigned stratum. This may highlight any outliers that may be changing the level of compliance for each given stratum and isolate specific sites that may be declining in health due to additional environmental factors.

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 possible 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 only been met for both Lignum Woodland and Lignum Swamp strata. 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 and 2019–20; however, this does not constitute a statistically significant change between years. Based on these results, the ecological objective is partially met with two, but not all, Lignum strata considered to be healthy and meeting the target condition.

6.6 Recommendations

Below we outline our recommendations to improve the existing monitoring protocol.

- To better represent the trends in Lignum populations we recommend that percentage cover of Lignum is recorded annually in each quadrat. This index will represent the general size of each population at each site (Table 13).
- To determine the relationships between sites within each stratum (based on the number of Lignum plants), we suggest completing an ordination, such as a principle component analysis, which would identify any outlying sites. This is important, as outliers can have a disproportionate effect when there is low site replication, as in this component (i.e. approximately 5 sites per stratum).
- Investigate a potential correlation between the number of Lignum plants at a site and the % LCI ≥4. For example, sites with high Lignum density may have a higher proportion of dead plants. A relationship between the number of plants within a site and the likelihood of a site being compliant may demonstrate a confounding factor the method.

Table 13 Table showing the overall vegetation cover and percentage of plants with a LCI ≥4 for each site within Hattah Lakes.

Lignum Site	Cover (%)	% LCI ≥4
H1	20	100%
H3	5	68.29%
H4	15	92.73%
H7	20	100%
H9	12	81.01%
H11	15	70.24%
H12	2	66.67%
H13	1	100%
H14	2	29.03%
H15	50	63.64%
H16	10	100%
H17	7	77.78%
H18	20	73.38%
H19	30	95.24%
H20	10	72.55%
H21	20	100.00%

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)*, 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 (i.e. Bloink et al. 2019, 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 20 minutes (longer when large numbers of waterbirds were present). Maximum species counts were agreed upon by the two observers. At the request of the Mallee CMA, where wetlands were dry, a 20-minute timed count was conducted of any non-waterbird species using or inhabiting the dry lake surface or riparian vegetation. 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 will be repeated, with each site visited in both spring 2019 and autumn 2020.

The following wetlands were surveyed:

- Lake Kramen;
- Lake Arawak;
- Lake Mournpall;
- Lake Hattah;
- Lake Lockie (two survey points);
- Lake Yerang;
- Lake Konardin;
- Lake Woterap;
- Nip Nip Lake;
- Lake Brockie;
- Lake Bulla;
- Little Hattah Lake;
- Lake Bitterang;
- Lake Cantala;
- Lake Yelwell.

7.5 Results

The fifteen wetlands in the Hattah Lakes icon site were visited between 7 and 8 October 2019 (spring) and again between 23 and 24 April 2020 (autumn). Seven wetlands held water during the spring survey period (Figure 6 in the 2019–20 Part B report). By surface area, Lake Mournpall was estimated to be 70% full; Lake Cantala 60% full; Lake Hattah 50% full; Lakes Bulla and Bitterang were 30% full and; Lake Arawak was 20% full. Lake Kramen was receiving environmental water and was estimated as 95% full during the spring survey. The remaining wetlands surveyed were dry with Lake Woterap classed as effectively dry (estimated to be less than 1% full with a tiny pool of remnant water rendered unsuitable for waterbirds by the presence of a large number of rotting Common Carp).

Only Lake Kramen retained water during the Autumn 2020 surveys (estimated at 100% full). All the remaining lakes were dry. The surface area and estimated water levels at each wetland are provided in Table 14 and Table 11 of the 2019–20 Part B report.

Table 14 Size of surveyed wetlands in the Hattah Lakes icon site that contained water during the waterbird census of the 2019-20 season, approximate area of surface water (estimated visually) and density of observed waterbirds.

Wetland	Spring 19							Autumn 20
	Lake Arawak	Lake Mournpall	Lake Hattah	Lake Bulla	Lake Bitterang	Lake Cantala	Lake Kramen	Lake Kramen
total area (ha)	40	243	61	40	73	101	880	
% full	20	70	50	30	30	60	97	100
surface water area (ha)	8	170.1	30.5	12	21.9	60.6	836	880
waterbird density (birds surface water area $^{-1}$)	15.6	1.3	4.9	31.6	30.6	1.3	0.5	0.2

Waterbirds were generally only recorded at wetlands that held water at the time of survey. Only two species were recorded at dry wetlands — a pair of Masked Lapwings (*Vanellus miles)* at Lake Woterap in Spring 2019 and four Australian White Ibis (*Threskiornis moluccus)* at Lake Mournpall in Autumn 2020 (Part B; Table 11). Waterbird species, and the total number of individuals of each species, recorded across all monitored wetlands at the Hattah Lakes icon site is provided in Table 11 of the 2019–20 Part B report. The results of surveys at individual wetlands is provided in Table 11 of the 2019–20 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.

7.5.1 Numbers of waterbirds at selected wetlands

A total of 2199 waterbirds, comprising 32 species, were observed during the spring 2019 surveys across the Hattah Lakes icon site, somewhat higher than last spring where 26 species were recorded. However, estimated abundance and richness fell greatly during the autumn 2020 surveys with only 156 waterbirds comprising 9 species recorded (Table 14). This is also significantly lower than the 28 species recorded in autumn 2019. The highest count of waterbird species was at Lake Bitterang (671) all recorded during the spring survey and it is notable that 577 of these (86%) were from the shorebird guild. Lake Bitterang was also notable for holding the only migratory shorebird species observed during the 2019–20 surveys with 20 Sharp-tailed Sandpipers and a single Common Greenshank observed feeding in the shallow waters of this lake. Dabbling ducks were most abundant at Lake Bulla during the spring survey (372), mostly composing Grey Teal (*Anas gracilis)*. Grebes and diving ducks (both of which favour deeper water) were best represented at Lake Kramen by total counts of 161 and 107 respectively for spring and autumn. Lakes Bulla and Bitterang displayed the highest density of waterbirds with 31.6 and 30.6 birds per hectare of surface water area (birds/ha) respectively.

7.5.2 Waterbird breeding

No waterbird breeding was observed during either the spring or autumn surveys. Some disused nests of colony-breeding waterbird species were observed at some of the wetlands but none of these were less than a year old and had not been rebuilt or used in recent months. No other evidence of waterbird breeding was observed.

Table 15 Total counts of waterbird species (by guild) and species richness, observed during fixed-point surveys at wetlands in the Hattah Lakes icon site during the 2019–20 season. Wetlands at which no waterbirds were observed are not shown here.

Wetland		Kramen	Arawak	Mournpall	Hattah	Bulla	Bitterang	Cantala	Totals
Coots & Rails		**82**			**5**			**1**	**88**
Eurasian Coot	*Fulica atra*	82						1	**83**
Dusky Moorhen	*Gallinula tenebrosa*								**0**
Black-tailed Native-hen	*Tribonyx ventralis*				5				**5**
Dabbling Ducks		**129**		**111**	**106**	**372**	**27**	**39**	**784**
Grey Teal	*Anas gracilis*	128		108	103	362	27	38	**766**
Chestnut Teal	*Anas castanea*					8			**8**
Pacific Black Duck	*Anas superciliosa*	1		3	3	2		1	**10**
Diving Ducks		**107**							**107**
Hardhead	*Aythya australis*	102							**102**
Musk Duck	*Biziura lobata*	5							**5**
Filter-feeding ducks						**6**			**6**
Australasian Shoveler	*Anas rhynchotis*					6			**6**
Pink-eared Duck	*Malacorhynchus membranaceus*								**0**
Fish-eaters		**13**		**36**	**3**		**3**	**29**	**84**
Australian Pelican	*Pelecanus conspicillatus*			27	3		1	22	**53**
Great Cormorant	*Phalacrocorax carbo*			2				3	**5**
Little Black Cormorant	*Phalacrocorax sulcirostris*	13							**13**
Little Pied Cormorant	*Microcarbo melanoleucos*			1			2		**3**
Pied Cormorant	*Phalacrocorax varius*			6				4	**10**
Grazing ducks		**19**		**45**	**22**		**44**	**5**	**135**

Wetland		Kramen	Arawak	Mournpall	Hattah	Bulla	Bitterang	Cantala	Totals
Australian Shelduck	*Tadorna tadornoides*	16					44		**60**
Australian Wood Duck	*Chenonetta jubata*	3		45	22			5	**75**
Grebes		**198**		**2**				**1**	**201**
Australasian Grebe	*Tachybaptus novaehollandiae*	30							**30**
Great Crested Grebe	*Podiceps cristatus*	11		2					**13**
Hoary-headed Grebe	*Poliocephalus poliocephalus*	157						1	**158**
Large wading birds				**34**			**1**	**3**	**38**
Australian White Ibis	*Threskiornis moluccus*			4					**4**
Eastern Great Egret	*Ardea modesta*							1	**1**
White-faced Heron	*Egretta novaehollandiae*			2					**2**
White-necked Heron	*Ardea pacifica*								**0**
Yellow-billed Spoonbill	*Platalea flavipes*			31			1	2	**34**
Royal Spoonbill	*Platalea regius*			1					**1**
Shorebirds			**125**		**9**	**2**	**577**	**5**	**718**
Red-necked Avocet	*Recurvirostra novaehollandiae*		73				368		**441**
Pied Stilt	*Himantopus leucocephalus*		19		2		183		**204**
Common Greenshank	*Tringa nebularia*						1		**1**
Masked Lapwing	*Vanellus miles*		16		6	2	5		**29**
Red-kneed Dotterel	*Erythrogonys cinctus*		15						**15**
Black-fronted Dotterel	*Elseyornis melanops*		1		1			5	**7**
Red-capped Plover	*Charadrius ruficapillus*		1						**1**
Sharp-tailed Sandpiper	*Calidris acuminata*						20		**20**
Swans		**2**			**2**		**2**		**6**
Black Swan	*Cygnus atratus*	2			2		2		**6**
Terns				**5**	**4**		**17**		**26**
Whiskered Tern	*Chlidonias hybridus*			5	4		17		**26**
	Total number of waterbirds	**550**	**125**	**237**	**151**	**380**	**671**	**83**	**2199**
	Species richness	**10**	**6**	**13**	**9**	**5**	**12**	**11**	**23**

7.5.3 Guild and species composition

The most abundant waterbird guild encountered during the 2019–20 monitoring surveys were dabbling ducks with a total count across all Hattah Icon Lakes of 784 birds representing 36% of all waterbirds counted (Table 16). This is consistent with the results of the last seasons monitoring when dabbling ducks represented 40% of the waterbirds observed. Grey Teal were the most abundant making up 98% of the observed dabbling ducks with a total count of 766 (Table 15). A group of eight Chestnut Teal (*Anas castanea)*, were observed at Lake Bulla and Pacific Black Ducks (*Anas superciliosa)* were in small numbers at several lakes.

Shorebirds (715) accounted for 32% of all waterbirds counted with the majority of these from Lakes Bitterang (577) and Arawak (125). This represents a significant increase on the numbers recorded during the previous season when shorebirds made up only 4% of records. The only migratory members of this guild were counted in the spring 2019 survey when 20 Sharp-tailed Sandpipers, and a single Common Greenshank were recorded at Lake Bitterang. The majority of shorebirds counted were Red-necked Avocets (441) accounting for 61% of all shorebirds. A total of 204 Pied Stilts (*Himantopus leucocephalus),* were counted, composing a further 28% of shorebirds with the remainder of this guild made-up by small numbers of Masked Lapwing (31); Red-kneed Dotterel (*Erythrogonys cinctus)* (15); Black-fronted Dotterel (*Elseyornis melanops)* (9) and; Red-capped Plover (*Charadrius ruficapillus)* (1).

After these two groups, there was a considerable drop-off to the next most abundant guild: the grebes. This group feeds by diving for small fish, crustaceans and other invertebrates. The three species of grebe within this guild made up 9% of the total waterbird count. Hoary-headed Grebes (*Poliocephalus poliocephalus)* made up the majority of this guild with 157 recorded at Lake Kramen.

There was a near four-way tie for the next most abundant guild: grazing ducks (6%), diving ducks (5%), coots and rails (4%) and fish-eaters (4%). The grazing ducks were represented by two species: Australian Wood Duck (*Chenonetta jubata)* and Australian Shelduck (*Tadorna tadornoides)*. The latter of these two species has a more diverse set of feeding habits and a higher tolerance for saline water. Australian Wood Duck has more a specific requirement for green fodder on the shoreline. The abundance of this species relative to that of the Australian Wood Duck has greatly increased since the previous season's surveys when the Australian Wood Duck was far more abundant. This change may reflect the reduction in available water and the salinity levels of wetlands across both icon sites. The diving ducks were also represented by two species: Musk Duck and Hardhead (*Aythya australis)*. As sub-surface feeders, these species have similar feeding requirements to the grebes, a fact reflected by their concentration on the deep and clear waters of Lake Kramen. The coots and rails guild was dominated by Eurasian Coots (*Fulica atra)* with a total of 82 birds recorded at Lake Kramen. The fish-eating guild fielded a richer species composition with five species, composed of Australian Pelican (*Pelecanus conspicillatus)* and four species of cormorant: Little Pied Cormorant (*Microcarbo melanoleucos)*, Great Cormorant (*Phalacrocorax carbo)*, Pied Cormorant (*P. varius)*, and Little Black Cormorant (*P. sulcirostris)*. A total of 53 Australian Pelicans was counted during the spring survey and none were observed during the autumn survey, which represents a significant drop in numbers since the previous seasons surveys when 1065 were counted in autumn 2018 alone.

The remaining four waterbird guilds made up a relatively small portion of the total count (< 4% combined). Large wading birds were responsible for 2% of records, terns accounted for 1% and Swans and Filter-feeding ducks both contributed <1% of the total waterbirds observed.

Table 16 Number of waterbirds by guild observed during the spring 2019 and autumn 2020 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 & Rails	11	77	88	44	4.00%
Dabbling Ducks	783	1	784	392	35.65%
Diving Ducks	106	1	107	53.5	4.87%
Filter-feeding ducks	6	0	6	3	0.27%
Fish-eaters	72	12	84	42	3.82%
Grazing ducks	132	3	135	67.5	6.14%
Grebes	145	56	201	100.5	9.14%
Large wading birds	38	4	42	21	1.91%
Shorebirds	720	0	720	360	32.74%
Swans	4	2	6	3	0.27%
Terns	26	0	26	13	1.18%
Total abundance	**2043**	**156**	**2199**	**1099.5**	**100.00%**
Species richness	**22**	**9**	**23**	**15.5**	

7.5.4 Species richness

A total of 23 waterbird species were observed from 11 guilds across both surveys at the wetlands of the Hattah Lakes icon site (Table 15 and Table 16). This represents a reduction in richness from the previous season which recorded 32 species across 12 guilds (Bloink et al. 2019). Species richness fell dramatically between surveys, with 22 and 9 species recorded in spring 2019 and autumn 2020, respectively. The highest species richness was recorded at Lake Mournpall (13 species), 12 species were observed at Lake Bitterang, and 11 species were observed at Lake Cantala (Part B; Table 13).

7.6 Discussion

The results of the spring 2019 monitoring were broadly consistent with previous years, keeping to the general understanding that waterbirds respond to flooding and the presence of water in the landscape. Waterbirds were almost exclusively observed at wetlands holding water. Lake Woterap was the only exception in spring, fielding a single pair of Masked Lapwings (this is a species often found farther from open water than most waterbird species). This trend held true for the Autumn 2020 surveys where very few waterbirds were recorded due to only Lake Kramen holding water. A small group of four Australian White Ibis were observed at Lake Mournpall, which was dry during autumn 2020. Similar to the masked lapwing, this species is often found further from standing water. No other water species were observed utilising dry lake beds.

The total number of waterbirds, species richness and species composition recorded at wetlands containing water reflected wetland characteristics, such as wetland size and topography, water levels, water quality and the habitats they provide.

Waterbird communities at the Hattah Lakes were characterised by dabbling ducks and shorebirds. The high proportion of these guilds, which forage in shallow water, distinguishes the reduction of deeper lakes in the Hattah Lakes icon site during the 2019–20 season. Species that rely on deeper clearer water, such as the fish-eater guild, were mostly found at Lake Kramen which had recently received environmental water.

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 2019–20 monitoring recorded much lower waterbird numbers compared with 2018–19, representing an almost 300% decrease (Bloink et al. 2019). This season a greater number of wetlands were surveyed as part of the current monitoring year (15 in 2019–20 compared with 13 in 2018–19). A 65% decrease in waterbird density was observed during the spring 2019 survey; however, there was almost a forty-fold decrease recorded in the autumn 2019 survey, compared with the previous year respectively. It is likely that the most significant factor driving these reductions is the number of water bodies retaining water (seven wetlands were holding water during both surveys in the 2018–19 monitoring period while only one wetland retained water by the autumn 2020 survey).

With the exception of Lake Kramen, no environmental water was delivered to the Hattah Lakes in 2019–20, and while several of the wetlands surveyed still held water during the spring survey, the availability of water in the local landscape was reduced from previous years. Aside from this reduction, likely associated with wetland drawdown and drying, the drop in waterbird numbers may be partially explained by reported breeding activity further inland. Some ephemeral lakes were reported to be still holding water from rainfall across the Lake Eyre Basin earlier in the year (BOM 2019). Such events can attract large numbers of water birds (e.g. Australian Pelicans) to colonial breeding events triggered by abundant fish populations in Lake Eyre and neighbouring water bodies (Kingsford and Porter 1993).

Unlike previous years, significantly fewer waterbirds were also recorded in autumn 2020 than spring 2019 (Table 16; Bloink et al. 2019, see also McKillop et al. 2018, Wood et al. 2018). It is likely that as wetlands dried over summer, waterbirds sought habitat elsewhere.

Species considered rare, threatened or near threatened recorded in 2019–20 surveys included the Whiskered Tern (*Chlidonias hybridus javanicus)*, Musk Duck, Pied Cormorant and Australasian Shoveler. Freckled Duck, Nankeen Night Heron (*Nycticorax caledonicus)*, Dusky Moorhen (*Gallinula tenebrosa)* and Little Egret (*Egretta garzetta)* were not recorded in the current surveys. Two migratory species were recorded at Lake Bitterang: the Sharp-tailed Sandpiper and Common Greenshank. These species were likely making use of the shallow water habitat the lake provided as it dried out.

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:

- Seven of the 15 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 of Threatened Vertebrate Fauna (DSE 2013), although only one retained water until the autumn 2020 survey. Two migratory species were recorded in the current season.
- No waterbird breeding was observed during either survey. Several nests were observed but none were less than a year old and had not been rebuilt or used in recent months.

In addressing the detailed objectives:

- Freckled Duck, Grey Falcon and White-bellied Sea-Eagle were not recorded during the 2019–20 surveys.
- No colonial waterbirds were observed to be breeding during the current season.
- Two migratory species were recorded in the current season.

8 Non-Waterbirds

8.1 General

At the request of Mallee CMA, the 2019–20 surveys included observations of non-waterbird species at lakes that were dry in order to provide a general appreciation of how varying water levels may affect the way birds use both fringing vegetation and wetland surfaces even when not inundated.

8.2 Methods

Non-waterbirds species were documented at wetlands when observed using the wetland surface or riparian vegetation. Where wetlands were dry, a 20-minute timed count was conducted of any non-waterbird species using or inhabiting the dry lake surface or riparian vegetation. Evidence of breeding and recruitment (i.e. nests, juveniles) were recorded incidentally.

8.3 Results

Fifteen wetlands were visited between 7 and 8 October 2019 and again between 23 and 24 April 2020. Eleven of the lakes were assessed as dry in spring 2019 and 14 in autumn 2020. A total of 933 non-waterbirds across 33 species were counted at the Hattah Lakes icon sites this season. Abundance was highest at Lake Lockie which yielded 278 non-waterbirds. Lake Lockie also displayed the highest level of species richness with 21 non-waterbird species. The lowest abundance was at Lake Little Hattah which had just 25 non-waterbirds present and Lake Bulla which had 18. Lake Kramen had the lowest non-waterbird species richness with just a single species observed using the immediate environs of the inundated wetland.

Non-waterbird species recorded at each site, including guild classification, are provided in Table 11 in the 2019–20 Part B report, along with total non-waterbird numbers and species richness for the 2019–20 season surveys.

8.4 Discussion

The guild composition and habitat preferences of non-waterbird species are more varied than among waterbirds. As a result, non-waterbirds tend to provide a somewhat less-definitive measure of the degree to which the program is achieving its goals. Fluctuations may simply reflect seasonal movements, meteorological or climatic conditions at the time of a survey or other influences beyond the scope of the program's aims.

However, some species of conservation significance were observed and all bird species, simply by their abundance/absence and the diversity of species present can be an indicator of ecosystem health at a given moment in time (Gill 2007). The Vulnerable Regent Parrot (*Polytelis anthopeplus)* was observed in small- to medium-sized flocks at eight wetlands. Recently-fledged immature birds (with adult birds in attendance) were observed leaving nest hollows in River red gums (*Eucalyptus camaldulensis)* on the shores of Lake Lockie during the spring 2019 survey. Adult Regent Parrots were also observed in courtship and copulation in fringing vegetation around Nip Nip Lake during the spring 2019 survey. Further medium sized groups were observed at Lake Lockie during autumn 2020 survey indicating the adults may have spent the majority of their breeding season in the area. This species has been in decline over much of its range since the 1990s and is known to be faithful to the same nesting area for many years (Baker-Gabb and Hurley 2011). The protection of large, hollow-bearing trees in known breeding areas is important to ensure these colonial breeding sites remain attractive to returning birds.

9 Fish Communities

9.1 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).

9.2 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).

9.3 Methods

9.3.1 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 three different flow categories referred to as 'macrohabitats', including:

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

9.3.2 Sampling methods

Fish sampling was undertaken in accordance with the methods detailed in Huntly et al. (2016). Fish sampling was undertaken 1–31 March. Sampling was only undertaken at the riverine sites, because Chalka Creek and the seven wetlands were dry (Table 16). A small amount of water may have been present in Lake Mournpall; however, it was determined in consultation with Mallee CMA that survey of this waterbody was not warranted due to fish relocation and fish kills that had occurred in the months prior. The location of sites was consistent with previous years.

Table 16 TLM Condition Monitoring fish sites for Hattah Lakes sampled in 2020

Location	Reach	Macrohabitat	Sites sampled (2020)	Site dry (2020)
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 due to water availability (Table 17).

Table 17 Summary of Hattah Lakes TLM condition monitoring sites sampled each year. Shaded rows indicate years where sampling occurred during a different season to the 2010-2020 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)		✓		✓			✓	✓	
2009	Not sampled								
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)	✓	✓		✓			✓	✓	
2020 (Mar)								✓	

Backpack electrofishing and fyke netting are the primary methods used for all sites except the Murray River sites, where boat electrofishing is 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.

Boat electrofishing was undertaken using Sustainable Rivers Audit protocols (e.g. 12 x 90 second shots) (MDBC 2007). Boat electrofishing was undertaken using a medium sized (4.0 m long) Smith Root 7.5 GPP boat electrofisher. All boat electrofishing was undertaken with the use of one 'netter' positioned at the front of the boat. 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. Seine netting (1 x 180 degree haul) was undertaken at all sites.

9.3.3 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.

9.4 Results

9.4.1 Overview summary

The 2020 survey included only the Murray River sites and recorded 637 fish from eleven species, nine of which were native (Table 18). Murray Cod *Maccullochella peelii* was captured in the second highest numbers recorded over the 2010–2020 monitoring period. No goldfish were recorded in 2019–20, the first time this species has not been detected over the monitoring period, however this species has been recorded in very low abundance on several occasions previously (2013, 2016–17).

The large-bodied Bony Herring *Nematalosa erebi* comprised over 39% of all fish recorded, followed by the small bodied Unspecked Hardyhead *Craterocephalus fulvus* (previously known as *Craterocephalus stercusmuscarum fulvus*) (24%) and Australian Smelt *Retropinna semoni* (2.5%). Carp *Cyprinus carpio* were less abundant than Murray Cod. Although only four Silver Perch were recorded, one was a Young of Year (51 mm FL), which represents only the second Young of Year of this species recorded by the TLM monitoring since 2014.

Table 18 Summary of the 2010–2020 Hattah fish monitoring results including flow guild designations (Baumgartner et al. 2014).

		Year									
		2010	2011	2012	2013	2014	2016	2017	2018	2019	2020
		# of sites sampled									
Common name	Flow guild	21	21	27	9	27	21	27	27	15	3
Native large-bodied											
Silver Perch	Flow dependent specialists	11	1	1	1	3	2		5	1	4
Spangled Perch	NA		1	1							
Golden Perch	Flow dependent specialists	32	78	41	12	35	31	41	34	44	21
Murray Cod	Long-lived apex predators	5		1	7	30	52		8	38	48
Bony Herring	Foraging generalists	672	126	337	270	1190	494	449	513	418	249
Native small-bodied											
Unspecked Hardyhead	Foraging generalists	214	1263	97	19	81	198	25	9	28	152
Carp Gudgeon complex	Foraging generalists	213	46029	14700	323	641	11026	34765	24393	8628	5
Murray-Darling Rainbowfish	Foraging generalists	23	39	10	11	32	98	77	4	31	37
Flat-headed Gudgeon	Foraging generalists	8	191	170	1	1	666	1404	1312	451	8
Dwarf Flat-headed Gudgeon	Foraging generalists		1				12	41	35	12	
Australian Smelt	Foraging generalists	401	203	37	27	133	1969	4838	7276	262	69
Exotic large-bodied											
Carp	NA	39	1126	604	81	6950	46	988	104	144	40
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	4
Oriental Weatherloach	NA		49	8		54	8		5		
Total		1820	54103	17441	1197	11552	27047	49456	59092	10461	637
Average fish per site		87	2,576	646	133	428	1,288	1,832	2,189	697	232

9.4.2 Iconic species: Murray Cod

Murray Cod abundance has fluctuated considerably over the course of the monitoring program. The highest abundances were recorded in 2016, 2020, 2019 and 2014 (where 52, 48, 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 from 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 mm TL) 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). Note – no Murray Cod were captured in 2017.

Macrohabitat	Waterbody	2006	2007	2008	2010	2012	2013	2014	2016	2018	2019	2020
Riverine	Murray River	6	7	2	4	1	7	26	52	8	26	48
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**	**48**

In 2020, an adult Murray Cod was recorded during Hattah TLM monitoring, the first record of an adult 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 most years except those proceeding major flooding events (2011–2012 and 2017) and in fairly consistent proportional abundances within years (Figure 37). 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 2019–20 results are indicative of some recovery based on a moderate increase in catch per unit effort and evidence of successive years of recruitment success.

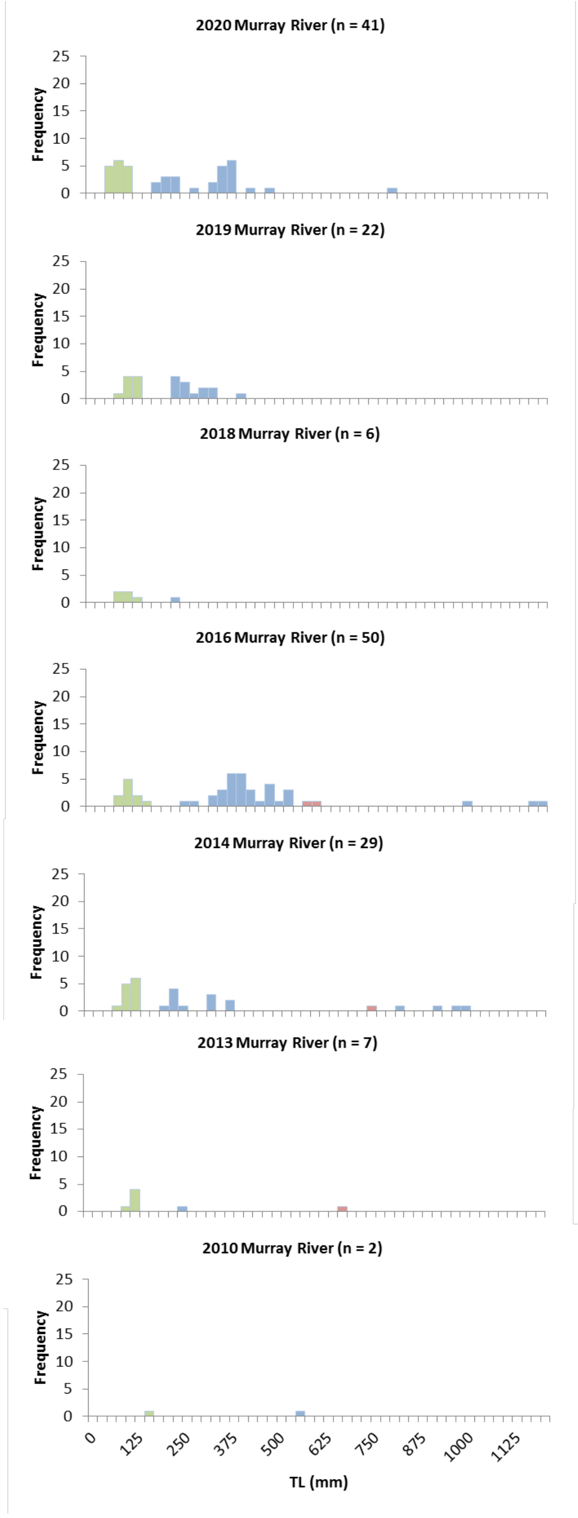

Figure 37 Unweighted length frequency histograms for Murray Cod captured during 2010–2020 TLM monitoring. Green shading indicates Young of Year (YOY). Red shading indicates fish of 'legal size' 550–750 mm under Victorian and NSW recreational fishing regulations. Note that these unweighted histograms are provided to show the range of sizes captured across the icon site and not intended to provide an accurate representation of population structure. Note – no Murray Cod were captured in 2017.

9.4.3 Lake Mournpall fish relocation

The source of Young of Year Murray Cod recorded at Lake Mournpall by the TLM monitoring in 2019 was unknown. Based on a range of factors including lack of connectivity, the most likely explanation for the sudden appearance of YoY cod was that a resident population had established in Lake Mournpall and that successful spawning had occurred in spring 2018 (Ecology Australia 2019).

Ecology Australia undertook a follow up survey on 11–12 September 2019 using boat electrofishing to target adult Murray Cod and obtain additional YoY Murray Cod for otolith analysis. All previous Lake Mournpall TLM sampling had been undertaken using backpack electrofishing of shallow habitats, rather than boat electrofishing of a wider range of depths. Conditions weren't conducive to efficient electrofishing due to high turbidity and almost no habitat structure to target, however one adult Murray Cod was observed (approximately 800 mm TL), 14 YoY Murray Cod were captured and retained for otolith removal, and a further five Murray Cod YoY were observed but not captured.

The otolith annual aging analyses confirmed that the Murray Cod ranging in size from 83–189 mm TL were all YoY as there were no obvious/distinct annual zones observed. Daily aging analyses estimated the samples to be between 150–217 days, suggesting a hatch date to be between 6 February and 2 April 2019, with most being from the same spawning event regardless of size. However, due to the 'wintering' effect on otolith growth zones, it was considered likely that the daily age is under-estimated and that the hatch dates were before Feb/March 2019, and based on expert opinion could possibly be from as early as mid-November 2018 (K Krusic-Golub pers comm. 2019).

As Lake Mournpall was in a draw-down phase and it was no longer feasible/ desirable to water the Hattah Lakes at that time (Lake Mournpall cannot be watered independently), Ecology Australia were engaged to relocate large bodied native fish (Murray Cod, Golden Perch) and turtles on two occasions (21–23 November 2019 and 8–10 January 2020). Coarse-meshed fyke nets were the primary method used and water depths were more optimal (lower) during the second event. A total of ten large Murray Cod (715–770 mm TL), six juvenile Murray Cod, 108 Golden Perch (including 90 YoY), two Silver Perch, three broad-shelled turtles, one Murray River turtle, and six eastern snake-necked turtles were relocated under permit to Kings Billabong in Mildura (See Table 20). By 4 February 2020, thousands of dead Carp were evident around the perimeter of Lake Mournpall (See Plate 3).

Table 20 Lake Mournpall fish relocation summary

Species	Relocation event 1 21–23 November 2019	Relocation event 2 8–10 January 2020
Murray Cod	7 (3 adult, 715–765 mm TL; 4 juvenile, 171–218 mm TL	8 (7 adult, 663–770 mm TL; 2 juvenile, 204–220 mm TL))
Golden Perch	9 (8 adult, 440–514 mm TL; 1 YoY 100 mm TL) 1 YoY dead Total relocated - 8	104 (12 adult, 421–545 mm TL; 1 juvenile, 147 mm TL; 90 YoY, 28–50 mm TL)) 4 YoY dead Total relocated - 100
Silver Perch	2 adult, 389–482 mm TL	0
Broad-shelled Turtle	1	2
Murray River Turtle	0	1
Eastern Snake-necked Turtle	6	0

Plate 1 – Large Murray Cod relocated from Lake Mournpall in November 2019.

Plate 2 – 86 YoY Golden Perch were relocated from Lake Mournpall in January 2020.

Plate 3 – Thousands of dead Carp around the perimeter of Lake Mournpall (4 February 2020).

9.4.4 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 21). 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 21 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	2020
Riverine	Murray River	20	10	23 (2)	12	20	31	28	30	35 (1)	21
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 2020, large Golden Perch (350–450 mm TL) again appear to be the dominant cohort in the Riverine habitats (Figure 38). Although this is a similar result to 2018–19, this differs from 2016–2017, when a more even spread of sizes was evident.

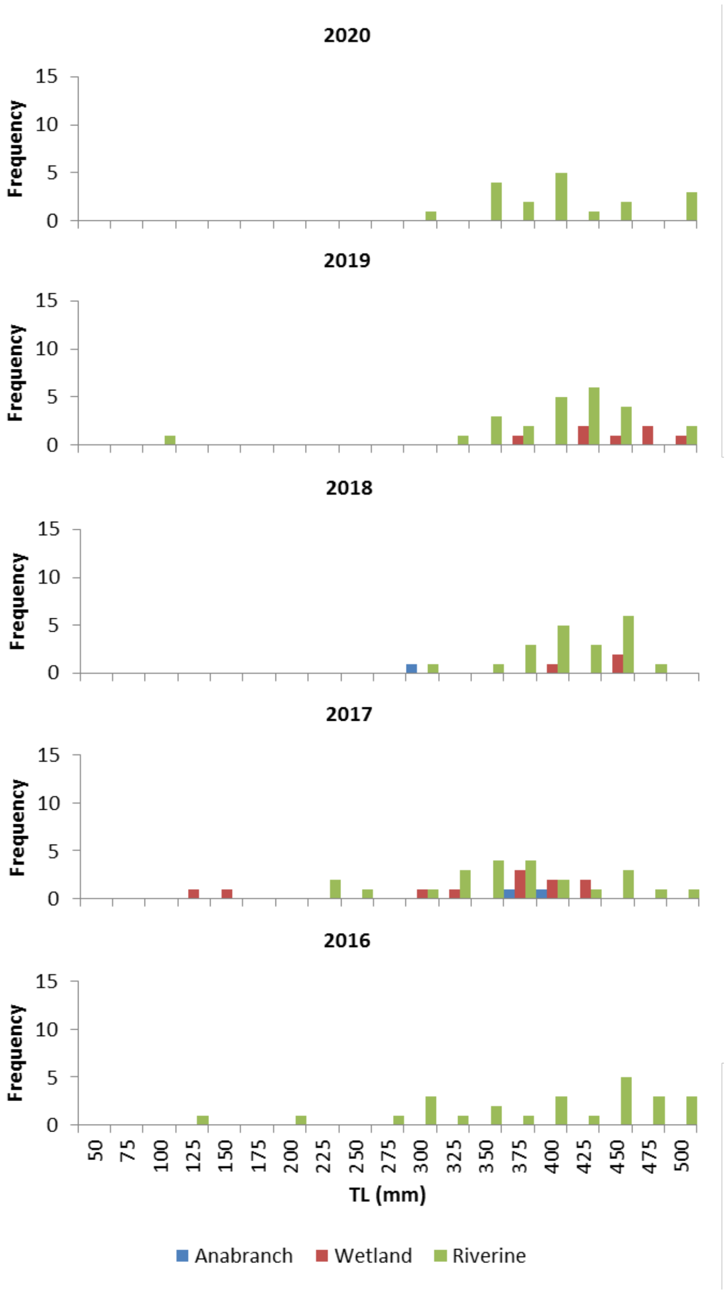

Figure 38 Unweighted length frequency histograms for Golden Perch captured during 2016–2020. Note that these unweighted histograms are provided to show the range of sizes captured across the macrohabitats but are not intended to provide an accurate representation of population structure.

9.4.5 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). No other macrohabitats were sampled in 2020 and therefore the icon site scale scores should be interpreted with caution (Figure 39).

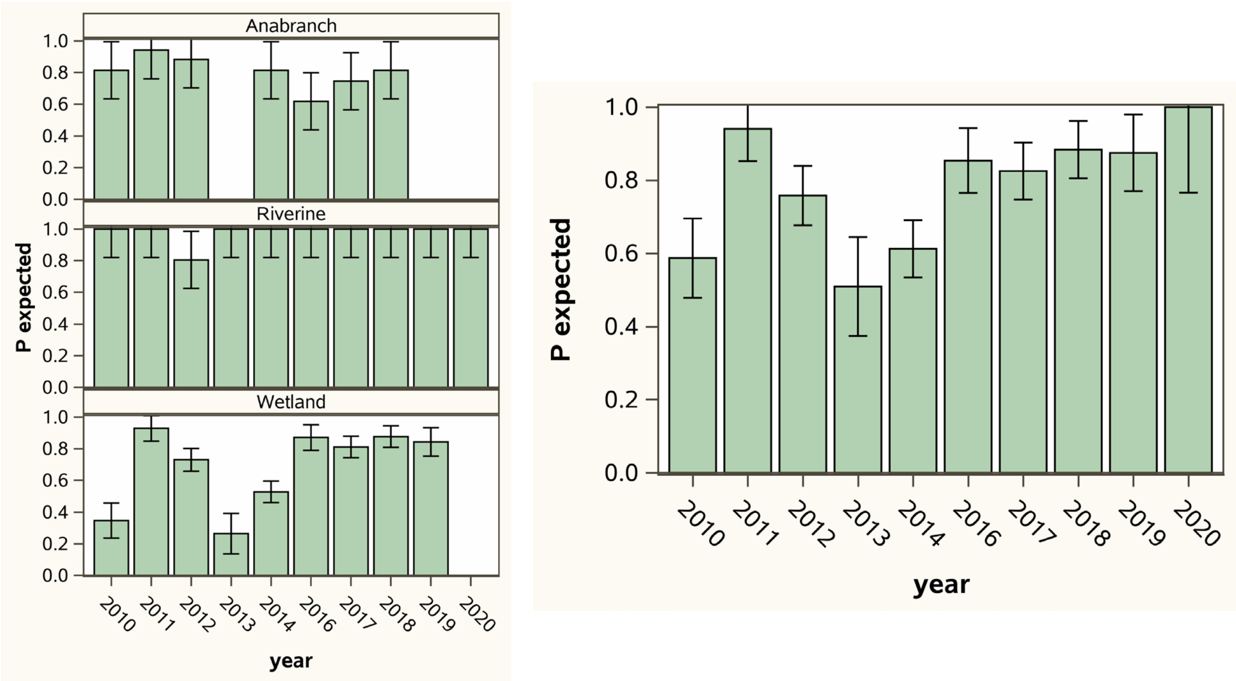

Figure 39 P expected scores at the macrohabitat scale (left) and icon site scale (right). Note that the icon site scale scores are provided as a guide only (refer to section 9.3.3).

9.4.6 Index – P nativeness

The P nativeness scores for the riverine macrohabitat are marginally higher than 2018–19, 2010–11 and 2013, but lower than 2014 and 2016 (see Figure 40). The lowest P nativeness scores for the riverine habitat were from 2012 and 2017. No other macrohabitats were sampled in 2020 and therefore the icon site scale scores should be interpreted with caution (Figure 41).

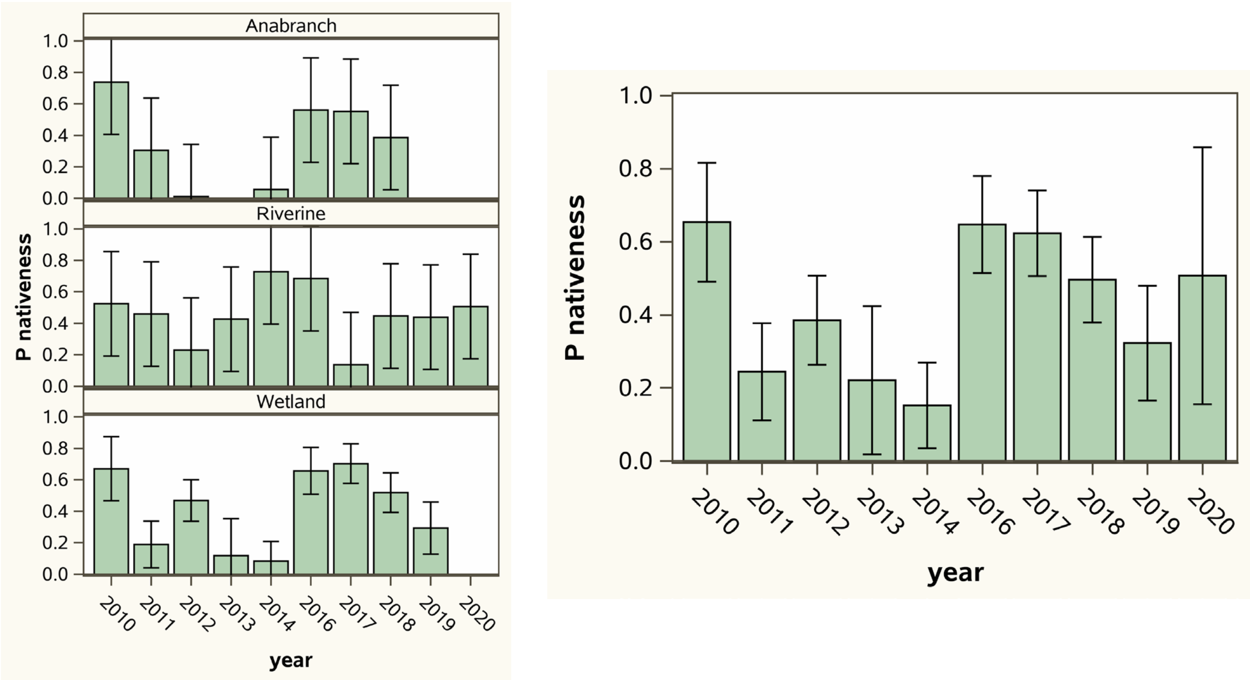

Figure 40 P nativeness scores at the macrohabitat scale (left) and icon site scale (right). Note that the icon site scale scores are provided as a guide only (refer to section 9.3.3).

9.4.7 Index - P recruits

The P recruits scores for the riverine macrohabitats are marginally higher than 2010, 2012, 2016–17 and 2019, but lower than 2011, 2013–14 and 2018. No other macrohabitats were sampled in 2020 and therefore the icon site scale scores should be interpreted with caution (Figure 42).

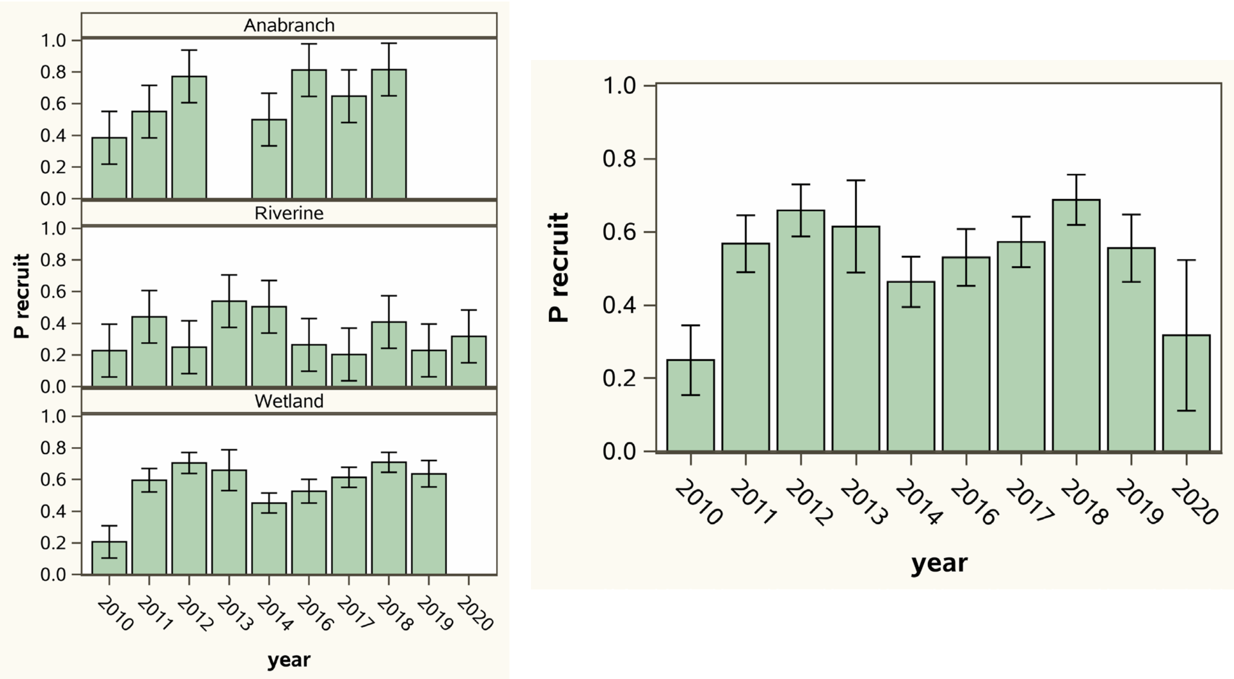

Figure 41 P recruits scores at the macrohabitat scale (left) and icon site scale (right). Note that the icon site scale scores are not particularly valid and are provided as a guide only (refer to section 9.3.3).

9.5 Discussion

For the first time over the duration of the monitoring program, the only macrohabitat sampled was the Murray River. Chalka Creek and all of the wetland sites were dry, with the possible exception of Lake Mournpall. Lake Mournpall wasn't sampled in autumn 2020 because water levels were very low and there was known to have been a large fish kill in early February 2020. Over the course of the autumn based monitoring program (2010–2020), 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.

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 2019–20 results are indicative of a recruitment led recovery (i.e. a population dominated by juveniles including Young of Year), however adult fish have likely been in low densities, with only one being recorded in 2020, the first in over three years. Although the numbers are too small to provide a reliable indication of population structure, they could be indicative of the 2016 event causing mortality or emigration, or both, as was observed in other areas such as the Mullaroo Creek (Tonkin et al. 2020). 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.

Recruitment of Golden Perch has rarely been detected by the 2010–2020 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 in March 2011, following sustained elevated river flows from late winter 2010 through to a flood peak in February 2011. 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.

The drawdown of Lake Mournpall, the subsequent surveys (September 2019), fish and turtle relocation events (November 2019 and January 2020), and fish kill (February 2020), has provided a more detailed understanding of the Lake Mournpall aquatic fauna community and will provide a useful point of reference for future surveys. The drawdown provided some unusual examples of conditions under which both Murray Cod and Golden Perch had recruitment success, yet Carp didn't. Despite very large numbers of large Carp (many over 11 kg) and most observed to be running ripe in September 2019, no Young of Year, no juvenile and hardly any sub-adult Carp have been detected, indicating possible recruitment failure and/or ovarian involution (egg reabsorption). In contrast, Murray Cod were confirmed to have spawned in late 2018/early 2019 (during the mid–late stages of the drawdown) on the basis of the otolith analyses and lack of flow or flood connection since December 2017 and November 2016 respectively. Golden Perch appears to have spawned in late 2019 (late stages of the drawdown) based on the large numbers of Young of Year that were detected in January 2020. Other interesting finds included low abundances of Silver Perch (recorded from other lakes, but not from Lake Mournpall during previous TLM surveys), together with low numbers of Broad-shelled Turtle and Murray River turtle.

As outlined by Ecology Australia (2019), it is recommend that Lake Mournpall be sampled in future using boat electrofishing rather than backpack electrofishing whenever suitable depths exist. When supplemented by the fyke nets and seine netting, this approach will ensure a better representation of the fish community (i.e. including adult Murray Cod and other large-bodied fish species). The relative efficacy of bait traps, fyke nets, and seine nets was intended to be assessed to determine the most appropriate technique to supplement electrofishing and ensure representative sampling of the fish community (Huntley et al. 2016). 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 inter annual variability in the scores are not masked.

9.6 Progress towards ecological objectives

Progress towards the ecological objectives cannot be assessed for 2020 due to most macrohabitats being dry.

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