The Living Murray: Annual condition monitoring at Hattah Lakes Icon Site 2017–18: Part A

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2017–18

Final Report

SLS Publication 186

The Living Murray: Annual Condition Monitoring at Hattah Lakes Icon Site 2017–18. Part A

Final report prepared for the Mallee Catchment Management Authority by the School of Life Sciences Albury–Wodonga and Mildura.

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Report Citation: Wood D, Romanin L, Brown P, Loyn R, McKillop T, Cheers G (2018) The Living Murray: Annual condition monitoring at Hattah Lakes Icon Site 2017–18. Part A. Final Report prepared for the Mallee Catchment Management Authority by the School of Life Sciences Albury–Wodonga and Mildura, SLS Publication 186/2018, June, 66pp.

Cover Image: Lake Bitterang flood runner, February 2018

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Document history and status

Version	Date Issued	Reviewed by	Approved by	Revision type
Draft	25/6/2018	Paul McInerney	David Wood	Internal scientific
Draft	30/6/2018	Andrew Greenfield	Paul Brown	External

Distribution of copies

Version	Quantity	Issued to
Draft	1 x Word	Andrew Greenfield Mallee Catchment Management Authority
Final	1 x Word, 1 x PDF	Andrew Greenfield Mallee Catchment Management Authority

Filename and path: Projects\Mallee CMA\TLM CM\17_01631 TLM CM 2017-18\01 Hattah\Reporting\Final

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Project Manager: Paul Brown

Client: Mallee Catchment Management Authority

Project Title: The Living Murray: Annual condition monitoring at Hattah Lakes Icon Site 2017–18. Part A

Document Version: Final

Project Number: 17/_01631, 3.4026.02

Contract Number: **001881**

Finalised 6 September 2018

Acknowledgements:

This project was undertaken with the support of the Murray–Darling Basin Authority, Victorian Department of Environment, Land, Water and Planning and Parks Victoria. The assistance and support provided by Jenny Collins, James Kellerman and Andrew Greenfield from the Mallee Catchment Management Authority is greatly appreciated.

The authors would also like to thank all current and former La Trobe University School of Life Sciences (formerly Murray–Darling Freshwater Research Centre) staff for their input into previous project design and development, contribution to the long-term data set and field data collection. Helen Missen and La Trobe staff for their administrative assistance and Dr Paul McInerney for reviewing this report.

This project was funded by The Living Murray initiative of the Murray–Darling Basin Authority. The Living Murray is a joint initiative funded by the New South Wales, Victorian, South Australian, Australian Capital Territory and Commonwealth governments, coordinated by the Murray–Darling Basin Authority.

The School of Life Sciences, Albury–Wodonga and Mildura offices are located on the land of the Latje Latje and Wiradjuri peoples. We undertake work throughout the Murray–Darling Basin and acknowledge the traditional owners of this land and water. We pay respect to Elders past, present and future.

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Executive summary

This report details the condition monitoring undertaken at Hattah Lakes in 2017–18 as part of The Living Murray (TLM) Condition Monitoring Program 2006–18. Icon site condition monitoring has been developed to determine the change in environmental condition of individual assets resulting from water application and the implementation of works programs under The Living Murray scheme.

This report documents inter-annual changes in whole-of-Icon site condition of by presenting structured chapters for each of the ecological components monitored; River Red Gum, Black Box, wetland vegetation, floodplain vegetation, Lignum, fish and birds.

During 2017, Hattah Lakes were inundated using permanent pumping infrastructure. Water was pumped to the Hattah Lakes from July–October 2017, reaching near maximum capacity, before both regulators were opened releasing water back to the Murray River.

Below is a 'Report card' (Table 1.1) which highlights each of the ecological objectives, for each component and indicates if the objective has been achieved, partially achieved or not achieved. The foundation for assigning the objective outcome is based (where applicable) on the result of targets and indices applied to each component.

Table 1.1 Report card indicating if the ecological objective for each component has been achieved, partially achieved or not achieved.

Component	**Objective**	**Achieved**	**Partially**	**Not**
River Red Gum	*Sustainable populations of River Red Gum*	X		
Black Box	*Sustainable populations of Black Box*		X	
Wetland & Floodplain vegetation	*Restore diversity, extent and abundance of wetland and floodplain vegetation*		X	
Lignum	*Restore a mosaic of healthy wetland and floodplain communities to maintain the ecological character of the Ramsar site*		X	
Fish	*Increase distribution, number and recruitment of local wetland fish—including hardyhead, Australian smelt and gudgeon by providing appropriately managed habitat*	X		
	Maximize use of floodplain habitat for recruitment of all indigenous freshwater fish	X		
Birds	*Maintain habitat for the Freckled Duck (Stictonetta naevosa), Grey Falcon (Falco hypoleucos) and White-bellied Sea-Eagle (Haliaeetus leucogaster) in accordance with action statements'*		X	
	Increase successful breeding events for colonial waterbirds to at least two years in ten (including spoonbills, egrets, night-herons and bitterns	n.a.		
	Provide suitable habitat for a range of migratory bird species (including Latham's Snipe Galinago hardwickii, Red-necked Stint Calidris ruficollis and Sharp-tailed Sandpiper Calidris acuminata)			X

River Red Gum

During 2017–18, River Red Gum at Hattah Lakes achieved the target of 85% of River Red Gums attaining a crown extent score ≥ 4. Continued improvement in tree condition has occurred over the past three surveys.

A high number of seedlings have dominated the recent monitoring round. In 2017–18 mean population status index exceeded the minimum threshold for River Red Gum populations for the first time since 2015.Increased mean population status index suggests a population moving closer to that of an indicative ‘inverse J-shaped’ curve and represents a more sustainable population.

Overall, health of the River Red Gum community is being maintained above current targets, and thus the specific adopted objective *sustainable populations of River Red Gum* is being met at Hattah Lakes icon site.

Black Box

While the frequency of trees with crown extent scores ≥ 4 declined in 2017–18, the target of ≥80% of trees meeting this level has been continually achieved since 2010–11.

Mean population status index also declined in 2017–18 (Figure 3.4), and the minimum threshold value (0.85) was not met, noting that this threshold has not been met since monitoring commenced in 2006.

Overall, the objective relating to Black Box health, *sustainable populations of Black Box*, is only partially being met for Black Box at Hattah Lakes icon site.

Wetland vegetation

No encroachment of drought tolerant species into wetlands was identified in 2017–18. Community composition at Hattah Lakes is largely dominated by aquatic, amphibious and terrestrial damp species due to a combination of floods and the delivery of environmental flows. The presence of drought tolerant species at Persistent Temporary Wetlands and Episodic Persistent Wetlands in 2017–18 was not seen as an encroachment, but rather part of the natural cycle of ephemeral wetlands.

The Whole-of-icon site score was calculated for the entire time series at Hattah Lakes wetlands for the first time this year (2017–18). No change in indices for water responsive species richness and abundance was detected over the whole icon site since TLM surveys began. The indices are not sensitive to vegetation condition when a wetland is inundated.

In each survey year, wetlands at Hattah Lakes were in various states of inundation (e.g. inundated, drawdown, intermittent-dry, long-dry), providing a mosaic of habitats and supporting a variety of vegetation communities across the icon site. The overarching ecological objective “to restore a mosaic of healthy wetland communities” at Hattah Lakes is being achieved.

Floodplain vegetation

Favourable environmental conditions have benefited the water responsive plant community at often- and sometimes-flooded areas of the floodplain at Hattah Lakes. However, the rarely-flooded sites at Hattah Lakes floodplains remain dominated by drought tolerant species. Therefore, the vision to preserve and maintain healthy floodplain plant communities at Hattah Lakes icon site is partially being met.

The Whole-of-icon site score was calculated for the entire time series at Hattah Lakes floodplains for the first time this year (2017–18). A trend of increased water responsive species richness and abundance was detected over the whole icon site since TLM surveys began.

Lignum

This year (2017–18) represents the first year that Lignum condition could successfully be undertaken using the new, refined method. Of the three Lignum communities (Lignum Swamp, Woodland and Shrubland) only the Lignum Woodland community exceeded the target of 85% plants with a Condition Index score of ≥4. At the icon site level, just over half of all sites were deemed compliant in 2017–18 resulting in an icon site Condition Index of 0.56.

Fish

The total number of fish recorded at Hattah Lakes in 2017–18 were the highest sampled from any TLM condition monitoring survey. The community comprised of 14 species (10 native, 4 non-native) with Murray cod (*Maccullochella peelii*), Silver perch (*Bidianus bidianus*) and Oriental weatherloach (*Misgurnus anguillicaudatus*) again recorded after being absent the previous monitoring year. The population was numerically dominated by Carp gudgeon (*Hypseleotris* spp.) and Eastern mosquitofish (*Gambusia holbrooki*). Mean proportion of sites where species richness exceeded reference levels was down slightly from 2016–17 but more than half of all sites exceeded the reference levels. Mean proportion of native fish biomass also increased from the previous year, with the reference value of 0.5 being achieved. The reference value (0.5) for the proportion of fish classed as recruits was also achieved and recorded the highest value across all monitoring years for 2017–18. As such, the objectives of '*Increasing distribution, number and recruitment of local wetland fish—including hardyhead, Australian smelt and gudgeon by providing appropriately managed habitat'* and to *'Maximize use of floodplain habitat for recruitment of all indigenous freshwater fish*' were deemed to be achieved for 2017–18 at Hattah Lake icon site.

Birds

Annual condition monitoring at Hattah Lakes icon site for 2017–18 recorded 32 species of waterbird. Substantially higher numbers of water birds were sampled in autumn 2018 than in spring 2017. Dabbling ducks were the most numerous guild of waterbirds followed by fish eating pelicans, cormorants and darters. Of interest, an Australian Painted Snipe, listed as endangered, was observed in concurrent bush birds surveys (on flooded wetland).

Hattah Lakes supports White-bellied Sea-Eagles, including at least one pair that bred successfully. Freckled duck were also observed at Hattah Lakes for the first time in many years. There was no evidence of Grey falcon. Therefore the objective; *maintain habitat for the Freckled Duck (Stictonetta naevosa), Grey Falcon (Falco hypoleucos) and White-bellied Sea-Eagle (Haliaeetus leucogaster) in accordance with action statements'* has only partially been met (please note that habitat was not investigated, but is inferred at least in-part by the presence of these species).

This year's assessments did not provide evidence of colonial breeding, however this would require targeted monitoring programs, as breeding colonies are highly localised and not always in predictable sites. Therefore the objective; *increase successful breeding events for colonial waterbirds to at least two years in ten (including spoonbills, egrets, night-herons and bitterns)* cannot be answered at the current time.

This year's assessments did not provide evidence that the Hattah Lakes provide habitat for transcontinental migratory shorebirds. Therefore the objective; *provide suitable habitat for a range of migratory bird species (including Latham's Snipe Galinago hardwickii, Red-necked Stint Calidris ruficollis and Sharp-tailed Sandpiper Calidris acuminata)* was not met.

1 Introduction

1.1 Purpose of the report

This report details the condition monitoring undertaken at Hattah Lakes in 2017–18 as part of The Living Murray (TLM) Condition Monitoring Program 2006–18, which was funded by the Murray–Darling Basin Authority. This work was conducted by La Trobe University; School of Life Science, formerly The Murray–Darling Freshwater Research Centre (MDFRC), for the Mallee Catchment Management Authority (CMA). This report represents a deliverable requirement for Contract No. 01631 between La Trobe University and the Mallee CMA.

1.2 Report structure

The Hattah Lakes Condition Monitoring Report for 2017–18 consists of two parts: Part A comprises the main report and Part B the supplementary material. This document Part A, contains structured reports for each of the ecological components monitored (River Red Gum, Black Box, wetland vegetation, floodplain vegetation, Lignum, fish and birds). Part B contains material that supports Part A content (e.g. site information, species lists, photo plates, etc.).

The objectives and mode of delivery for TLM condition monitoring at the Hattah Lakes have largely remained consistent for the duration of the program. Data analysis and reporting has benefited from a process of continuous-improvement that commenced in July 2013 (Robinson 2013). This review process was ongoing during 2013–16 (Brown *et al.* 2015a; Robinson 2014a, b) and drove a series of refinements. Data collection and sampling design for most ecological components has remained consistent. The exception being the Lignum monitoring component, which in 2016-17 adopted new methods. No condition monitoring was funded during the survey period 2014–15; the only sampling that took place during this ‘gap’ was for tree structure and this has been included where possible.

1.3 The Hattah Lakes

The Hattah Lakes icon site is one of six sites initially identified as ecologically significant under The Living Murray program (MDBMC 2003)(Figure 1.1). The icon site is part of the 48 000 ha Hattah–Kulkyne National Park located in the north-west of Victoria (Figure 1.2). The Hattah Lakes system contains 18 freshwater lakes, 12 of which are Ramsar-listed (Butcher & Hale 2011), connected by a series of floodplain channels fed by the Murray River during periods of high flow. The mosaic of water bodies includes creeks and lakes of varying depths and acts as a sink, or store, for nutrients and sedimentary deposits including plant and animal propagules from the surrounding catchments (MDBA 2012c). The Hattah Lakes have significance in protecting endangered species of flora and fauna in Australia and provide important refuges for a range of biota including fish, birds and vegetation. Hattah Lakes also has significant social and cultural value, having provided sanctuary for Indigenous society for thousands of years. The economic values of Hattah Lakes include recreational and tourism values as well as the provision of flood control and a potential emergency water supply for the local township of Hattah (MDBA 2012c). More detailed information on the economic, social, cultural and environmental values of the Hattah Lakes icon site is contained in TLM Foundation Report (MDBC 2005) and in the Environmental Management Plan (MDBA 2012c).

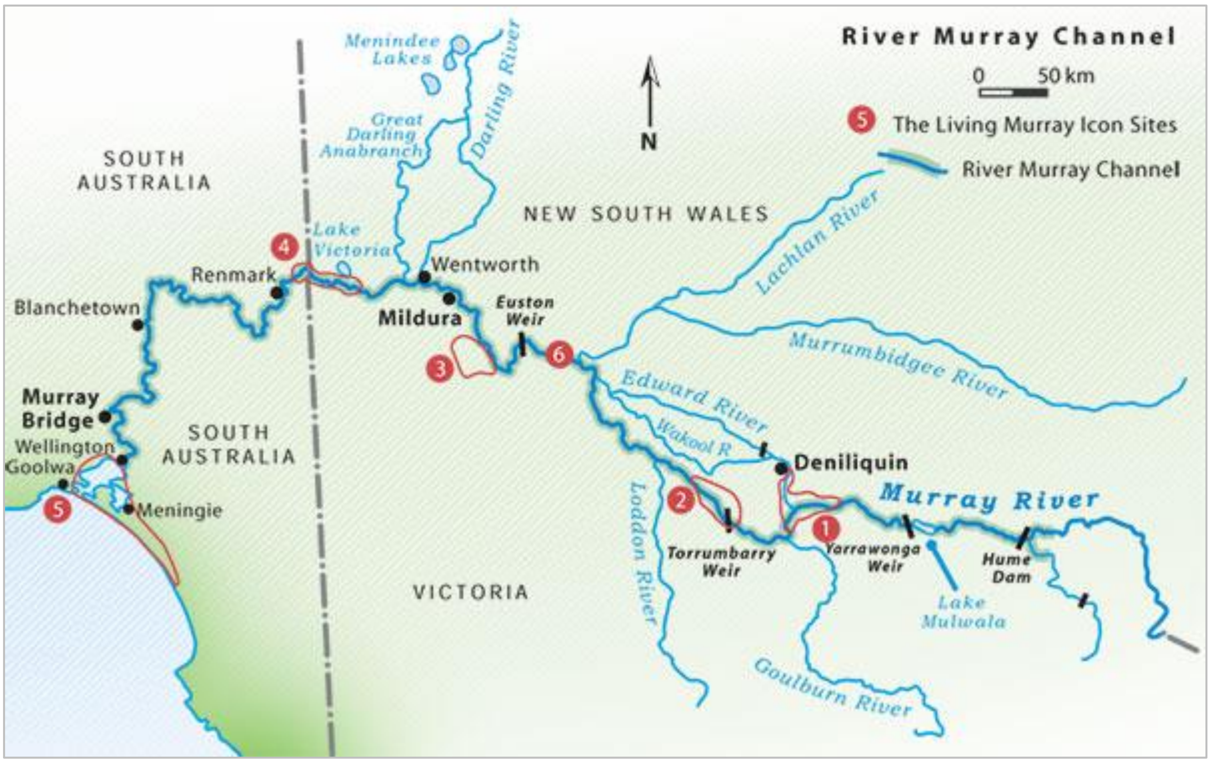


Figure 1.1 Locations of TLM icon sites: (1) Barmah–Millewa Forest, (2) Gunbower–Koondrook–Perricoota Forest, (3) the Hattah Lakes, (4) Chowilla Floodplain and Lindsay–Mulcra–Wallpolla Islands, (5) Lower Lakes, Coorong and the Murray Mouth and (6) the Murray River Channel (image courtesy of MDBA).

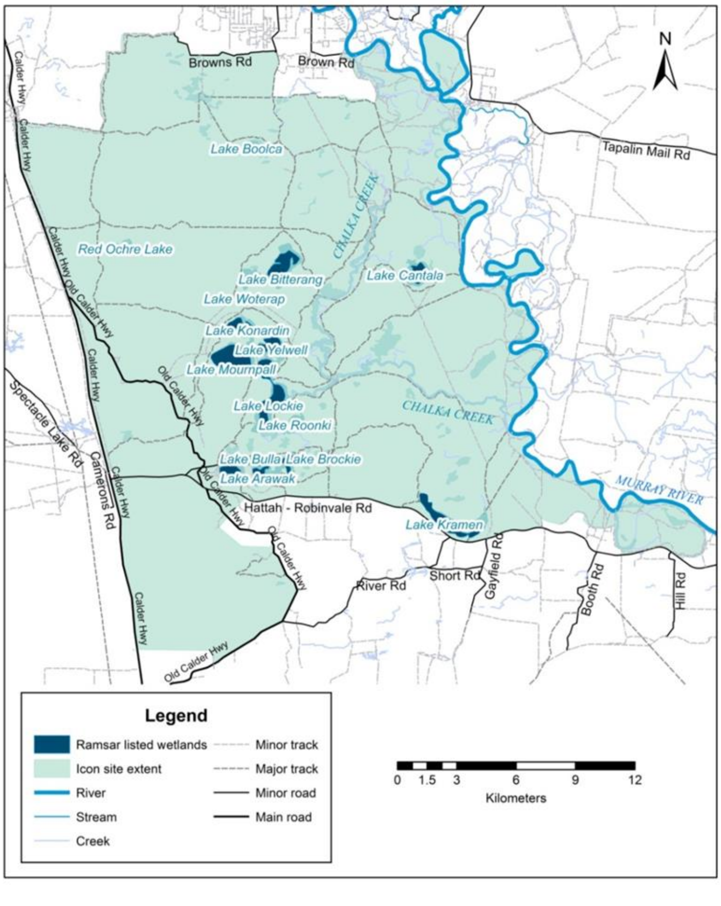


Figure 1.2 Hattah Lakes icon site (Ramsar-listed lakes shown in dark blue).

1.3.1 Hydrology

A major risk to the floodplain communities at the Hattah Lakes is altered water regimes (Butcher & Hale 2011; MDBA 2012a, c; MDBC 2006). There have been substantial changes to timing of flows and reductions in frequency, duration and magnitude of flooding at Hattah Lakes as a result of river regulation and water extraction (Ecological Associates 2007; MDBC 2006; SKM 2003). Extraction of water from the Murray River upstream of Hattah Lakes has resulted in the mean discharge in the Murray River adjacent to Hattah Lakes being approximately 50% of unregulated volume estimates (Maheshwari *et al.* 1993). The timing of flooding (i.e. River Murray flows above the commence-to-flow (CTF) level in Chalka Creek), is delayed from natural patterns by approximately two months (shifted from August to October). Flooding frequency is reduced by 57% and duration by 65% (MDBC 2006).

To overcome these changes in hydrology, pumping has become necessary to maintain the ecological condition of the lakes. Between 2005 and 2010, transportable pumps were used to deliver water into the Hattah Lakes from the Murray River. In late 2009 and 2010 heavy rains caused localised flooding and this was followed in late-2010 to mid-2011 by overbank flooding (Figure 1.3). In October 2013, a permanent pump station, regulators and stop banks were built on the Murray River. This new infrastructure was used to deliver 61 GL of water via Chalka Creek to the lakes and surrounding low-lying floodplain between October 2013 and January 2014. The partial recession of water throughout 2014 was followed by a further 'top-up' flow, delivering 92 GL via the pump station during winter 2014. The lakes and wetlands filled again and the surrounding, more elevated floodplain, was inundated. In the spring of 2014 regulators on north and south Chalka Creek were opened to allow a controlled discharge of environmental water to return from the floodplain to the Murray River (Brown *et al.* 2015b; Wood *et al.* 2015). This was the first time that environmental watering via pumps and regulators has been used to simulate the two-way connection between the Murray River and its floodplain wetlands at such a scale during an otherwise low-flow period (Figure 1.3).

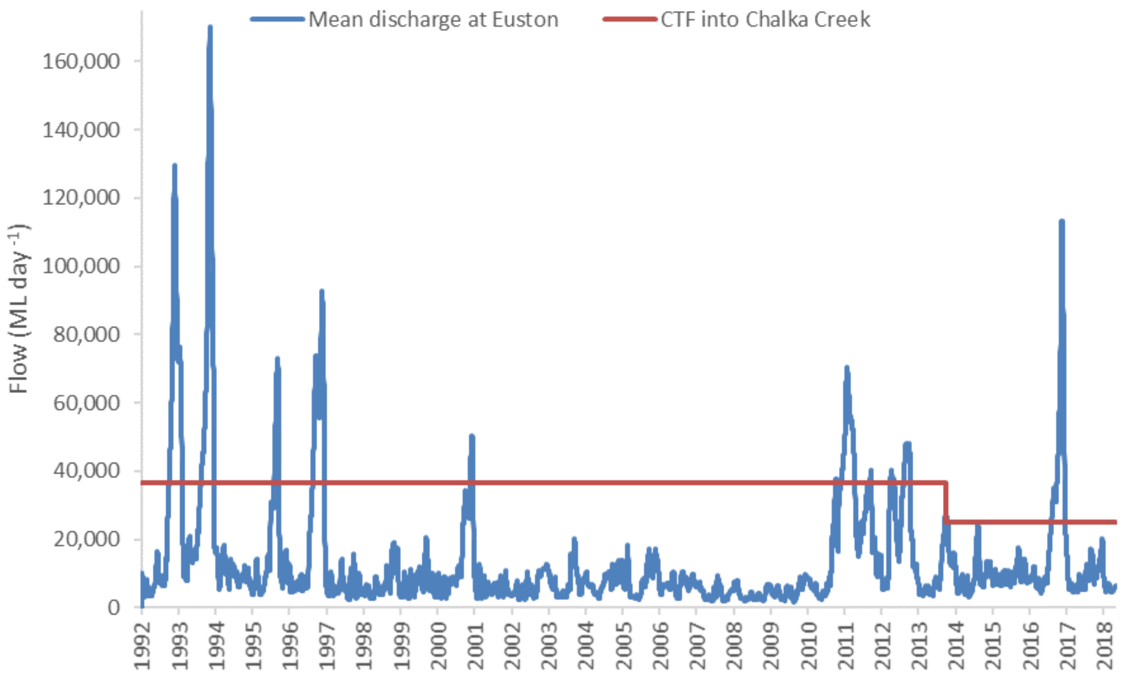


Figure 1.3 Historical discharge (ML day^{-1}) at Euston weir on the Murray River (January 1992 to May 2018) is shown in blue (data courtesy of SA Water Connect). Commence to flow (CTF) into Chalka Creek (36 700 ML day^{-1} prior to October 2013, and approximately 25 000 ML day^{-1} thereafter) is shown in orange.

In 2016, following above average rainfall in the upper Murray River catchment, the discharge at Euston exceeded the commence-to-flow level for Messengers Crossing at Hattah Lakes and Chalka

Creek began to flow through open regulators in August. The regulator was closed and around 35 GL of environmental water was pumped into Chalka Creek in September and October until a level of ~43.8 m AHD was reached, after which the regulators were opened. Murray River flows continued to increase until November 2016 when they peaked at 113 000 ML/day^{-1} on 14 November, eventually delivering the largest flood in Hattah Lakes since 1993. In December 2016, Murray River flows returned to below sill-level at Messengers Regulator with water draining from the Hattah Lakes until sill level was achieved.

During 2017, Hattah Lakes were again inundated. Using permanent pumping infrastructure water was pumped to the Hattah Lakes from July–October reaching near maximum capacity (44.85 m AHD) before both regulators were opened releasing water back to the Murray River until sill level was reached during December. This report presents observations recorded during and immediately following extensive artificial flooding of a moderate area of the Hattah Lakes icon site.

2 River Red Gum

AUTHOR: DAVID WOOD

2.1 Introduction

River Red Gum (*Eucalyptus camaldulensis*) is widespread throughout the Murray–Darling Basin. Common along water courses and frequently inundated areas of the floodplain, River Red Gums play an important functional role through carbon cycling and the provision of habitat (Baldwin 1999; Briggs & Maher 1983; Briggs *et al.* 1997; MDBC 2003). River Red Gum is a structurally dominant species along the Murray River and adjacent flood runners and wetlands of Hattah-Kulkyne National Park.

Flooding is an integral part of River Red Gum ecology and provides an important source of water to maintain populations. Changes in flooding regime and groundwater status threaten the condition, recruitment and long term sustainability of River Red Gum communities, particularly on the lower Murray River floodplain (Maheshwari *et al.* 1995; MDBC 2006). The Living Murray (TLM) Program aims to maintain the condition and extent of River Red Gum communities at Hattah Lakes through environmental works and the delivery of environmental water.

River Red Gum are monitored on an annual basis as outlined in the Condition Monitoring Program Plan for Hattah Lakes (Huntley *et al.* 2016). Condition monitoring reports on River Red Gum condition and population status at the icon site scale, with reference to specific targets and indices.

2.2 Ecological objective

Ecological objectives for Hattah Lakes have been in refinement since interim objectives were first developed by the Ministerial Council in 2003 (MDBMC 2003). The most recent version of the ecological objective for River Red Gum is based on an understanding of environmental responses learned through monitoring, evaluation, research, modelling and consultation activities over ten years (MDBC 2006). The ecological objective for River Red Gum is:

> *Maintain and, where practical, restore the ecological charter of the Ramsar site with respect to the Strategic Management Plan*

The specific adopted objective for River Red Gum, resulting from the refinement process (Robinson 2014a) is:

> *Sustainable populations of River Red Gum*

2.3 Sampling method

Two methods were used to assess the condition of River Red Gum at Hattah Lakes: tree condition monitoring and population status.

Comprehensive detail on tree condition monitoring and size-class distribution methods are available in the Condition Monitoring Program design for Hattah Lakes (Huntley *et al.* 2016).

2.3.1 Tree condition

Tree condition monitoring is a ground-based monitoring method used to detect changes in River Red Gum condition based on assessing a number of variables for each tree (MDBA 2012b). For each sample tree crown extent, crown density, new tip growth, epicormic growth, leaf die-off, bark cracking, reproductive extent and mistletoe load were scored and the diameter at breast height (DBH) measured (MDBA 2012b).

Twenty–seven sites, each comprising 30 River Red Gum trees were established in 2007–08 and sampled annually to 2017–18 (with the exception of five sites in 2010–11 and 1 site in 2016–17 due to flooding and all sites during 2014–15 as the program did not run).

To compensate for the loss of sample trees due to mortality, for each live tree lost, a replacement was selected (the closest live tree). Accordingly, only the live tree component of the sample set for any given year are considered when comparing inter-year differences in tree condition. For more detailed information on site establishment, locations and sampling, refer to (Huntley *et al.* 2016).

2.3.2 Population status

Population size-class distribution surveys are used to inform population status assessments. These assessments are used to evaluate long-term sustainability of River Red Gum at Hattah Lakes and relate closely to the objective of restoring healthy floodplain communities (MDBA 2012c).

Size-class distribution of River Red Gum is assessed on a three-year rolling cycle (or "monitoring round") such that for each year approximately one third of sites are sampled. Transects were established in 2006–09 covering 52.8 ha which represents approximately 1.14% of the extent of River Red Gum community at Hattah Lakes. For more detailed information on site establishment, locations and sampling, refer to (Huntley *et al.* 2016).

Each transect was navigated end-to-end using a hand-held GPS. Each River Red Gum tree within the transect had its diameter-at-breast-height (DBH) measured and its position recorded. While DBH may not be a consistent indicator of age for an individual tree (Roberts & Marston 2011; Snowball 2001), in the absence of a suitable alternative it is used here as a proxy where it is assumed that, on average, the larger the DBH of the tree, the older it is.

Sites first surveyed during 2006–09 and reassessed in 2009–12, 2012–15 and 2015–18 monitoring rounds are presented in this report. To examine temporal trends in population structure, all live trees were classified into 15 cm DBH categories. Counts are square-root transformed to adjust for the high proportion of seedlings.

2.4 Indices and points of reference

Suitable indices and associated points of reference for reporting on the condition and maintenance of River Red Gum have recently been developed (Brown *et al.* 2015a; Robinson 2014a). This report incorporates these updated measures to evaluate and report on River Red Gum condition at Hattah Lakes.

2.4.1 Tree condition

The target developed for River Red Gum condition at Hattah 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. This point of reference is based on TLM condition monitoring data collected during 2007–13 that indicates River Red Gum trees with less than 40% foliated crown are at significantly higher risk of mortality (MDFRC, *unpublished data*).

The percentage of sampled trees with a crown extent score ≥ 4 was calculated per site and averaged across all sites. The mean is the estimate of the frequency of trees within the population with a crown extent score ≥ 4 across the Hattah Lakes icon site. The standard error of the mean is expressed in plots as error bars (± SE).

2.4.2 Population status

The *population status index* is based on the 'inverse J-shaped' curve (George *et al.* 2005) which is an ideal structure in sustainable tree populations. The method for calculation of the index is based on the example provided in Robinson (2013). The index was calculated as the difference (distance) between the rank order of the reference curve (i.e. inverse J-shaped curve) and the rank order of the sampled population for each site. This was then averaged across the icon site. The metric of comparison used was Spearman's Rho (ρ) which was then converted to an index value of between zero and one:

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

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

Where x *and* y are the ranks of the observed data, and inverse J-curve DBH size-classes.

For population status, a minimum threshold reference point of a mean population status index value of 0.80 has been adopted for River Red Gum at Hattah Lakes (Brown *et al.* 2015a). This is based on previous data and is in line with values achieved toward the end of the millennium drought.

2.5 Results

2.5.1 Tree condition

The mean frequency of River Red Gum trees with a crown extent score ≥ 4 increased slightly at Hattah Lakes over the past year (Figure 2.1). This follows the trend since 2015–16 of increasing frequency of trees with a crown extent score ≥ 4. This indicates an overall increase in crown extent (i.e. condition) for River Red Gum. This survey (2017–18) recorded the highest percentage of trees with crown extent scores ≥ 4 from all monitoring years. The target of 85% of River Red Gums attaining a crown extent score ≥ 4 has been achieved at Hattah Lakes during 2017-18, as it has every year of monitoring since 2011–12.

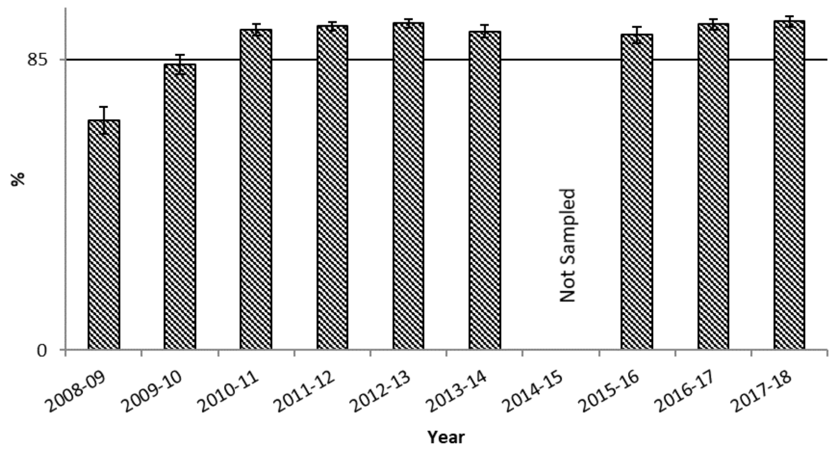


Figure 2.1 Mean frequency (± SE) of trees with crown extent scores ≥ 4 recorded in River Red Gum trees at sites sampled annually in summer between 2008–09 and 2017–18 (except for 2014–15) (minimum threshold 85%).

2.5.2 *Population status*

During the most recent monitoring round (2015–18), seedlings dominated the River Red Gum population at Hattah Lakes (Figure 2.2). This is a marked difference to earlier monitoring rounds (2006–09 and 2009–12) where comparatively low seedling abundance was recorded. During 2015–18, the majority of trees were less than 2 cm DBH, as was the case in 2012–15 (Figure 2.3). There is little evidence of a shift between size classes in small trees from 2012–15 to 2015–18, indicating that the majority of seedlings surveyed in 2012-15 have died and been replaced by an entirely new cohort of seedlings in subsequent years.

Results from the most recent monitoring round (2015–18) indicate that the mean population status index exceed the minimum threshold for River Red Gum populations (Figure 2.4). This trend of increasing population status index suggests a population moving closer to that of an indicative 'inverse J-shaped' curve and represents a more sustainable population.

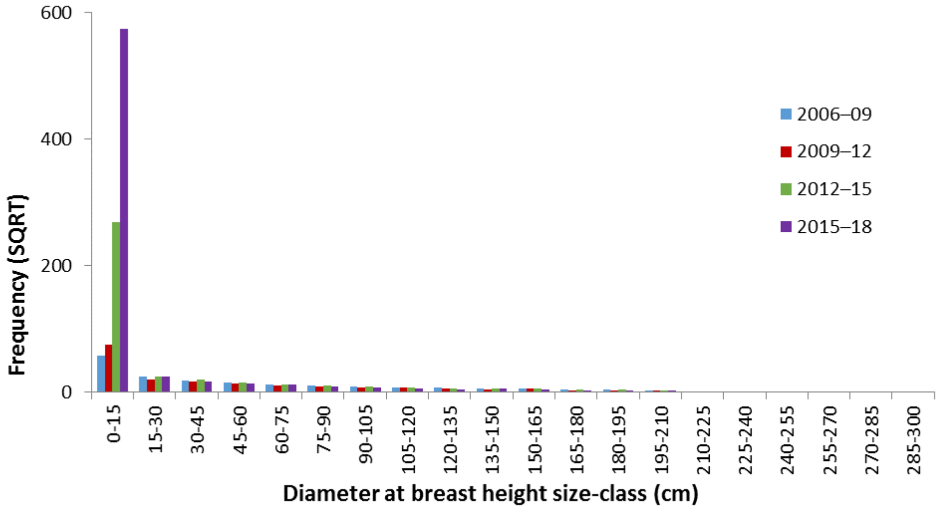


Figure 2.2 Size-class distribution of live River Red Gum trees (0–300 cm DBH) at Hattah Lakes; *n*(2006–09)= 5200, *n*(2009–12)= 6944, *n*(2012–15)= 73 823, *n*(2015–18)= 330 539.

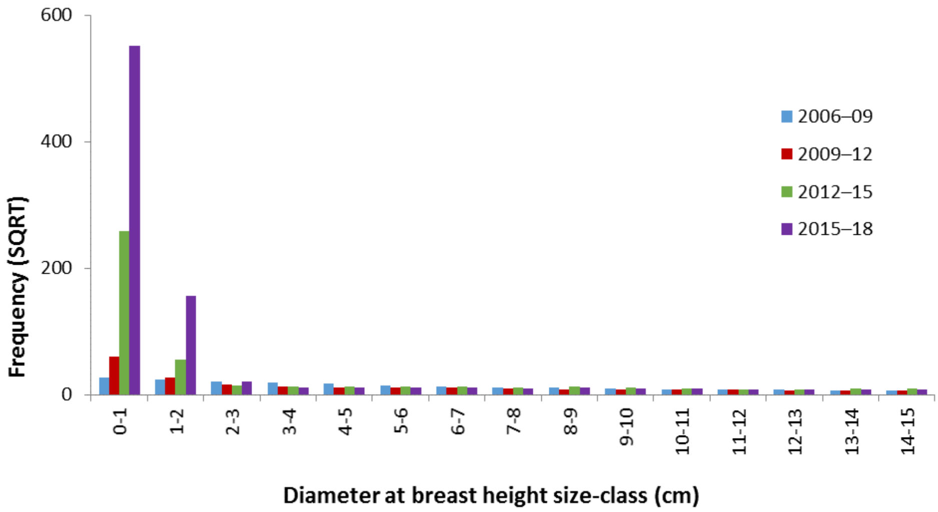


Figure 2.3 Size-class distribution of live River Red Gum trees (0–15 cm DBH) at Hattah Lakes; *n*(2006–09)= 3415, *n*(2009–12)= 5687, *n*(2012–15)= 72 073, *n*(2015–18)= 329 022.

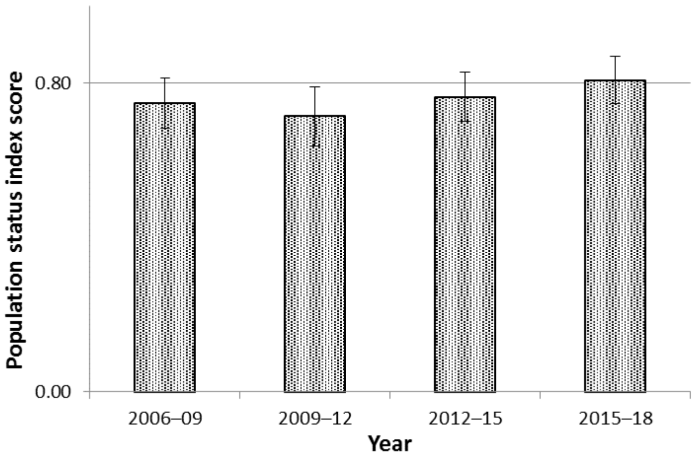


Figure 2.4 Population status index (± 95% CI) for River Red Gum trees based on level of correlation with the reference 'inverse j-shaped' curve (minimum threshold 0.8).

2.6 Discussion

River Red Gum condition has improved over the past three surveys at Hattah Lakes, as evidenced by an increase in the frequency of trees achieving a crown extent score of ≥ 4. It is likely that the primary driver of improved River Red Gum condition since 2015 was natural inundation that occurred in late 2016, followed by artificial inundation during winter/spring 2017. Increased water availability is known to induce a positive response from River Red Gums, with increased foliage and reproductive vigour (Roberts & Marston 2011) a common outcome.

While successive inundations have increased tree condition, they may have acted adversely on seedlings. Since 2013, a large proportion of Hattah Lakes has received extensive inundation on three occasions. While each inundation results in a large number of seedlings germinating, many seedlings from previous inundations are killed by drowning on each occasion. A lack of progression between size classes from 2012–15 to 2015–18 confirms the high seedling mortality. Regular large-scale inundation provides little opportunity for seedlings to grow sufficiently before they are flooded and drowned by the subsequent inundations. Ideally, the period between large-scale inundations should be extended (where control exists, i.e. environmental watering) to allow establishment of a proportion of these seedlings. During periods between the large-scale flooding, the focus should be to deliver small and moderate scale inundation to provide sufficient water for growth and development of the seedlings (as opposed to drowning them).

As River Red Gum condition is currently high and the population deemed sustainable at Hattah Lakes, it is recommended that environmental watering for the purpose of maintaining River Red Gum condition should not be considered a priority over the next 1-2 years. Additionally, in the absence of flooding for 1-2 years, newly germinated seedlings will be able to grow and establish themselves, increasing their ability to withstand further inundation.

As of 2017–18, it is deemed that the overall health of the River Red Gum community is being maintained above current targets, therefore the specific adopted objective *sustainable populations of River Red Gum* is being met for River Red Gum communities at Hattah Lakes icon site.

3 Black Box

AUTHOR: DAVID WOOD

3.1 Introduction

Black Box (*Eucalyptus largiflorens*) is a common species at Hattah Lakes and one of only a few large tree species. Black Box generally occur higher on the floodplain (i.e. less frequently flooded) than River Red Gum, although there is considerable overlap in their distributions. Both eucalypts play an ecologically similar role in their provision of carbon and habitat for floodplain flora and fauna (Briggs & Maher 1983; Mac Nally *et al.* 2001).

Black Box is a drought tolerant flood responsive species that is adapted to varying environmental conditions through its ability to utilise water from floods, rainfall, creeks and groundwater (Holland *et al.* 2006; Jolly *et al.* 1993; McCarthy *et al.* 2009). As part of The Living Murray (TLM) Program, Black Box trees are monitored to ensure sustainable communities are maintained.

Black Box are monitored on an annual basis as outlined in the Condition Monitoring Program Plan for Hattah Lakes (Huntley *et al.* 2016). Condition monitoring reports on Black Box condition and population status at the icon site scale, with reference to specific targets and indices.

3.2 Ecological objectives

Ecological objectives for Hattah Lakes have been in refinement since interim objectives were first developed by the Ministerial Council in 2003 (MDBMC 2003). The most recent version of the ecological objective for Black Box is based on an understanding of environmental responses learned through monitoring, evaluation, research, modelling and consultation activities over ten years (MDBC 2006). 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*

The specific adopted objective resulting from the refinement process (Robinson 2014a) is:

> *Sustainable populations of Black Box*

3.3 Sampling method

In order to address objectives, two methods were employed to assess the condition of Black Box at Hattah Lakes: tree condition monitoring and population status.

Comprehensive detail on tree condition monitoring and size-class distribution assessments are provided in the Condition Monitoring Program design for the Hattah Lakes (Huntley *et al.* 2016).

3.3.1 Tree condition

Eighteen sites each comprising of 30 Black Box trees were established in 2007–08 and sampled annually to 2017–18, except for some sites in 2010–11 due to flooding and all sites in 2014–15 as the program did not run.

See Section 2.3.1 for more details on the tree condition sampling method.

3.3.2 Population status

Size-class distribution of Black Box is assessed on a three-year rolling cycle (or “monitoring round”) such that for each year approximately one third of sites are sampled. Transects were established in

2006–09 covering 25.1 ha, which represents approximately 0.39% of the areal extent of Black Box at the Hattah Lakes.

See Section 2.3.2 for more details on the population status sampling method.

3.4 Indices and points of reference

Suitable indices and associated points of reference for reporting on the condition and maintenance of Black Box have recently been developed (Brown *et al.* 2015a; Robinson 2014a). This report incorporates these updated measures to evaluate and report on Black Box condition at Hattah Lakes.

3.4.1 Tree condition

The target developed for Black Box tree condition at the Hattah Lakes icon site is:

- *80% of trees with crown extent score ≥ 4*

See Section 2.4.1 for more detail on development of points of reference for tree condition.

3.4.2 Population status

A minimum threshold reference point of a mean population status index value of 0.85 has been adopted for Black Box population status at Hattah Lakes (Brown *et al.* 2015a). This is based on previous data and is in line with values achieved toward the end of the millennium drought.

See Section 2.4.2 for more detail on development of points of reference for population status.

3.5 Results

3.5.1 Tree condition

While there was a decline in the frequency of trees with crown extent scores ≥ 4 in 2017–18, the target of more than 80% meeting this level has continually been achieved since 2010–11 (Figure 3.1).

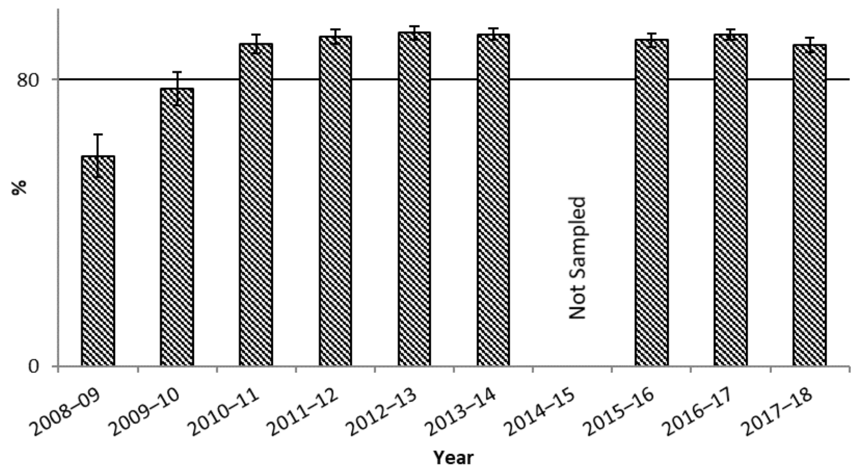


Figure 3.1 Mean frequency (± SE) of trees with crown extent scores ≥ 4 recorded in Black Box at sites sampled annually in summer between 2008–09 and 2017–18 (except for 2014-15)(minimum threshold 0.8).

3.5.2 Population status

An overall decline in the total number of live Black Box in survey sites has occurred at Hattah since the previous monitoring round, suggesting mortality has occurred over past few years. This is mostly evident in trees under 15 cm DBH (Figure 3.2) and particularly in seedlings ≤ 3 cm (Figure 3.3). Despite recent declines trees in the smallest size-class (0–15 cm DBH) remain dominant the population.

Mean population status index has declined from the previous monitoring round (Figure 3.4) with the minimum threshold value of 0.85 not being achieved. This threshold has not been achieved since monitoring commenced. The move further away from that threshold in 2015–18 indicates the population is continuing its trajectory away from that of an indicative 'inverse J-shaped' curve.

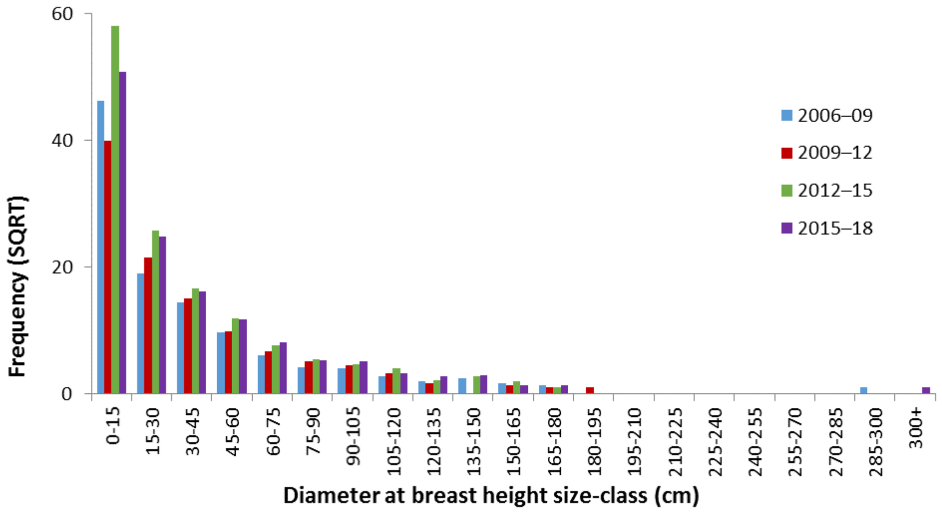


Figure 3.2 Size-class distribution of live Black Box trees (0–300 cm DBH) at Hattah Lakes; *n*(2006–09)= 2903, *n*(2009–12)= 2494, *n*(2012–15)= 4601, *n*(2015–18)= 3753.

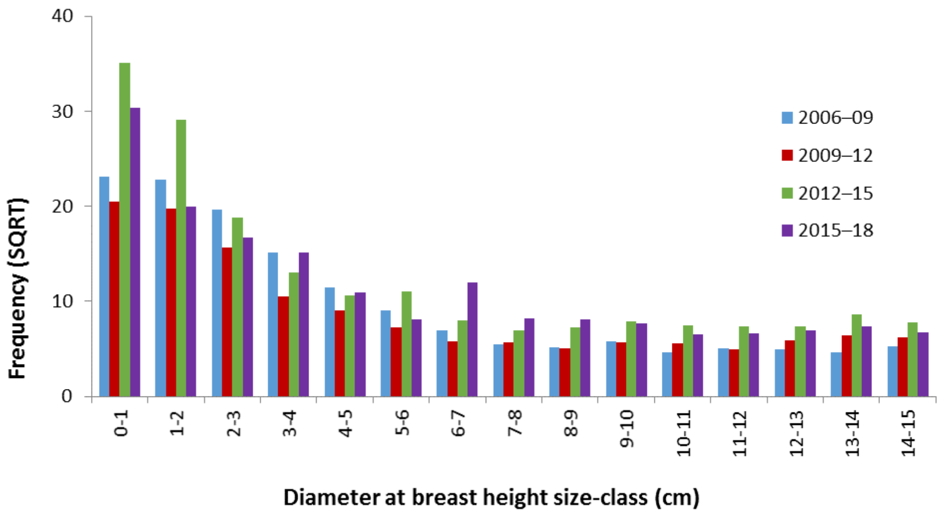


Figure 3.3 Size-class distribution of live Black Box trees (0–15 cm DBH) at Hattah Lakes; *n*(2006–09)= 2141, *n*(2009–12)= 1595, *n*(2012–15)= 3570, *n*(2015–18)= 2587.

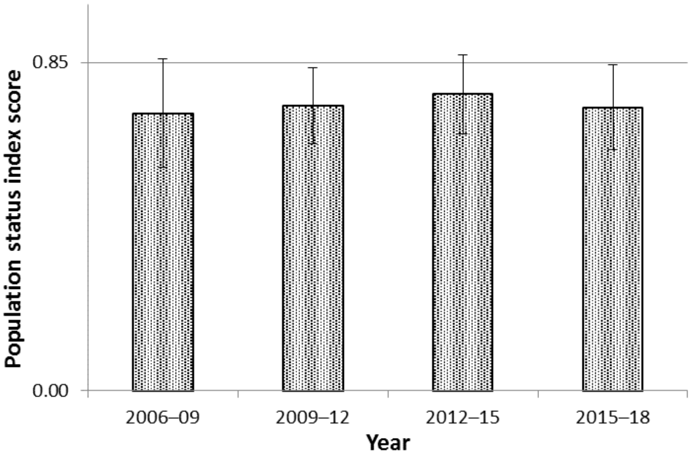


Figure 3.4 Population status index (± 95% CI) for Black Box trees calculated based on level of correlation with the reference 'inverse j-shaped' curve (minimum threshold 0.85).

3.6 Discussion

While a slight decline in Black Box condition was observed (as indicated by a slight decline in mean frequency of trees with crown extent scores ≥ 4), this change is not significant. While flooding has occurred twice at Hattah Lakes in the past two years (natural in 2016 and artificial in 2017), much of the Black Box community was not inundated due to its location high on the floodplain. As such, the remainder of the community is reliant on groundwater and rainfall during these periods in order to maintain condition (Roberts & Marston 2011). Natural variability in these factors, as well as tree physiology and geology, could also explain the decline.

While the overall size-class distribution suggests a relatively sustainable population (as indicated by an indicative 'J-shaped' curve), it appears that there is high variability across the Black Box community (i.e. see large confidence intervals calculated from population status index). Black Box drop seed as a positive response to inundation and generally rely on inundation for germination (George *et al.* 2005). With only some areas of Black Box inundated in the past two years, there are few seedlings and it is likely that seedling germination has been patchy across the whole community.

It is currently difficult to artificially inundate much of the Black Box community at Hattah Lakes. As groundwater is a significant source of moisture for many floodplain species, particularly Black Box, quality and depth of sub–surface water should be monitored. These components may be able to be locally influenced using artificial flooding such that Black Box may benefit (Overton 2013).

As of 2017–18, it is deemed that the overall health of Black Box is partially being maintained above current targets. While tree condition is being maintained above the current target, population status index is currently below the threshold value. Therefore, the specific adopted objective sustainable populations of Black Box is only partially being met for Black Box at Hattah Lakes icon site.

4 Wetland vegetation communities

AUTHOR: LOUISE ROMANIN

4.1 Introduction

Wetlands of the Murray–Darling Basin can be permanent, temporary or ephemeral bodies of water of various depths. During overbank flooding, wetlands become connected to the river system and remain inundated as flood waters recede (Young 2001). During drawdown, wetlands provide a wet/dry ecotone that is high in species diversity compared with adjacent terrestrial and aquatic communities (Brock & Casanova 1997). Hydrology strongly influences the distribution and abundance of species found in river floodplain systems. River regulation has led to a reduction in the frequency, magnitude and duration of flooding events in the lower reaches of the Murray–Darling system (Rogers & Ralph 2011; Young 2001). If overbank floods continue to become less frequent and less variable, it is anticipated that river floodplain habitat will shrink and wetland vegetation communities will be replaced by drought tolerant species. The Living Murray (TLM) Program is a large-scale restoration project that attempts to ameliorate the negative effects of regulation on wetlands and the floodplain. Condition monitoring of wetland vegetation communities at the Hattah Lakes icon site has been undertaken since 2007–08. This chapter reports on the findings of these surveys over the last decade.

4.2 Ecological objectives

The vision for the Hattah Lakes icon site is to:

> *Preserve and, where possible, enhance the biodiversity values of Hattah Lakes; and restore healthy examples of all original wetland and floodplain communities that represent the communities which would be expected under natural flow conditions (MDBA 2012c).*

The overarching ecological objective for vegetation at Hattah Lakes is:

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

The adopted objective for vegetation at Hattah Lakes is:

> *Restore diversity, extent and abundance of wetland and floodplain vegetation (Robinson 2014b)*

This chapter reports on the established vision statement and overarching ecological objective for wetlands at Hattah Lakes. Following the detailed methods described for wetland vegetation in The Living Murray: Condition Monitoring Program design for the Hattah Lakes (Huntley *et al.* 2016), this chapter will:

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

4.3 Method

When condition monitoring began in 2007–08, wetland sites were established to represent the various sizes, shapes, commence-to-flow levels and vegetation communities that exist at Hattah Lakes. Nine wetlands have been surveyed annually since 2007–08. Additionally, monitoring began at Lake Kramen in May 2011, monitoring at Chalka Creek North began in 2011–12 and monitoring at Lake Bitterang began in 2012–13. All 12 wetland sites were surveyed since 2012–13. However, no monitoring occurred in 2014–15 due to changes in program funding.

Each year, surveys were conducted between December and March following the methods described in The Living Murray: Condition Monitoring Program design for Hattah Lakes (Huntley *et al.* 2016).

4.3.1 *Wetland classifications*

To assist with data analysis, each wetland was assigned to one of three water regime classes (WRC) based largely on information from Ecological Associates (2007), as described in Brown *et al.* (2016) (Table 4.1).

Table 4.1 Water regime class for each wetland surveyed under TLM Program at the Hattah Lakes Icon Site (Brown *et al.* 2016; Ecological Associates 2007).

Water regime class	Wetlands
Semi-permanent wetlands	Lakes Bulla, Hattah and Mournpall
Persistent temporary wetlands	Lakes Boich, Bitterang, Brockie, Chalka Creek, Chalka Creek North, Little Hattah, Nip Nip and Yerang
Episodic wetlands	Lake Kramen

4.3.2 *Field survey methods*

Wetland vegetation survey procedures were based on those developed by Nicol & Weedon (2006). Vegetation was sampled at three or four permanently established transects per wetland. Along each transect, quadrats were surveyed at various elevations depending on the depth of the wetland. These transects extended from the base of the wetland up to the wetland edge, beyond the tree line. Specific details regarding the number of transects, quadrats and elevations at each individual wetland are included in Part B of this report. Comprehensive detail of the survey methods used at Hattah Lakes can be found in section 6 of The Living Murray: Condition Monitoring Program design for Hattah Lakes (Huntley *et al.* 2016).

Quadrat size and number (the use of 15 x 1 m x 1 m cells) was determined by Nicol & Weedon (2006) based on the results of species–area curves from the Chowilla icon site. Due to the likely similarity of plant communities between the Chowilla and Hattah Lakes icon sites, the same sampling design and intensity was adopted for Hattah Lakes. However, given the size of individual quadrats in comparison to the area surveyed, there may be some species with patchy distributions or low abundances, not captured within the sampled quadrats. The seasonality of plant life cycles means that some species may not have been present at the time of the survey.

4.3.3 *Plant species classification*

Plant species identification

Plants were identified using the Flora of Victoria Volumes 2 and 3 (Walsh & Entwisle 1994, 1996) and the online version (http://data.rbg.vic.gov.au/vicflora/), Flora of New South Wales Volumes 1–4 (Harden 1992, 1993, 2000, 2002) and the online version (http://plantnet.rbgsyd.nsw.gov.au) and information from field guides (Cunningham *et al.* 1992; Sainty & Jacobs 1981). As the study area is in Victoria, scientific and common names follow those used in the Flora of Victoria (online). Where species are not recognised for Victoria, scientific and common names follow the Flora of New South Wales (published and online).

The conservation significance of plant species was determined using listings in the Flora of Victoria (online version). Non-native species are identified with an asterisk (*) throughout this report.

Some plant species samples could only be identified to genus or family level, or were unidentifiable due to insufficient plant material. It was not possible to determine if these particular species were the same as those recorded in previous years, which can affect between-year comparisons at the species level.

Functional groups

The plant functional group (FG) approach has been widely used to assist in interpreting and predicting change in plant community function and dynamics in relation to a disturbance (Brock & Casanova 1997). Minor changes in species composition or inconsistencies in taxonomic resolution may affect between-year comparisons and the ability to detect ecologically significant changes in community structure. The use of functional groups helps to minimise these inconsistencies by detecting changes in community structure based on plant responses to water regimes (Campbell & Nielsen 2014).

Plant species recorded in surveys at Hattah Lakes were classified into functional groups (Data analysis

Point of reference assessment

As part of an adaptive management process, TLM Program recently underwent refinements to develop site-specific ecological targets (a point of reference) that link back to the vision statement and ecological objectives (Robinson 2014a, b). As the program continues to evolve, further improvements have been made and the ecological targets set in Brown *et al.* (2016) and Huntley *et al.* (2016) have been refined in this report to be consistent across the TLM icon sites in the Mallee Catchment Management Authority region (i.e. Hattah Lakes and the Lindsay–Mulcra–Wallpolla Islands). This is for all understorey vegetation components (i.e. wetland and floodplain communities).The ecological targets for wetland vegetation (

Table 4.3) were developed using data from 2007–08 to 2015–16 and following the methods described and recommended in Huntley *et al.* (2016).

Table 4.2). Functional group classification for each species is provided in Part B of this report. The classification of plant species into these groups is based largely on Brock & Casanova (1997) and Reid & Quinn (2004). Species that were not classified in either of these studies were assigned to functional groups based on field observations and information in the Flora of Victoria (online version) and Cunningham *et al.* (1992). An additional floating (F) functional group was 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) were assigned where species were identified to genus or family level only.

4.3.4 Data analysis

Point of reference assessment

As part of an adaptive management process, TLM Program recently underwent refinements to develop site-specific ecological targets (a point of reference) that link back to the vision statement and ecological objectives (Robinson 2014a, b). As the program continues to evolve, further improvements have been made and the ecological targets set in Brown *et al.* (2016) and Huntley *et al.* (2016) have been refined in this report to be consistent across the TLM icon sites in the Mallee Catchment Management Authority region (i.e. Hattah Lakes and the Lindsay–Mulcra–Wallpolla Islands). This is for all understorey vegetation components (i.e. wetland and floodplain communities).The ecological targets for wetland vegetation (

Table 4.3) were developed using data from 2007–08 to 2015–16 and following the methods described and recommended in Huntley *et al.* (2016).

Table 4.2 Functional groups used to classify plant species recorded during TLM surveys at the Hattah Lakes icon site.

Functional Group	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.

Table 4.3 Ecological targets for wetland vegetation communities at the Hattah Lakes icon site (developed using data from 2007–08 to 2015–16 and following the methods described in Huntley *et al.* (2016).

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

Using the indices in

Table 4.3, wetland vegetation is considered to be in good condition when:

- water responsive species richness in a WRC is at or above the 80th percentile (adapted from Huntley *et al.* (2016))
- 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 water responsive plant species (e.g. species associated with the following functional groups; S, F, Arf, Arp, Atl, Ate, Atw, A and Tda)

- 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 4.3) score = 1 (compliant), and transects with water responsive species richness below the point of reference score = 0 (non-compliant)
- the proportion of compliant transects was calculated for each WRC in each year.

The same steps (above) were applied to determine if water responsive species abundance was in good condition for each WRC using the sum of abundance of water responsive plant species, averaged across each transect in each year.

A Whole-of-icon site score was determined for water responsive species richness (Index 1) and water responsive species abundance (Index 2) (

Table 4.3) using the methods described in Brown *et al.* (2016). The calculation of this score requires that WRC scores be weighted according to the relative number of wetlands within each WRC at Hattah Lakes (Brown *et al.* 2016). The statistical weighting follows the process detailed in Sutherland (2006) and a worked example, showing equations, is presented in Brown *et al.* (2015a). 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

The intent of one of the original ecological objectives 'non-macrophyte vegetation in lakes' was 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). This was determined by analysing the presence/absence of plant species through functional group representation in each WRC in each survey year. This will be considered with respect to whether or not the presence of drought tolerant species is a natural occurrence at that place and time. For example, the presence of a drought tolerant community may be a reflection of the natural dry phase of an ephemeral wetland, which is expected to have inter-flood dry periods. Therefore, this objective may only be relevant to some wetlands in some years (Huntley *et al.* 2016).

4.3.5 Graphs that visually display the proportion of functional group abundance data for each survey year, in each WRC, were created in Microsoft Excel. For display purposes, functional groups A, Arf, Arp, Ate, Atl (for definitions see Data analysis

Point of reference assessment

As part of an adaptive management process, TLM Program recently underwent refinements to develop site-specific ecological targets (a point of reference) that link back to the vision statement and ecological objectives (Robinson 2014a, b). As the program continues to evolve, further improvements have been made and the ecological targets set in Brown *et al.* (2016) and Huntley *et al.* (2016) have been refined in this report to be consistent across the TLM icon sites in the Mallee Catchment Management Authority region (i.e. Hattah Lakes and the Lindsay–Mulcra–Wallpolla Islands). This is for all understorey vegetation components (i.e. wetland and floodplain communities).The ecological targets for wetland vegetation (

Table 4.3) were developed using data from 2007–08 to 2015–16 and following the methods described and recommended in Huntley *et al.* (2016).

Table 4.2) 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.

4.4 Results

4.4.1 Wetland inundation state

The historic and current inundation state of each wetland provided context for data analysis (Table 4.4). Twelve wetlands were surveyed in 2017–18. During 2017–18 surveys, 11 wetlands were inundated (i.e. at least half of the quadrats were inundated), one wetland was classified as in ‘drawdown’ (i.e. less than half of the quadrats were inundated) and one was classified at intermittent-dry (i.e. all quadrats were dry, but wetland held water less than two years ago) (Table 4.4). The wetland that was drawing down was Chalka Creek North, where water recedes rapidly. The intermittent-dry wetland was Lake Kramen, which had dried since the last survey in 2016–17 after receiving environmental flows in 2014.

Prior to widespread flooding in 2016, which peaked in November, a little environmental water was delivered to the Hattah Lakes. These conditions inundated all wetlands except Lake Kramen. Ten of the twelve wetlands (i.e. excluding Lakes Kramen and Bitterang) were also inundated in the 2010–11 flood. Lake Kramen was last flooded in 1993–94, but received environmental flows in 2011 and 2014. Lake Bitterang flooded in 1993–94 and November 2016 and had environmental flows delivered in 2013, 2014 and 2017. Environmental flows of various magnitudes have been delivered to the Hattah Lakes over the last decade (Table 4.4).

Table 4.4 Hydrological state of wetlands surveyed at Hattah Lakes in 2017–18. Key: SPW = semi-permanent wetland; PTW = persistent temporary wetland; EPW = episodic wetland; inundated = at least half the quadrats were inundated during the survey; drawdown = less than half the quadrats were inundated during the survey; intermittent-dry = all quadrats dry, but wetland held water less than two years ago and may still display a vegetation response to inundation.

Water Regime Class	Wetland	Hydrological state 2017–18	Inundated (environmental or natural)
SPW	Lake Bulla	Inundated	2006, 2010, 2013, 2014, 2015, 2016, 2017
SPW	Lake Hattah	Inundated	2006, 2009, 2010, 2013, 2014, 2015, 2016, 2017
SPW	Lake Mournpall	Inundated	2006, 2009, 2010, 2013, 2014, 2015, 2016, 2017
PTW	Lake Boich	Inundated	2010, 2013, 2014, 2016, 2017
PTW	Lake Bitterang	Inundated	2010,2013, 2014, 2016, 2017
PTW	Lake Brockie	Inundated	2006, 2010, 2013, 2014, 2015, 2016, 2017
PTW	Chalka Creek	Inundated	2005, 2006, 2009, 2010, 2013, 2014, 2015, 2016, 2017
PTW	Chalka Creek North	Drawdown	2010, 2013, 2014, 2016, 2017
PTW	Lake Little Hattah	Inundated	2005, 2006, 2009, 2010, 2013, 2014, 2016, 2017
PTW	Lake Nip Nip	Inundated	2010, 2013, 2014, 2016, 2017
PTW	Lake Yerang	Inundated	2006, 2009, 2010, 2013, 2014, 2015, 2016, 2017
EPW	Lake Kramen	Intermittent-dry	2011, 2014

4.4.2 Data summary

A total of 64 plant species were recorded in 2017–18 across all wetlands at Hattah Lakes. Vegetation taxa richness was highest at Lake Kramen (37) which, as mentioned above, was dry, and at Chalka Creek North (25) which was in a draw–down phase, while taxa richness among remaining wetlands was low (23 from all inundated wetlands combined) due to significant and widespread inundation. Ten non-native species and six species that have conservational significance in Victoria were recorded from surveys. Spring Flat-sedge (*Cyperus gymnocaulos*) and River Red Gums (*Eucalyptus camaldulensis*) fringing the wetlands were the most common species in inundated wetlands. Two wetlands (Lake Boich and Lake Nip Nip) were devoid of vegetation in quadrats due to high levels of inundation. Detailed information about which species were recorded where and photo points of wetlands are included in Part B of this report.

4.4.3 Point of reference assessment

Water responsive species richness

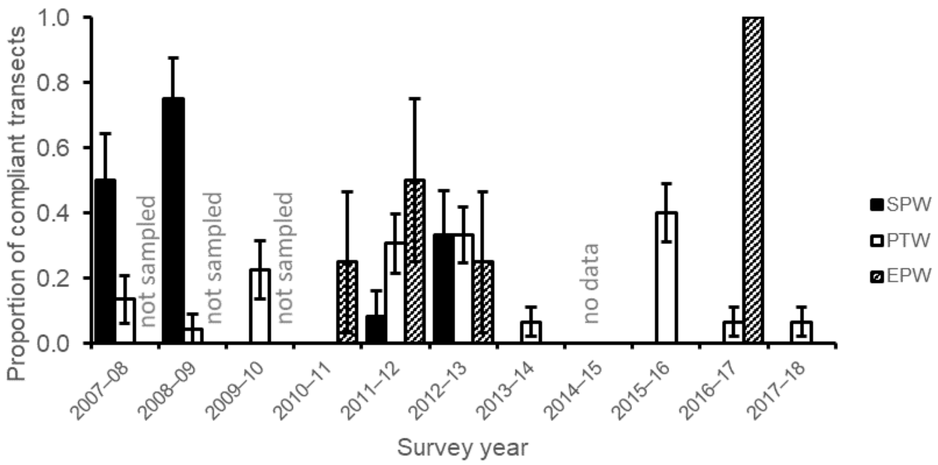
Scores were calculated for water responsive species richness for each WRC, using the ecological targets Index 1 in

Table 4.3 (Figure 4.1a). Water responsive species richness is highly affected by inundation, and as such, lower richness scores are expected during 'wet' survey years. Due to the level of inundation in both semi-permanent wetlands (SPWs) and persistent temporary wetlands (PTWs), few species were recorded during 2017–18 surveys and scores were extremely low (or zero) for these WRCs (Figure 4.1a).

Lake Kramen, an episodic wetland (EPW), had completely dried since the 2016–17 surveys. Despite highest species richness being recorded at Lake Kramen in 2017-18, values were lower than in 2016–17, with no sites meeting the water responsive species richness target. Lower species richness at Lake Kramen is likely influenced by the dominance of one species, Southern Liquorice (*Glycyrrhiza acanthocarpa*), across the lake bed (Figure 4.1a).

Species richness for SPW was relatively high in 2007–08 and 2008–09, reflecting water recession following environmental flows delivered to these wetlands during drought years. Responses for PTW were variable across all survey years.

(a)



(b)

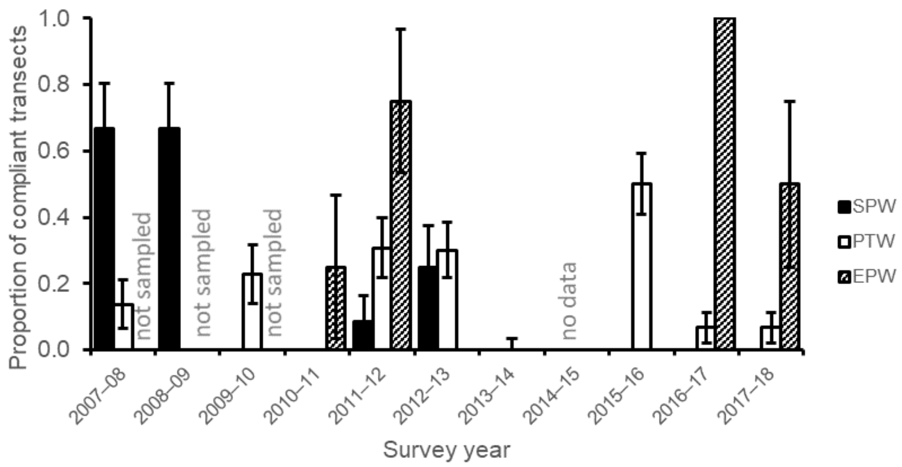


Figure 4.1 Proportion of transects (± SE) meeting the reference value for (a) water responsive species richness and (b) water responsive species abundance scores for wetlands at Hattah Lakes. Scores were based on 80th percentile indices, specific to each water regime class (WRC). Key: SPW = semi-permanent wetland, PTW = persistent temporary wetland, EPW = episodic wetland. Sampling for EPW (i.e. Lake Kramen) did not commence until 2010–11. No surveys were undertaken in 2014–15.

Water responsive species abundance

Scores were calculated for water responsive species abundance for each WRC, using the ecological targets Index 2 in

Table 4.3 (Figure 4.1b). The highest abundance scores were found at Lake Kramen (EPW). Abundance scores were negatively affected by extensive inundation at both SPW and PTW in 2017–18 (Figure 4.1b).

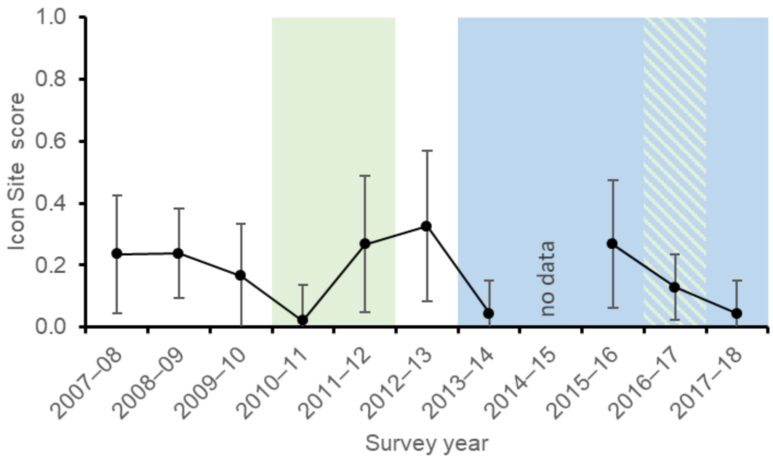
Whole-of-icon site score

A Whole-of-icon site score was determined for both species richness (Figure 4.2a) and species abundance (Figure 4.3 a) for each year that monitoring occurred. Calculations were based on the number of transects surveyed in 2017–18 that were equal to or greater than the reference listed in

Table 4.3 for each WRC. The weighted icon site score for species richness was 0.044 (±0.11) and abundance was 0.086 (±0.14). Both of these values were lower than the values calculated for 2016–17. Extensive inundation from environmental watering in 2017–18 at both SPW and PTW is likely responsible for reductions in overall icon site scores for species richness and abundance metrics.

2017–18 marks the first occurrence of ‘Whole-of-icon site’ scores being calculated for each individual year that surveys have been undertaken at Hattah Lakes wetlands as part of TLM. There has been no increase in water responsive species richness since 2007. There appears to be a trend towards decreased species richness when the Hattah Lakes are in flooded condition, since inundated sites only support a few floating or submerged aquatic plants (Figure 4.2a and Figure 4.2b). There is no apparent difference in species abundance between flooded and non-flooded periods (Figure 4.3 a and Figure 4.3 b).

(a)



(b)

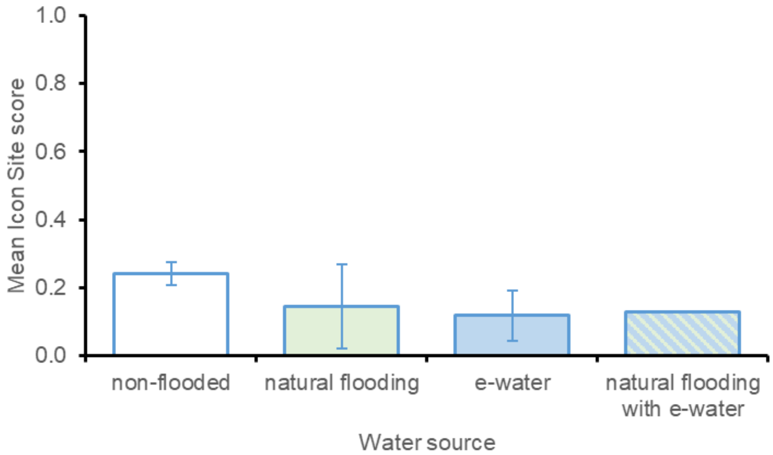
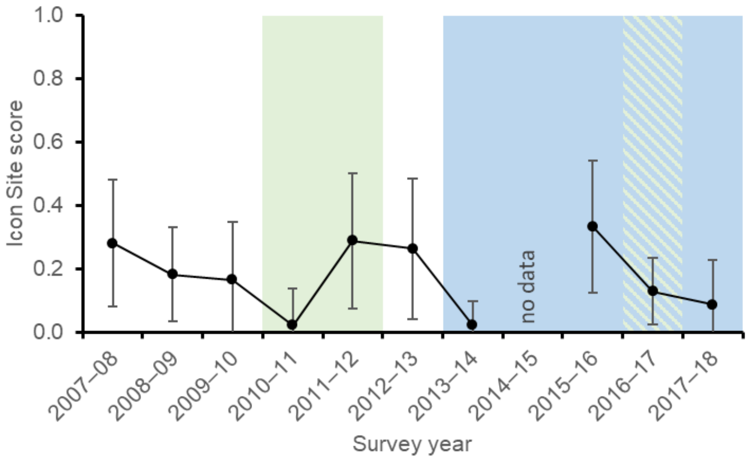


Figure 4.2. (a) Whole-of-icon site scores (± 95% CI for two sampled comparisons with normally distributed error variance) for water responsive species richness at Hattah Lakes wetlands. The total area in each water regime class (WRC) was used to weight the average strata scores for each WRC into an overall icon site mean score. (b) The mean Whole-of-Icon site score (± SE) of each flooding period as indicated (a) above; non-flooded (white) *n* = 4, natural flooding (green) *n* = 2, environmental water (e-water) (blue) *n* = 3, natural flooding with e-water (green and blue), *n* = 1.

(a)



(b)

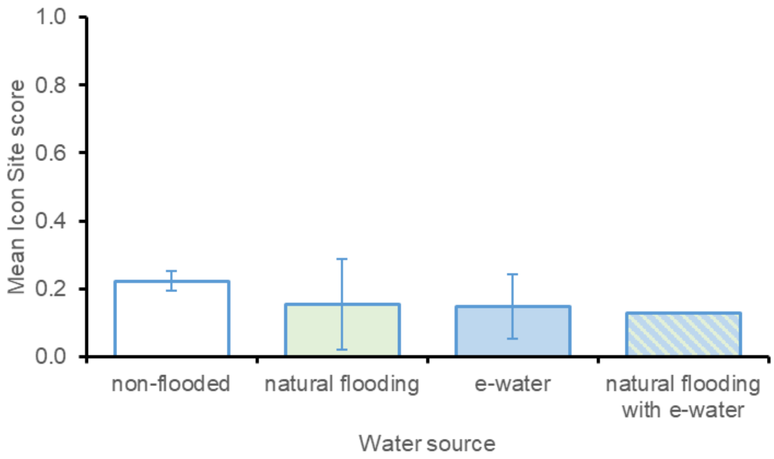


Figure 4.3 (a) Whole-of-icon site scores (± 95% CI for two sampled comparisons with normally distributed error variance) for water responsive species abundance at Hattah Lakes wetlands. The total area in each water regime class (WRC) was used to weight the average strata scores for each WRC into an overall icon site mean score. (b) The mean Whole-of-Icon site score (± SE) of each flooding period as indicated (a) above; non-flooded (white) *n* = 4, natural flooding (green) *n* = 2, environmental water (e-water) (blue) *n* = 3, natural flooding with e-water (green and blue), *n* = 1.

4.4.4 Drought tolerant vegetation in wetlands

Despite continued inundation at SPW, the plant community had increased from four species in 2016-17 to nine species in 2017–18. The majority of the community recorded were fringing amphibious eucalypts; River Red Gum (*Eucalyptus camaldulensis*) (Figure 4.4a). Spiny Flat-sedge (*Cyperus gymnocaulos*), an amphibious sedge, was recorded on the edges of Lakes Hattah and Mournpall in low abundance. Drought tolerant plants (Tdr) have not been recorded in SPW since 2012–13, a product of continued inundation during the last four surveys.

Community composition at PTW was made up of plant species from a variety of functional groups in all survey years (Figure 4.4b). The proportion of drought tolerant (Tdr) plants has been minimal since 2013–14, likely due to repeated inundation over the last five years (Figure 4.4b). Seven drought tolerant plant species (~20% proportion of abundance) were recorded at PTW in 2017–18, the majority of which occurred at Chalka Creek North, which was drawing down following the delivery of environmental water in 2017.

The vegetation community at Lake Kramen (EPW) was comprised of species from a variety of functional groups in almost all survey years (Figure 4.4c), noting that surveys commenced after environmental flows were delivered in 2010–11. In 2017-18, drought tolerant (Tdr) species were most common on the drying wetland bed (Figure 4.4). Twenty of 39 species, comprising ~45% of the plant abundance, were from the Tdr functional group. For more detailed information about which species were recorded and where, refer to Part B of this report.

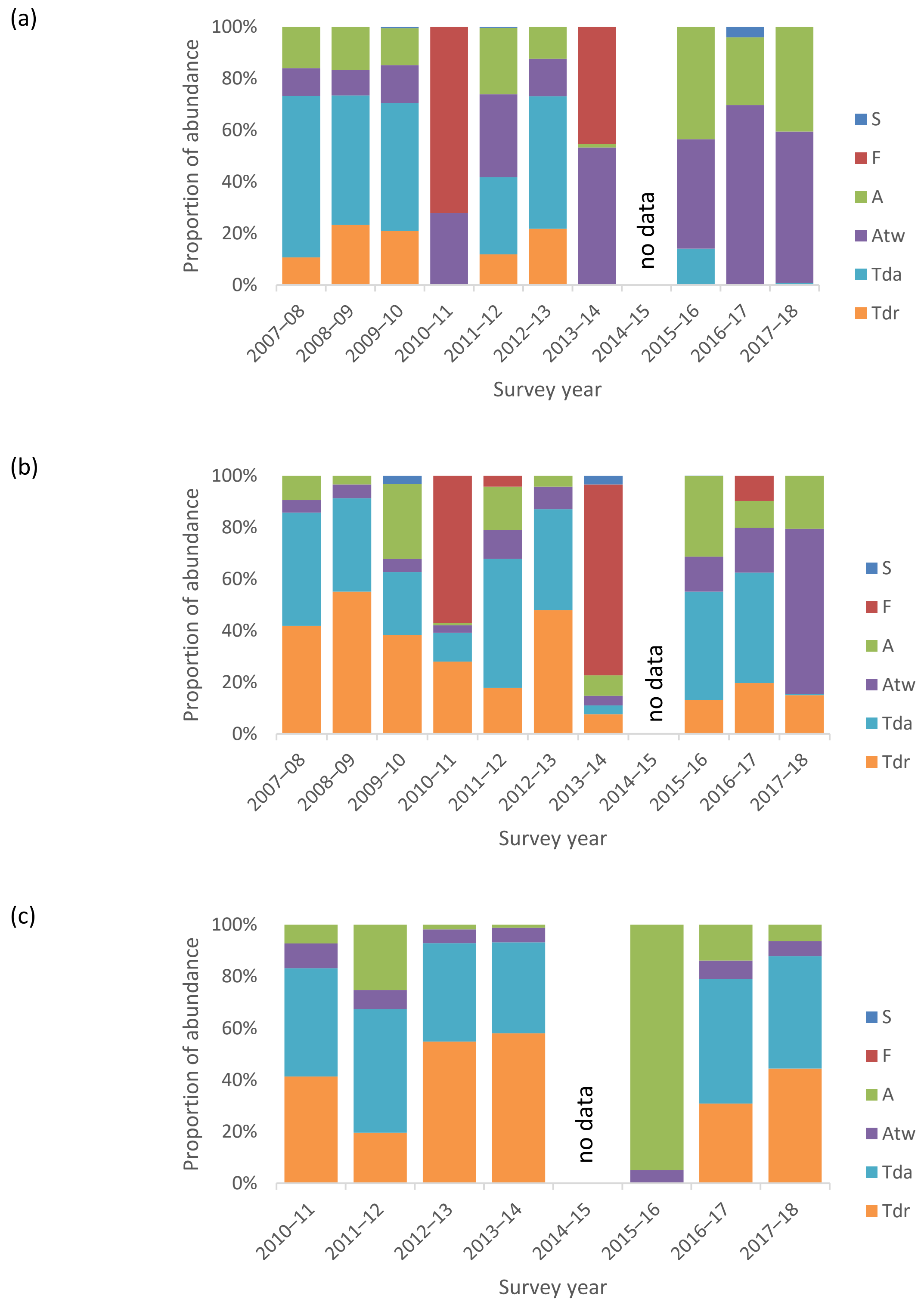


Figure 4.4 Proportion of sum of abundance for each functional group in (a) semi-permanent wetlands, (b) persistent temporary wetlands, and (c) episodic wetlands. Key: plant species functional groups; S = submerged, F = floating detached, A = aquatic and amphibious species, Atw = amphibious woody plants, Tda = terrestrial damp species, Tdr = drought tolerant plants.

4.5 Discussion

Frequent inundation has resulted in the reduction of our two key metrics, namely water responsive species richness and abundance at Hattah Lakes since 2010. This suggests that wetlands are receiving too much water or are inundated too frequently to achieve the adopted objective for wetland vegetation. Also, the indices set for Hattah Lakes wetlands may not be sensitive to positive changes in the condition of frequently inundated wetland communities.

4.5.1 Semi-permanent wetlands

Vegetation community composition within SPW in 2017–18 has not changed significantly from surveys conducted in 2016-17. Semi-permanent wetlands are relatively deep and remain at least half full between 76 and 91% of the time and dry events are rare (Ecological Associates 2007). Fewer plant species are expected during inundation and are limited to a few floating and/or submerged species (Campbell *et al.* 2014). Although species richness and abundance remained low in 2017–18, this is to be expected in semi-permanent wetlands during an inundation phase. An increase in species richness and abundance is anticipated as water draws down from these wetlands.

The benefit of extensive inundation, with limited plant development, is not well reflected in the ecological targets for SPW, which rely on high species richness and abundance scores for water responsive species. The highest richness and abundance scores for SPW were recorded in 2007–08 and 2008–09 when amphibious species emerged in response to recession of environmental water. While the presence of amphibious species may reflect a positive wetland vegetation response water responsive species richness and abundance scores have not increased and consistent species richness score of zero (e.g. in 2013–14, 2015–16, 2016–17 and 2017-18) do not satisfactorily reflect wetland condition. A measure of plant health, rather than just species presence and abundance may better reflect wetland condition.

While improvements in vegetation health are not evident from ecological target scores alone, the proportional functional group data indicates that community composition is dominated by water responsive species in all survey years. Such transformations in community composition over time are desirable and demonstrate that the ecological vision to 'preserve healthy wetland communities' is being maintained for SPW at the Hattah Lakes icon site.

4.5.1 Persistent temporary wetlands

Community composition at PTW is comprised of plant species from diverse functional groups that have varied with each survey year. Terrestrial species that require damp habitats (Tda) were few in PTW, reflecting high inundation levels due to environmental water delivered to these wetlands in late 2017. Woody species tolerant of wetting and drying (Atw) comprised the greatest proportion of the PTW community. The proportion of drought tolerant species (Tdr) has diminished during the last four years in comparison to drought years (2007–08 to 2009–10), and in 2017–18 contributed only ~15% of the total proportion of species abundance. This is likely a result of repeat inundation since 2010–11, from both natural flooding and environmental water. Persistent temporary wetlands are shallower than SPWs and can dry intermittently (Ecological Associates 2007), providing habitat for drought tolerant floodplain plants (Boulton *et al.* 2014).

The intent should not be to eradicate drought tolerant species from PTW, since they encompass an important part of the wetland community between inter-flood periods. Their prolonged encroachment or the number of years in which drought tolerant species are dominant however, requires constraint. An encroachment of drought tolerant species into PTW was not evident at Hattah Lakes in 2017–18.

Since 2007, hydroperiod of PTW has been variable, providing a mosaic of habitats to support plant species from a variety of functional groups. We have seen a cumulative increase in ecological target scores; scores in 2015–16 (following flooding in 2010–11 and environmental flows in 2013, 2014 and 2015) were higher than scores in 2012–13 (following flooding in 2010–11). Given that only two wetlands were drawing down in 2015–16 compared to seven in 2012–13, the comparatively high scores, particularly in relation to species abundance, reflect the benefit of consecutive inundation.

Drying lakebeds provide a wet/dry ecotone which is particularly high in species diversity (Brock & Casanova 1997). Repeated inundation is likely to facilitate vegetative growth (e.g. lateral growth from underground root systems) or completion of plant life cycles (e.g. the replenishment of seedbanks), enabling species to respond with greater abundance following subsequent flows. Similar observations have been made in wetlands in south-west New South Wales (Campbell *et al.* 2012). It is likely that wetland vegetation communities at Hattah Lakes have benefited from repeated inundation since flooding in 2010–11. It remains to be seen whether species richness and abundance will increase in future surveys when flood waters begin to drawdown or if the seed bank will be diminished after successive wet years leading to decreased diversity (Brock 2011).

4.5.2 Episodic wetlands

Across all wetlands in 2017–18, the highest species richness and abundance was recorded at Lake Kramen. Lake Kramen was the only wetland at Hattah that was completely dry during monitoring. Even though none of the transects met environmental targets for species richness, average richness at EPW was much higher than the other WRCs.

For the past two survey years, the majority of plant richness and abundance recorded at Hattah Lakes occurred at Lake Kramen. This is a positive vegetation response at a wetland that was long-dry. Environmental flows were delivered to the wetland in 2011 and 2014 but before this the wetland received no flooding from 1993–94 to 2011. Seed bank diversity tends to decrease during long periods of drought, dramatic decreases in number and diversity of germinants are found after 12 years in dry storage (Brock 2011). We can infer that the seed bank at this site is well adapted to extended dry phases.

Episodic wetlands receive flows only rarely and can have long-dry periods (median is 625 days) in between inundation cycles (Ecological Associates 2007). Therefore, this water regime class supports not only water responsive plant species, but also drought tolerant species. In 2017–18, the plant community at Lake Kramen was made up of both water responsive and drought tolerant species. As with PTW, drought tolerant plants are an important part of the wetland community.

4.5.3 Whole-of-icon-site scores

As mentioned above, Whole-of-icon site scores have been calculated for the entire time series of TLM monitoring at Hattah Lakes wetlands for the first time in 2017–18. We have found the score to be sensitive to flooding. Decreases in richness and abundance of water responsive species are detected while the wetlands are inundated. The highest Whole-of-icon site richness scores were in 2012–13 when no flooding occurred at Hattah Lakes wetlands and receding floodwaters provided ideal niches for water responding terrestrial species to complete their life cycles.

4.6 Progress towards ecological objectives

Community composition at Hattah Lakes is largely dominated by aquatic, amphibious and terrestrial damp species due to a combination of floods and the delivery of environmental flows. No encroachment of drought tolerant species into wetlands was identified. The presence of drought tolerant species at PTW and EPW in 2017–18 was not seen as an encroachment. Drought tolerant species make up an important part of the natural cycle as ephemeral wetlands drawdown following inundation. There were no drought tolerant species recorded at SPW in 2017–18. Therefore, favourable environmental conditions have helped to maintain healthy wetland communities at the Hattah Lakes icon site.

In each survey year, wetlands at Hattah Lakes were in various states of inundation (e.g. inundated, drawdown, intermittent-dry, long-dry), providing a mosaic of habitats and supporting a variety of vegetation communities across the icon site. Variable wetting and drying regimes result in changes in plant community composition over time and across the landscape (Capon 2005; James *et al.* 2007; Warwick & Brock 2003), including variations in species richness and abundance. An increase in the diversity of wetland habitats is associated with an increase in species richness and diversity (Stein *et al.* 2014; Thoms *et al.* 2006). Therefore, the overarching ecological objective to restore a mosaic of healthy wetland communities at Hattah Lakes is being achieved.

4.7 Recommendations

As recommended in Brown *et al.* (2016), wetland indices were updated in this report to reflect the 80th percentile, rather than the 90th percentile. For consistency, these targets should be updated in The Living Murray: Condition Monitoring Program design for the Hattah Lakes (Huntley *et al.* 2016).

A method to determine differences in the Whole-of-Icons Site scores between survey years should be developed. Additionally, a minimum target score may be considered in order to assess whether ecological targets are being met. The methods and recommendations in Richardson (2014a) are based on only aquatic species and the indices have since been updated to include water responsive terrestrial species as recommended in (Brown *et al.* 2016). We recommend that resources be allocated to improving on this statistical method.

As recommended in Brown *et al.* (2016), now that references have been trialled for each icon site, a workshop should be held to include scientists, field work researchers/contractors and TLM icon site managers to discuss outcomes of this approach. This may assist in addressing the following sorts of queries:

- Is the regular occurrence of a zero score meaningful (particularly for SPW where water retention is expected for longer periods)? What is the best way to evaluate low species richness and abundance scores during extensive inundation?
- Is there a minimum number of years of data required to set an appropriate reference index? Only five years of data were available to set targets for EPW, compared with nine years data for other WRCs.

It is anticipated that the composition and abundance of species in amphibious and terrestrial damp functional groups will increase in future surveys when wetlands are allowed to draw down. Comparisons of ongoing condition monitoring data (as wetlands draw down), to vegetation responses following natural floods will be useful in guiding the delivery of future environmental flows.

The presence of Common carp in wetlands at Hattah may impact the development of aquatic vegetation in the system. It would be useful to analyse existing TLM condition monitoring data to investigate links between the presence of Common carp and the diversity abundance of vegetation in wetlands. This may improve our understanding of the effect of Common carp on the health of wetlands at the Hattah Lakes icon site and enable predictions of the benefits of Common carp management.

5 Floodplain vegetation communities

AUTHOR: LOUISE ROMANIN

5.1 Introduction

Floodplains are defined as areas of relatively flat land that are inundated when adjacent rivers overflow their banks during a flood (Young 2001). In arid landscapes, floodplains provide critical aquatic and riparian habitat for flora and fauna that are both reliant on and tolerant of flooding (Rogers & Ralph 2011). The distribution and abundance of floodplain vegetation is strongly influenced by hydrology and many species have adapted to depend on flooding (Brock & Casanova 1997). River regulation has led to a reduction in the frequency, magnitude and duration of flooding in the lower reaches of the Murray–Darling River system (Rogers & Ralph 2011; Young 2001). If floods continue to become less frequent and less variable, it is anticipated that these floodplain vegetation communities will be replaced by drought tolerant species in the long term (Nicol & Weedon 2006; Roberts & Marston 2011; Rogers & Ralph 2011; Young 2001). The Living Murray (TLM) Program is a large-scale restoration project that attempts to ameliorate the negative effects of regulation on wetlands and the floodplain. Condition monitoring of floodplain vegetation communities at the Hattah Lakes icon site has been undertaken since 2007–08. This chapter reports on the findings of these surveys over the last decade.

5.2 Ecological objectives

The ecological objectives used for floodplain vegetation communities are consistent with those used for wetland vegetation communities described in Section 4.2.

This chapter reports on the established vision statement and overarching ecological objective for floodplain vegetation at Hattah Lakes. Following the detailed methods described for floodplain vegetation in The Living Murray: Condition Monitoring Program design for the Hattah Lakes (Huntley *et al.* 2016), this chapter will:

- assess water responsive species richness and abundance against a point of reference
- assess the condition of the whole icon site using species richness and abundance scores
- analyse changes in vegetation community composition over time.

5.3 Method

There are six floodplain understorey monitoring locations (H1–H6) established under TLM at the Hattah Lakes icon site. Locations were established in 2007–08 to represent three different flood return frequencies (FRFs), often, sometimes and rarely, represent three floodplain elevations as outlined in Table 5.1. Locations H1, H2, H3, H5 and H6 each consist of three FRFs (i.e. one often-, one sometimes- and one rarely-flooded site per FRF = 15 sites). Location H4 has two FRFs (i.e. one often- and one sometimes-flooded site = 2 sites). Comprehensive detail on floodplain vegetation assessments are provided in the Condition Monitoring Program design for the Hattah Lakes icon site(Huntley *et al.* 2016).

Surveys have been undertaken annually at these 17 sites since 2007–08, excluding 2014–15 when no data was collected due to changes in program funding. In 2010–11, only 14 sites were surveyed as flooding prevented access to some sites. All 17 sites were surveyed in this survey year (2017–18). Each year, surveys were conducted following the methods described in The Living Murray: Condition Monitoring Program design for Hattah Lakes (Huntley *et al.* 2016).

Table 5.1 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.

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 Field survey methods

At each location in each FRF, there are four permanently established quadrats, spaced 50 m apart and each consisting of 15 x 1 m x 1 m cells. Floodplain vegetation surveys follow the methods described in Section 4.3.1. The methods to identify plant species and the use of plant functional group are described in Section 4.3.3.

5.3.2 Data analysis

Point of reference assessment

As part of an adaptive management process, TLM Program recently underwent refinements to develop site-specific ecological targets that link back to the vision statement and ecological objectives (Robinson 2014a, b). Ecological targets for Hattah floodplain understorey were set using data from 2007–08 to 2015–16 and are listed in Table 5.2 (Brown *et al.* 2016; Huntley *et al.* 2016). To be consistent across Mallee CMA TLM icon sites, floodplain vegetation is deemed to be in good condition when:

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

Table 5.2 Ecological targets for floodplain understorey vegetation at the Hattah Lakes icon site (developed using data from 2007–08 to 2015–16, adapted from Brown *et al.* (2016) and Huntley *et al.* (2016).

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

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 water responsive plant species (see Section 4.3.3)
- 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 quadrats was calculated for each FRF.

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.

A Whole-of-icon site score was determined for water responsive species richness and water responsive species abundance (

Table 4.3) using the methods described in Brown *et al.* (2016). The calculation of this score requires that FRF scores be weighted according to the relative area of each FRF within the floodplain at Hattah Lakes (Brown *et al.* 2016). The statistical weighting follows the process detailed in Sutherland (2006) and a worked example, showing equations, is presented in Brown *et al.* (2015a). These Whole-of-icon site scores were calculated for each survey year since 2007-08 (excluding 2014-15). These values 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 (MDBA 2018).

Plant functional groups

The use of plant functional groups is a widely accepted method of interpreting changes in plant communities in relation to disturbance, while minimising the effects of changes in species composition or inconsistencies in taxonomic classification (Brock & Casanova 1997; Campbell *et al.* 2014). Functional groups help demonstrate the impact of flood inundation on community composition. Graphs that display the proportion of functional group abundance data for each survey year, in each FRF, were created in Microsoft Excel. For display purposes, functional groups A, Arf, Arp, Ate, Atl (for definitions see Data analysis

Point of reference assessment

As part of an adaptive management process, TLM Program recently underwent refinements to develop site-specific ecological targets (a point of reference) that link back to the vision statement and ecological objectives (Robinson 2014a, b). As the program continues to evolve, further improvements have been made and the ecological targets set in Brown *et al.* (2016) and Huntley *et al.* (2016) have been refined in this report to be consistent across the TLM icon sites in the Mallee Catchment Management Authority region (i.e. Hattah Lakes and the Lindsay–Mulcra–Wallpolla Islands). This is for all understorey vegetation components (i.e. wetland and floodplain communities).The ecological targets for wetland vegetation (

Table 4.3) were developed using data from 2007–08 to 2015–16 and following the methods described and recommended in Huntley *et al.* (2016).

Table 4.2 in Section 4.3.3) were combined into one amphibious functional 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 species (Tda).

5.4 Results

5.4.1 Floodplain inundation state

The historic and current inundation state of each floodplain site provided context for data analysis (Table 5.3). Environmental water was delivered to the Hattah Lakes icon site in 2017 with most floodplain locations being at least partially inundated for a brief period (excluding H2, H3 and H1C). Widespread flooding, which peaked in November 2016, inundated all floodplain sites except one (H3C). Prior to this, three sites had not been inundated by overbank flows for 23 years (i.e. H1C, H2C and H6C), and H3C remains long-dry (last inundated 1993–94). Seventeen sites were surveyed during 2017–18 (Table 5.3):

- Fifteen sites were intermittent-dry (i.e. dry during this survey, but held water less than two years ago and may still show some vegetation response to inundation)
- One site remained inundated (e.g. at least half of the four quadrats per site were inundated)
- One site remained long-dry (i.e. dry for at least two survey years; last inundated 1993–94)

Table 5.3 Hydrological state of each floodplain site surveyed at Hattah Lakes in 2017–18. Key: RRG = River Red Gum overstorey, BB = Black Box overstorey; Intermittent-dry = dry during survey, but held water less than two years ago and may still show some vegetation response to inundation, Inundated = at least half the quadrats inundated, long-dry = dry for at least the last two surveys; (F) = flood, (E) = environmental flows.

Flood return frequency	Site	Vegetation community	Hydrological state in 2017–18 surveys	Previous inundation year (source)
Lower floodplain	H1A	RRG	Intermittent-dry	2010–11 (F) 2016 (F) 2017 (E)
Lower floodplain	H2A	RRG	Intermittent-dry	2010–11 (F) 2016 (F)
Lower floodplain	H3A	RRG	Intermittent-dry	2010–11 (F) 2016 (F)
Lower floodplain	H4A	RRG	Intermittent-dry	2014 (E) 2016 (F) 2017 (E)
Lower floodplain	H5A	RRG	Inundated	2015 (E) 2016 (F) 2017 (E)
Lower floodplain	H6A	RRG	Intermittent dry	2015^ (E) 2016 (F) 2017 (E)
Mid floodplain	H1B	RRG	Intermittent-dry	2010–11 (F) 2016 (F) 2017 (E)
Mid floodplain	H2B	RRG	Intermittent-dry	2010–11 (F) 2016 (F)
Mid floodplain	H3B	RRG	Intermittent-dry	2010–11 (F) 2016 (F)
Mid floodplain	H4B	RRG	Intermittent-dry	2010–11 (F) 2016 (F) 2017 (E)
Mid floodplain	H5B	RRG	Intermittent-dry	2014 (E) 2016 (F) 2017 (E)
Mid floodplain	H6B	BB	Intermittent-dry	2014 (E) 2016 (F) 2017 (E)
Higher floodplain	H1C	BB	Intermittent-dry	1993–94 (F) 2016 (F)
Higher floodplain	H2C	BB	Intermittent-dry	1993–94 (F) 2016 (F)
Higher floodplain	H3C	BB	Long-dry	1993–94 (F)
Higher floodplain	H5C	BB	Intermittent-dry	2014* (E) 2016 (F) 2017 (E)
Higher floodplain	H6C	BB	Intermittent-dry	1993–94 (F) 2016 (F) 2017 (E)

*Partially inundated (three out of four quadrats were inundated with environmental flows in 2013–14). This site was also partially inundated by floodwater in 2010–11 (three out of four quadrats).

^Partially inundated during surveys (e.g. three of four quadrats surveyed were inundated, while water had receded from one).

5.4.2 Data summary

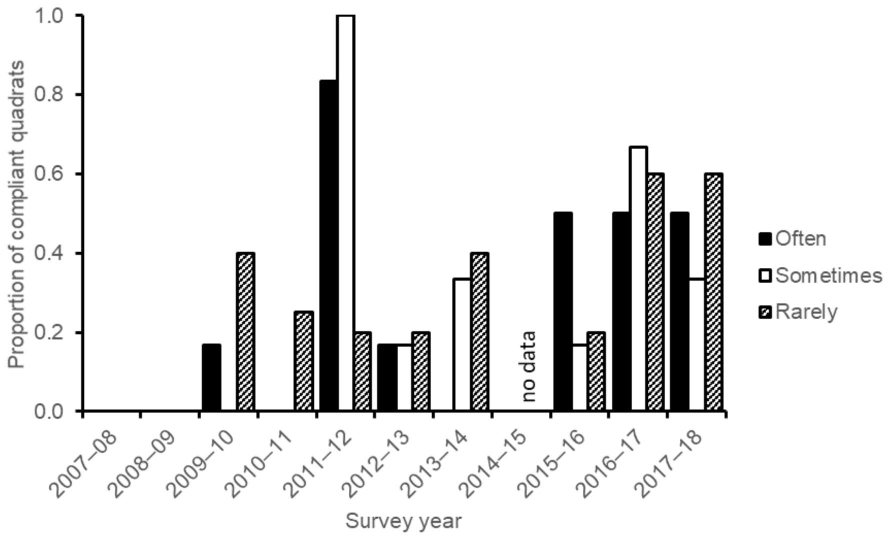
A total of 124 plant species were recorded in 2017–18 on the floodplain at Hattah Lakes. The three most abundant species recorded were two terrestrial damp species from the Tda functional group; Lesser Joyweed (*Alternanthera denticulata*), Common Sneezeweed (*Centipeda cunninghamii*) and the dry adapted species Caustic Weed (*Euphorbia dallachyana*) from the Tda functional group. There were 19 non-native species and 8 species that have conservational significance in Victoria, including Lagoon Spurge (*Phyllanthus lacunarius*) from the Tda functional group, which had declined in abundance compared to last year (i.e. an abundance of 36 in 2017–18 compared to 75 in 2016–17). The vulnerable species Sand Sida (*Sida ammophila*) from the Tdr functional group was recorded at the highest abundance since surveying started in 2007 (i.e. abundance of 3 in 2007–08, 2013–14 and 2015–16 and abundance of 38 in 2017–18). Detailed information relating to which species were recorded and where can be found, along with wetland photo-point photos, in Part B of this report.

5.4.3 *Point of reference assessment*

Water responsive species richness

Scores were calculated for water responsive species richness for each FRF, using Index 1 of the ecological targets in Table 5.2 (Figure 5.1a). This score at often-flooded sites has remained the same for the last three survey years. Only one of the six often-flooded sites remained inundated during 2017–18 surveys, two were inundated in 2016–17. We would expect that many water responsive species would have germinated in the still-damp soils of recently drawn down floodplains, thus increasing species richness. Therefore, the lack of change at this site is unexpected. The highest species richness scores for the lower floodplain were recorded in 2011–12 following widespread inundation in 2010–11.

(a)



(b)

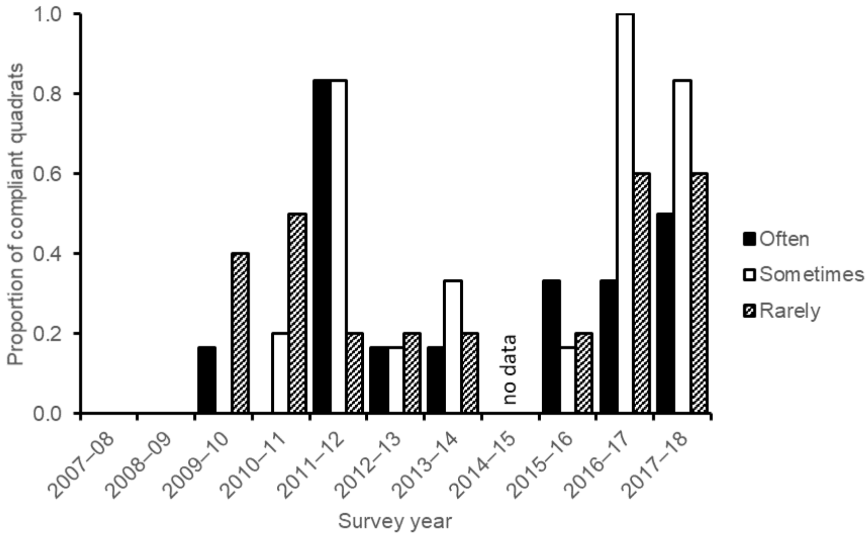


Figure 5.1 Proportion of transects (± SE) meeting the reference value for (a) water responsive species richness and (b) water responsive species abundance scores for floodplains at Hattah Lakes (*n* = 17 sites in all years except 2010–11 where *n* = 14). No surveys were undertaken in 2014–15. Scores were based on 80th percentile indices, specific to each floodplain elevation (i.e. often-, sometimes- and rarely-flooded).

One third of the sometimes-flooded sites met their water responsive species richness targets during the 2017–18 surveys. Species richness scores were elevated in 2016–17 following flooding in November 2016 and had since decreased as the sites dried.

Water responsive species richness at rarely-flooded sites remained high in 2017–18. Four of the five higher floodplain sites had not been inundated since 1993–94. As a product of their low expected species richness, these long-dry communities meet species richness targets in most years.

Species richness scores were zero at all FRFs in 2007–08 and 2008–09 (drought years).

Water responsive species abundance

Scores were calculated for water responsive species abundance for each FRF, using Index 2 of the ecological targets in Table 5.2 (Figure 5.1). Species abundance had increased at often-flooded sites since the last survey year. Rarely-flooded sites had the same abundance scores as those recorded in last year's (2016–17) surveys. Sometimes-flooded sites also had high species abundance scores, but these had decreased since last year's surveys. All levels of the floodplain have benefitted from flooding in November 2016 and the delivery of environmental water in 2017–18.

Species abundance scores were zero at all FRFs in 2007–08 and 2008–09 (drought years).

Whole-of-icon site score

A Whole-of-icon site score was determined for both species richness (Index 1) and species abundance (Index 2). Calculations were based on the number of sites surveyed in 2017–18 that were at or above the point of reference listed in Table 5.2 and weighted by area of each FRF. The weighted icon site score for species richness was 0.551 (±0.543). The weighted icon site score for species abundance was 0.633 (±0.539). Both of these scores were lower than those calculated for 2016–17.

The Whole-of-icon site scores were calculated for every survey year and plotted as a time series. Both species richness and species abundance had increased since 2007–08 and appear responsive to watering events (Figure 5.2a & Figure 5.3a). The Whole-of-icon site scores achieved in 2016–17 were the highest since monitoring began and these scores have remained elevated during this survey season (2017–18). The combination of some environmental water plus natural flooding that occurred in 2016 appears to have boosted species richness and abundance scores more than natural flooding or environmental water alone (Figure 5.2b & Figure 5.3b). However, this result should be viewed with caution, since this combination of events has not been replicated. An increase in icon site score was observed in 2009–10, prior to natural flooding at Hattah Lakes. This may be attributed to surveys being completed in autumn instead of summer and plants responding to reduced temperatures and autumn rainfall. The Whole-of-icon site species richness score fluctuates from year to year but an increase in species richness through time is apparent. Whole-of-icon site abundance scores fluctuate more with natural flooding than richness scores, but here, too, an increase in abundance over time was recorded (Figure 5.2b & Figure 5.3b).

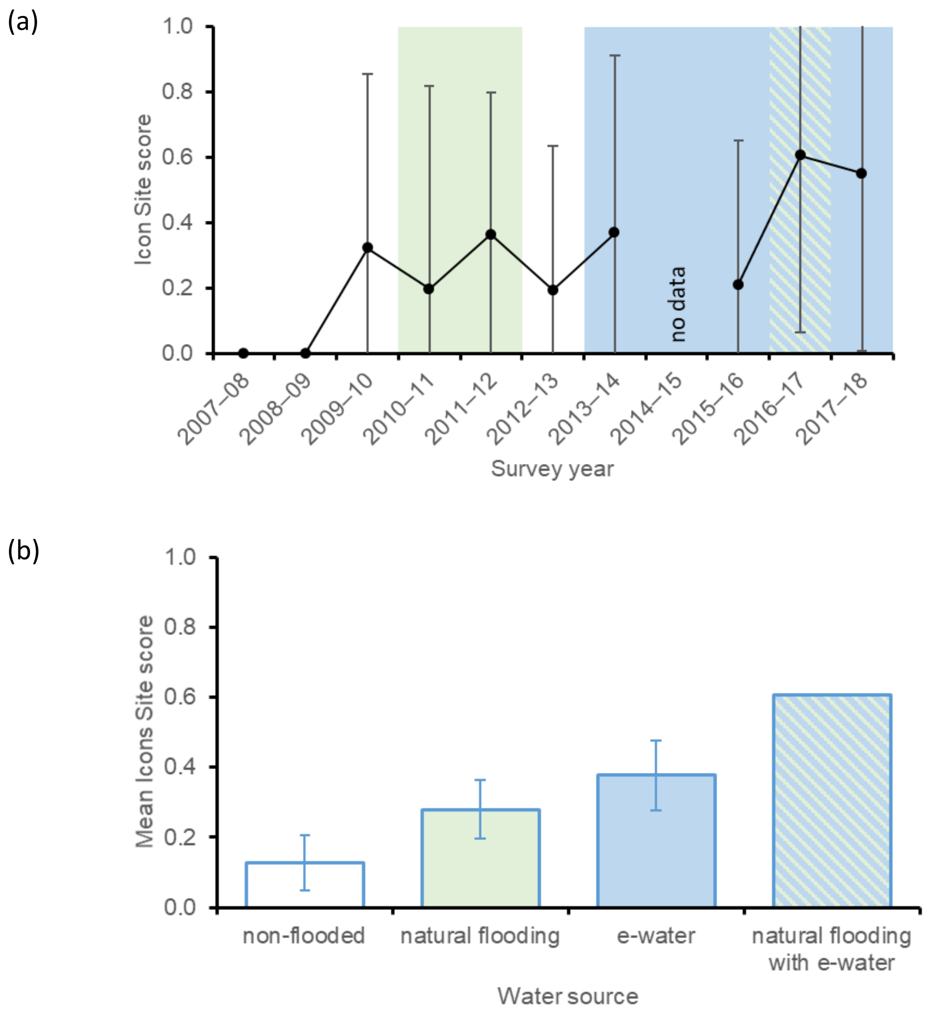
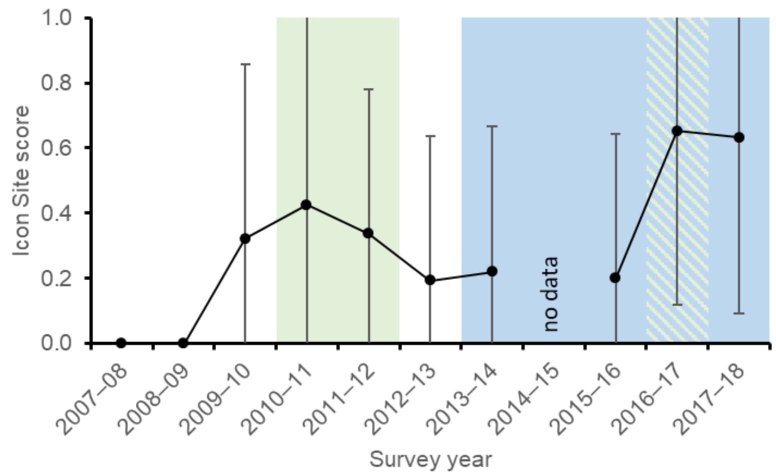


Figure 5.2 a) Whole-of-icon site scores (± 95% CI for two sampled comparisons with normally distributed error variance) for water responsive species abundance at Hattah Lakes floodplains plotted as a time series. The total area in each flood return frequency (FRF) was used to weight the average strata scores for each FRF into an overall icon site mean score. (b) The mean Whole-of-Icon site score (±SE) of each flooding category; non-flooded *n* = 6, natural flooding *n* = 3, environmental water (e-water) *n* = 1.

(a)



(b)

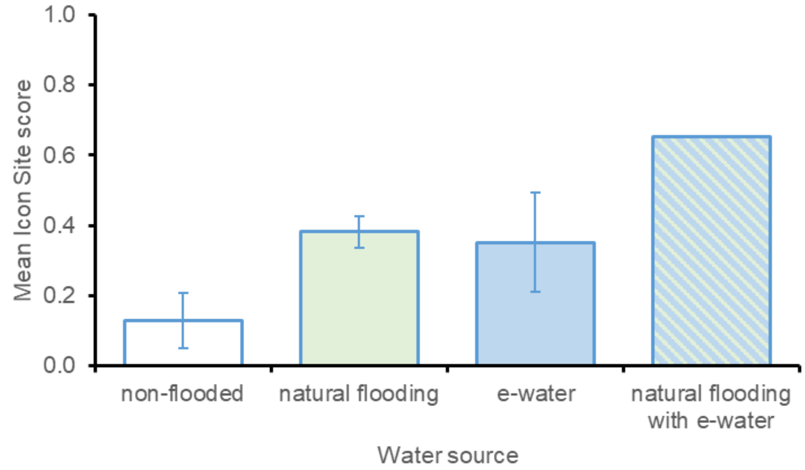


Figure 5.3 a) Whole-of-icon site scores (± 95% CI for two sampled comparisons with normally distributed error variance) for water responsive species abundance at Hattah Lakes floodplains plotted as a time series. The total area in each flood return frequency (FRF) was used to weight the average strata scores for each FRF into an overall icon site mean score. (b) The mean Whole-of-icon site score (± SE) of each flooding category; non-flooded *n* = 6, natural flooding *n* = 3, environmental water (e-water) *n* = 1.

5.4.4 Plant functional groups

Changes in community composition over time were similar between often- and sometimes-flooded sites (Figure 5.4a & Figure 5.4b). The proportion of amphibious (A) species increased and drought tolerant (Tdr) species decreased at often-flooded sites compared to the previous survey year. A higher proportion of drought tolerant species (Tdr functional group) were found at the sometimes-flooded compared to often-flooded sites (35.6% cf. 16.6%). Following the extensive natural flooding in 2010–11 there has been a greater proportion of amphibious and terrestrial damp species than in drought years (2007–08 to 2009–10) especially at the sometimes-flooded sites. In 2017–18, the greatest proportion of the vegetation community in both often- and sometimes-flooded sites was made up of terrestrial damp species (Tda functional group).

Rarely-flooded sites were dominated by drought tolerant species (Tdr functional group) in all survey years (Figure 5.4c). In 2017–18, the proportion of terrestrial damp species (Tda functional group) decreased compared to 2016–17.

For more detailed information about which species were recorded and where, refer to in Part B of this report.

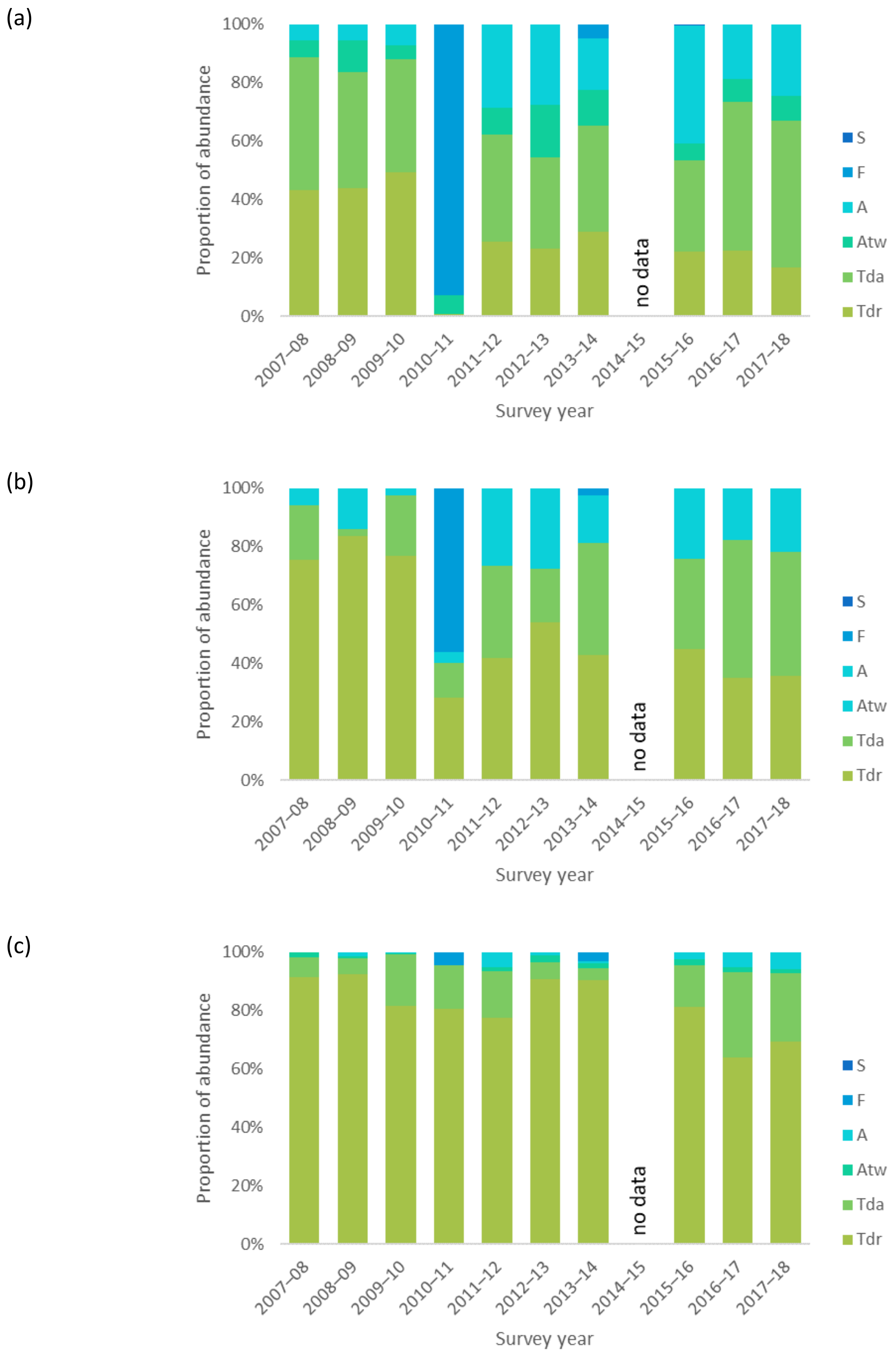


Figure 5.4 Proportion of sum of abundance for each functional group in (a) often-, (b) sometimes- and (c) rarely-flooded sites (*n* = 17 sites in all years except 2010–11 where *n* = 14). No surveys were undertaken in 2014–15. Key: plant species functional groups; S = submerged, F = floating detached, A = aquatic and amphibious species, Atw = amphibious woody plants, Tda = terrestrial damp species, Tdr = drought tolerant plants.

5.5 Discussion

The Whole-of-icon site scores indicate that the water responsive plant community at Hattah floodplains has benefitted from increased environmental water allocations with an observed increase in water responsive species richness and abundance. Understorey vegetation communities at often- and sometimes-flooded sites at Hattah Lakes have benefited from a regular inundation since 2010. All sites in these communities were inundated by flooding that peaked in November 2016 and two of the lower floodplain sites remained inundated during 2017–18 surveys. The rarely-flooded sites on higher floodplain elevations benefited from inundation in November 2016, however, they remain dominated by drought tolerant species. Flooding inundated four of the five sites, three of which were last inundated in 1993–94. One site remains long-dry and has not been inundated for approximately 24 years (i.e. since 1993–94).

5.5.1 Often-flooded

Natural flooding in 2016 was followed by delivery of large volumes of environmental water to the Hattah Lakes system in 2017–18. Two of the six often-flooded sites remained inundated during 2017–18 surveys. Water responsive species richness at the often-flooded sites has remained static since 2015–16, however increases in abundance were observed, and we expect species richness among inundated sites to increase as water recedes. Repeated wetting and drying can decrease species richness by exhausting the soil seed bank; flooding cues seed germination, but some species are unable to replenish soil seed stores within dry periods or complete their life cycles within wet periods (Brock 2011).

Community composition at often-flooded sites has changed over the last decade of monitoring. The proportion of drought tolerant species had decreased this survey year compared to 2016–17. As anticipated, during drought years, the vegetation community was dominated by drought tolerant species (Tdr functional group). In 2010–11, all sites were inundated by floodwater and community composition was heavily dominated by floating species (F functional group). In subsequent years, species from a suite of terrestrial and amphibious functional groups were recorded in response to flooding and delivery of environmental flows that inundated some sites. The overall proportion of drought tolerant species at often-flooded sites has decreased since surveys conducted during drought years (2007–08 to 2009–10), and the proportion of terrestrial damp and amphibious species has increased since 2010–11. Consecutive inundation through two floods and delivery of environmental flows over the last few years have helped improve and maintain the water responsive plant community on the lower floodplain at Hattah Lakes.

5.5.2 Sometimes-flooded

Water responsive species abundance scores have decreased since 2016–17 (following flooding in November 2016) but remain as high as the values recorded in 2011–12 following the widespread 2010–11 floods. Water responsive species richness scores decreased compared to last year's (2016–17) surveys, only one third of sites met the terrestrial damp species richness target. The volumes of water delivered to Hattah Lakes floodplains through environmental water may have supported growth but not been enough to promote increases in species richness.

Community composition of sometimes-flooded sites at Hattah Lakes was variable from year to year, and has changed over the last decade. Vegetation community composition was heavily dominated by drought tolerant species during drought years (2007–08 to 2009–10). Since 2010–11, there has been a decrease in the proportion of drought tolerant species and an increase in species from terrestrial damp and amphibious functional groups. As seen in often-flooded sites, the combination of two floods and delivery of environmental flows has helped improve and maintain the water responsive plant community on the sometimes-flooded sites at Hattah Lakes since 2010–11.

5.5.3 Rarely-flooded

Within higher elevation, rarely-flooded areas of the floodplain at Hattah Lakes, community composition was dominated by drought tolerant species in all survey years. Four sites were briefly inundated in November 2016, but one site remains within the category 'long-dry '(i.e. not inundated for approximately 23 years). The proportion of terrestrial damp species remains slightly elevated compared with very dry years but, in general, community composition remains dominated by drought tolerant species.

The highest water responsive species richness and abundance scores among rarely-flooded areas of the floodplain were recorded in 2016–17 and scores remained elevated in 2017–18. Four of the rarely-flooded sites were inundated just prior to surveys in 2016–17 which lead to a flush of plant growth. The benchmark against which rarely-flooded sites are assessed is skewed meaning the target is easily achieved (Brown *et al.* 2016). The data used to set the reference for rarely-flooded sites is from a period when the majority of these sites were long-dry (e.g. 2007–08 to 2015–16), as this was the only data available at the time. Therefore, few water responsive species were present in this data set, making the ecological target easier to achieve and less reflective of response to inundation (e.g. rarely-flooded sites only need to record 1.6 water responsive species to meet the target for Index 1 in Table 5.2) (Brown *et al.* 2016). This may explain why scores for rarely-flooded sites were comparatively higher than often- and sometimes-flooded sites, even though the rarely-flooded floodplain was predominantly long-dry (Figure 5.1).

It was recommended in the 2016–17 report that ecological targets be recalculated to include post inundation data (Figure 5.5b). Using the updated data means that none of the flood return frequency categories met richness targets during years of drought, as compared to sometimes, often- and rarely-flooded transects being compliant in 2009–10 when using the original ecological targets (Figure 5.5a). It is evident that in 2016–17 more transects were compliant at often- and sometimes-flooded sites compared to rarely-flooded when using the updated targets. However, rarely-flooded sites continued to increase in richness during the 2017–18 survey year using the updated targets. It could be argued that including more years of data creates an index that more closely reflects the conditions found at Hattah Lakes. However, adoption of this method must be decided in consultation.

(a)

(b)

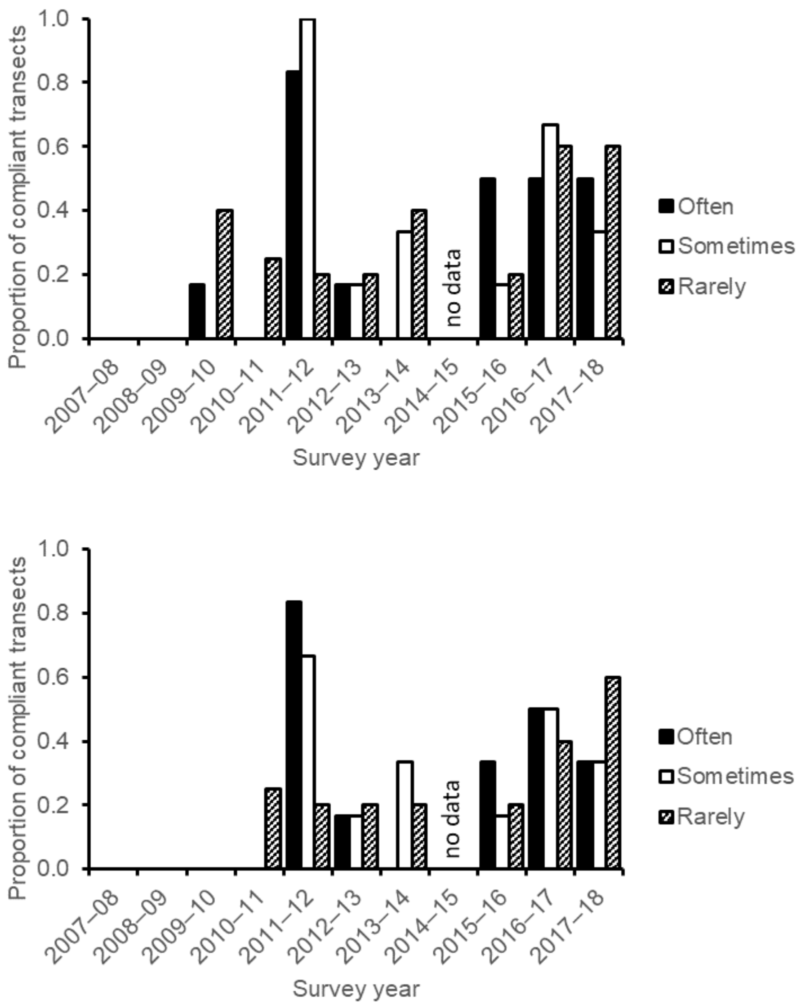


Figure 5.5 Species richness scores calculated using (a) data from 2007–08 to 2015–16 and (b) data from 2007–08 to 2016–17.

5.5.4 Whole-Of-icon-site score

Overall, Whole-of-icon site scores improved through time. This is the first time the Whole-of-icon site scores have been calculated for the entire time series of TLM monitoring at Hattah Lakes floodplains. An overall increase in richness and abundance of water responsive species has been detected following flooding of the icon site. This increase is especially evident after the last two survey years as Whole-of-icon site scores have reached the highest levels since surveys began. It appears that water response species richness fluctuates annually in response to watering, whereas species abundance increases slowly and maintains an elevated level for a number of years post-watering. Species richness appears to display an immediate response to favourable conditions with a burst of recruitment as water cues germination from the soil seed bank. Abundance, on the other hand, may be maintained for a longer period by increases in soil moisture from the floodplains and water retained in the network of lakes at Hattah. While species richness and abundance within wetlands does not appear to be benefitting from environmental watering, both metrics increased within floodplain vegetation communities.

5.6 Progress towards ecological objectives

Over the last few years, favourable environmental conditions have benefited the water responsive plant community at often- and sometimes-flooded areas of the floodplain at Hattah Lakes. The combination of two floods (2010–11 and 2016) and delivery of environmental flows to some sites in between floods, has helped to improve and maintain the water responsive plant community. The majority of the rarely-flooded sites at Hattah Lakes was last inundated in 1993–94. Though widespread flooding in November 2016 inundated some of the higher floodplain, these communities remain dominated by drought tolerant plant species. Therefore, the vision to preserve and maintain healthy floodplain plant communities at Hattah Lakes icon site is partially being met.

5.7 Recommendations

As recommended in Brown *et al.* (2016), now that references have been trialled for each icon site, a workshop should be held to include scientists, field work researchers/contractors and TLM icon site managers to discuss outcomes of this approach. This may assist in addressing the following sorts of questions:

- Why do sites at the rarely-flooded sites at Hattah score higher than often- and sometimes-flooded sites in some years? Even with the reference index updated to include data that incorporates flooding years this anomaly continues.

A method to determine differences in the Whole-of-icon site scores between surveyed years should be developed. Additionally, a minimum target score may be considered in order to assess whether ecological targets are being met. The methods described in Richardson (2014) are missing important details required to do this. We recommend that resources be allocated to improving on this statistical method.

Using the Whole-of-icon site score it appears that there has been an increase in water responsive species richness and abundance at Hattah floodplains. We cannot determine from these scores, however, if this increase in richness and abundance is positive for the floodplain. The analyses performed as part of TLM condition monitoring do not differentiate between native and exotic components. We could be falsely celebrating an increase in ecosystem health when we should be concerned about weed invasion. It would be valuable to analyse the proportion of exotic species in these floodplain environments and whether this proportion has increased over the past decade.

To improve our understanding of the benefits of multiple flows on floodplain vegetation, it would be informative to analyse species abundance and diversity data in relation to inundation history. This includes analysing vegetation response to inundation at sites that have received multiple flows between 2010 and 2017 compared to sites that were last inundated in 2010–11 or 1993–94. It would also be beneficial to look at changes over time specifically at sites that have received multiple flows, to look at species richness and abundance responses to one, two or more flows. This could be undertaken using data that has already been collected through TLM condition and intervention monitoring.

6 Lignum

AUTHOR: DAVID WOOD

6.1 Introduction

Tangled Lignum (*Duma florulenta* (Meisn.) T. M. Schust; formerly known as *Muehlenbeckia florulenta* Meisn.), hereafter referred to as Lignum, is considered one of the most ecologically significant native floodplain shrub of Australia (Roberts & Marston 2011). It comprises a tangled mass of normally leafless stems growing up to 3 m tall and 3 m wide. Communities are made up of separate male and female plants that can form dense thickets, dominating large areas of lowland river floodplain throughout the Murray–Darling Basin (Cunningham *et al.* 1992; Sainty & Jacobs 1981).

Lignum condition is strongly influenced by soil moisture and is therefore highly dependent on flood regimes in arid areas where rainfall alone is unlikely to sustain these communities (Craig *et al.* 1991). During extended dry periods, above-ground biomass of Lignum may appear lifeless and dead (dry, brown leafless stems), but may remain viable as underground rootstock. Within 2-4 weeks of heavy rainfall or flooding, Lignum rootstock may regenerate from dormancy, producing a green flush of shoots, leaves and flowers (Craig *et al.* 1991; Jensen 2008). Regeneration, however, can be highly variable, with the likelihood of successful regeneration varying among locations and diminishing with increased length of dormancy (Freestone *et al.* 2017). Ideally, Lignum requires flooding every 3 to 10 years (possibly more frequently in saline soils) (Craig *et al.* 1991) because once dormant, the maximum critical time period during which successful regeneration can occur, may be exceeded.

Monitoring of Lignum at Hattah Lakes as part of The Living Murray (TLM) condition monitoring first occurred during 2007. Monitoring has occurred annually, with the exception of 2014–15 as the TLM Program did not run. Recently, a review of the TLM Program was undertaken, with recommendations suggesting changes to the survey design, data collection method and new analyses (Brown *et al.* 2015a; Huntley *et al.* 2016; Robinson 2014b). These recommendations were first incorporated into the 2016–17 monitoring program, however flooding during surveys meant most sites could not be assessed. This sampling period (2017–18) represents the first year that all sites could be assessed using the new method recommended during the review process. As a consequence, only data from 2017–18 is displayed in this report.

6.2 Ecological objectives

Ecological objectives for Hattah Lakes have been in refinement since interim objectives were first developed by the Ministerial Council in 2003 (MDBMC 2003). The most recent version of the ecological objective for Lignum is based on an understanding of Lignum responses to environmental conditions learned through monitoring, evaluation, research, modelling and consultation activities over ten years (MDBA 2012c). The ecological objective for Lignum at Hattah Lakes is:

> *Preserve and, where possible, enhance the biodiversity values of the Hattah Lakes; and restore healthy examples of all original wetland and floodplain communities that represent the communities which would be expected under natural flow conditions(MDBA 2012c).*

The specific adopted objective resulting from the refinement process (Robinson 2014b) is:

> *Restore a mosaic of healthy wetland and floodplain communities to maintain the ecological character of the Ramsar site*

6.3 Methods

At Hattah Lakes, Lignum is assessed across 16 sites, from three different strata: Lignum Shrubland, Lignum Woodland and Lignum Swamp. Surveys are undertaken annually at established sites consisting of 20 m X 20 m quadrats. Specifically, condition of all Lignum plants within each quadrat is assessed using the Lignum Condition Index (LCI) (Table 6.1). Additionally, each plant is assessed for leaf and flower abundance and the sex determined where possible. Lignum surveys for the 2017–18 monitoring period occurred during spring/summer 2017–18 (inundation delayed some sampling until summer 2018) and represents the first full survey of Lignum at Hattah under the new, revised method.

Table 6.1 The Lignum Condition Index (LCI) used to assess Lignum plant condition. Adapted from Scholz *et al.* (2007).

% 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

Comprehensive detail on Lignum condition monitoring methods are available in the Condition Monitoring Program design for the Hattah Lakes icon site (Huntley *et al.* 2016).

6.4 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*

At a strata level, Lignum Condition Index scores of plants were pooled and the percent of Lignum plants with an LCI of ≥4 was calculated. Each stratum was then assessed as being either 'compliant' or 'non-compliant' where:

- compliant = 1, *if ≥85% plants had LCI score of ≥4*,
- non-compliant = 0, *if <85% plants had LCI score ≥4*

At the icon site level, the Lignum Condition Index scores of all plants were pooled and the percent of plants with an LCI of ≥4 was calculated. If more than 85% of the plants had LCI scores ≥4 the site was deemed to be in good condition and to have attained the site-specific target.

To assist with reporting at an icon site level (as opposed to individual components), indices for Lignum were determined by calculating each site as compliant or non-compliant. The proportion of compliant sites (i.e. sites with ≥ 85% plants that are at or above the reference condition) was used to determine the icon site Condition Index. Annual changes to this Index indicate changes to Lignum condition, whereby a change of 0.3 between years will indicate significant changes in Lignum condition (Robinson 2014b).

6.5 Results

The proportion of Lignum plants with a LCI score of ≥4 did not exceed the target of 85% for Lignum Shrubland and Lignum Swamp communities at Hattah Lakes (Figure 6.1). However, the target was achieved for Woodland communities. At the icon site level, the target was not achieved, with a mean frequency of 82.3% (±10.1 Standard Error) of Lignum plants achieving a LCI score of ≥4. The icon site Condition Index was calculated at 0.56, with nine of 16 sites determined compliant (sites with ≥85% plants having a LCI score of ≥4).

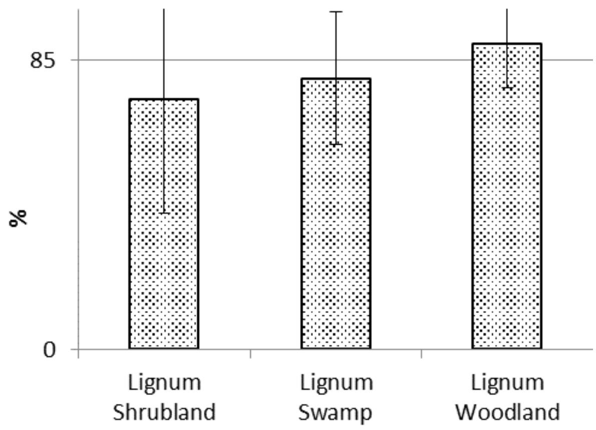


Figure 6.1 Mean frequency (± SE) of Lignum plants with a LCI score of ≥4 for Lignum Shrubland (n=5), Lignum Swamp (n=4), and Lignum Woodland (n=7) (target value = 85%).

6.6 Discussion

During 2017–18 all Lignum sites at Hattah Lakes were assessed, in contrast to 2016–17, when the majority of sites were inundated and access was severely restricted (only three sites were assessed). While empirical data collection was not possible, it is likely that flooding in late 2016 has improved Lignum condition. Lignum responds rapidly to inundation, with new growth and increased rates of germination that can result in an increase in individual and community condition. In addition, a proportion of the Lignum community was inundated for a second time within a year when environmental water was delivered to Hattah Lakes during winter/spring 2017. These factors are likely to have increased the LCI scores at Hattah Lakes.

The differences in the frequency of plants with a LCI score ≥4 between each community are possibly explained by spatial distribution and therefore flooding frequency. Lignum Woodland is the most dominant Lignum community group among potential areas of artificial flooding, and as such, it was inundated more frequently than Lignum Shrubland and Lignum Swamp communities. The latter communities rely on rainfall and natural flooding for inundation.

Ongoing data collection will enable determination of trends in Lignum condition at Hattah Lakes. Ongoing monitoring, using both previous and current survey methods, will allow us to undertake compatibility testing between the two methods. This may result in the ability to combine current data collected using the new method with previous data. This is important for determining long-term trends in Lignum condition at the icon Site.

In 2017–18, one out of the three Lignum communities, Lignum Woodland, met the target of ≥85% plants having a LCI score of ≥4. At the icon site level, just over half of all sites were deemed compliant in 2017–18 resulting in an icon site Condition Index of 0.56.

7 Fish

AUTHORS: DAVID WOOD, LOUISE ROMANIN & PAUL BROWN

7.1 Introduction

Off-channel wetland habitats, such as the Hattah Lakes, are important to fish communities for a number of reasons: (1) They provide habitat diversity, which is important for reproduction (nursery zones), (2) food resources (high productivity), (3) improved rates of survival for multiple life stages of fish (Junk *et al.* 1989; Lyon *et al.* 2010; Souter 2005). Inundation of the floodplain not only triggers some species of fish to move onto the floodplain; but allows all species to benefit from the associated high productivity pulses in the river (Junk *et al.* 1989; Junk & Wamtzem 2004; Lyon *et al.* 2010).

Condition monitoring reports on the change in environmental condition at the icon site scale over time to determine if ecological objectives are being met. Spatial and temporal variation and trends in native fish population demographics (i.e. diversity, spatial distribution and abundance) are interpreted with respect to progress towards achieving ecological objectives.

7.2 Ecological objectives

Ecological objectives for Hattah Lakes have been in refinement since the interim objectives were first developed by the Ministerial Council in 2003 (MDBMC 2003). The revised ecological objectives for fish at Hattah Lakes incorporates an understanding of environmental responses learned through monitoring, evaluation, research, modelling and consultation activities over the past decade (MDBA 2012c).

Overarching objective:

> *Maintain high quality habitat for native fish in wetlands and support successful breeding events.*

With more detailed objectives stating:

> *Increase distribution, number and recruitment of local wetland fish — including hardyhead, Australian smelt and gudgeon by providing appropriately managed habitat*
>
> *Maximize use of floodplain habitat for recruitment of all indigenous freshwater fish.*

7.3 Methods

The most recent survey, undertaken during March 2018 (2017–18 monitoring period) assessed seven wetlands, the adjacent Murray River and Chalka Creek (Table 7.1). Fish sampling has occurred at Hattah Lakes since 2005–06, with the number of water bodies being sampled differing between years due to water availability (Table 7.2).

Table 7.1 Location of fish sampling sites within each macrohabitat and waterbody.

Macrohabitat	Waterbody/reach	Site codes		
Anabranch	Chalka Creek	Cha1	Cha2	Cha3
Riverine	Murray River	Mur1	Mur2	Mur3
Wetland	Lake Arawak	Ara1	Ara2	Ara3
	Lake Bulla	Bul1	Bul2	Bul3
	Lake Hattah	Ha1	Ha2	Ha3
	Lake Little Hattah	LH1	LH2	LH3
	Lake Lockie	Loc1	Loc2	Loc3
	Lake Mournpall	Mour1	Mour2	Mour3
	Lake Yerang	Yer1	Yer2	Yer3

Table 7.2 Sites sampled for fish at the Hattah Lakes icon site from 2005–2006 to 2017–2018 within each reach/wetland. The month of each survey and the corresponding 'year' are included. (N.B. Shaded cells indicate inundation; ticks indicate site sampled).

	Month/Year of survey (Monitoring period)													
Reach/Wetland	Sep '05	Jan '06	Nov '06 (2006—07)	Dec '07 (2007—08)	Nov '08 (2008—09)	May '10 (2009—10)	Mar '11 (2010—11)	Mar '12 (2011—12)	Mar '13 (2012—13)	Mar '14 (2013—14)	(2014—15)	Mar '16 (2015—16)	Apr '17 (2016—17)	Mar '18 (2017—18)
	(2005—06)													
Murray River			✓	✓	✓	✓	✓	✓	✓	✓	Not Sampled	✓	✓	✓
Chalka Creek	✓		✓			✓	✓	✓		✓		✓	✓	✓
Lake Mournpall			✓	✓	✓	✓*	BG	✓	✓	✓		✓	✓	✓
Lake Hattah			✓	✓	✓	✓*	BG	✓	✓	✓		✓	✓	✓
Lake Bulla			✓	✓	✓		✓	✓		✓		✓	✓	✓
Lake Arawak			✓	✓			✓	✓		✓		✓	✓	✓
Lake Lockie		✓	✓			✓	✓	✓		✓			✓	✓
Lake Yerang			✓				✓	✓		✓		✓	✓	✓
Lake Little Hattah		✓	✓			✓	✓	✓#		✓			✓	✓

*Backpack electrofishing only
# Netting only, at one site only, in Lake Little Hattah due to limited water.
BG = Blue-green algae bloom present

A nested sampling design consisting of sites, within reaches, within macrohabitats, was used to assess the condition of fish assemblages across the Hattah Lakes system (Huntley *et al.* 2016). These methods are consistent with those prescribed in The Living Murray (TLM) Fish Condition Monitoring Approach v.2 (MDBA 2010). In practice, only a single example of anabranch (Chalka Creek) and a single example of riverine macrohabitat (Murray River) is sampled; each having three sites. Chalka Creek (i.e. Channel macrohabitat) is sampled to determine what part of the fish community is occupying this different habitat type while the Murray River adjacent to Hattah Lakes (i.e. Riverine macrohabitat), the source of fish in the Hattah lakes system, is sampled as a comparison.

Comprehensive details of the sampling design and methods used and sites sampled are contained in Huntley et al (2016).

7.4 Indices and points of reference

An independent review into TLM icon site Condition Monitoring Plans (Robinson 2013) provided a range of recommendations on how to better report on the ecological condition of icon sites. Following detailed investigations of the suitability and sensitivity of a suite of indices the following three were recommended (Brown *et al.* 2016; Robinson 2014b).

Expectedness Index - For each reach, the proportion of sites where species richness exceeds the reference-level for 'expected richness'. This effectively combines indices for diversity and expectedness. Reference values follow Reference Condition for Fish (RC-F) scores determined in Wood et al (2016) and are presented below.

P Expected (RC-F) = 4.95 (Riverine), 5.05 (Wetland), 4.85 (Anabranch)

Nativeness Index - For each site, the proportion of fish biomass that is comprised of native species.

P Native = 0.5

Recruitment Index - For each site, the count of native fish recruits as a proportion of the total count for all the native species.

P Recruits = 0.5

In this publication we report against these indices and their reference values as recommended in most recent review of TLM methodologies (Brown *et al.* 2016).

7.4.1 Index calculation

Below we present the workings involved to calculate each of the indices. Further information can be sourced from Huntley et al (2016).

P Expected

Reference level is the expected icon site species richness based on the combined data set from 2005–2006 to 2016–17 (Huntley *et al.* 2016). Values of *P Expected* can only lie between zero and one. A linear mixed model was fitted to the data using the lme4 package in R (Bates *et al.* 2014), such that "Year" is a fixed effect; and "Waterbody" nested within "Macrohabitat," are random effects (i.e. representative of a broader distribution of these elements in the population of sites that is the icon site)(Brown *et al.* 2016). To be consistent with the condition monitoring survey design for the nearby icon site at Lindsay-Mulcra and Wallpolla islands, data was analysed from waterbodies categorised as either 'riverine', 'slow-flow anabranch', or 'wetland'. Annual mean estimates (±95% confidence interval) are plotted for each survey-year 2007–08 to the most recent, 2017–18. *Post hoc* comparisons of means for year-to-year change (Tukey Contrasts) were estimated using the multcomp package in R (Hothorn *et al.* 2008).

P Native

Most fish were measured and weighed at capture. Some fish (e.g., small-bodied species), were unable to be accurately weighed in the field. For those fish that were measured (L mm, standard length) but not weighed, we estimated the weight ($\overline{W}$, grams) based on:

$\overline{W}$ = 10[a+(b.Log(L/c))]

Where a and b, respectively, represent the constant and slope of the exponential weight-for-length curve (W=aLb) and c is a constant to allow conversion from fork length or total length to standard length (Robinson 2012). Where species were abundant at a site, 50 individuals were measured and weighed as they were encountered across all the replicates. The remainder in any replicate, were simply counted.

Because unmeasured and unweighed individual fish were present in some replicates in previous survey years, we estimated the total biomass (B') from the product of the species' mean estimated weights ($\overline{W}$) and the total counts (n) of all individuals. (i.e. B' = $\overline{W}$n). The biomass of native species as a proportion of the total biomass (P Native) was calculated for each replicate. Where a species was present in a replicate with no measured representatives in that replicate, mean species' weight for that sampling year was used. If no mean recorded weight was available for that species for that year (i.e. fish were observed but not caught), mean weight from all years was used.

Although calculated as a proportion at each site, the data is a continuous ratio of native biomass and total biomass (native + alien fish biomass), and must be analysed as such. Values can only lie between zero and one. A linear mixed model was fitted to the data using the lme4 package in R (Bates *et al.* 2014), such that "Year" is a fixed effect; and "Site" nested within "Waterbody," nested within "Macrohabitat," are random effects (i.e. representative of a broader distribution of these elements in the population of sites that is the icon site)(Brown *et al.* 2016). Annual mean estimates (±95% confidence interval) are plotted for each survey year 2007–08 to the most recent, 2017–18. *Post hoc* comparisons of means for year-to-year change (Tukey Contrasts) were estimated after adjustment for multiple-comparisons using the multcomp package in R (Hothorn *et al.* 2008).

P Recruits

Exotic species were excluded from calculations. A 'recruit' is defined as an individual with a total or fork length less than or equal to the size originally defining a young-of-year (i.e. age 0+ years) in the Sustainable Rivers Audit methodology (Robinson 2012) and reproduced in the recent TLM review document (Brown *et al.* 2016). Data here are counts as proportions. The true proportional nature of the data is taken advantage of by fitting a general linear mixed model, with a binomial error-distribution and a logit-link function, using the lme4 package in R (Bates *et al.* 2014). The model essentially performs a weighted 'regression' using the size of the denominator (count of native fish at a site) to weight the analysis by sample-size. Proportions from large sample sizes are more important to the model than proportions from small sample sizes. The model selected was such that "Year" is a fixed effect; and "Site" nested within "Waterbody," are random effects (i.e., representative of a broader distribution of these elements in the population of sites that is the icon site)(Brown *et al.* 2016). Annual mean estimates (±95% confidence interval) are plotted for each survey-year 2007–08 to the most recent, 2016–17. *Post hoc* comparisons of means for year-to-year change (Tukey Contrasts) were estimated using the multcomp package in R (Hothorn *et al.* 2008).

7.5 Results

During 2017–18, 59 116 fish were sampled using standardised survey methods across Hattah Lakes. This comprised of ten species of native and four species of non-native fish were sampled (Table 7.3). Two main species; the native Carp gudgeon (*Hypseleotris* spp.) and non-native Eastern gambusia (*Gambusia holbrooki*) dominated the fish community. These two species were evenly distributed throughout the Hattah Lakes and Murray River and combined, numerically equated to over 84% of the fish community, by abundance. The native Bony herring (*Nematalosa erebi*) were the most abundant large-bodied species. Most species were recorded in numbers obtained previously though TLM, with the exception of Australian smelt (*Retropinna semoni*) which were recorded in their highest numbers and Un-specked hardyhead (*Craterocephalus stercusmuscarum fulvus*) which were recorded in their lowest across all years.

Notable species additions to this monitoring period was the re-appearance of Murray cod (*Maccullochella peelii*) and Silver perch (*Bidianus bidianus*) (all from the Murray River sites) as well as Oriental weatherloach (*Misgurnus anguillicaudatus*). These species were absent from the previous monitoring period (2016-17) but had all been present during other monitoring years at Hattah Lakes. A total of 8 Murray cod were recorded with measured fish ranging in length between 64–104 mm (total length) indicating young-of-year and a single fish at 220 mm (total length).

Golden perch were predominantly caught from the Murray River with only a few sampled from within the Hattah Lakes. Across all measured fish, length ranged between 283–470 mm (total length). This indicates a lack of recruitment in recent years. Common carp at Hattah lakes were recorded in relatively low numbers during 2017–18. Their population appears to be dominated by two distinct peaks; 50–200 mm (fork length) and 400–500 mm (fork length) (Figure 7.1). These likely relate to spawning following flooding in 2016 and environmental watering around 2013–14.

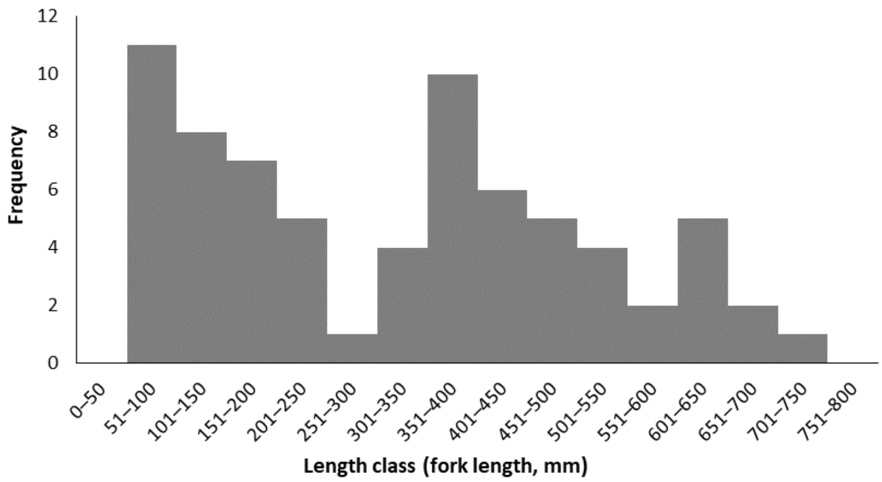


Figure 7.1 Length frequency from a measured subsample of Common carp (*n* = 71) from the 2017–18 survey.

7.5.1 Species Richness

For 2017–18, mean proportion of sites where species richness exceeded reference level was down slightly from 2016–17 (Figure 7.2). However, greater than half the sites recorded the expected number of species during 2017–18. The decline over the past year was not significant (P>0.05) and large confidence intervals (95%) for 2017–18, along with most other monitoring years, reflects large variability amongst habitat type and individual waterbodies.

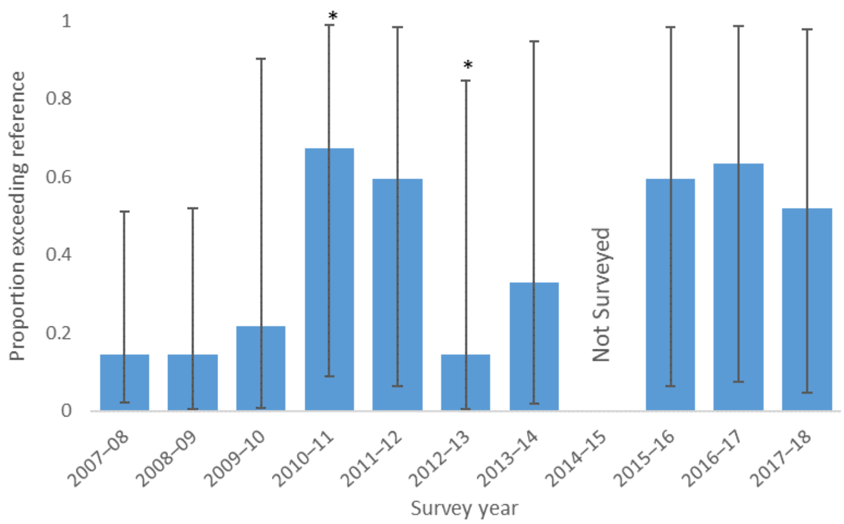


Figure 7.2 The mean proportion of sites in each survey year (±95% Confidence intervals) where the species richness exceeds the reference levels of expected species-richness. * Marks a statistically significant change between successive years surveyed (P<0.001).

Table 7.3 Summary counts of all fish sampled at the Hattah Lakes icon site over ten sampling years as part of Condition Monitoring (NB. 2014–15 not sampled).

	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2015–16	2016–17	2017–18
Native	**27 184**	**2120**	**1579**	**47 932**	**15 395**	**671**	**2146**	**14 548**	**41 640**	**33 589**
Large-bodied	**56**	**6**	**720**	**206**	**381**	**290**	**1258**	**579**	**490**	**560**
Bony herring	17		672	126	337	270	1190	494	449	513
Golden perch	31	3	32	78	41	12	35	31	41	34
Murray cod	7	2	5		1	7	30	52		8
Silver perch	1	1	11	1	1	1	3	2		5
Spangled perch				1	1					
Small-bodied	**27 128**	**2114**	**859**	**47 726**	**15014**	**381**	**888**	**13 969**	**41 150**	**33 029**
Australian smelt	5156	107	401	203	37	27	133	1969	4838	7276
Carp gudgeon	20 927	1959	213	46 029	14700	323	641	11 026	34 765	24 393
Dwarf flathead gudgeon				1				12	41	35
Flathead gudgeon	1045		8	191	170	1	1	666	1404	1312
Murray-Darling rainbowfish		2	23	39	10	11	32	98	77	4
Un-specked hardyhead		46	214	1263	97	19	81	198	25	9
Non-native	**126**	**136**	**241**	**6171**	**2046**	**526**	**9406**	**12 499**	**7816**	**25 503**
Large-bodied	**126**	**136**	**71**	**1211**	**763**	**82**	**7060**	**62**	**993**	**128**
Common carp	20	24	39	1126	604	81	6950	46	988	104
Goldfish	106	112	32	36	151	1	56	8	5	19
Oriental weatherloach				49	8		54	8		5
Small-bodied			**170**	**4960**	**1283**	**444**	**2346**	**12 437**	**6823**	**25 375**
Eastern mosquitofish			170	4960	1283	444	2346	12437	6823	25 375
Grand Total	**27310**	**2256**	**1820**	**54 103**	**17 441**	**1197**	**11 552**	**27 047**	**49 456**	**59 116**

7.5.2 *Proportion of native fish biomass - P Native*

The current monitoring year saw an increase in the mean proportion of native fish biomass at a site, however unlike the previous three monitoring years (2013–14, 2015–16 and 2016–17) this increase was not considered significant (P>0.05) (Figure 7.3). This monitoring period (2017–18) achieved the fourth highest P native value across all monitoring years. As such, the reference level of 0.5 was achieved for 2017–18, as it has for every monitoring year (with the exception of 2013–14).

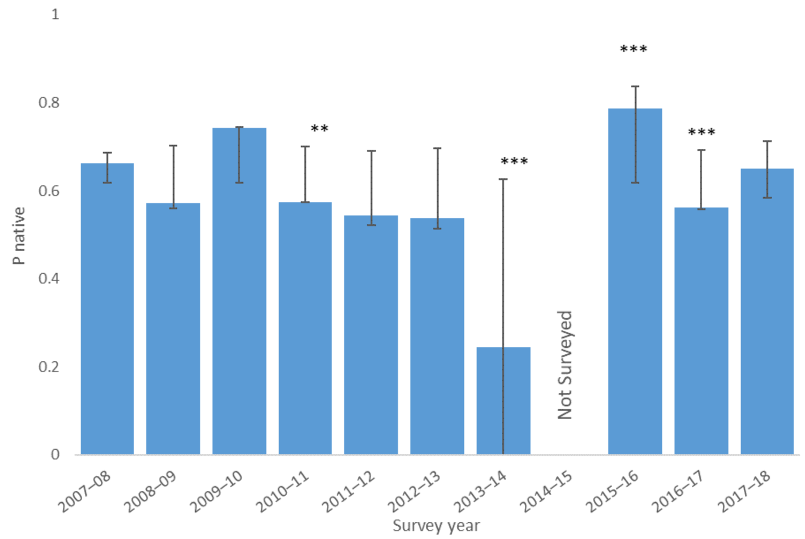


Figure 7.3 The estimated mean proportion (±95% confidence intervals) of fish biomass that is native fish biomass at a site (P Native) during fish surveys of the Hattah Lakes icon site between 2007–08 and 2017–18. *** Marks a statistically significant change between successive years surveyed (P<0.001).

7.5.3 *Proportion of native fish recruitment - P Recruits*

The proportion of fish classed as recruits sampled for this monitoring year (2017–18) was the highest across all monitoring years at Hattah Lakes (P recruit = 0.71) (Figure 7.4). Subsequently, for 2017–18 the reference value of 0.5 was achieved. The reference value has only been achieved on three occasion; 2011–12, 2016–17 and 2017–18 across all monitoring years. While an increase in P recruit occurred between 2016–17 and 2017–18, it was not significant.

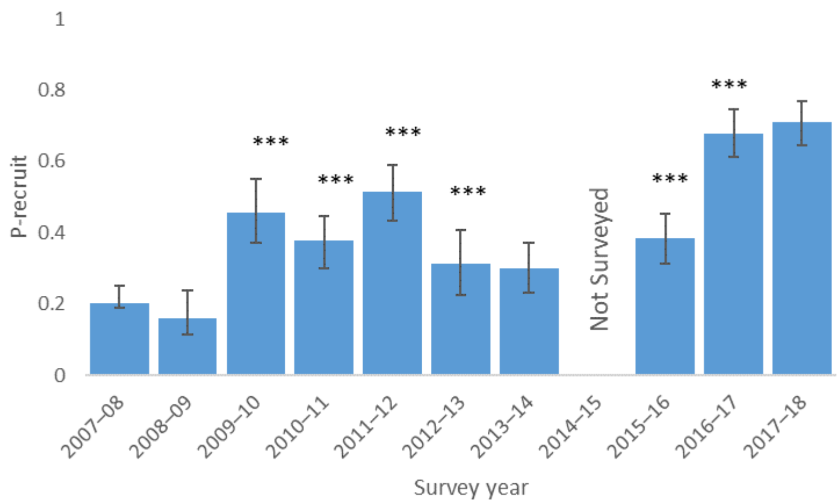


Figure 7.4 The estimated proportion (±95% confidence intervals) of native fish that are 'recruits' (P Recruit) each survey year during fish surveys of the Hattah Lakes icon site between 2007–08 and 2017–18. *** Marks a statistically significant change between successive years surveyed (P<0.001).

7.6 Discussion

During 2017–18, the total number of fish recorded was the highest from all survey years at the Hattah Lakes icon site. The wetlands and Chalka Creek were numerically dominated by small-bodied fish species, as has been the case during sampling years when water was readily available in the lakes system. This is not unusual, with wetlands renown for harbouring high abundances of small-bodied fish (Beesley *et al.* 2012; King *et al.* 2003), with many species (e.g. gudgeon, hardyhead) highly adapted to these habitats. With reference to the objective '*Increase distribution, number and recruitment of local wetland fish—including hardyhead, Australian smelt and gudgeon by providing appropriately managed habitat'* both gudgeons and Australian smelt were recorded from all sites across the wetlands system in numbers greater than any other survey for Australian smelt and third highest for gudgeon. Being predominantly annual species, high numbers of these species indicates strong recruitment in the past year. Abundance of Un specked hardyhead during this monitoring period was the lowest recorded (with the exception of the first monitoring year when they were not detected). Hardyhead were recorded from only one wetland and from the Murray River. These results are not unusual, and previous TLM condition monitoring surveys have consistently recorded this species in relatively low and highly variable frequency (never more than a few hundred fish; with the exception of 2010–11).

While small-bodied fish species generally thrive in wetland habitats, native large bodied species (i.e. Murray cod, Golden perch and Silver perch) are not commonly encountered. These species do not typically breed in lentic environments, preferring main channels, such as the Murray River, for reproductive activity. While large bodied adults are generally not associated with floodplain wetland habitat, wetlands can provide optimal nursery habitats for juvenile fish (Beesley *et al.* 2010; Koehn *et al.* 2014), which enter during flooding or pumped inflows following spawning in the main channel (Brown *et al.* 2015b). However maintaining connectivity between floodplain wetlands and rivers such that juvenile fish may return to the breeding population without being stranded in ephemeral wetlands is an important management consideration. Ideally, natural flooding and the connectivity it provides is the best means to do so. However, as competition for water resources increases (e.g. agriculture, climatic variability etc), capacity to effectively manipulate water regulating structures to achieve a similar outcomes to natural flooding is of increasing importance to both managers and scientists. Recent investigation at Hattah Lakes has shown that careful manipulation of pumping and regulating structures has successfully allowed mature Golden perch to return to the Murray River (Wood & Brown 2018; Wood *et al.* 2015). Very few Golden perch (four) were sampled from within the Hattah Lakes wetland complex this year, with the majority of fish collected from the Murray River. Interestingly, samples comprised exclusively adult fish, indicating a lack of recruitment during recent watering events.

Despite an absence from 2016–17 surveys, both Murray cod and Silver perch were recorded in 2017–18. Silver perch are not typically recorded in high abundance within or adjacent to Hattah lakes, and their population is considered irregular though the mid-Murray (Lintermans 2007). The absence of Murray cod in 2016–17 samples was of some concern, since the species had previously been recorded in high abundance. It's presence during the current monitoring year is encouraging, especially since the population consisted almost entirely of new recruits.

In 2017–18 we recorded the highest proportion of native new recruits among samples since monitoring commenced in 2007–08, indicating that for this year, the objective to *'Maximize use of floodplain habitat for recruitment of all indigenous freshwater fish'* has been met. The majority of small-bodied fish species have annual life cycles, and high numbers are suggestive of strong recruitment during the past 12 months. Juveniles of large bodied fish species that move laterally to wetland habitats via connection (e.g. flooding, pumped) and utilize improved habitat conditions and food resources before exiting to re-join the larger, basin-scale breeding population.

Common carp, Goldfish and Oriental weatherloach were recorded in comparatively low abundance in 2017–18. Goldfish and Oriental weatherloach were only recorded from the wetlands while Common carp were numerically equally distributed between wetlands and the Murray River. In 2017–18 Eastern mosquitofish were recorded in the highest abundance since monitoring commenced. This is of concern, since Eastern mosquitofish compete with native species for food resources and are aggressive towards other small fish (Macdonald *et al.* 2012). Presently, very little can be done to control this species without any detrimental effects to the native fishes. It has been determined previously that pumping to the Hattah Lakes can 'filter' the fish community, importantly, almost excluding non-native species (Vilizzi *et al.* 2013). While pumping was undertaken during 2017, much of the Hattah lakes retained water (and the resulting fish community) that entered the lakes during natural flooding only six months prior. For pumping to be effective at excluding non-native fish species from the Hattah Lakes fish community, pumping should be considered immediately after wetland drying, essentially re-setting the system.

With the exception of hardyhead, which has never been a dominant species at Hattah Lakes, the objective relating to '*Increasing distribution, number and recruitment of local wetland fish—including hardyhead, Australian smelt and gudgeon by providing appropriately managed habitat'* has been achieved by the high number and wide distribution of gudgeon and Australian smelt. The achievement of the objective *'Maximize use of floodplain habitat for recruitment of all indigenous freshwater fish*' is supported by the highest proportion of fish classed as recruits during 2017–18 from all monitoring years.

8 Birds

AUTHORS: RICHARD LOYN AND GARRY CHEERS

8.1 Introduction

The icon sites include a range of wetland types that provide valuable habitat for waterbirds. Environmental flows are intended to enhance those values, and waterbirds are included in programs for monitoring the condition of the icon sites. Waterbirds have been monitored regularly at eight wetlands across the Hattah Lakes icon site (Henderson *et al.* 2014). This report presents results from this monitoring program for the 2017-18 year (spring 2017 and autumn 2018).

8.2 Ecological objective

Ecological objectives have been set for each icon site, as summarised by (Henderson *et al.* 2014). Overarching objectives are to;

> *provide habitat for a range of waterbird species, including threatened and migratory species.*

More specific objectives for Hattah Lakes are to;

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

The objectives about breeding waterbirds required separate targeted monitoring programs (Willis *et al.* 2015), since breeding colonies are highly localised and not always in predictable locations. This report focuses on the monitoring program relating to objectives 2 and 3 about waterbirds.

8.3 Sampling method

Waterbirds were counted at each site using a timed area-search from a specified vantage point in accordance with The Living Murray (TLM) Standard Waterbird Assessment Approach (http://www.birdlife.org.au/documents/ATL-Starter-Kit-2012.pdf). This involves recording numbers of all bird species observed from the vantage point in the set period, following the 20-minute area-search method devised for bush-birds by (Loyn *et al.* 2017). Small increases in time spent were allowed when large numbers of birds were present, up to 30 minutes total, and 30 minutes has become the standard for these waterbird counts over recent years (Loyn *et al.* 2017). The method has been used for monitoring these sites since 2005 (Loyn *et al.* 2017).

The present chapter reports on waterbird surveys conducted in spring 2017 and autumn 2018. Most wetlands were counted once in spring (September-October 2017) and again in autumn (March 2018. Counts were made on three dates at Lake Lockie B (in September 2017, January and March 2018) and two at each of the other sites. One site at Hattah (Lake Yerang) could not be accessed in spring (September-October 2017) and it was surveyed in January and March 2018. All other sites were surveyed once in September-October 2017 and once in March 2018. Extra counts of waterbirds were made at several wetland sites in the Hattah Lake system: floodwater at the Bitterang levy in spring 2017; flooded woodland near Lake Bitterang in spring 2017; two sites near Lockie B in spring 2017 (when Lockie B itself was not safely accessible); and Lake Waterap in spring and autumn 2018.

Some additional counts of waterbirds were made in the course of doing surveys of woodland birds in Black Box woodlands in Hattah-Kulkyne National Park in 2017-18, as in previous years. Those surveys consisted of 10-minute searches of 1-ha samples of habitat, with numbers of birds counted both for the area itself and (separately) for surrounding areas outside the site. The focus was on bush-birds, but waterbirds were also counted when present.

8.4 Results

Total waterbirds observed (Table 8.1) and waterbird guild composition (Tables 8.2 and 8.3) data are presented below. Results of individual waterbird counts in 2017-18 are presented in Part B; Table 7.1. Detailed guild classifications are presented in Part B; Table 7.2, following a previous report (Loyn *et al.* 2017).

At the Hattah Lakes, Lake Kramen was dry over the whole year but all other lakes were filled by environmental flows, with high water levels in spring 2017 receding somewhat by autumn 2018 (Table 8.2).

Table 8.1 Total numbers of waterbird species observed on standard sites in the Hattah Lakes, spring 2017 and autumn 2018.

Waterbird species	Spring 2017	Autumn 2018	Waterbird species	Spring 2017	Autumn 2018
Freckled Duck	0	2	Australian Pelican	21	105
Black Swan	10	3	White-necked Heron	1	1
Australian Shelduck	4	0	Great Egret	13	12
Australian Wood Duck	23	56	White-faced Heron	2	6
Pink-eared Duck	0	7	Little Egret	0	1
Grey Teal	97	170	Nankeen Night Heron	2	0
Pacific Black Duck	12	13	Australian White Ibis	13	3
Hardhead	20	12	Yellow-billed Spoonbill	2	41
Australasian Grebe	5	14	Black-tailed Native-hen	16	8
Hoary-headed Grebe	5	154	Dusky Moorhen	0	2
Great Crested Grebe	26	28	Eurasian Coot	14	35
Australasian Darter	15	20	Black-winged Stilt	2	11
Little Pied Cormorant	0	7	Red-necked Avocet	0	97
Great Cormorant	9	5	Black-fronted Dotterel	0	7
Little Black Cormorant	44	18	Red-kneed Dotterel	6	13
Pied Cormorant	2	5	Masked Lapwing	2	8

Table 8.2 Total numbers of waterbird guilds, wetland area inundated and waterbird density observed on standard sites in the Hattah Lakes, spring 2017 and autumn 2018.

Waterbird guilds	Spring 2017	Autumn 2018	Mean	Mean as % all waterbirds
Coots	14	35	24.5	4.0
Dabbling ducks	109	183	146	23.7
Diving ducks	20	12	16	2.6
Filter-feeding ducks	0	9	4.5	0.7
Fish-eaters (cormorants, darter & pelican)	91	160	125.5	20.4
Grazing ducks	27	56	41.5	6.7
Grebes	36	196	116	18.9
Gulls	0	0	0	0
Large wading birds	33	64	48.5	7.9
Shorebirds	10	136	73	11.9
Swans	10	3	6.5	1.1
Terns	0	0	0	0
Waterhens	16	10	13	2.1
All grazers (coot, hens, swan, grazing ducks)	67	104	85.5	13.9
All waterbirds	**366**	**864**	**615**	**100**
Full area (ha)	606	611	608.5	98.9
Area of surface water	486.6	386.6	436.6	7.1
Total waterbirds per ha surface water	0.75	2.23	1.5	0.2

Table 8.3 Mean numbers of waterbird species and guilds observed on woodland bird survey sites at Hattah Lakes, subject to different degrees of flooding 2017-18.

Woodland sites	Number of sites	Mean number of Waterbirds	Standard Error
Mean dry	153	0.17	0.08
Mean 2-30% flooded	17	5.59	1.35
Mean 50-100% flooded	14	15.10	2.90

8.4.1 Numbers of waterbirds in selected wetlands

Total numbers of waterbirds counted in surveyed wetlands were substantially higher in autumn than in spring (Table 8.1), though not as high as in 2016–17 (Loyn et al. 2017). The highest counts were at Lake Lockie during autumn 2017 with 383 waterbirds recorded. Waterbird densities were generally low in spring at the Hattah Lakes (mean of 0.75/ha compared with 2.23/ha in autumn (Table 8.2). This was perhaps in part because extensive areas of woodland had been flooded during that watering event, providing lots of new alternative habitat for local waterbirds and many waterbirds had spread out to occupy those new habitats. The mean density of waterbirds in flooded woodland was much higher (15.1 / ha, ± 2.9 SE), based on counts in woodland bird sites that had been flooded by 50% or more (Table 8.3). High densities of waterbirds were also recorded at new floodwaters in open habitats, such as an area of near the Bitterang levy (9.9 / ha, Part B).

8.4.2 Waterbird breeding

No signs of colonial breeding events were observed in the current year (though as mentioned above, the current program was not designed to measure breeding). Evidence of breeding was observed for Australasian Darter (two juveniles at Yerang in January and another in March), Australasian Grebe (a nest in October and three juveniles in March near Lake Bitterang during woodland surveys), Australian Wood Duck (two broods near Lake Bitterang during woodland surveys in October), Black Swan (a pair with two young at Lockie B in January), Black-winged Stilt (five juveniles with 19 adults at Lockie A and three juveniles with eight adults at Lockie B in March), Eurasian Coot (three juveniles at Bulla, six juveniles at Lake Hattah and two juveniles at Mournpall in March), Great Crested Grebe (five juveniles at Bulla in September and four more in March; two juveniles at Lake Hattah, three at Bitterang and one at Waterap in March), Grey Teal (a pair with four small ducklings near Lake Bitterang during woodland surveys in October) and Hoary-headed Grebe (three juveniles near Lake Bitterang during woodland surveys in March). It is likely that common waterbirds such as Grey Teal bred widely and inconspicuously between surveys at many locations.

8.4.3 Guild and species composition

Dabbling ducks were the most numerous waterbird guild on most wetlands, constituting 24% of the waterbird community (based on mean of spring and autumn means across all sites, Table 2.2). Birds in this guild take animal and vegetable food in shallow water by upending or dabbling. Grey Teal were by far the most numerous species in that guild, with just a few Pacific Black Duck.

Fish-eating pelicans, cormorants and darters were the next most numerous guild on the Hattah Lakes (20%). Pelicans reach below the water surface to catch fish (or yabbies, as reported by local residents), while cormorants and darters dive to catch fish or other prey in the water column. Australian Pelicans were the most numerous species, followed by Little Black Cormorant: flocks of these species were sometimes found feeding communally on open waters. Australasian Darters were common, with individuals seen or heard on the margins of most wetlands visited: this species specialises at spearing fish in shallow flowing water among vegetation. Flocks of Great Cormorants were sometimes seen flying overhead, but they were more often found on the river than in flooded wetlands. Little Pied Cormorants were widespread but remarkably few were recorded on the counts: they take fish, frogs, tadpoles and crustaceans in shallow vegetated waters. Pied Cormorants specialise at taking fish from open water and only a few were seen on these assessments.

Grebes were the third most numerous guild (19%) in the Hattah Lakes where breeding was recorded for all three Australian species (Australasian, Hoary-headed and Great Crested Grebes). These species dive to catch fish or other aquatic animals in open water, and they rely on fresh water for breeding. The two smaller species (Australasian and Hoary-headed Grebes) are generally common over much of Australia, whereas Great Crested Grebes tend to be scarce, and rather little is known of their breeding numbers or distribution in Australia (notwithstanding the cosmopolitan distribution of the species in Eurasia). Several pairs of Great Crested Grebes were seen with broods of young birds on large open wetlands at Hattah. On a less happy note, one was found dead at Lake Bulla and rangers have told us of two birds of this species found dead near the Hattah Lakes (S. Southon, pers. comm.).

Shorebirds constituted 12% of the waterbird community, with some species scattered in low numbers (Masked Lapwing and Black-fronted Dotterel) and others recorded locally in substantial numbers (Red-necked Avocet and Black-winged Stilt feeding from open water; Red-kneed Dotterels mainly on vegetated margins where water was advancing or receding). No transcontinental migratory shorebirds were observed this year. The rarest shorebird found was an Australian Painted Snipe in flooded Black Box woodland at Hattah in spring 2017.

Large wading birds (herons, egrets, ibis and spoonbills) were widespread and common on many wetlands, constituting 8% of the waterbird community. The most numerous species were Yellow-billed Spoonbill, Great Egret, Australian White Ibis and White-faced Heron. Spoonbills wade in shallow water to catch invertebrates and small fish; herons and egrets wade in shallows or long grass seeking small fish, tadpoles and frogs and ibis probe in wet mud for invertebrates.

Grazing ducks (6.7%) were represented mainly by Australian Wood Duck, which graze extensively from swards of green terrestrial vegetation on wetland margins. A few pairs of Australian Shelduck were seen mainly along the Murray River, and were probably breeding in low numbers in nearby wetlands.

Diving ducks were scarce (2.6%) and this year they were represented mainly by one species (Hardhead) on the Hattah Lakes in spring. A few Musk Duck were also recorded at Hattah (giving their territorial whistles as if about to breed), and a male Blue-billed Duck was seen on Lake Konardin. Substantial numbers of Blue-billed Duck were seen on Lake Kramen in recent years when it held water (Loyn et al. 2017) but not in the current year.

Filter-feeding ducks were also scarce (0.7%), but groups of two species (Pink-eared Duck and Australasian Shoveler) were found on various wetlands. A third species (Freckled Duck) was found in autumn, when two were seen at Lockie B. This represents the first record of this iconic species in the Hattah-Kulkyne National Park for many years.

Coot (4%) and swans (1%) were recorded at various wetlands, generally in low numbers: these species feed on aquatic vegetation, swans by reaching below the surface (upending if necessary) and coot by diving. Eurasian Coot were found mainly among trees along the shallow margins of large lakes, often feeding from water among river red gum regrowth where they bred.

Our guild of waterhens includes three relatives of the Eurasian Coot (Purple Swamphen, Dusky Moorhen and Black-tailed Native-hen). They share the coot’s mainly vegetarian diet but generally feed from the surface of shallow water (Dusky Moorhen) or from vegetation growing on the landward margins of wetlands. Purple Swamphens were not recorded during the waterbird surveys, although there is a resident population at Kings Billabong near Mildura. Dusky Moorhens proved rare, but two were seen on Little Hattah Lake: the species regularly enters the area to breed during floods. Flocks of Black-tailed Native-hens were observed at a number of wetlands as waters receded.

Gulls and terns were remarkably scarce, and on the standard wetlands they were not recorded. Away from the standard sites, Caspian Terns were sometimes seen fishing along the Murray River on various occasions.

8.4.4 Overview

The main feature of the Hattah Lakes, compared with the Lindsay-Mulcra-Wallpolla icon site, was the high abundance of fish-eating pelicans, cormorants and darters (constituting 20% of the waterbird community, vs 4% in the Lindsay-Mulcra-Wallpolla icon site). Grebes and diving ducks were also more numerous at Hattah than elsewhere. Concentrations of Australian-breeding shorebirds were found round some wetlands, especially in autumn as water receded leaving extensive wet mudflats. Notable records included 206 Red-necked Avocets, 29 Red-kneed Dotterels and 17 Black-fronted Dotterels at Lake Lockie in autumn 2017 (some at non-standard sites). A single record of Australian Painted Snipe in flooded forest near Lake Bitterang in spring 2017 is important, as the species is little known and listed as Vulnerable globally and Endangered in Victoria. The species is cryptic and hard to find and it is quite likely that more individuals would have been present at various locations in the Hattah Lakes and elsewhere.

When water levels were high in spring, more birds were observed among trees round the fringes of these lakes than in open water. Bird counts in surrounding flooded forest beyond the wetland boundaries (conducted as part of a parallel project on woodland birds) revealed mean densities of 16 (±4) waterbirds/ha in such sites when fully flooded (Table 8.3).

8.5 Discussion

Dynamic patterns of fluctuation in waterbird numbers have been recognised for many years, in response to fluctuating availability of water over vast areas of the continent (Chambers & Loyn 2006). Hence, the number of waterbirds at a given site is influenced by the availability of water elsewhere, as well as the current value of that particular site. Waterbirds are highly transient and abundance can change rapidly as waters ebb and flow in different parts of the continent.

8.5.1 Patterns of response

Our results accord with the general pattern for previous years, that waterbirds are attracted new floodwaters wherever they occur, but the composition of guilds and species is influenced by local conditions (Loyn *et al.* 2017). The Hattah Lakes continue to be substantially more attractive than other wetlands for fish-eating pelicans, cormorants and grebes. Some of the Hattah Lakes have retained water continuously in recent years through environmental flows (e.g. Lakes Bitterang and Waterap), and this may have enabled them to develop abundant populations of fish species, attractive to fish-eating birds. However, it is also possible that these fish populations have had negative effects on other build guilds by competing for plant and invertebrate food.

It was pleasing to find a number of threatened species using the Hattah Lakes, as such species are often highlighted in discussions of the importance of icon sites such as the Hattah Lakes. The records of Freckled Ducks were the first made for many years, and although only two birds were seen it is hoped that more may be found in future years. The single Australian Painted Snipe in spring represents a newly described taxon whose population and status are hard to determine. Both these species are endemic to Australia, and ephemeral wetlands such as the Hattah Lakes are likely to be important for their global conservation. They are listed respectively as Endangered or Critically Endangered in Victoria (DSE 2013). A Glossy Ibis was also of interest, although this species has a wide global distribution and larger numbers are known to occur in northern Australia (it is listed as Near-threatened in Victoria). Several more common waterbirds are listed as threatened in Victoria (e.g. Hardhead and Blue-billed Duck), but in most cases the numbers observed were low compared with other sites where they are known to occur. Great Crested Grebes may be an exception, and the Hattah lakes clearly provide a significant breeding habitat for the small population of this species in south-eastern Australia. Similarly, our records of a juvenile White-bellied Sea-Eagle (accompanied by an adult close to its nest at Lake Bitterang) show that the Hattah Lakes can support breeding pairs of this species, listed as Vulnerable in Victoria. All these species have clearly benefitted from the provision of environmental flows to the Hattah Lakes, as they were using aquatic habitats that would have been dry without such flows.

Higher densities of waterbirds were found in surrounding flooded Black Box woodlands than in the wetlands themselves. This may be for a variety of reasons. Trees in flooded forests offer preferred nesting sites for a range of ducks (many of which nest in tree hollows or ledges) and for cormorants and large wading birds (most of which nest in crowns of living trees) (Marchant and Higgins 1990). Newly flooded areas outside the wetland boundary are likely to enjoy high nutrient levels, promoting production of invertebrate food (Baldwin & Mitchell 2000; McInerney *et al.* 2017). Trees provide shelter and perches that may be used at times by most waterfowl species. Any assessment of the effects of environmental flows must clearly consider effects beyond the designated wetland boundaries.

8.5.2 *Implications for management*

The results show that environmental flows can be useful to waterbirds wherever they are applied, as waterbirds made use of all wetlands fed by environmental flows and had previously been absent from those wetlands when they were dry (Loyn et al. 2017). However, they appear to be more valuable when they reach well into the treed hinterland of designated wetlands, including woodlands of River Red Gum and Black Box, attracting higher densities of waterbirds than those found on open lakes at Hattah. Nevertheless, fish-eating birds may benefit more from the latter situation, as observed in the Hattah Lakes. Clearly a mix of strategies is needed to provide habitat for the full suite of waterbird species in the broader landscape.

In defining management objectives for icon sites or Ramsar-listed wetlands, it has been customary to emphasise their potential for conserving threatened species or international migrants listed under international treaties. This may lead to unintended outcomes when those species form very small proportions of the waterbird community, and when the sites in question support very small proportions of the global species population. It has become clear that the sites considered in this report do not usually attract large numbers of threatened waterbird species, and they rarely attract more than a handful of international migratory shorebirds (Loyn *et al.* 2017). From this perspective, it was pleasing that some threatened waterbird species were recorded in the current year, including Freckled Duck, Glossy Ibis and Australian Painted Snipe at the Hattah Lakes. The recent environmental flows have clearly delivered some benefits to those species.

We were surprised not to find at least a few migratory shorebirds at some wetlands and suspect that the rapid revegetation of mudflats as water recede may limit the feeding opportunities for those species (which generally feed in flocks on open shorelines providing clear views of potential predators). At Hattah the treed nature of the wetlands may also be a deterrent. Studies of the geological substrate and the invertebrate fauna of the mudflats would be needed to shed further light on the rarity of international migratory shorebirds at all these sites, compared with certain wetlands elsewhere in the Murray Valley which regularly attract hundreds of these birds (e.g. many of the lakes near Kerang and Swan Hill). It remains possible that several of the wetlands we examined could have the potential to support migratory shorebirds when suitable conditions generate the open wet muddy surfaces favoured by those birds.

The results show that the Hattah Lakes support a population of White-bellied Sea-Eagles, including at least one pair that bred successfully. They also show that the lakes can attract Freckled Duck, albeit in low numbers (n=2), and this is the first evidence of that for many years. No Grey Falcons were observed, and there is no evidence to suggest that this species of arid woodland would ever be more than a casual visitor to the Hattah lakes.

This year's assessments did not provide evidence of colonial breeding, unless the widespread breeding of Great Crested Grebes is considered colonial.

This year's assessments did not provide evidence that the Hattah Lakes provide habitat for transcontinental migratory shorebirds, and indeed we have argued in previous reports that they would rarely attract more than small numbers of those species.

This year's assessments show that the Hattah Lakes provide important habitat for many waterbirds when they are flooded, including one endangered species not mentioned in the Ecological Objectives for the site (Australian Painted Snipe). We suggest that the Ecological Objectives focus too narrowly on a subset of species for which the Hattah Lakes may or may not be important, and do not adequately recognise the role the Lakes play as part of a dynamic set of habitats across continental Australia.

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