Northern Australia Environmental Resources Hub

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Characterising vegetation zones along the lower Fitzroy River, Western Australia

Report

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THE UNIVERSITY OF WESTERN AUSTRALIA

GOVERNMENT OF WESTERN AUSTRALIA

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Front cover photograph: Riparian vegetation on the riverbank at site RB02. Photo: Fiona Freestone.

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Executive summary

This report presents a synthesis of plant survey information collected as part of project 1.3.3: Environmental water needs of the Fitzroy River, Western Australia, under the Australian Government's National Environmental Science Program (NESP) through the Northern Australia Environmental Resources Hub.

The Fitzroy River and its catchment have high environmental, cultural and economic significance. There is increasing interest in developing this water resource for irrigated agriculture, which may impact important environmental values if natural river flow or groundwater levels are altered. Riparian vegetation species composition, distribution and physical structure are largely driven by surface and sub-surface water flows, creating broad vegetation zones. The identification and characterisation of these zones provides a foundation for water managers to assess the impact of potential changes in surface and sub-surface flows on riparian vegetation. The aim of this report was to characterise four broad vegetation zones along the lower Fitzroy River:

1) riverbank
2) top of bank
3) floodplain
4) off-channel wetlands and flood-runner channels.

Field work was undertaken in collaboration with Traditional Owners from Walalakoo, Yi-martuwarra and Gooniyandi Native Title groups and pastoralists. We surveyed 58 sites along 300 kms of the lower Fitzroy River during the dry season of 2018. Rapid vegetation techniques were used to measure woody vegetation composition and structure, understorey composition and soil properties.

We found broad differences among the four vegetation zones surveyed along a hydrological gradient from the main channel to the floodplain of the lower Fitzroy River. These differences are attributed to different flooding and drying patterns associated with each zone. For example, riverbank zones are flooded to depths that can partially submerge riverbank vegetation for prolonged periods. Riverbanks are dominated by trees that are likely to have high year-round water requirements and are therefore less likely to be resilient to changes in water availability. Floodplain zones are infrequently flooded and are characterised by trees that can tolerate extended inter-flood dry periods. The floodplain is directly related to the extent of large floods and an increase in water-take may reduce how far the floodplain zone extends. Top-of-bank zones, off-channel wetlands and flood-runner channels support greater riparian plant species richness and recruitment in an otherwise dry environment. Flow reductions may see an encroachment of floodplain or drought-tolerant species into these zones, changing the composition of species and potentially lowering species richness and decreasing structural complexity.

It is likely that alterations to the natural flow regime will have different impacts on each zone. A synthesis of information collected through this project, including this report, can help develop a framework of the relative vulnerability of key species to changes in water regime and inform ongoing vegetation monitoring.

1. Introduction

1.1 Context

The work undertaken in this report was completed under the Australian Government's National Environmental Science Program through the Northern Australia Environmental Resources Hub project 1.3.3: Environmental water needs of the Fitzroy River, Western Australia. Data pertaining to the environmental water needs of key plant species was collected in the dry season of 2018. Rapid vegetation surveys were conducted within an area of approximately 300 km of the lower Fitzroy River. Data were used to develop a model of vegetation distribution in relation to flood inundation (Canham et al., in press). This report summarises the complete data set from these surveys including findings and outcomes that were not reported in Canham et al. (in press).

1.2 Background

The Fitzroy River and its catchment have high environmental, cultural and economic significance (Poelina et al., 2019, Douglas et al., 2019). The cultural significance has been recognised with the National Heritage listing of the flow values of the Fitzroy River, its tributaries, floodplains and Jila sites, which demonstrate the four distinct expressions of the Rainbow Serpent tradition associated with Indigenous interpretations of the different ways in which water flows within the catchment (Australian Government, 2011). There is increasing interest in developing this water resource for irrigated agriculture; however, important environmental values may be impacted if there are changes to the natural flow regime of the river or if groundwater levels are altered (Douglas et al., 2019). This includes riparian vegetation because its species composition, distribution and physical structure is largely driven by surface and sub-surface water flows (Rivaes et al., 2017, White and Stromberg, 2011, Lawson et al., 2015).

Along many rivers, particularly those with large, wide floodplains, there is a natural zonation of plant species along a hydrological gradient from the banks of the river channel to the edge of the floodplain (Casanova and Brock, 2000, Deane et al., 2017, Jansson et al., 2019). Areas closest to the main channel are often dominated by species that tolerate high-velocity flows and long periods of inundation (Bejarano et al., 2011). Areas further from the main channel, on the floodplain, are dominated by species that withstand dry conditions (Capon et al., 2016). Access to shallow alluvial water tables is important for some riparian species (O'Grady et al., 2006, Pettit and Froend, 2018), particularly in environments that experience long dry periods, such as the Fitzroy River. The broad vegetation zones reflect hydrological patterns in which the dominant plant species in each zone are likely to have different water requirements. The identification of different vegetation zones and characterisation of species composition, structure and health provides a foundation for water managers to assess the potential impact of changes in surface and sub-surface flows on riparian and floodplain vegetation.

To our knowledge, zonation of riparian vegetation along the Fitzroy River has not previously been described as part of a systematic study, although previous work does provide observations of species distributions. For example, Pollino et al. (2018) synthesised information in publications and vegetation mapping to determine the distribution of key

riparian species in the Fitzroy River catchment, as part of a broader northern Australian study. Storey et al. (2001) surveyed locations along the Fitzroy River, including a combination of habitats on the main channel and off-channel billabongs, creeks and waterholes. They described some of the dominant species and general habitat; however, there is limited quantitative data. Fox et al. (2001) produced a broad-scale (1:2,000,000) map of vegetation in the Australian tropical savanna, which includes some distinction between floodplain and riparian vegetation units. However, this information is too coarse to inform water management decision-making.

Based on a review of the literature and field observations, four broad vegetation zones were identified along a hydrological gradient from the banks of the lower Fitzroy River to the edge of the floodplain (Figure 1.1):

1. riverbank
2. top of bank
3. floodplain
4. off-channel wetlands and flood-runner channels.

Each zone is likely to support different combinations of species, reflecting plant water requirements. The aim of this report is to characterise the dominant species and structure for each of the four vegetation zones.

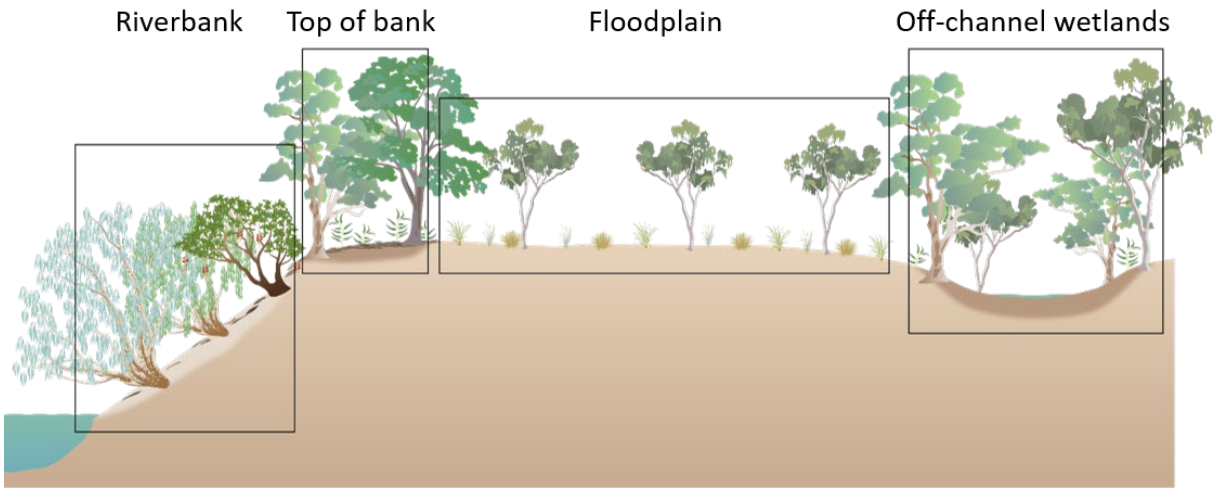


Figure 1.1. Cross-section of the different vegetation zones found in the lower Fitzroy River, WA.

2. Methods

Field work was undertaken in collaboration with Traditional Owners, pastoralists and the Western Australian Department of Water and Environmental Regulation (DWER). Rapid vegetation surveys included measurements of woody vegetation composition and structure, understorey composition and soil properties.

2.1 Study location

The Fitzroy River catchment is located in far northern Western Australia, occupying an area of approximately 93,830 km^2 (Figure 2.1). The Fitzroy River has 20 tributaries including the Margaret River, and includes important off-channel wetlands and flood-runner channels that are of great significance to local people (Poelina et al., 2019). Surveys were undertaken within an area spanning approximately 300 km of the lower Fitzroy River, from Fitzroy Crossing to Willare, including the lower reaches of the Margaret River, Cunningham Anabranch and off-channel wetlands and flood-runner channels. The survey area is hereafter referred to as the lower Fitzroy River.

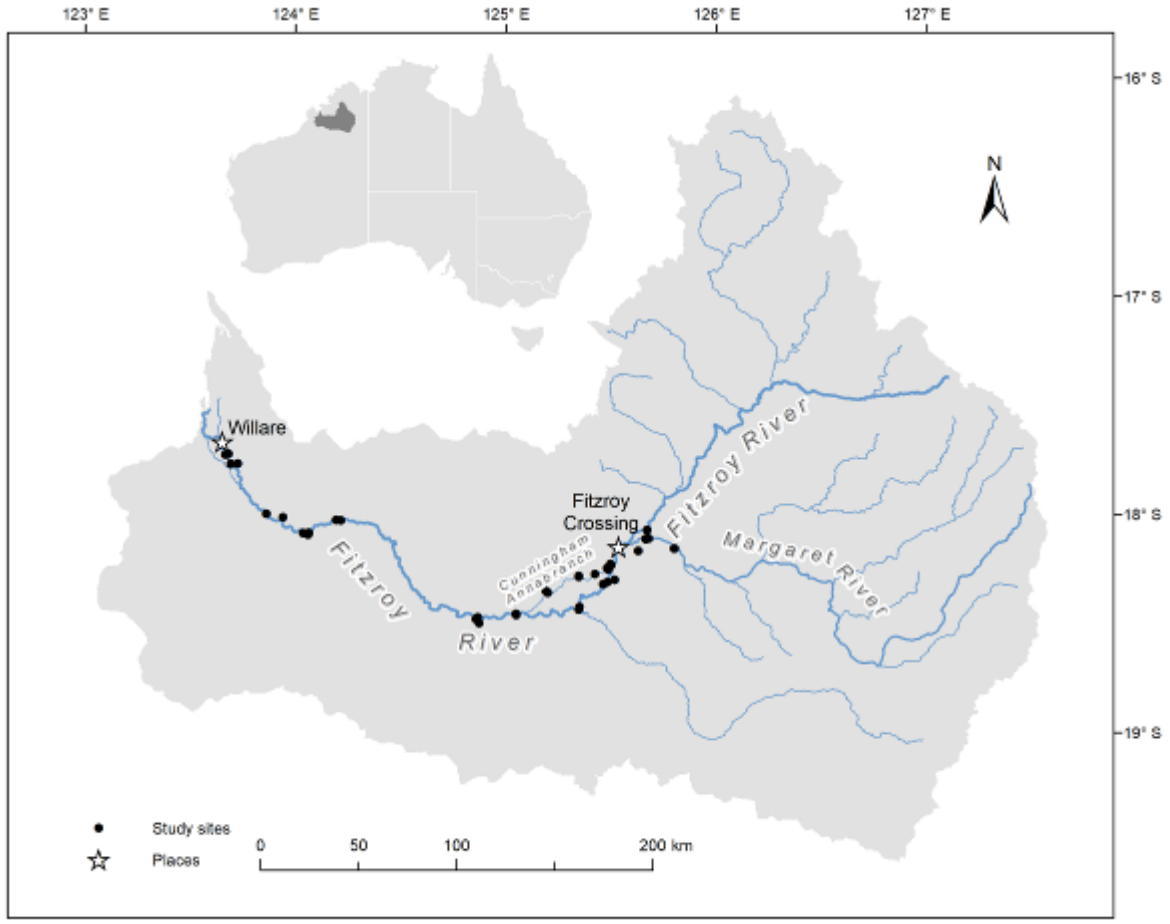


Figure 2.1. The Fitzroy River catchment where 58 sites (black circles) were surveyed during the dry season in 2018. Sites were located in the lower Fitzroy River catchment between Fitzroy Crossing and Willare at the Fitzroy River (n=33), the Margaret River (n=10), the Cunningham Anabranch (n=6) and off-channel wetlands and flood-runner channels (n=9).

2.1.1 Climate

The lower Fitzroy River is a semi-arid region with variable interannual rainfall, but with a distinct summer wet season. The long term (1997–2018) annual average rainfall at Fitzroy Crossing is 680 mm, which predominantly occurs between December and March (Aero station 003093, BOM 24/02/2020; Figure 2.2). Maximum temperatures are frequently above 40 °C in the wet season with relative humidity as high as 90% (Aero station 003093, BOM 07/01/2020). Maximum temperatures reach 30 °C in winter and rarely drop below 10 °C overnight (Aero station 003093, BOM 07/01/2020).

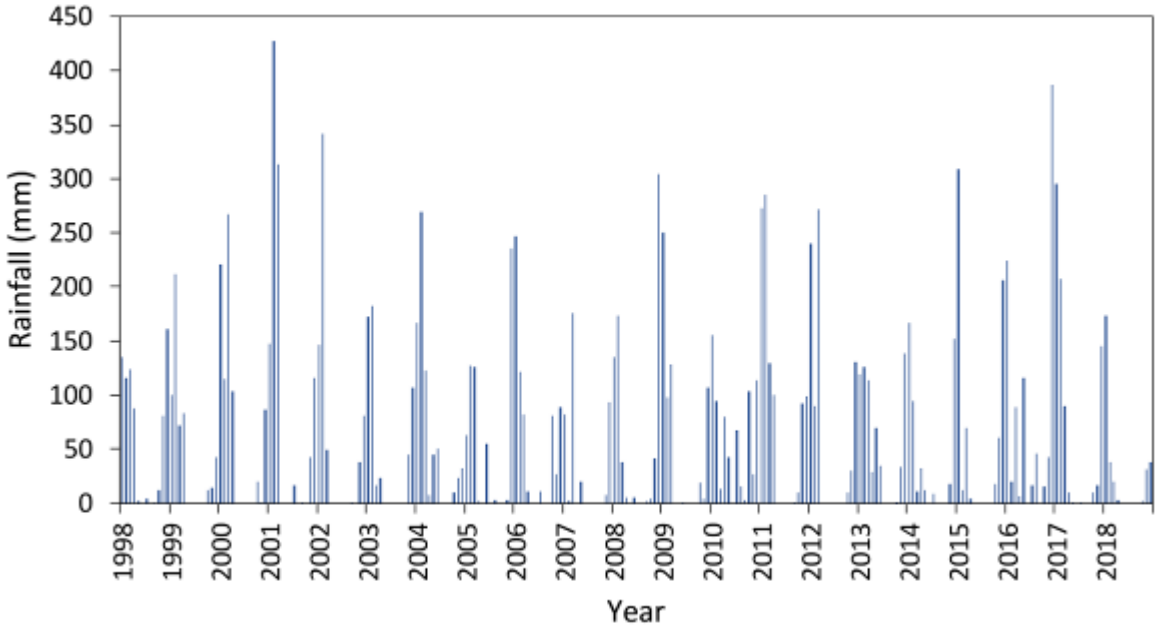


Figure 2.2. Total monthly rainfall at Fitzroy Crossing from 1998 to 2018 (BOM station 003093 07/01/2020).

2.1.2 Hydrology

Historically, flooding of the Fitzroy River typically occurs towards the end of summer with great interannual variability in magnitude and duration (Figure 2.3).

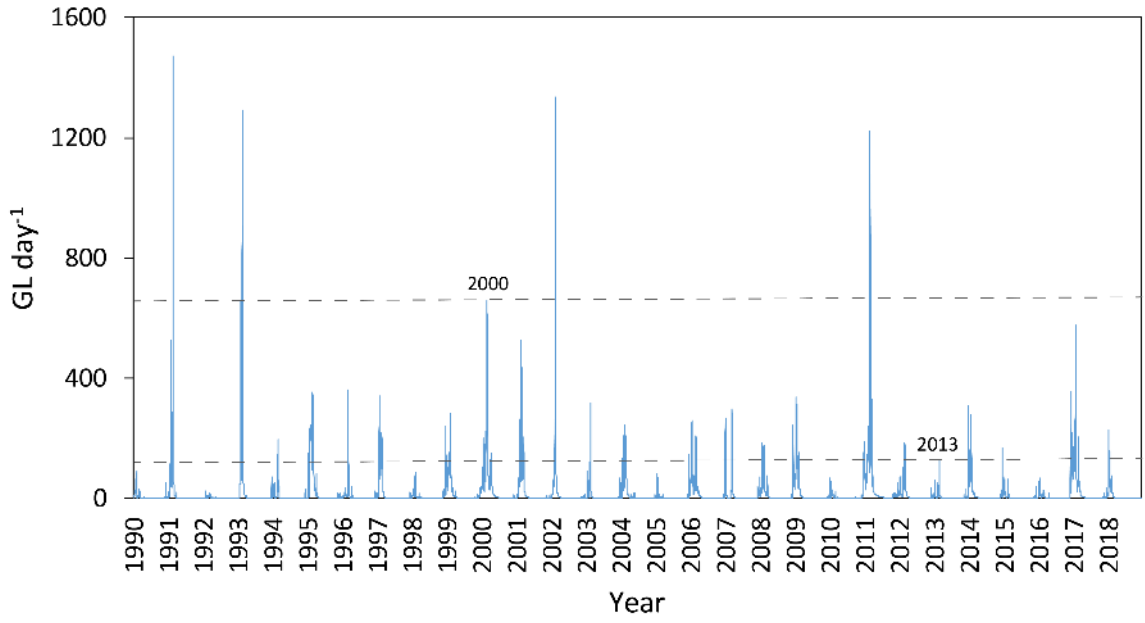


Figure 2.3. Daily mean Fitzroy River discharge (Fitzroy Crossing, site 802055 Department of Water and Environmental Regulation, accessed 08/01/2020). Dashed lines show examples of a small flood (2013) and a large flood (2000).

2.2 Study design

Site selection was stratified to sample the four broad vegetation zones: riverbank, top of bank, floodplain and off-channel wetlands (Table 2.1, Figure 2.4 and Figure 2.5). A total of 58 sites were selected in collaboration with Traditional Owners from Walalakoo, Yi-martuwarra and Gooniyandi Native Title groups, based on cultural significance and accessibility. For a complete site list and GPS coordinates see Appendix Table 4.1. Each site extended 40 m in length, approximately parallel with either the river or off-channel wetland, and 10 m perpendicular to it (i.e. 40 m x 10 m = 0.04 ha survey area). Woody species composition and structure, understorey composition and soil properties were measured at each site. Surveys were conducted during the dry season between July and September 2018.

Table 2.1. Description of vegetation zones, number of sites surveyed (total 58) and sites codes for vegetation surveys undertaken in the lower Fitzroy River in 2018.

Zone	Definition	No. of sites	Site codes
Riverbank	Riparian zone adjacent to the rivers edge, typically characterised by steep slopes. Observed to be approximately 10–20 m wide from top of bank to water level at the time of the survey.	16	RB01 – RB16
Top of bank	Riparian zone adjacent to the riverbank where land flattens out and tree cover is generally high.	16	TB01 – TB16
Floodplain	Flat open land away from the river, generally sparsely vegetated.	17	FP01 – FP17
Off-channel wetlands	Includes floodplain wetlands, depressions and distributary channels (flood runners) located on the floodplain away from the main river channel, usually with fringing tree cover (hereafter collectively referred to as off-channel wetlands).	9	OC01 – OC09

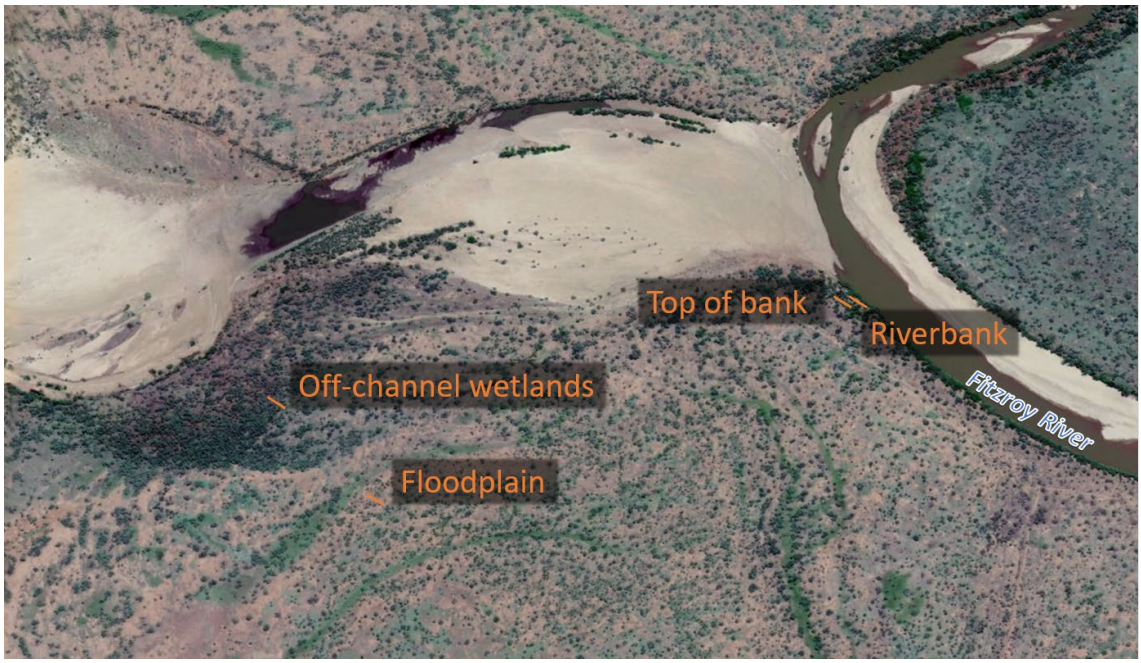


Figure 2.4. A visual representation of survey sites (orange line) representing vegetation zones in relation to the Fitzroy River: riverbank, top of bank, floodplain, and off-channel wetlands and floodrunners.

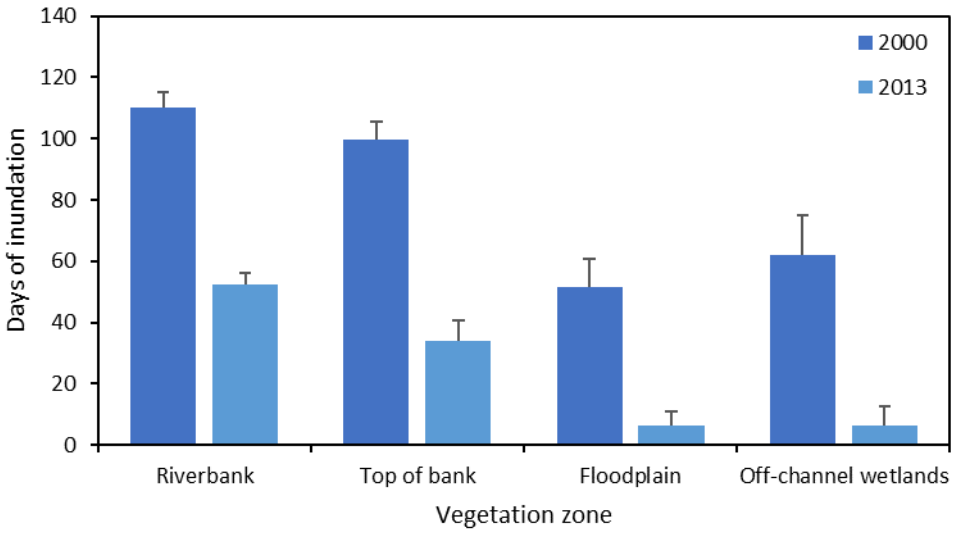
Figure 2.5. Vegetation zones surveyed in 2018 along the lower Fitzroy River: (a) riverbank (site RB04), (b) top of bank (site TB12), (c) floodplain (site FP09) and (d) off-channel wetlands (site OC04). Photos: F Freestone, 2018.

To help characterise the vegetation zones surveyed, modelled estimates of the duration of flooding and maximum water depth were determined for each site. This information was obtained from a MIKE21 hydrodynamic model developed by the CSIRO (Karim et al., 2018) and accessed via a spatial raster dataset. Two contrasting years were selected: data from 2000 to represent a large flood year (1-in-25 annual exceedance probability (AEP)) and 2013 to represent a small flood year (1-in-2 AEP; Figure 2.3). Data for the number of days of inundation and the maximum water depth were extracted from the pixel corresponding with the centre of the study site.

The number of days of inundation were greatest at riverbank sites, both in large (~110 days) and small flood years (~53 days; Figure 2.6a). In 2013, the small flood year, floodplain sites had the lowest number of inundation days and in 2000, during the large flood, both floodplain and off-channel wetlands had fewer inundation days compared with riverbank and top-of-bank sites. In the small flood (2013), 15 (of 17) floodplain sites and 8 (of 9) off-channel wetlands were not inundated at all. In the large flood (2000), 4 floodplain and 2 off-channel wetlands were not inundated.

The average maximum water depth at riverbank sites was ~6 m in the large flood year (2000), and ~3.5 m in the small flood year (2013) (Figure 2.6b). In contrast, despite being geographically close, top-of-bank sites had lower maximum water depths, with means of ~2.5 (2000) and ~0.7 m (2013), which reflects topography of the steep banks that characterise the lower Fitzroy River. Off-channel wetlands and floodplain sites generally experienced ~1 m of inundation in the large flood year (2000), compared with ~0.1 m maximum water depth in the small flood year (2013).

(a) Days of inundation



(b) Maximum water depth

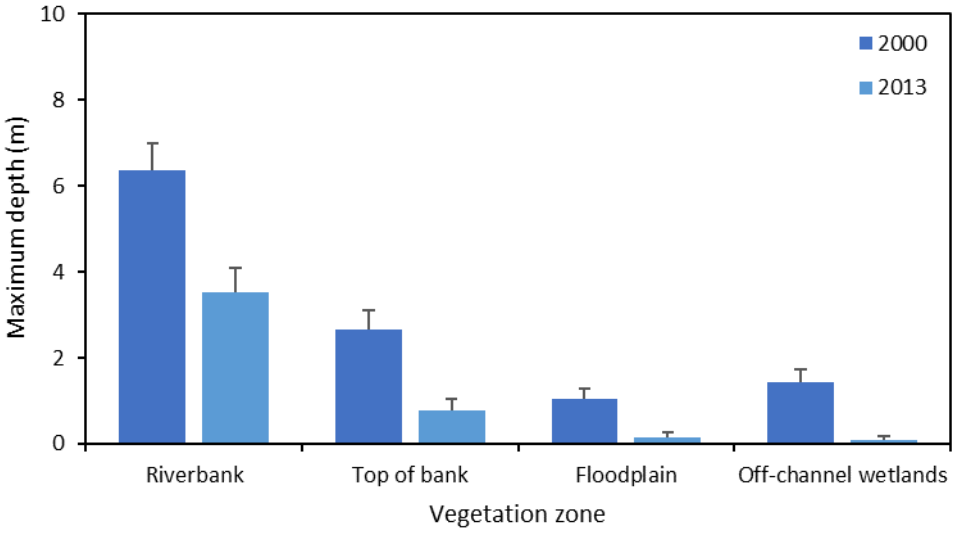


Figure 2.6. Mean (+1 standard error) modelled days of inundation (a) and maximum water depth (b) at study sites along the lower Fitzroy River for each vegetation zone: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9), during a large flood (2000) and a small flood (2013).

Species identification

Plant species were identified using a combination of plant keys (Dixon, 2007, Wheeler et al., 1992) and expert knowledge from Kevin Kenneally and Matthew Barrett. Naming conventions and conservation and weed status (where applicable) follow FloraBase, the Western Australian Flora website (https://florabase.dpaw.wa.gov.au). Non-native species are identified throughout this report with an asterisk (*) at the end of the scientific name.

2.2.1 Woody vegetation

Tall woody vegetation

Tree health was assessed for every live tree greater than 1.5 m tall, rooted within the 40 m x 10 m site. Canopy condition was assessed for each tree, following the methods described in the Dampier Peninsula report prepared by DWER (2017). Canopy condition included three components of tree health: crown density, proportion of dead branches and degree of epicormic growth. Each component was scored using the definitions provided in Appendix Table 4.2. The three component scores were then added together for each tree, with the final score being used to assign an overall tree condition category (Appendix Table 4.3). Diameter at breast height (DBH) was measured for each tree. Measurements of DBH were summed for multi-stemmed trees (e.g. such as *Barringtonia acutangula*) and total DBH for each tree was classified into 10 cm DBH categories (11th category: 100+ cm). Basal area was calculated for each tree as

$$Basal\ area = \pi(\frac{DBH}{2})^2$$

Stand basal area (m^2/ha) was then calculated as the sum of all tree basal area for each site and divided by the site area (0.04 ha). Tree height was recorded for the tallest tree at each site using a Nikon Forestry Pro Laser Rangefinder.

Small woody vegetation

Individual tree seedlings, suckers and resprouts were counted at each 40 m x 10 m site using three categories: small seedlings (0–0.5 m tall), tall seedlings (0.5–1.5 m tall) and resprouts (e.g. resprout or sucker from parent tree).

2.2.2 Understorey composition

Each 40 m x 10 m site was divided into 4 x 10 m x 10 m quadrats. A 1 m x 1 m cell was randomly placed within each quadrat and used to survey understorey, with a total of four cells surveyed per site. All living plants within each cell were recorded and identified to species level, where possible. The presence of leaf litter, seedlings, grasses, herbs and shrubs as a proportion within each quadrat.

A complete list of species in each vegetation zone is reported in the Appendix: riverbank Table 4.5, top of bank Table 4.6, floodplain Table 4.7 and off-channel wetlands Table 4.8. For a complete list of species, see Appendix Table 4.9.

2.2.3 Vegetation structure

Vegetation structure was assessed at each site using a line point intercept method. A sampling pole was constructed using an extendable pole with a laser pointer attached at 1.5m to the pole pointing downwards (to measure ground cover structure), and a GRS Densitometer was attached facing upwards (to measure canopy cover).

One hundred points were surveyed around the perimeter of the site (i.e. one point every metre around 40 m x 10 m site). At each point, ground cover (i.e. < 1.5m) was classified as either leaf litter, bare ground or vegetation, and canopy cover was recorded as present or absent.

2.2.4 Soil properties

To determine field texture, one scoop of soil was sampled randomly from within each site. A small handful of soil from the sample was misted with water, then the damp soil was moulded into a bolus. The damp bolus was then gently squeezed between thumb and forefinger to create a ribbon which was measured for length at the point that they broke off and could no longer support their own weight. The ribbon length was used to determine the soil type and approximate clay content as classified by McDonald et al. (1998).

3. Results

3.1.1 Woody vegetation

Tall woody vegetation

A total of 1,872 live trees > 1.5 m tall were assessed representing 32 species, including four non-native species (*Azadirachta indica*, Calotropis procera*, Parkinsonia* sp.* and *Vachellia farnesiana**), across 13 families (for complete species list, species code and associated vegetation zones see Appendix Table 4.4). The most commonly represented families were Myrtaceae (10 species: four *Melaleuca* spp., three *Eucalyptus* spp., two *Corymbia* spp. and *Lophostemon grandiflorus*), Moraceae (five *Ficus* spp.) and Fabaceae (five spp.).

Mean tree species richness was highest at top-of-bank sites (~six spp.) and lowest at the floodplain sites (two spp.) (Figure 3.1). A total of 20 species were recorded at top-of-bank sites compared with 14 at riverbank sites, 12 at floodplain sites and 14 at off-channel wetlands (Figure 3.2 and Figure 3.3). Riverbank sites were dominated by *Barringtonia acutangula*, *Melaleuca argentea* and *Melaleuca leucadendra* (Figure 3.2a and Figure 3.3a). *Ficus racemosa, M. argentea* and *Pandanus* sp. were exclusively found at riverbank sites. *Melaleuca leucadendra* and *Nauclea orientalis* were predominantly recorded at riverbank sites with minor occurrences elsewhere (130 counts riverbank/two counts off-channel wetlands and 12 counts riverbank/two counts top-of-bank, respectively). *Atalaya hemiglauca* and *Bridelia tomentosa* were most commonly found at top-of-bank sites (Figure 3.2b and Figure 3.3b). *Eucalyptus microtheca* dominated floodplain sites (Figure 3.2c and Figure 3.3c), occurring as a monospecific stands at 41% of sites (seven of 17 sites). Off-channel wetlands had the highest count of *Eucalyptus camaldulensis* (Figure 3.2d and Figure 3.3d), however there were large differences among sites. For example, the high count of *E. camaldulensis* in off-channel wetlands was due to one site (OC09) where 101 trees were measured. These trees were approximately 6 m tall and predominantly < 20 cm DBH (see image in Figure 3.4), possibly the result of a recruitment event following a previous flood (Figure 2.3).

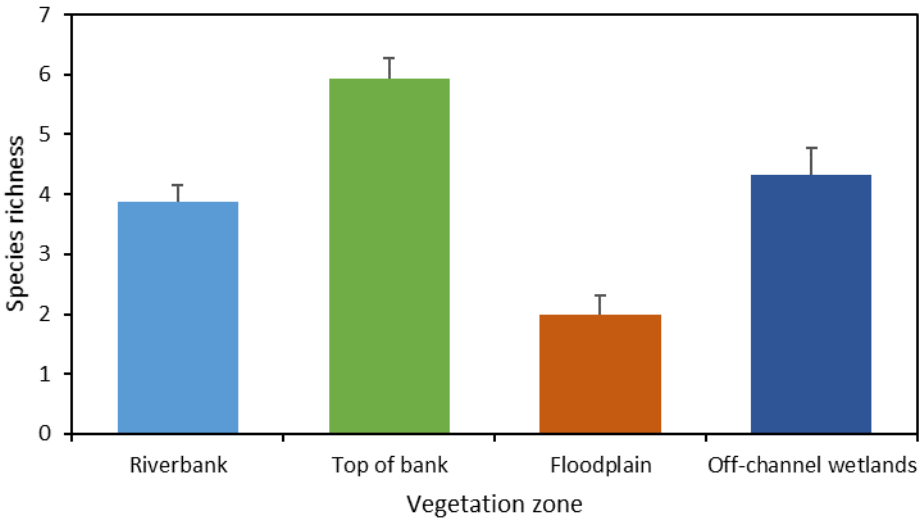


Figure 3.1. Mean (+1 standard error) tree species richness for each vegetation zone: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9). Values are the mean and standard error for each habitat type.

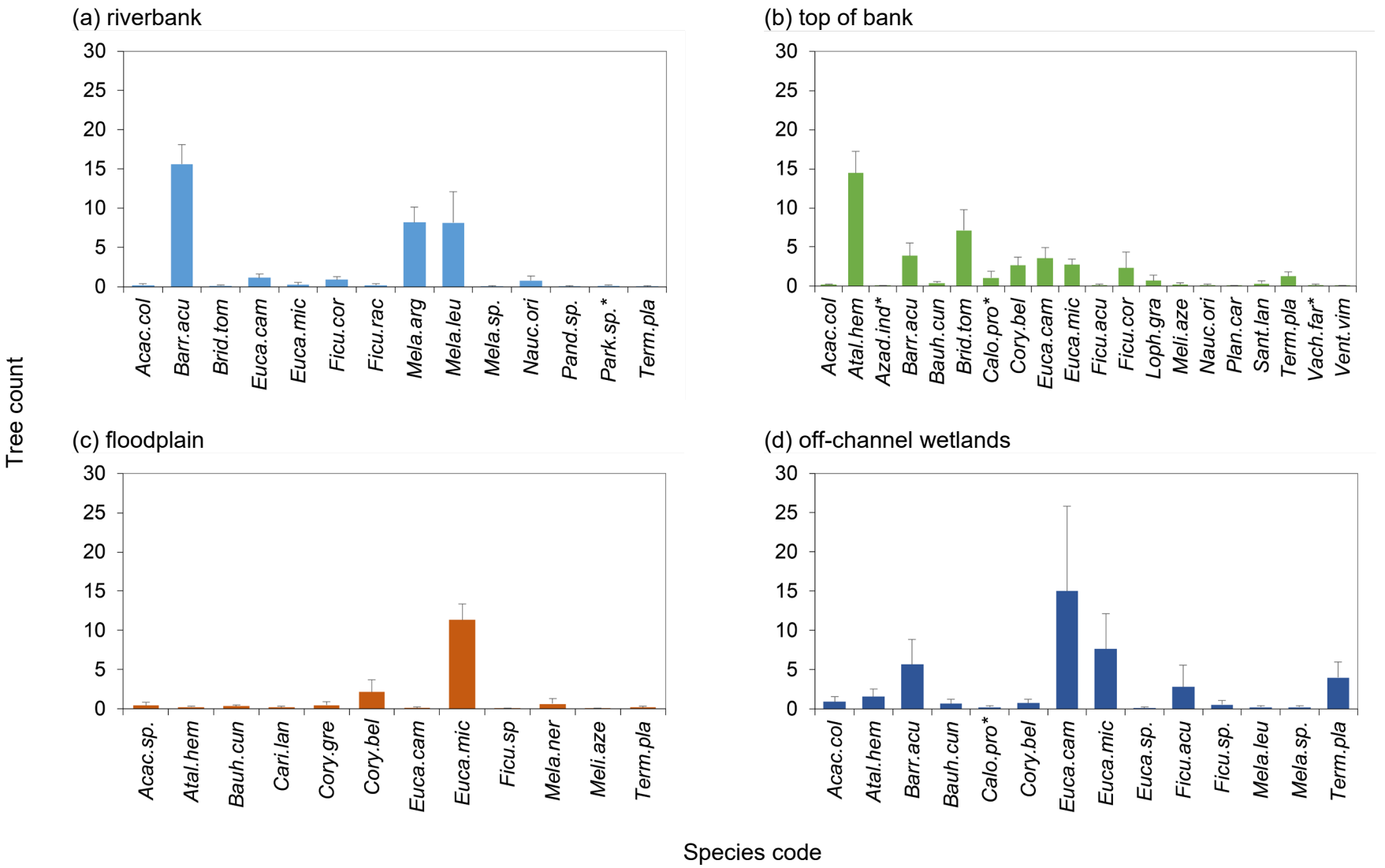


Figure 3.2. Mean (+1 standard error) count of live trees (> 1.5 m tall) per site for each vegetation zone in the lower Fitzroy River: a) riverbank (n=16), b) top of bank (n=16), c) floodplain (n=17) and d) off-channel wetlands (n=9). For complete species list and corresponding species code, refer to Appendix Table 4.4.

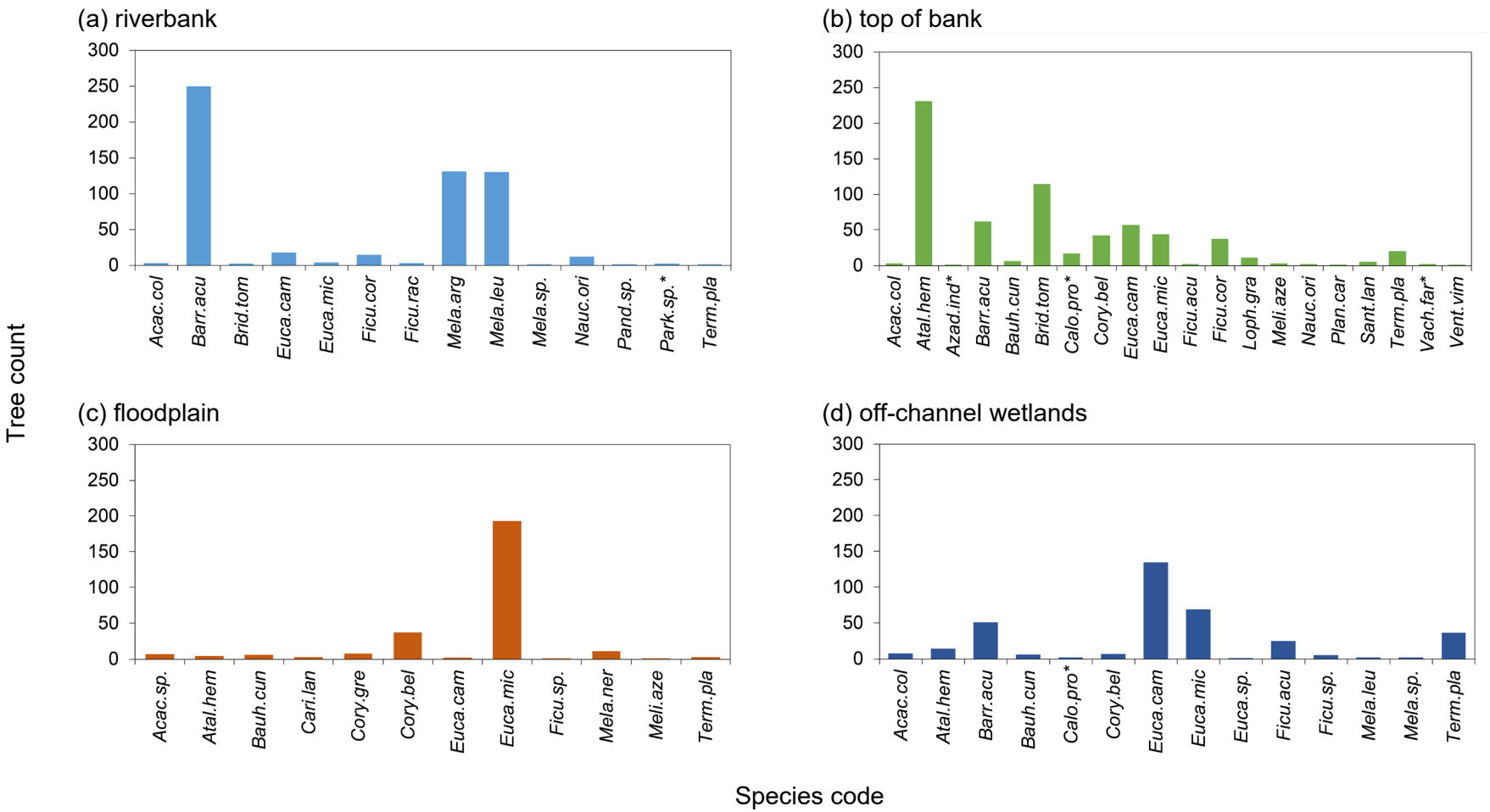


Figure 3.3. Total count of live trees (> 1.5 m tall) by species for all sites within each vegetation zone in the lower Fitzroy River: a) riverbank (n=16), b) top of bank (n=16), c) floodplain (n=17) and d) off-channel wetlands (n=9). For complete species list and corresponding species code, refer to Appendix Table 4.4.

Figure 3.4. Riparian vegetation regeneration at off-channel wetland OC09. Approximately 101 x 6 m tall Eucalyptus camaldulensis were measured. Photo: Fiona Freestone 2018.

Barringtonia acutangula, *M. argentea* and *M. lecuadendra* were very common at riverbank sites, with *B. acutangula* present at all riverbank sites (Table 3.1). The most common species at top-of-bank sites were *Atalaya hemiglauca* (94% of sites), *E. camaldulensis* and *E. microtheca*. *Eucalyptus microtheca* was common on the floodplain, occurring at 82% of floodplain sites and very few other species were detected commonly on the floodplain. Off-channel wetlands were dominated by *E. camaldulensis* and *E. microtheca*, with *Terminalia platyphylla* found at 56% of sites. *Eucalyptus camaldulensis*, *E. microtheca* and *T. platyphylla* were the only species recorded in all vegetation zones.

Table 3.1. Percentage of sites where species were present (riverbank and top of bank n=16, floodplain n=17, off-channel wetlands n=9). Key: blank = 0%, light blue = 0–24%, dark blue = 25–49%, light green = 50–74%, dark green = 75–100%.

Species	Riverbank	Top of bank	Floodplain	Off-channel wetlands
Acacia colei	6	19		33
Acacia sp.			6	
Atalaya hemiglauca		94	18	33
Barringtonia acutangula	100	56		33
Bauhinia cunninghamii		25	24	22
Bridelia tomentosa	13	56		
Carissa lanceolata			6	
Corymbia greeniana			12	
Corymbia bella		44	24	33
Eucalyptus camaldulensis	25	75	6	78
Eucalyptus microtheca	6	69	82	78
Eucalyptus sp.				11
Ficus aculeata		6		11
Ficus coronulata	38	25		
Ficus racemosa	6			
Ficus sp.			6	11
Lophostemon grandiflorus		6		
Melaleuca argentea	75			
Melaleuca leucadendra	75			11
Melaleuca nervosa			6	
Melaleuca sp.	6			11
Melia azedarach		6	6	
Nauclea orientalis	19	13		
Pandanus sp.	6			
Planchonia careya		6		
Santalum lanceolatum		6		
Terminalia platyphylla	6	44	6	56
Ventilago viminalis		6		
*Azadirachta indica**		6		
*Calotropis procera**		19		11
*Parkinsonia sp.**	6			

Canopy condition was classified as good in all vegetation zones, with riverbanks scoring the highest of all zones (Figure 3.5). Individual sites were predominantly in good condition, with only three sites in moderate condition (TB14, FP07 and OC05; Figure 3.6a–d). Riverbank sites predominantly scored towards the upper end of the good category with three sites scoring < 18 (Figure 3.6a). All zones had one or more sites in very good condition.

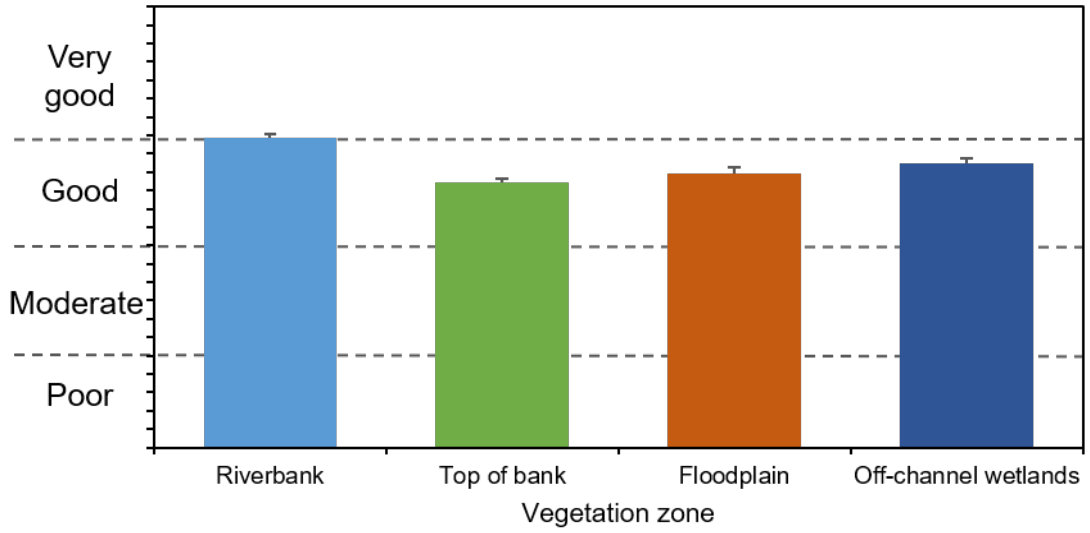


Figure 3.5. Mean (+1 standard error) canopy condition per vegetation zone: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9). Score key: <5 = poor, 6–11 = moderate, 12–17 = good, 18+ = very good.

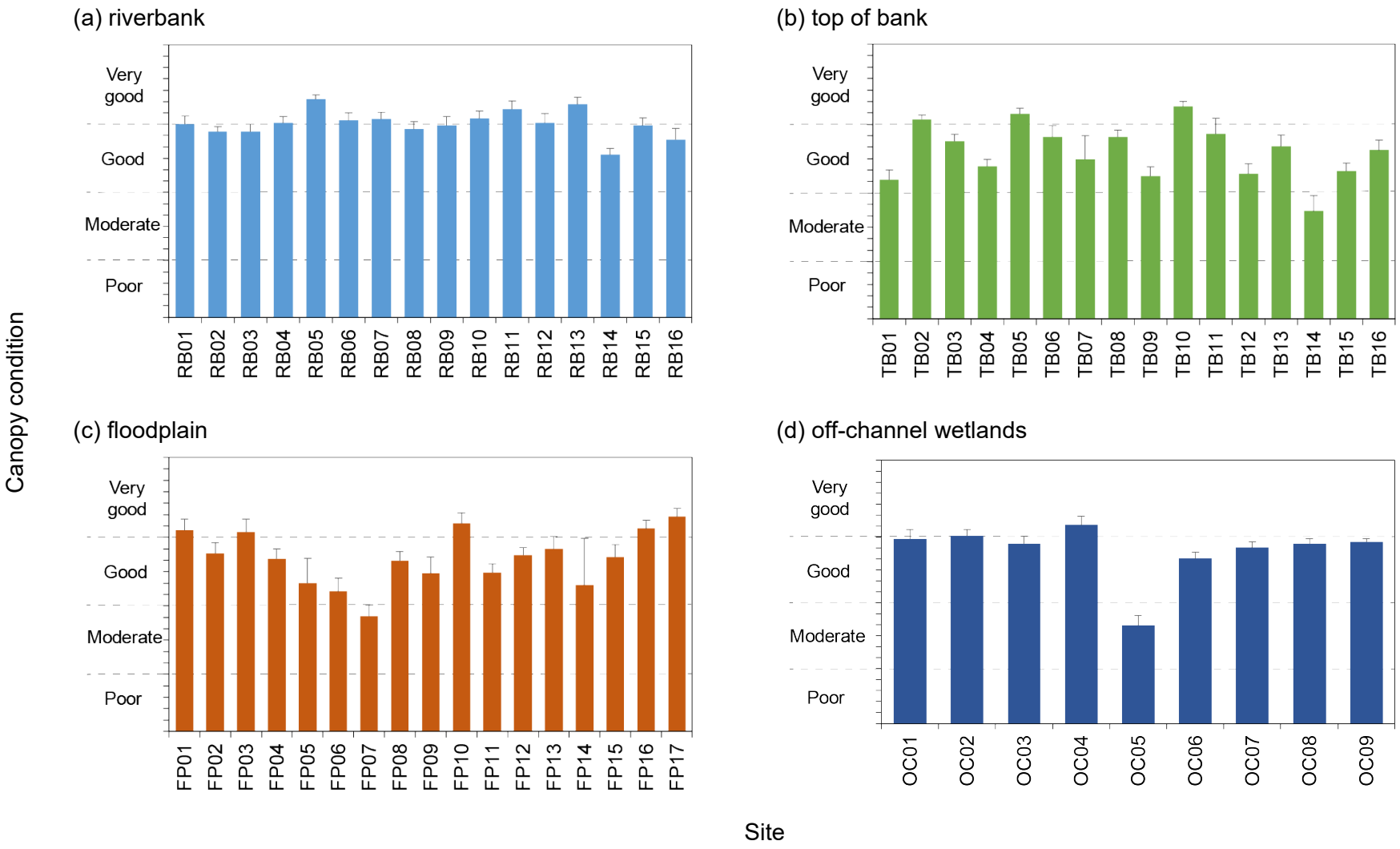


Figure 3.6. Mean (+1 standard error) canopy condition at each site within each vegetation zone: a) riverbank (n=16), b) top of bank (n=16), c) floodplain (n=17) and d) off-channel wetlands (n=9). Score key: <5 = poor, 6–11 = moderate, 12–17 = good, 18+ = very good.

The tallest trees typically occurred at top-of-bank sites, with a mean maximum height of approximately 13 m (Figure 3.7). The mean maximum height of off-channel wetland trees was approximately 11 m. The maximum height was lowest for floodplain trees, at approximately 7 m.

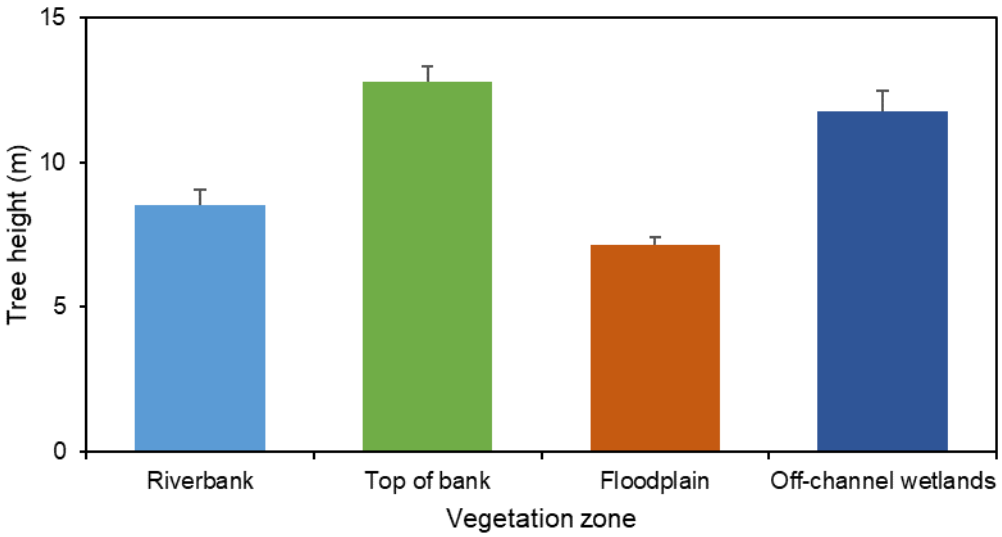


Figure 3.7. Mean (+1 standard error) maximum tree height: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9).

The DBH was measured for 1872 trees greater than 1.5 m tall (Figure 3.8). Of these, 47 had a DBH greater than 100 cm, 21 of which were *M. argentea*. The largest tree was a *M. argentea* at RB08 on the riverbank, which had a DBH of 288 cm. The majority of large trees (83%) were found at riverbank sites, which had 39 of the 47 trees recorded with a DBH greater than 100 cm (Figure 3.8a). Smaller trees with a DBH < 10 cm were more commonly found at the top of the bank and off-channel wetlands (Figure 3.8b and d). The majority of floodplain trees were < 20 cm DBH with only five trees in DBH categories > 50 cm (Figure 3.8c). The largest tree recorded on the floodplain was *E. microtheca* which measured 79 cm DBH.

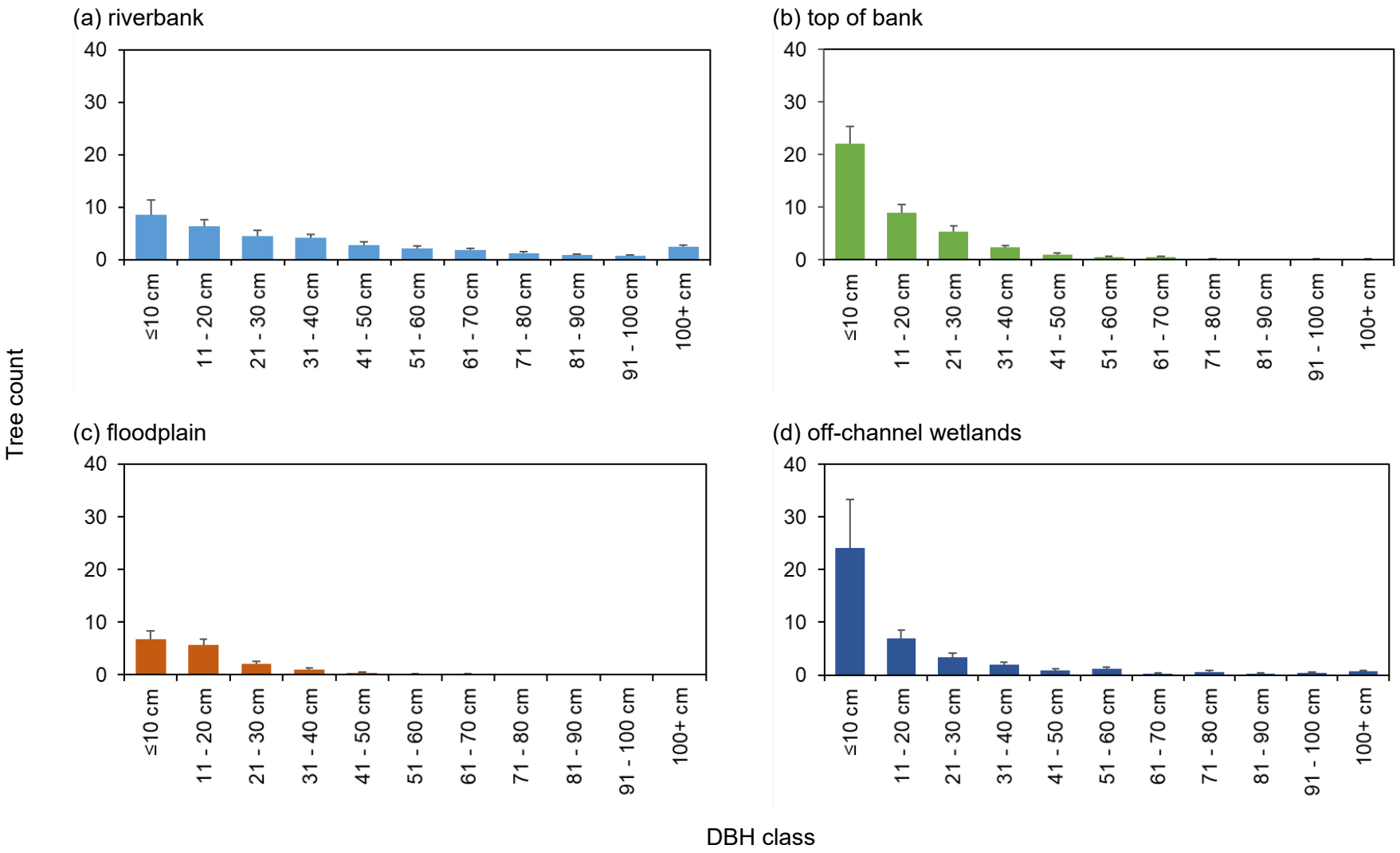


Figure 3.8. Mean (+1 standard error) count of trees > 1.5 m tall in each DBH class per vegetation zone: a) riverbank (n=16), b) top of bank (n=16), c) floodplain (n=17) and d) off-channel wetlands (n=9).

Stand basal area was greatest at riverbank sites (mean value ~197 m^2/ha), more than double the next highest at off-channel wetlands (~70 m^2/ha). Floodplain habitats had the smallest stand basal area, with a mean of approximately 12 m^2/ha (Figure 3.9).

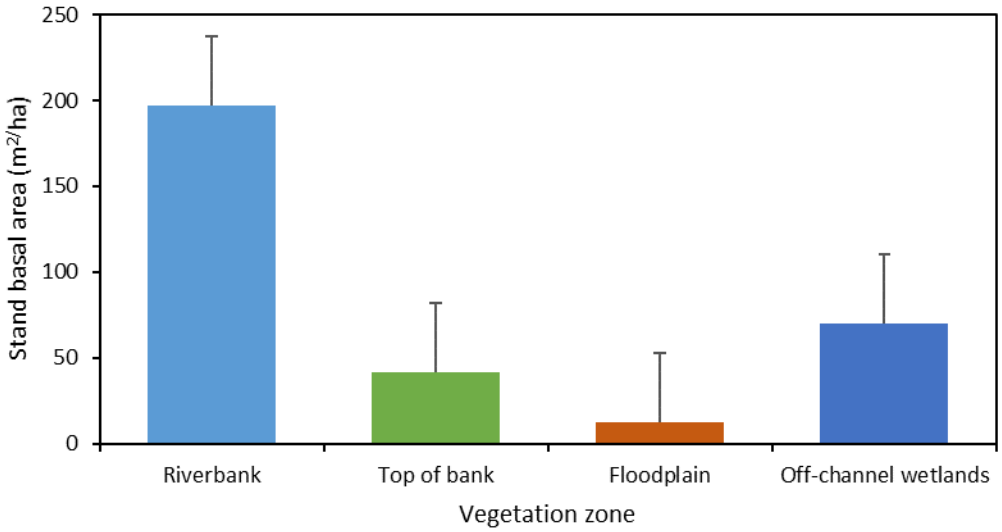


Figure 3.9. Mean (+1 standard error) stand basal area (m^2/ha) for each vegetation zone: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9). Data shown is mean per zone with standard error bars.

Seedlings were most commonly recorded at top of the bank sites and off-channel wetlands, although there was a high degree of variability among sites, particularly within off-channel wetlands (Figure 3.10). This variability was mostly due to the large number of seedlings recorded at sites OC01 (343 small seedlings) and OC05 (145 resprouts). Three top-of-bank sites also had a high number of seedlings (i.e. > 100) compared with the mean value of 31 for this zone.

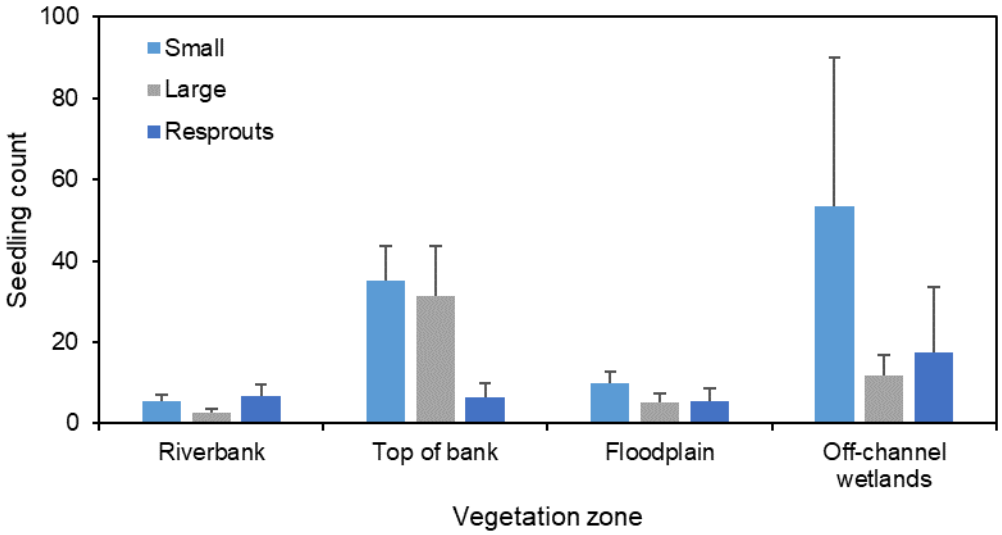


Figure 3.10. Mean (+1 standard error) number of seedlings recorded in riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9). Key: small seedlings = < 0.5 m tall, large seedlings = 0.5–1.5 m tall, resprouts = resprouts/suckers.

3.1.2 Understorey composition

Understorey data collected during field surveys does not provide a comprehensive list of species found in this region, nor were specific species targeted for surveys. A total of 71 understorey species from 22 families were recorded, with Poaceae and Asteraceae the most common families (11 and 8 species respectively). More than one third of species were recorded just once (27 species). For a complete list of species recorded during these surveys, see Appendix: riverbank Table 4.5, top of bank Table 4.6, floodplain Table 4.7 and Off-channel wetlands Table 4.8. For a complete list of species see Appendix Table 4.9.

Understorey species richness was generally low with total species richness for each vegetation zone ranging from 16 (riverbank 16 sites) to 29 (floodplain 17 sites) (Figure 3.11a). Mean species richness was less than 5 for all vegetation zones (Figure 3.11b). More than half of the species recorded across all zones were found at only one site each (i.e. 40 species recorded at only one site, not necessarily the same site). For example, 6 species were found at only one riverbank site (33% of all species recorded at riverbanks, Appendix Table 4.5), 12 species were found at only one top-of-bank site (43%, Appendix Table 4.6), 21 species were found at only one floodplain site (68%, Appendix Table 4.7) and 22 species were found at only one off-channel wetlands site (81%, Appendix Table 4.8).

The total number of non-native species was greatest at top-of-bank sites (total of seven species across all sites), representing 24% of all species recorded within this zone. The number of non-native species was lower for other zones, representing less than 10% of species richness at floodplain and off channel sites and 11% of the riverbank (Figure 3.11b).

The 10 most commonly recorded understorey species across all vegetation zones are shown in Table 3.2. The two most common species recorded at riverbank sites were non-native: *Cynodon dactylon** and *Xanthium occidentale** (Appendix Table 4.5). *Jatropha gossypiifolia** was the most common top-of-bank species, recorded at 11 of 16 sites (Appendix Table 4.6). Various grasses were the most common species found at floodplain sites and off-channel wetlands, including *Chrysopogon pallidus* and *Ennoapogon* sp. (recorded at 3 floodplain sites, Appendix Table 4.7) and *Cynadon dactylon** (at 7 off-channel wetlands, Appendix Table 4.8).

One species of conservation significance was recorded: *Thespidium basiflorum* (Priority 1; FP08 and OC06). The majority of species recorded were found at 3 sites or less, with 27 species recorded at only one site.

Seven non-native species were recorded (Table 3.3), with *Cynodon dactylon** from the Poaceae family the most common.

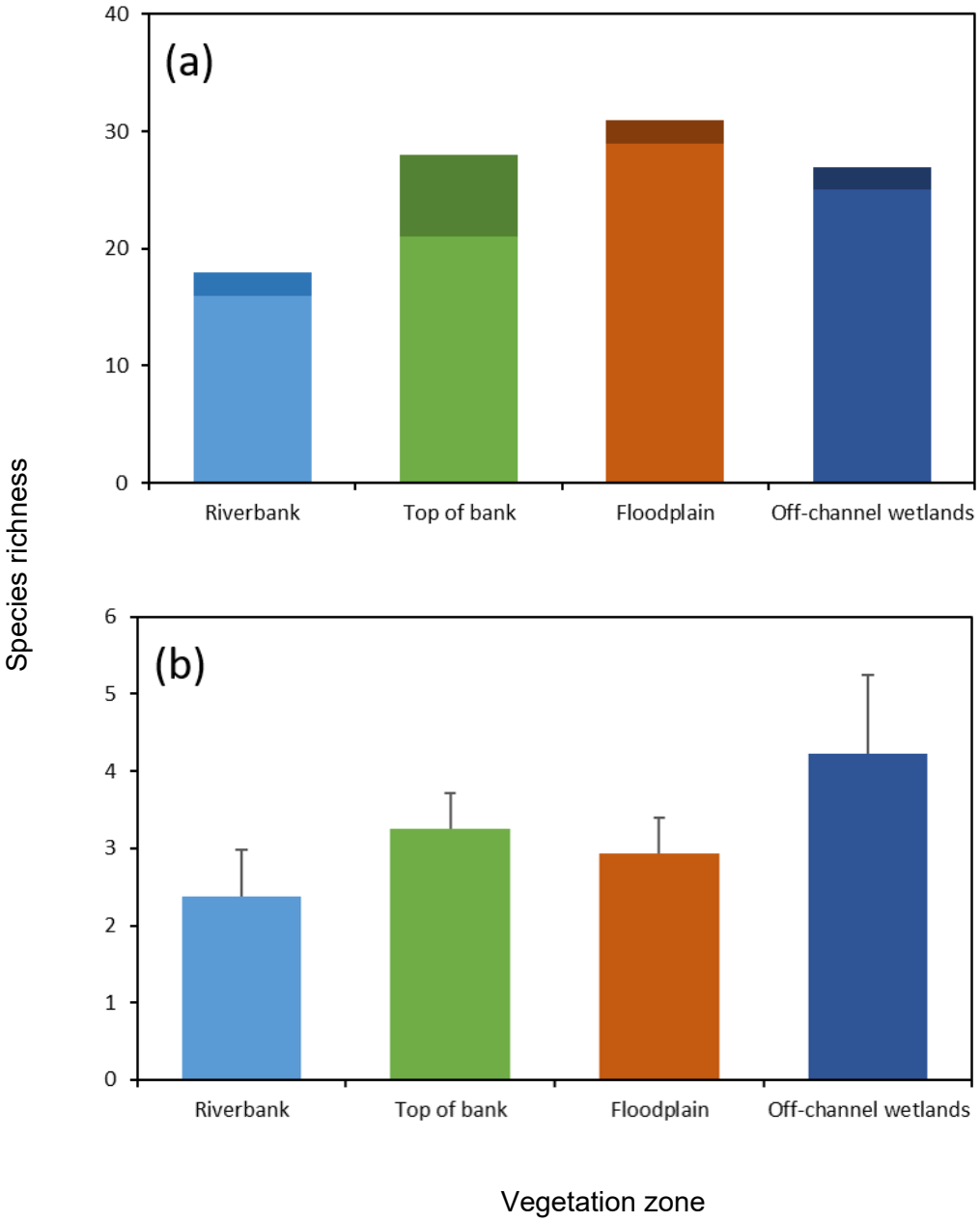


Figure 3.11. Understory species richness (a) total count and (a) mean (+1 standard errpr) for each vegetation zone: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9). Key: lighter shades = native species, darker shades = non-native species.

Table 3.2. Common understorey species recorded on the lower Fitzroy River during the 2018 dry season.

Species	Family	Sites
*Cynodon dactylon**	POACEAE	RB03, RB06, RB07, RB08, RB09, RB12, RB16, TB03, TB08, OC07
*Xanthium occidentale**	ASTERACEAE	RB03, RB05, RB06, RB09, TB02, TB03, TB15, OC07
Achyranthes aspera	AMARANTHACEAE	RB07, RB13, TB07, TB10, TB13, OC05, OC06
Ennoapogon sp.	POACEAE	RB07, TB07, TB13, FP07, FP13, FP14
Dentella misera	RUBIACEAE	FP08, FP17, OC01, OC06
Glinus lotoides	MULLUGINACEAE	RB03, RB09, RB11, RB13
*Jatropha gossypiifolia**	EUPHORBIACEAE	TB01, TB02, TB05, TB14
Phyllanthus sp.	PHYLLANTHACEAE	FP06, OC01, OC03, OC06
Pterocaulon sp.	ASTERACEAE	RB06, RB09, RB13, FP01
Alternanthera sp.	AMARANTHACEAE	FP03, FP17, OC01

Table 3.3. Non-native understorey species recorded on the lower Fitzroy River during the 2018 dry season.

Species	Family	Sites
*Clitoria ternatea**	FABACEAE	TB09
*Cynodon dactylon**	POACEAE	RB03, RB06, RB07, RB08, RB09, RB12, RB16, TB03, TB08, OC06, OC07
*Euphorbia hirta**	EUPHORBIACEAE	TB16
*Jatropha gossypiifolia**	EUPHORBIACEAE	TB01, TB02, TB05, TB14
*Malvastrum americanum**	MALVACEAE	TB13, FP01
*Passiflora foetida**	PASSIFLORACEAE	TB09
*Xanthium occidentale**	ASTERACEAE	RB03, RB05, RB06, RB09, TB02, TB03, TB15, OC07

Figure 3.12. From left to right: Solanum dioicum (sighted nearby, not recorded), Hibiscus fluvialis and Pterocaulon sp.

All zones had a high proportion of leaf litter (> 40%) (Figure 3.13). The highest proportion of shrubs was found in top-of-bank sites (13%), while off-channel wetlands had the highest proportion of herbs (39%). The most common family, Poaceae (grasses), comprised 10–16% structure for all zones.

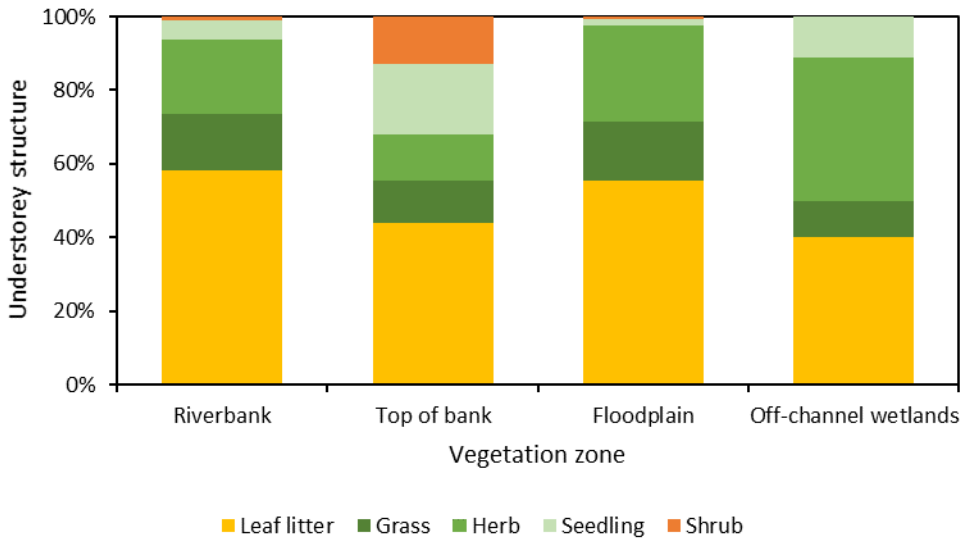


Figure 3.13. Proportion of understorey structure for each vegetation zone, based on 1 m x 1 m survey cells: a) riverbank (n=16), b) top of bank (n=16), c) floodplain (n=17) and d) off-channel wetlands (n=9).

3.1.3 Vegetation structure

Riverbank sites had the greatest canopy cover (79%), compared with both top-of-bank and off-channel wetlands which had a canopy cover of approximately 65%. Trees were comparatively sparse at floodplain sites with a mean canopy cover only 28% (Figure 3.14).

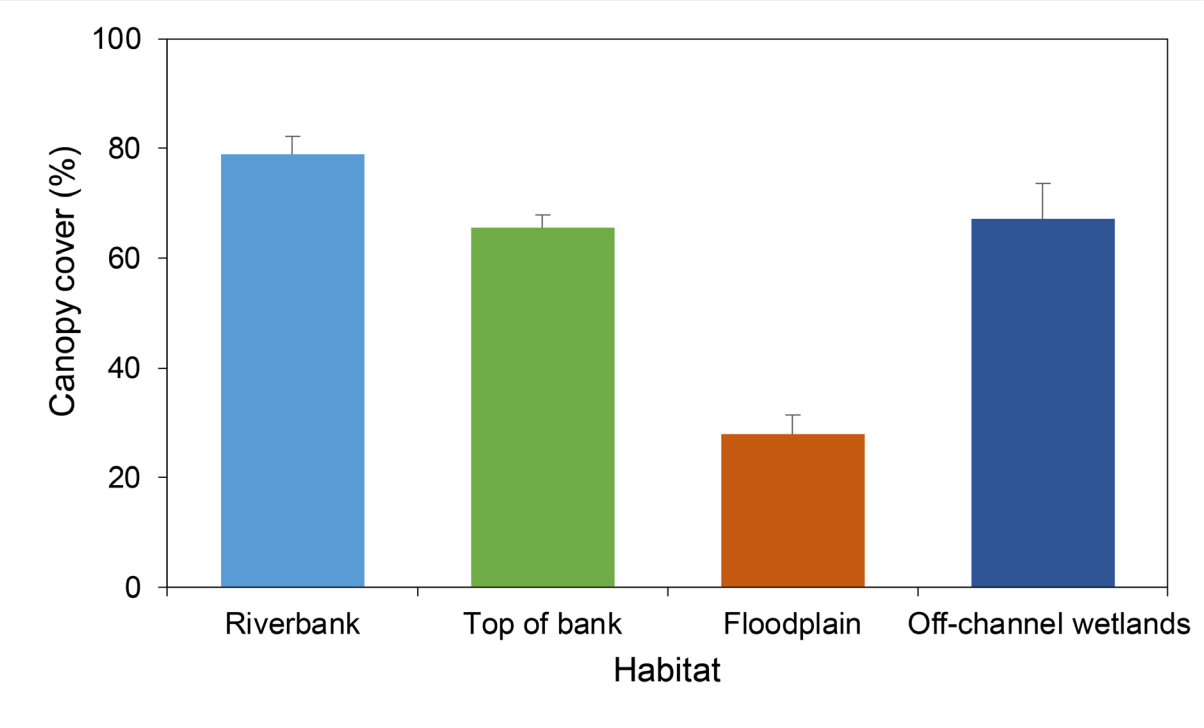


Figure 3.14. Percent canopy cover for each vegetation zone: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9). Values are the mean and standard error for each zone.

Ground cover composition (including vegetation <1.5 m tall) was predominantly comprised of leaf litter or bare ground (Figure 3.15). Riverbank sites had a large proportion of bare ground, accounting for 56% of the assessed area on average. In contrast, leaf litter dominated top-of-bank (77% cover) and off-channel wetlands (63% cover). Generally, there was a low cover of vegetation, accounting for only 3% at riverbank sites and 8% at top-of-bank sites and off-channel wetlands. There was a greater proportion of vegetation cover on the floodplain (~26%), which was predominantly grasses.

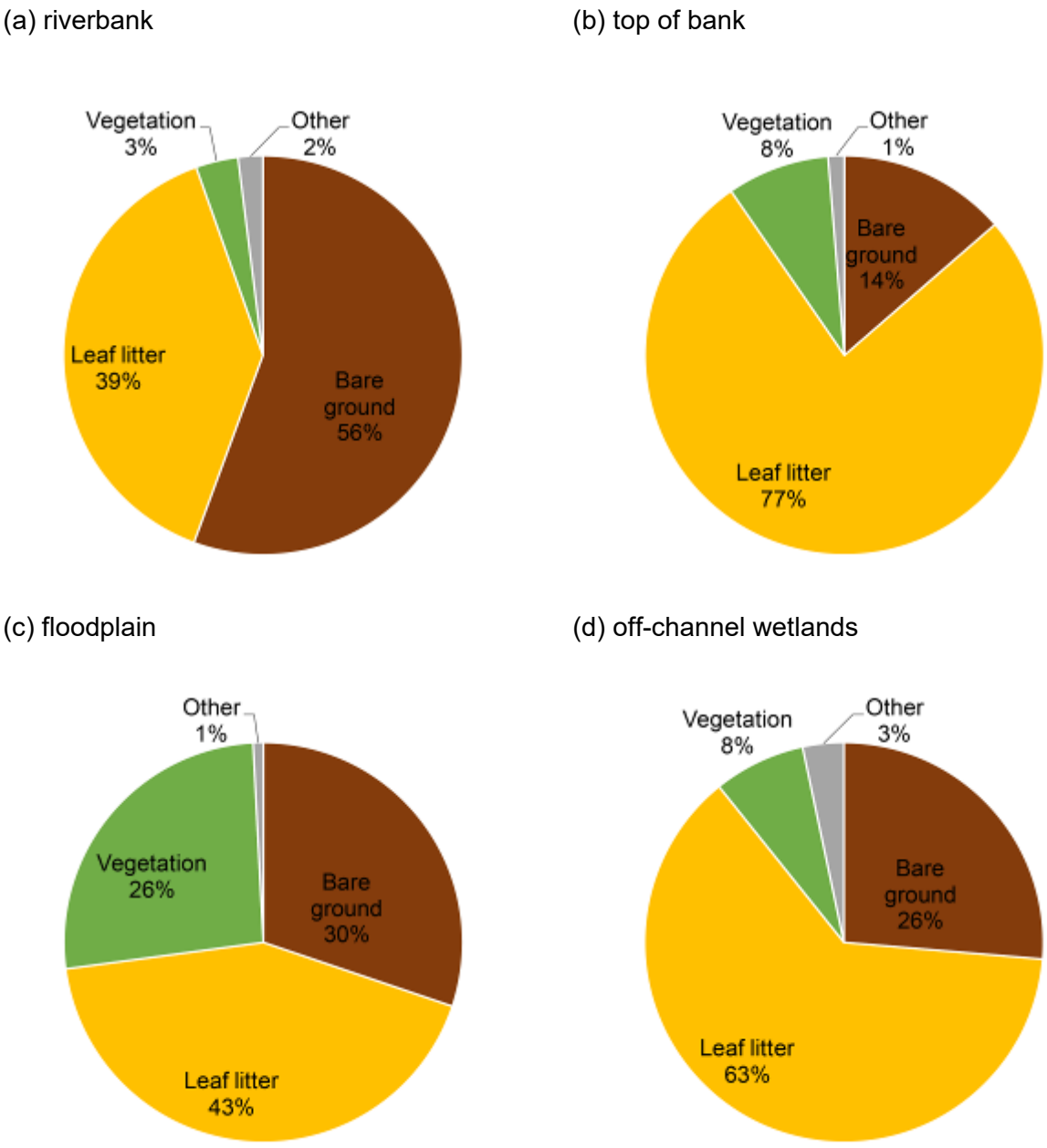


Figure 3.15. Proportion of ground cover for each vegetation zone: a) riverbank (n=16), b) top of bank (n=16), c) floodplain (n=17) and d) off-channel wetlands (n=9).

3.1.4 Soil properties

Off-channel wetlands had the highest proportion of clay, with an average estimated clay content of 40% (Figure 3.16). The lowest proportion of clay content was observed at riverbank sites with a mean clay content of 23%. Riverbank sites were predominantly sandy and three sites had a clay content of less than 10%.

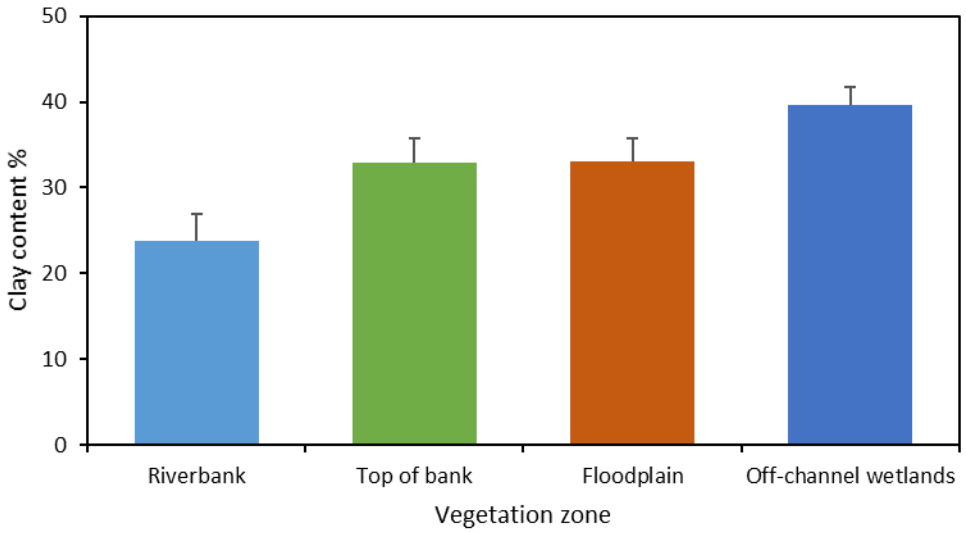


Figure 3.16. Mean (+1 standard error) clay content (%) for each vegetation zone: riverbank (n=16), top of bank (n=16), floodplain (n=17) and off-channel wetlands (n=9).

4. Discussion

This assessment of riparian vegetation of the lower Fitzroy River provides a snapshot of species composition and vegetation structure during the dry season of 2018. We identified 32 tree species and determined the zones in which they most commonly occurred. Broadly, different zones supported different tree species with only three tree species found in all vegetation zones – *Eucalyptus camaldulensis*, *E. microtheca* and *T. platyphylla*. We found that tree canopy was generally in healthy (good) condition in all zones. There was evidence of tree recruitment but it was highly variable across sites and zones, and signs of mass recruitment (i.e. the presence of > 100 seedlings) were only apparent at five sites. We identified 71 understorey species, more than a third of which were recorded at only one site each, meaning that site-level understorey species diversity was generally low. This low diversity may be due to the dry season timing of the surveys, when some ephemeral species may have already senesced, or it may have been an artefact of the survey design or effort, which was primarily designed to target woody overstorey species (see limitations in Section 4.2.1).

The findings in this report characterise plant species composition and structure within each broad vegetation zone of the lower Fitzroy River. These differences are attributed to flooding and drying patterns associated with each zone, as flooding characteristics strongly influence plant species distribution, composition and structure (Brock et al., 2006, Capon et al., 2016). The characteristics of each vegetation zone surveyed in this study are discussed below.

4.1.1 Riverbank

Riverbanks along the lower Fitzroy River are typically narrow (~10–20 m wide at the time of the survey), steep and sandy. Due to their close proximity to the river, they are the wettest vegetation zone and can potentially be inundated to a depth of ~3.5 m for ~1.5 months even during a small flood (Figure 2.6). Therefore, vegetation in this zone needs to tolerate prolonged periods of inundation. The most common trees found along the riverbank were *Barringtonia acutangula, Melaleuca argentea* and *M. leucadendra* (Figure 4.1). These species have physiological mechanisms that allow them to tolerate periodic submergence (Choudhury, 2005, McLean, 2014, Fielding and Alexander, 2001) and are widespread on the banks of freshwater rivers and creeks in northern Australia (Brock, 2001).

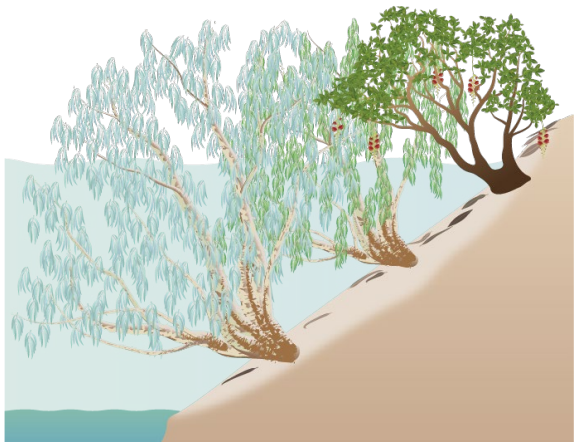


Figure 4.1. Riverbanks are dominated by large Melaleucas and Barringtonia acutangula.

Some of the largest trees along the lower Fitzroy River were recorded at riverbank sites. While not typically tall (average 8.5 m for the tallest tree), riverbanks had the highest count of large trees (e.g. > 100 cm DBH) with average basal area of 197 m^2/ha, more than 2.5 times that recorded in any other zone, making riverbanks an important habitat for old growth trees. Tree canopy condition at riverbanks was healthy and in slightly better condition than other zones, provinding greater canopy cover and shading to the ground below than any other zone (mean value of 79% cover). The structure and condition of trees on the riverbank may be attributed to their close proximity and year-round access to water compared with other zones (O'Grady et al., 2006).

Ground cover on the riverbank was low, with 56% bare and 39% covered in leaf litter. Understorey species richness was lower than any other zone and the two most common species recorded were non-native (*Cynodon dactylon** and *Xanthium occidentale**). Few seedlings were recorded on the riverbank indicating low recruitement in this vegetation zone. The large proportion of bareground and low evidence of seeding recruitment is likely due to the frequency, depth and fast flowing floodwater that riverbanks are exposed to most years.

4.1.2 Top of bank

Top-of-bank zones form part of the narrow riparian zones found along the lower Fitzroy River but differ from the adjacent riverbank zone. While riverbanks are steep, the top of the bank is relatively flat and maintains greater vegetation cover than the floodplain further from the river. Top-of-bank soils had a higher clay content (23% clay) than the riverbank and while only shallowly inundated during a small flood (i.e. ~1 m), may remain inundated for a prolonged period of time of approximately one month (Figure 2.6). These conditions support greater riparian species richness and recruitment in an otherwise dry environment (Pettit et al., 2016).

Tree species richness was greatest in top-of-bank sites (total 20 species recorded; mean of 6 per site) compared with other zones (total 12–14 species; mean of 2–4 per site, Figure 4.2). Similar to riverbanks, tree canopy was in good condition and canopy cover was relatively high (65.5%). However, unlike the riverbank, top-of-bank trees were much taller (13 m) and and stand basal area was nearly five times smaller at 41.5 m^2/ha compared with riverbank 197 m^2/ha. Trees at top-of-bank sites had a much higher proportion of ‘saplings’ (e.g. < 20 cm DBH), with almost half of the trees measured at < 10 cm DBH. Top-of-bank sites had the highest count of large seedlings (i.e. 0.5–1.5 m tall) compared with other zones. Riparian woody recruitment typically suffers high levels of mortality in arid wet-dry regions (Capon et al., 2016). The high count of seedlings and saplings at the top of the bank may indicate that this vegetation zone is important for woody recruitment in an otherwise unpredictable landscape.

The most common woody species recorded at top-of-bank sites was *Atalaya hemiglauca*. This species is widespread throughout the Kimberley and found in a wide range of habitats in northern Australia (Brock, 2001, Wheeler et al., 1992). This species typically propagates from root suckers, resulting in a clustered spatial distribution (Lamacraft et al., 1983), which is consistent with this survey, where a total of 231 *A. hemiglauca* were counted in top-of-bank sites with an average of 14 per site.

Figure 4.2. Top-of-bank zones have high tree species richness, with tall trees and a high canopy cover.

Top-of-bank sites had the highest proportion of non-native understorey species (24%) compared to other zones, with the most common being *Jatropha gossypiifolia**. Few species were recorded in more than one site (i.e. 12 species were recorded at only one site). Top-of-bank sites had the highest proportion of shrubs (13% of vegetation composition) and ground composition was predominantly made up of leaf litter (77%).

4.1.3 Floodplain

The floodplain of the lower Fitzroy River is an extremely large, flat and open area that can extend up to 30 km wide (Karim et al., 2018). The floodplain is a particularly harsh environment for vegetation, and during a small flood may only be shallowly inundated (e.g. ~10 cm depth) and for a short time (e.g. a week; Figure 2.6). Vegetation that occurs on the floodplain typically requires periodic flooding but must also tolerate long dry periods. Floodplain species may be physiologically adapted to tolerate drier conditions (Rosas et al., 2019), and may utilise either stored soil moisture or groundwater if it is available (Steggles et al., 2017, Costelloe et al., 2008). Unlike riverbank and top-of-bank zones, species found at floodplain zones are unlikely to withstand prolonged inundation.

Floodplain sites had the lowest tree species richness of all zones with only two species on average per site. *Eucalyptus microtheca* was the dominant floodplain tree species, recorded as a monospecific stand at 41% of sites (Figure 4.3). *Eucalyptus microtheca* is widespread across northern Australia, occurring along watercourses and on the heavy soils of floodplains (Atlas of Living Australia, accessed 27/05/2020). The species requires periodic flooding to sustain populations (Cunningham et al., 1992) but in other systems *E. microtheca* has been observed to develop deep root systems to access groundwater (Costelloe et al., 2008).

Trees were also smaller at floodplain zones than other vegetation zones, with the smallest maximum tree height (mean of 7 m) and smallest stand basal area of all vegetation zones (mean of 12 m^2/ha). The majority of floodplain trees had a DBH smaller than 20 cm, with only

five trees larger than 50 cm DBH. Though tree canopy was in good condition, canopy cover was lowest on the floodplain compared to all other vegetation zones (28% cover), reflecting low water availability on the floodplain compared with other vegetation zones (Lite et al., 2005).

Ground cover composition included a high proportion of vegetation (26%) compared with other vegetation zones. Poaceae was the most common family recorded on the floodplain, including two native species *Chrysopogon pallidus* and *Ennoapogon* sp. Many of the grasses and sedges found on the floodplain were senescing due to the timing of the survey (towards the end of the dry season) and were therefore not able to be identified. Like other arid tropical floodplains, it appears that these communities are dominated by terrestrial grasses (Pettit et al., 2016), however due to the timing of the survey it is unclear if the floodplain supports an aquatic vegetation community.

There were few seedlings recorded on the floodplain and just one species of conservation significance was recorded at one site (*Thespidium basiflorum,* Priority 1).

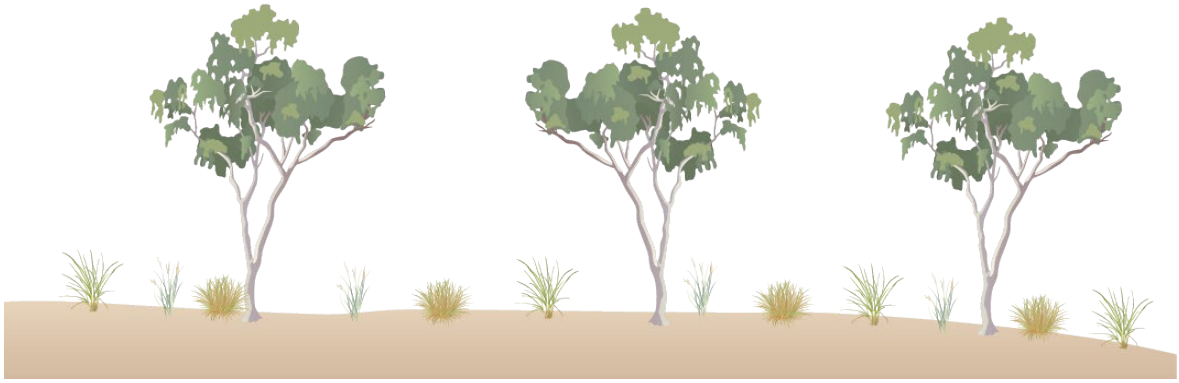


Figure 4.3. Floodplains are sparsely vegetated, typically dominated by monospecific stands of Eucalyptus microtheca.

4.1.4 Off-channel wetlands and flood-runner channels

Off-channel wetlands and flood-runner channels had the heaviest soils compared to other vegetation zones, with an average estimated clay content of 40%. Off-channel wetlands differ from the surrounding floodplain because they experience a longer period of inundation (Figure 2.6) and are an important habitat refuge (Pettit et al., 2016).

There were similarities between off-channel wetlands and top-of-bank zones. The tallest trees in off-channels wetlands were 12 m tall on average with a canopy cover of ~65%, compared with 13 m tall and 65.5% cover for top-of-bank sites. Tree canopy condition was in good condition in off-channel wetlands.

The most common tree species were *Eucalyptus camaldulensis* and *E. microtheca*, two of the most common and widely distributed Eucalypts in Australia (Capon et al., 2016). The high count of *E. camaldulensis* is partially attributed to one site where more than 100 x 6 m tall trees were recorded. *Eucalyptus camaldulensis* germinates from seed in large numbers when environmental conditions are favourable, such as in response to flooding (Capon et al.,

2016) and it is likely that the recruitment cohort recorded during this survey germinated in response to a large flood in previous years.

A high proportion of sapling trees (< 10 cm DBH) were recorded in off-channel wetlands as well as a few older trees (e.g. 100 cm + DBH). Average stand basal area was 70 m^2/ha, second highest after riverbank sites. Off-channel wetlands also had the greatest count of small seedlings (< 0.5 m tall) and the greatest count of resprouts compared with all vegetation zones. Similar to the top-of-bank zone, it is likely that off-channel wetlands are important for recruitment of woody species (Figure 4.4).

Understorey species richness was greatest in off-channel wetlands with an average of four species per site. The most common species recorded was *Cynodon dactylon** from the Poaceae family. Compared with other vegetation zones, off-channel wetlands had the highest number of species recorded at only one site each (22 species recorded at only one site). Ground cover was dominated by leaf litter, with 63% cover, and off-channel wetlands had the the greatest proportion of herbs (39%) compared with other zones.

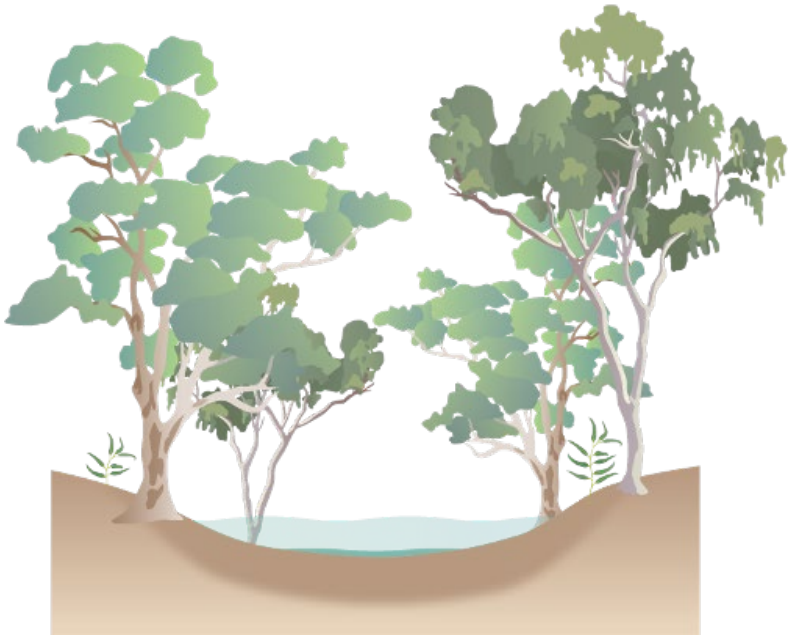


Figure 4.4. Off-channel wetlands likely provide important refuge for woody species recruitment.

4.2 Summary

We described the vegetation species composition and structure of four broad vegetation zones along the lower Fitzroy River. Due to the physiological and structural differences in vegetation, it is likely that there are differences in the water requirements to support the vegetation communities in each zone. Riverbank zones are dominated by large trees that are likely to have high year-round water requirements and are therefore less likely to be resilient to changes in water availability (McLean, 2014). Top-of-bank and off-channel wetlands support greater riparian species richness and recruitment in an otherwise dry environment. Flow reductions may see an encroachment of floodplain or drought tolerant species into these zones, changing the composition of species and potentially lowering species richness and decreasing structural complexity (Pettit et al., 2016). Similarly, the spatial extent of the floodplain is directly related to the extent of large floods. An increase in water-take may reduce how far the floodplain zone extends (Kingsford, 2016), and therefore allow for an encroachment of savanna species. For further information about the potential impacts of water extraction on the spatial distribution of woody riparian species in the lower Fitzroy River, see Canham et al. (in press).

4.2.1 Limitations

The information presented in this report provides a snapshot of the vegetation composition and structure for each vegetation zone; however, it does not represent a comprehensive vegetation survey. There are several limitations that should be considered when interpreting and using this dataset. Although we covered a large part of the lower Fitzroy River, site location was limited by physical access (e.g. track availability and condition) as well as permission to access land. Due to the emphasis on collecting data across a range of inundation values, there was an emphasis on surveying a greater number of sites along a large stretch of river, rather than surveying fewer sites more intensively. The rapid vegetation survey techniques used may have missed naturally rare species, and further surveys are recommended to target these species. Future surveys should also consider seasonality – undertaking surveys early in the dry season would improve plant identification as trees are more likely to be in flower or fruit immediately following the wet season.

This work focussed mainly on woody vegetation and did not capture all understorey species. Survey techniques may have missed naturally rare and/or ephemeral understorey species, for example *Solanum dioicum* which was sighted nearby, but not recorded within survey cells (Figure 3.12). Many arid floodplain understorey species have short lifespans (Brock et al., 2006) and maintain a persistent soil seedbank during dry periods (Capon et al., 2016). To properly describe understorey vegetation, surveys should be undertaken with consideration to the timing of the survey, both in relation to season and flooding because the detection of ephemeral understorey species is likely to decrease as plants senesce during the dry season. Targeted surveys should be considered to learn more of any one particular species.

4.2.2 Ongoing research

This project aims to further develop a framework for assessing the relative risk of changes in water regime to riparian vegetation. Ongoing research aims to investigate the water sources for dominant tree species at the end of the dry season to help determine if plants are using groundwater. We will also assess plant functional traits. Understanding species distributions, plant water sources and their physiological traits will allow us to gain a better understanding of species water requirements and the species most vulnerable to changes in water regime. This information will inform ongoing vegetation monitoring with a view to detecting change in response to threatening processes.

References

AUSTRALIAN GOVERNMENT. 2011. *National Heritage Places - West Kimberley* [Online]. Available: https://www.environment.gov.au/heritage/places/national/west-kimberley [Accessed 29 June 2021].

BEJARANO, M. D., NILSSON, C., DEL TÁNAGO, M. G. & MARCHAMALO, M. 2011. Responses of riparian trees and shrubs to flow regulation along a boreal stream in northern Sweden. *Freshwater Biology,* 56**,** 853-866.

BROCK, J. 2001. *Native Plants of Northern Australia,* Frenchs Forest, New South Wales, Australia, Reed New Holland.

BROCK, M., CAPON, S. & PORTER, J. 2006. Disturbance of plant communities dependent on desert rivers. *In:* KINGSFORD, R. (ed.) *Ecology of Desert Rivers.* Cambridge, UK: Cambridge University Press.

CANHAM, C. A., BEESLEY, L., GWINN, D. C., DOUGLAS, M. M., SETTERFIELD, S. A., FREESTONE, F. L., PUSEY, B. J. & LOOMES, R. C. in press. Predicting the occurrence of riparian woody species to inform environmental water policies in an Australian tropical river. *Freshwater Biology*.

CAPON, S., JAMES, C. & GEORGE, A. 2016. Riverine trees and shrubs. *In:* CAPON, S., JAMES, C. & REID, M. (eds.) *Vegetation of Australian Riverine Landscapes.* Clayton South, Victoria, Australia: CSIRO Publishing.

CASANOVA, M. T. & BROCK, M. A. 2000. How do depth, duration and frequency of flooding influence the establishment of wetland plant communities? *Plant Ecology,* 147**,** 237-250.

CHOUDHURY, J. K. 2005. Plant resources of haors and floodplains. Dhaka, Bangladesh: IUCN Bangladesh Country Office.

COSTELLOE, J. F., PAYNE, E., WOODROW, I. E., IRVINE, E. C., WESTERN, A. W. & LEANEY, F. W. 2008. Water sources accessed by arid zone riparian trees in highly saline environments, Australia. *Oecologia,* 156**,** 43-52.

CUNNINGHAM, G. M., MULHAM, W. E., MILTHORPE, P. L. & LEIGH, J. H. 1992. *Plants of Western New South Wales,* Collingwood, Victoria, Australia, CSIRO Publishing.

DEANE, D. C., NICOL, J. M., GEHRIG, S. L., HARDING, C., ALDRIDGE, K. T., GOODMAN, A. M. & BROOKES, J. D. 2017. Hydrological-niche models predict water plant functional group distributions in diverse wetland types. *Ecological Applications,* 27**,** 1351-1364.

DIXON, D. 2007. *Ficus carpentariensis* – a new sandpaper fig for northern Australia and a revision of the *F. opposita* complex (Moraceae: *Ficus* subg. *Ficus* sect. *Sycidium* inrormal group *F. copiosa*). *Nuytsia,* 16**,** 269-284.

DOUGLAS, M. M., JACKSON, S., CANHAM, C. A., LABORDE, S., BEESLEY, L., KENNARD, M. J., PUSEY, B. J., LOOMES, R. & SETTERFIELD, S. A. 2019. Conceptualizing hydro-socio-ecological relationships to enable more integrated and inclusive water allocation planning. *One Earth,* 1**,** 361-373.

DWER 2017. Groundwater-dependent ecosystems of the Dampier Peninsula. Perth, Western Australia, Australia: Department of Water and Environmental Regulation.

FIELDING, C. R. & ALEXANDER, J. 2001. Fossil trees in ancient fluvial channel deposits: evidence of seasonal and longer-term climatic variability. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 170**,** 59-80.

FOX, I. D., NELDNER, V. J., WILSON, G. W., BANNINK, P. J., WILSON, B. A., BROCKLEHURST, P. S., CLARK, M. J., DICKINSON, K. J. M., BEARD, J. S., HOPKINS, A. J. M., BEESTON, G. R., HARVEY, J. M., THOMPSON, E. J., RYAN, T. S., THOMPSON, S. L., BUTLER, D. W., CARTAN, H., ADDICOTT, E. P., BAILEY, L. P., CUMMING, R. J., JOHNSON, D. C., SCHMEIDER, M., STEPHENS, K. M. & BEAN, A. R. 2001. The vegetation of the Australian tropical savannas. Darwin, Northern Territory, Australia: Queensland Herbarium, Environmental Protection Agency and the Cooperative Research Centre for the Sustainable Development of Tropical Savannas.

JANSSON, R., STRÖM, L. & NILSSON, C. 2019. Smaller future floods imply less habitat for riparian plants along a boreal river. *Ecological Applications,* 29**,** e01977.

KARIM, F., PEÑA-ARANCIBIA, J., TICEHURST, C., MARVANEK, S., GALLANT, J., HUGHES, J., DUTTA, D., VAZE, J., PETHERAM, C., SEO, L. & KITSON, S. 2018. Floodplain inundation mapping and modelling for the Fitzroy, Darwin and Mitchell catchments. . CSIRO, Australia: Technical report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments.

KINGSFORD, R. 2016. Flow alteration and its effects on Australia's riverine vegetation. *In:* CAPON, S., JAMES, C. & REID, M. (eds.) *Vegetation of Australian Riverine Landscapes.* Clayton South, Victoria, Australia: CSIRO Publishing.

LAMACRAFT, R. R., FRIEDEL, M. H. & CHEWINGS, V. H. 1983. Comparison of distance based density estimates for some arid rangeland vegetation. *Australian Journal of Ecology,* 8**,** 181-187.

LAWSON, J. R., FRYIRS, K. A., LENZ, T. & LEISHMAN, M. R. 2015. Heterogeneous flows foster heterogeneous assemblages: relationships between functional diversity and hydrological heterogeneity in riparian plant communities. *Freshwater Biology,* 60**,** 2208-2225.

LITE, S. J., BAGSTAD, K. J. & STROMBERG, J. C. 2005. Riparian plant species richness along lateral and longitudinal gradients of water stress and flood disturbance, San Pedro River, Arizona, USA. *Journal of Arid Environments,* 63**,** 785-813.

MCDONALD, R., ISBELL, R., SPEIGHT, J., WALKER, J. & HOPKINS, M. 1998. *Australian soil and land survey field handbook,* Canberra, Australian Capital Territory, Australia, Australian Collaborative Land Evaluation Program: Canberra.

MCLEAN, E. H. 2014. *Patterns of water use by the riparian tree Melaleuca argentea in semi-arid northwest Australia.* PhD, The University of Western Australia.

O'GRADY, A. P., EAMUS, D., COOK, P. G. & LAMONTAGNE, S. 2006. Groundwater use by riparian vegetation in the wetdry tropics of northern Australia. *Australian Journal of Botany,* 54**,** 145-154.

PETTIT, N., DOWE, J. & DIXON, I. 2016. Riparian vegetation of tropical northern Australia. *In:* CAPON, S., JAMES, C. & REID, M. (eds.) *Vegetation of Australian Riverine Landscapes.* Clayton South, Victoria, Australia: CSIRO Publishing.

PETTIT, N. E. & FROEND, R. H. 2018. How important is groundwater availability and stream perenniality to riparian and floodplain tree growth? *Hydrological Processes,* 32**,** 1502-1514.

POELINA, A., TAYLOR, K. S. & PERDRISAT, I. 2019. Martuwarra Fitzroy River Council: an Indigenous cultural approach to collaborative water governance. *Australasian Journal of Environmental Management,* 26**,** 236-254.

POLLINO, C., BARBER, E., BUCKWORTH, R., CADIEGUES, M., DENG, A., EBNER, B., KENYON, R., LIEDLOFF, A., MERRIN, L., MOESENEDER, C., MORGAN, D., NIELSEN, D., O'SULLIVAN, J., PONCE REYES, R., ROBSON, B., STRATFORD, D., STEWART-KOSTER, B. & TURSCHWELL, M. 2018. Synthesis of knowledge to support the assessment of impacts of water resource development to ecological assets in northern Australia: asset descriptions. A technical report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments. CSIRO, Australia CSIRO.

RIVAES, R., BOAVIDA, I., SANTOS, J. M., PINHEIRO, A. N. & FERREIRA, M. T. 2017. Importance of considering riparian vegetation requirements for the long-term efficiency of environmental flows in aquatic microhabitats. *Hydrology and Earth System Sciences,* 21**,** 5763-5780.

ROSAS, T., MENCUCCINI, M., BARBA, J., COCHARD, H., SAURA-MAS, S. & MARTÍNEZ-VILALTA, J. 2019. Adjustments and coordination of hydraulic, leaf and stem traits along a water availability gradient. *New Phytologist,* 223**,** 632-646.

STEGGLES, E. K., HOLLAND, K. L., CHITTLEBOROUGH, D. J., DOUDLE, S. L., CLARKE, L. J., WATLING, J. R. & FACELLI, J. M. 2017. The potential for deep groundwater use by Acacia papyrocarpa (Western myall) in a water-limited environment. *Ecohydrology,* 10**,** e1791.

STOREY, A., DAVIES, P. & FROEND, R. 2001. Fitzroy River system: environmental values. . University of Western Australia and Edith Cowan University, Perth, Western Australia, Australia: Report prepared for Water and Rivers Commission.

WHEELER, J., RYE, B., KOCH, B. & WILSON, A. 1992. *Flora of the Kimberley Region,* Como, Western Australia, Australia, Department of Conservation and Land Management.

WHITE, J. M. & STROMBERG, J. C. 2011. Resilience, restoration, and riparian ecosystems: case study of a dryland, urban river. *Restoration Ecology,* 19**,** 101-111.

Appendix

Table 4.1. List of sites and their associated rivers for each vegetation zone and associated waypoint coordinates.

Zone	Site	River	Latitude	Longitude
Riverbank	RB01	Fitzroy River	-18.2999	125.5191
	RB02	Cunningham Anabranch	-18.3349	125.377
	RB03	Fitzroy River	-17.8287	123.6974
	RB04	Fitzroy River	-18.4853	125.3801
	RB05	Fitzroy River	-18.2794	125.5325
	RB06	Fitzroy River	-18.0579	123.8708
	RB07	Margaret River	-18.1537	125.7106
	RB08	Fitzroy River	-18.1437	124.0742
	RB09	Fitzroy River	-18.0839	124.2074
	RB10	Margaret River	-18.1156	125.7041
	RB11	Fitzroy River	-18.5262	124.8932
	RB12	Fitzroy River	-18.5085	125.077
	RB13	Margaret River	-18.198	125.836
	RB14	Cunningham Anabranch	-18.4089	125.2302
	RB15	Fitzroy River	-18.3673	125.4959
	RB16	Fitzroy River	-17.7858	123.6728
Top of bank	TB01	Fitzroy River	-18.2994	125.5194
	TB02	Cunningham Anabranch	-18.3341	125.3773
	TB03	Fitzroy River	-17.8285	123.6975
	TB04	Fitzroy River	-18.4851	125.3803
	TB05	Fitzroy River	-18.2775	125.5329
	TB06	Fitzroy River	-18.0577	123.8708
	TB07	Margaret River	-18.1538	125.7104
	TB08	Fitzroy River	-18.1437	124.0743
	TB09	Fitzroy River	-18.084	124.2076
	TB10	Margaret River	-18.1156	125.7042
	TB11	Fitzroy River	-18.5264	124.8922
	TB12	Fitzroy River	-18.5088	125.0778
	TB13	Margaret River	-18.1982	125.8357
	TB14	Cunningham Anabranch	-18.4086	125.2302
	TB15	Fitzroy River	-18.3674	125.4963
	TB16	Fitzroy River	-17.7858	123.6732

Zone	Site	River	Latitude	Longitude
Floodplain	FP01	Fitzroy River	-18.2932	125.5133
	FP02	Cunningham Anabranch	-18.3319	125.3781
	FP03	Fitzroy River	-17.8268	123.7311
	FP04	Fitzroy River	-18.4734	125.3825
	FP05	Fitzroy River	-18.2737	125.5295
	FP06	Fitzroy River	-18.0736	123.951
	FP07	Margaret River	-18.1584	125.6988
	FP08	Fitzroy River	-18.1468	124.0753
	FP09	Fitzroy River	-18.0856	124.2294
	FP10	Margaret River	-18.1158	125.7027
	FP11	Fitzroy River	-18.5332	124.8851
	FP12	Fitzroy River	-18.5138	125.0775
	FP13	Margaret River	-18.1989	125.8352
	FP14	Margaret River	-18.2119	125.6621
	FP15	Cunningham Anabranch	-18.4031	125.2205
	FP16	Fitzroy River	-18.3584	125.5147
	FP17	Fitzroy River	-17.7823	123.6866
Off-channel wetlands and flood-runner channels	OC01	Off the main channel	-18.1462	124.0474
	OC02	Off the main channel	-18.5533	124.8999
	OC03	Off the main channel	-18.2932	125.5137
	OC04	Off the main channel	-18.3459	125.5503
	OC05	Off the main channel	-18.1569	125.6965
	OC06	Off the main channel	-18.1524	124.0713
	OC07	Off the main channel	-18.5361	124.8842
	OC08	Off the main channel	-18.2113	125.6616
	OC09	Off the main channel	-18.3216	125.4551

Table 4.2. Tree canopy condition assessment scores, derived from DWER (2017).

Score	Definition
Crown density	
9	Very dense leaf clumps distributed over crown. Very little light penetrating clumps.
7	Dense leaf clumps unevenly distrusted over crown.
5	Clumps of average density equally distributed or dense clumps unevenly distributed.
3	Clumps sparse and poorly spread.
1	Very few leaves anywhere in crown.
Dead branches	
9	No visible dead branches or branchlets except thin twigs inside new leaf development and lowest branches being shed.
7	Dead branches evident on close inspection. Not all over crown.
5	Small branches dead, not all over crown. Easily observed but not seriously affecting crown.
3	Large and/or small branches dead over part of crown. Serious.
1	Large and small branches dead over most of the crown.
Epicormic growth	
5	Nil epicormics growth with normal foliar growth concentrated at the branch extremities.
4	Slight in part of crown only.
3	Moderate over most of crown.
2	Severe on crown or stem.
1	Severe on crown and stem.

Table 4.3. Tree condition categories, derived from DWER (2017).

Score	Definition
18-23	Very good
12-17	Good
6-11	Moderate
<5	Poor

Table 4.4. Tall woody species and associated vegetation zone. An asterisk (*) denotes non-native species. Unidentified species not presented.

Species	Family	Species code	Riverbank	Top of bank	Floodplain	Off-channel wetlands
Acacia colei	FABACEAE	*Acac.col*	✓	✓		✓
Acacia sp.	FABACEAE	*Acac.sp.*			✓	
Atalaya hemiglauca	SAPINDACEAE	*Atal.hem*		✓	✓	✓
*Azadirachta indica**	MELIACEAE	*Azad.ind**		✓		
Barringtonia acutangula	LECYTHIDACEAE	*Barr.acu*	✓	✓		✓
Bauhinia cunninghamii	FABACEAE	*Bauh.cun*		✓	✓	✓
Bridelia tomentosa	PHYLLANTHACEAE	*Brid.cun*	✓	✓		
*Calotropis procera**	APOCYNACEAE	*Calo.pro**		✓		✓
Carissa lanceolata	APOCYNACEAE	*Cari.lan*			✓	
Corymbia greeniana	MYRTACEAE	*Cory.gre*			✓	
Corymbia bella	MYRTACEAE	*Cory.bel*		✓	✓	✓
Eucalyptus camaldulensis	MYRTACEAE	*Euca.cam*	✓	✓	✓	✓
Eucalyptus microtheca	MYRTACEAE	*Euca.mic*	✓	✓	✓	✓
Eucalyptus sp.	MYRTACEAE	*Euca.sp.*				✓
Ficus aculeata	MORACEAE	*Ficu.acu*		✓		✓
Ficus coronulata	MORACEAE	*Ficu.cor*	✓	✓		
Ficus racemosa	MORACEAE	*Ficu.race*	✓			
Ficus sp.	MORACEAE	*Ficu.sp.*			✓	✓
Lophostemon grandiflorus	MYRTACEAE	*Loph.gra*		✓		
Melaleuca argentea	MYRTACEAE	*Mela.arg*	✓			
Melaleuca leucadendra	MYRTACEAE	*Mela.leu*	✓			✓
Melaleuca nervosa	MYRTACEAE	*Mela.ner*			✓	
Melaleuca sp.	MYRTACEAE	*Mela.sp.*	✓			✓
Melia azedarach	MELIACEAE	*Meli.aze*		✓	✓	
Nauclea orientalis	RUBIACEAE	*Nauc.ori*	✓	✓		
Pandanus sp.	PANDANACEAE	*Pand.sp.*	✓			
*Parkinsonia sp.**	FABACEAE	*Park.sp.**	✓			
Planchonia careya	LECYTHIDACEAE	*Plan.car*		✓		
Santalum lanceolatum	SANTALACEAE	*Sant.lan*		✓		
Terminalia platyphylla	COMBRETACEAE	*Term.pla*	✓	✓	✓	✓
*Vachellia farnesiana**	FABACEAE	*Vach.far**		✓		
Ventilago viminalis	RHAMNACEAE	*Vent.vim*		✓		

Table 4.5. Understorey species located at riverbank sites. No species recorded at RB02, RB04, RB14 and RB15. Unidentified species not presented.

Riverbank				Site											
Species	Family	Structure	Conservation status	RB01	RB03	RB05	RB06	RB07	RB08	RB09	RB10	RB11	RB12	RB13	RB16
Achyranthes aspera	AMARANTHACEAE	Herb						✓						✓	
Atalaya hemiglauca	SAPINDACEAE	Tree							✓		✓				
Barringtonia acutangula	LECYTHIDACEAE	Tree		✓			✓								
*Cynodon dactylon**	POACEAE	Grass			✓		✓	✓	✓	✓			✓		✓
Ennoapogon sp.	POACEAE	Grass						✓							
Euphorbia dallachyana	EUPHORBIACEAE	Herb					✓								
Euphorbia myrtoides	EUPHORBIACEAE	Herb					✓								
Glinus lotoides	MOLLUGINACEAE	Herb			✓					✓		✓		✓	
Hibiscus fluvialis	MALVACEAE	Herb									✓				
Melaleuca leucadendra	MYRTACEAE	Tree												✓	
Pterocaulon sp.	ASTERACEAE	Herb					✓			✓				✓	
Trichodesma zeylanicum	BORAGINACEAE	Herb/shrub						✓							
*Xanthium occidentale**	ASTERACEAE	Herb/shrub			✓	✓	✓			✓					

Table 4.6. Understorey species located at top-of-bank sites. No species recorded at TB12. Unidentified species not presented.

Top of bank				Site														
Species	Family	Structure	Conservation status	TB01	TB02	TB03	TB04	TB05	TB06	TB07	TB08	TB09	TB10	TB11	TB13	TB14	TB15	TB16
Acacia sp.	FABACEAE	Tree											✓					
Achyranthes aspera	AMARANTHACEAE	Herb								✓			✓		✓			
Atalaya hemiglauca	SAPINDACEAE	Tree					✓		✓	✓			✓				✓	✓
Atalaya hemiglauca	SAPINDACEAE	Seedling				✓						✓						
Barringtonia acutangula	LECYTHIDACEAE	Seedling			✓													
Basilicum polystachyon	LAMIACEAE	Herb			✓													
*Clitoria ternatea**	FABACEAE	Herb/climber										✓						
*Cynodon dactylon**	POACEAE	Grass				✓					✓							
Echinochloa sp.	POACEAE	Grass									✓							
Ennoapogon sp.	POACEAE	Grass								✓					✓			
Eucalyptus sp.	MYRTACEAE	Seedling			✓									✓				
*Euphorbia hirta**	EUPHORBIACEAE	Herb																✓
Hibiscus fluvialis	MALVACEA	Herb											✓					
*Jatropha gossypiifolia**	EUPHORBIACEAE	Shrub		✓	✓			✓								✓		
*Malvastrum americanum**	MALVACEAE	Herb/shrub													✓			
Paspalidium jubiflorum	POACEAE	Grass												✓				
*Passiflora foetida**	PASSIFLORACEAE	Woody/climber										✓						
Pterocaulon serrulatum	ASTERACEAE	Herb/shrub															✓	
Solanum petraeum	SOLANACEAE	Shrub															✓	
Vigna lanceolata var. lanceolata	FABACEAE	Herb/climber									✓							
*Xanthium occidentale**	ASTERACEAE	Herb/shrub			✓	✓											✓	

Table 4.7. Understorey species located at floodplain sites. No species recorded at FP02, FP04, FP11, FP12 and FP16. Unidentified species not presented.

Floodplain				Site											
Species	Family	Structure	Conservation status	FP01	FP03	FP05	FP06	FP07	FP08	FP09	FP10	FP13	FP14	FP15	FP17
Acacia sp.	FABACEAE										✓				
Alternanthera sp.	AMARANTHACEAE	Herb			✓										✓
Aristida holathera var. holathera	POACEAE	Grass						✓							
Basilicum polystachyon	LAMIACEAE	Herb							✓						
Calotis breviseta	ASTERACEAE	Herb													✓
Chrysopogon pallidus	POACEAE	Grass									✓	✓	✓		
*Cynodon dactylon**	POACEAE	Grass													✓
Cyperus iria	CYPERACEAE	Sedge					✓								
Cyperus sp.	CYPERACEAE	Sedge		✓	✓										
Dentella misera	RUBIACEAE	Herb							✓						✓
Ennoapogon sp.	POACEAE	Grass						✓				✓	✓		
Eriachne sp.	POACEAE	Grass								✓					
Eucalyptus microtheca	MYRTACEAE	Tree				✓	✓								
Goodenia sp.	GOODENIACEAE	Herb/shrub							✓						
Heliotropium ovalifolium	BORAGINACEAE	Herb							✓						✓
Heteropogon contortus	POACEAE	Grass											✓		
*Malvastrum americanum**	MALVACEAE	Herb/shrub		✓											
Paspalidium jubiflorum	POACEAE	Grass												✓	
Phyllanthus lacerosus	PHYLLANTHACEAE	Shrub							✓						
Phyllanthus sp.	PHYLLANTHACEAE	Herb/shrub					✓								
Polymeria quadrivalvis	CONVOLVULACEAE	Herb							✓						
Pterocaulon sp.	ASTERACEAE			✓											
Sehima nervosum	POACEAE	Grass										✓			
Streptoglossa tenuiflora	ASTERACEAE	Herb							✓						
Thespidium basiflorum	ASTERACEAE	Herb	Priority One						✓						

Table 4.8. Understorey species located at off-channel wetland sites. No species recorded at OC02. Unidentified species not presented.

Off-channel wetlands				Site							
Species	Family	Structure	Conservation status	OC01	OC03	OC04	OC05	OC06	OC07	OC08	OC09
Acacia sp.	FABACEAE			✓							
Achyranthes aspera	AMARANTHACEAE	Herb					✓				
Alternanthera angustifolia	AMARANTHACEAE	Herb						✓			
Alternanthera sp.	AMARANTHACEAE	Herb		✓							
Atalaya hemiglauca	SAPINDACEAE	Tree					✓				
Basilicum polystachyon	LAMIACEAE	Herb						✓			
Bauhinia cunninghamii	FABACEAE	Tree								✓	
Centipeda minima	ASTERACEAE	Herb									✓
*Cynodon dactylon**	POACEAE	Grass						✓	✓		
Dentella misera	RUBIACEAE	Herb		✓				✓			
Eragrostis tenellula	POACEAE	Grass		✓							
Eucalyptus camaldulensis (seedling)	MYRTACEAE	Seedling									✓
Goodenia sp.	GOODENIACEAE	Herb/shrub			✓						
Ludwigia perennis	ONAGRACEAE	Herb									✓
Phyllanthus maderaspatensis	PHYLLANTHACEAE	Herb/shrub							✓		
Phyllanthus sp.	PHYLLANTHACEAE	Herb/shrub		✓	✓			✓			
Sphaeranthus indicus	ASTERACEAE	Herb									✓
Terminalia platyphylla	COMBRETACEAE	Tree		✓		✓					
Thespidium basiflorum	ASTERACEAE	Herb	Priority one					✓			
Vigna lanceolata var. lanceolata	FABACEAE	Herb/climber		✓							
Wahlenbergia sp.	CAMPANULACEAE	Herb		✓							
*Xanthium occidentale**	ASTERACEAE	Herb/shrub							✓		

Table 4.9. Total understorey species list (excluding unidentified species). Count refers to the total number of individual plants of that species recorded across all sites surveyed. Unidentified species not presented.

Species	Family	Structure	Naturalised status	Conservation status	Count
Acacia sp.	FABACEAE	Tree			3
Achyranthes aspera	AMARANTHACEAE	Herb	Native to WA		10
Alternanthera angustifolia	AMARANTHACEAE	Herb	Native to WA		1
Alternanthera sp.	AMARANTHACEAE	Herb			4
Aristida holathera var. holathera	POACEAE	Grass	Native to WA		1
Atalaya hemiglauca	SAPINDACEAE	Tree	Native to WA		19
Atalaya hemiglauca (seedling)	SAPINDACEAE	Seedling	Native to WA		6
Barringtonia acutangula	LECYTHIDACEAE	Tree	Native to WA		2
Barringtonia acutangula (seedling)	LECYTHIDACEAE	Seedling	Native to WA		1
Basilicum polystachyon	LAMIACEAE	Herb	Native to WA		4
Bauhinia cunninghamii	FABACEAE	Tree	Native to WA		1
Calotis breviseta	ASTERACEAE	Herb	Native to WA		1
Centipeda minima	ASTERACEAE	Herb	Native to WA		3
Chrysopogon pallidus	POACEAE	Grass	Native to WA		7
*Clitoria ternatea**	FABACEAE	Herb/ climber	Alien to WA		4
*Cynodon dactylon**	POACEAE	Grass	Alien to WA		27
Cyperus iria	CYPERACEAE	Sedge	Native to WA		1
Cyperus sp.	CYPERACEAE	Sedge			5
Dentella misera	RUBIACEAE	Herb	Native to WA		9
Echinochloa sp.	POACEAE	Grass			4
Ennoapogon sp.	POACEAE	Grass			14
Eragrostis tenellula	POACEAE	Grass	Native to WA		1
Eriachne sp.	POACEAE	Grass			1
Eucalyptus camaldulensis (seedling)	MYRTACEAE	Seedling	Native to WA		1
Eucalyptus microtheca	MYRTACEAE	Tree	Native to WA		2
Eucalyptus sp. (seedling)	MYRTACEAE	Seedling			2
Euphorbia dallachyana	EUPHORBIACEAE	Herb	Native to WA		1
*Euphorbia hirta**	EUPHORBIACEAE	Herb	Alien to WA		1
Euphorbia myrtoides	EUPHORBIACEAE	Herb	Native to WA		1
Glinus lotoides	MOLLUGINACEAE	Herb	Native to WA		6

Species	Family	Structure	Naturalised status	Conservation status	Count
Goodenia sp.	GOODENIACEAE	Herb/ shrub			5
Heliotropium ovalifolium	BORAGINACEAE	Herb	Native to WA		5
Heteropogon contortus	POACEAE	Grass	Native to WA		1
Hibiscus fluvialis	MALVACEAE	Herb	Native to WA		2
*Jatropha gossypiifolia**	EUPHORBIACEAE	Shrub	Alien to WA		11
Ludwigia perennis	ONAGRACEAE	Herb	Native to WA		1
*Malvastrum americanum**	MALVACEAE	Herb/ shrub	Alien to WA		2
Melaleuca leucadendra	MYRTACEAE	Tree	Native to WA		1
Paspalidium jubiflorum	POACEAE	Grass	Native to WA		6
*Passiflora foetida**	PASSIFLORACEAE	Woody/ climber	Alien to WA		3
Phyllanthus lacerosus	PHYLLANTHACEAE	Shrub	Native to WA		1
Phyllanthus maderaspatensis	PHYLLANTHACEAE	Herb/ shrub	Native to WA		2
Phyllanthus sp.	PHYLLANTHACEAE	Herb/ shrub			4
Polymeria quadrivalvis	CONVOLVULACEAE	Herb	Native to WA		1
Pterocaulon serrulatum	ASTERACEAE	Herb/ shrub	Native to WA		1
Pterocaulon sp.	ASTERACEAE	Herb			4
Sehima nervosum	POACEAE	Grass	Native to WA		1
Solanum petraeum	SOLANACEAE	Shrub	Native to WA		2
Sphaeranthus indicus	ASTERACEAE	Herb	Native to WA		4
Streptoglossa tenuiflora	ASTERACEAE	Herb	Native to WA		3
Terminalia platyphylla	COMBRETACEAE	Tree	Native to WA		3
Thespidium basiflorum	ASTERACEAE	Herb	Native to WA	Priority one	5
Trichodesma zeylanicum	BORAGINACEAE	Herb/ shrub	Native to WA		2
Vigna lanceolata var. lanceolata	FABACEAE	Herb/ climber	Native to WA		2
Wahlenbergia sp.	CAMPANULACEAE	Herb			1
*Xanthium occidentale**	ASTERACEAE	Herb/ shrub	Native to WA		17