The Darling Anabranch Adaptive Management Monitoring Plan

Condition Monitoring 2010

The Murray~Darling Freshwater Research Centre

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Executive summary

This report details the first year of Condition Monitoring undertaken along the Great Darling Anabranch system between September and November 2010 as part of the *Darling Anabranch Adaptive Management Monitoring Program.*

The Darling Anabranch is an ancestral path of the Darling River, which extends approximately 450 km south from its offtake on the Darling River (approximately 50 km south of Menindee, NSW). The Darling River system is characterised by high variability in flood occurrence and intensity and periods of above average and below average flooding frequency. The Darling Anabranch has undergone significant changes in water regime since European settlement. After construction of the Menindee Lakes Scheme and prior to construction of the Darling Anabranch Pipeline (completed in 2007), the Darling Anabranch received an annual replenishment flow of up to 50 GL $year^{-1}$ (ceasing in 2002) to supply the stock and domestic requirements of adjacent landholders. Approximately 3 GL of this was extracted for consumptive purposes. With construction and operation of the pipeline, the Darling Anabranch has been returned to an ephemeral system, with managed environmental flows released from Lake Cawndilla. Flows from the Darling River also naturally enter the Darling Anabranch during periods of moderate to high flow (>10 GL day^{-1}).

Ecological data for the Darling Anabranch is limited; however, it is likely that the ecology of the Darling Anabranch would have been severely impacted upon by the modified water regime. The return to a wetting and drying regime is expected to have beneficial outcomes for the flora and fauna communities overall.

The Darling Anabranch Adaptive Management Monitoring Plan (DAAMMP) was developed to generate knowledge that will inform decision-making in adaptive management of environmental flow releases in the Darling Anabranch. The DAAMMP is consistent with The Living Murray monitoring programs, of which Condition Monitoring is one component. The approach of Condition Monitoring is to monitor at pre-determined, permanent sites according to a pre-determined schedule. Regular time series data of Condition Monitoring 'snapshots' allow changes in condition to be observed and an assessment of whether ecological objectives are being achieved. Condition Monitoring for 2010 reports on the following components: Tree condition; Natural organic matter load; Understorey vegetation composition; Lignum condition; and *Typha* distribution.

The DAAMMP incorporates 17 monitoring sites along the Darling Anabranch system. The importance of the Anabranch Lakes in the Darling Anabranch system is recognised; however, monitoring of these is currently outside the scope of the DAAMMP. Site 1, near the upstream junction of the Old Darling Anabranch and the Darling River, was unable to be accessed between September and November 2010, due to wet weather and high flow conditions.

Sites vary markedly in channel morphology, dominant overstorey community and understorey vegetation composition and condition (as observed at the time of this survey). Sites also varied considerably in the amount of water present during the September to November 2010 Condition Monitoring. All sites except 9a and 9b had some water present at the time of survey.

Black Box (*Eucalyptus largiflorens*) is the dominant tree species in the riparian zone within the 16 sites assessed across the Darling Anabranch system. River Red Gum (*Eucalyptus camaldulensis*) and River Cooba (*Acacia stenophylla*) are more common at downstream sites. Disturbance was generally scarce, with the major disturbance being grazing by domestic stock and/or goats and rabbits. Presence of seedlings and saplings within sites was generally scarce. There was dense regeneration of eucalypts within and along the edges of the channel at several sites, notably sites 10 and 11.

Thirty trees were assessed at each site for tree condition and response variables. Mean tree condition at most sites was stressed. All but one site (site 14) recorded positive scores for potential trajectory of tree condition, based on epicormic growth, new tip growth and leaf die-off. That is, condition of trees at most sites would be expected to remain stable or improve based upon the potential trajectory (PT) scores. The presence of water at most sites could account for the mostly positive PT scores, with trees responding to recent flows in the Darling Anabranch and/or recent rainfall. It is considered that the subsequent above average rainfall in the area and sustained high flows through the system will lead to the observed positive responses resulting in an increase in tree condition, at least in the short-term.

Understorey surveys were carried out at the 16 established sites at four elevations – In-channel, Mid-bank, Tree-line, and Floodplain, with four replicates at each site. Floodplain quadrats could not be completed at all elevations at all sites due to high flow conditions at the time of surveying.

In total 209 plant species from 46 families were recorded from the 16 sites surveyed along the Darling Anabranch system between September and November 2010. One hundred and fifty seven species are native (75%) and 52 are exotic (25%). No listed threatened species were recorded. Four exotic species are listed as Class 4 weeds under the *Noxious Weed Act 1993* (NSW). There is a relatively high proportion of exotic species overall (25%), however, a lower proportion at the individual site level. Further, 67% of exotic species were recorded less than 20 times, indicating that most exotic species were not widespread at the time of surveying. This could be a reflection of the long-dry conditions experienced throughout the region; an expansion of exotic species cover is expected with conditions of high rainfall and high flows (at the time of writing).

Species were classified into one of 16 functional groups to assist in interpreting and predicting change in plant community function and dynamics. The vast majority of species (at least 87%) belong to terrestrial functional groups. This reflects the ‘long-dry’ period preceding Condition Monitoring. With the reinstatement of a wetting and drying regime, it is anticipated that the proportion of species in the terrestrial dry functional group would decrease and the proportion of species in the amphibious functional groups would increase.

Flood inundation modelling data is lacking for the Darling Anabranch system and uneven channel morphology adds complexity to the selection of elevations that represent a particular flood inundation frequency. Floodplain elevations may require review in subsequent years of Condition Monitoring. The availability of spatial elevation data and inundation modelling would add confidence to the placement of understorey vegetation quadrats.

Lignum condition was assessed at 10 sites; the remaining six sites did not support Lignum communities. Lignum condition varied considerably along the Darling Anabranch, over half the sites fall into the poor category, three sites in the stressed category and only one (site 6) is considered in good condition.

Positive responses were observed in Lignum plants at the majority of sites (e.g. new green growth and flowering). Condition Monitoring during subsequent years will aid in determining if these result in an improvement in Lignum community condition. With sustained high flows and above average rainfall across the Darling Anabranch region (at the time of writing), soil moisture may have been maintained at a sufficient level for long enough to enable Lignum seedlings to establish. Further, overbank flooding along parts of the Darling Anabranch could lead to the establishment of new Lignum seedlings further away from the main channel, provided that soil moisture is sustained and grazing impacts do not impede new growth.

Live *Typha* plants were recorded at only three sites, two within the Murray River Lock 9 weir pool (permanently wet) and site 6 which had been inundated for approximately eight weeks prior to surveying. Plants were sparse but widespread across site 6, suggesting that they were re-shooting from rhizomes. At sites 15 and 16 *Typha* stands extended along the bank of the channel, varying in density from 5 to 10% to about 70% cover.

The generally stable water level in the Lock 9 weir pool provides ideal conditions for the development, growth and expansion of *Typha* at sites 15 and 16. The dense stands around Oakbank Dam suggest that the operation of this structure may also have favoured its growth. These stands are expected to remain stable or expand even further under a permanent water regime. It is possible that the current high water levels in the Murray River may place stress on the existing *Typha* stands, however, the average height of plants (3 to 4 m) means it is unlikely they will be completely drowned.

1. Introduction

Much of the following information is sourced from the Darling Anabranch Adaptive Management Monitoring Plan documents (Campbell and Wallace 2009; Wallace et al. 2009).

1.1. Purpose of the report

This report details the first year of Condition Monitoring undertaken along the Great Darling Anabranch system from September to November 2010 as part of the *Darling Anabranch Adaptive Management Monitoring Program*. This work was conducted by The Murray-Darling Freshwater Research Centre (MDFRC) for the Department of Environment, Climate Change and Water (DECCW) and forms a deliverable for Contract No. 0901427/6092-09-11 LMW01 between DECCW and the MDFRC.

1.2. The Great Darling Anabranch system

The study area is in the Darling Riverine Plain biogeographic region (NPWS 2003: Figure 1.1). The Great Darling Anabranch (the Darling Anabranch) is an ancestral path of the Darling River, which extends approximately 450 km south from its off take on the Darling River (approximately 50 km south of Menindee, NSW). It empties into the Murray River downstream of the junction of the Murray and Darling Rivers and is therefore not a true anabranch.

The Darling Anabranch is a naturally ephemeral stream. In the 1870s the channel from the Darling River to the Darling Anabranch was deepened to enable flows of 10 GL day^{-1} in the Darling River to enter the Darling Anabranch. Prior to this, flows only entered the Darling Anabranch via a channel to the north that connected the river to Tandou Creek when the Darling River was running at 20 GL day^{-1} (Lloyd 1992). Until construction of the Menindee Lakes Scheme in the 1960s, the upper reaches of the Darling Anabranch received inflows approximately every two and a half years (Scholz et al. 2003). Since regulation, inflows to the Darling Anabranch are supplied from Lake Cawndilla via Tandou and Redbank Creeks. The original path from the junction of the Darling Anabranch and Tandou Creek to the Darling River is now commonly referred to as the Old Darling Anabranch and will be referred to thus within this report.

There are approximately 20 ephemeral deflation basin lakes (the Anabranch Lakes) associated with the Darling Anabranch of which several are over 5000 ha in size. The largest lake, Traveller's Lake, is over 10 000 ha (Winning and Murray 1992). The Anabranch Lakes and associated marginal vegetation are listed in the Directory of Important Wetlands in Australia and collectively cover an area of 269 000 ha (Winning and Murray 1992). The majority of lakes are covered by Western Lands Lease and are individually managed for grazing and cropping. There is a small nature reserve encompassing Nearie Lake, managed by NSW National Parks and Wildlife Service.

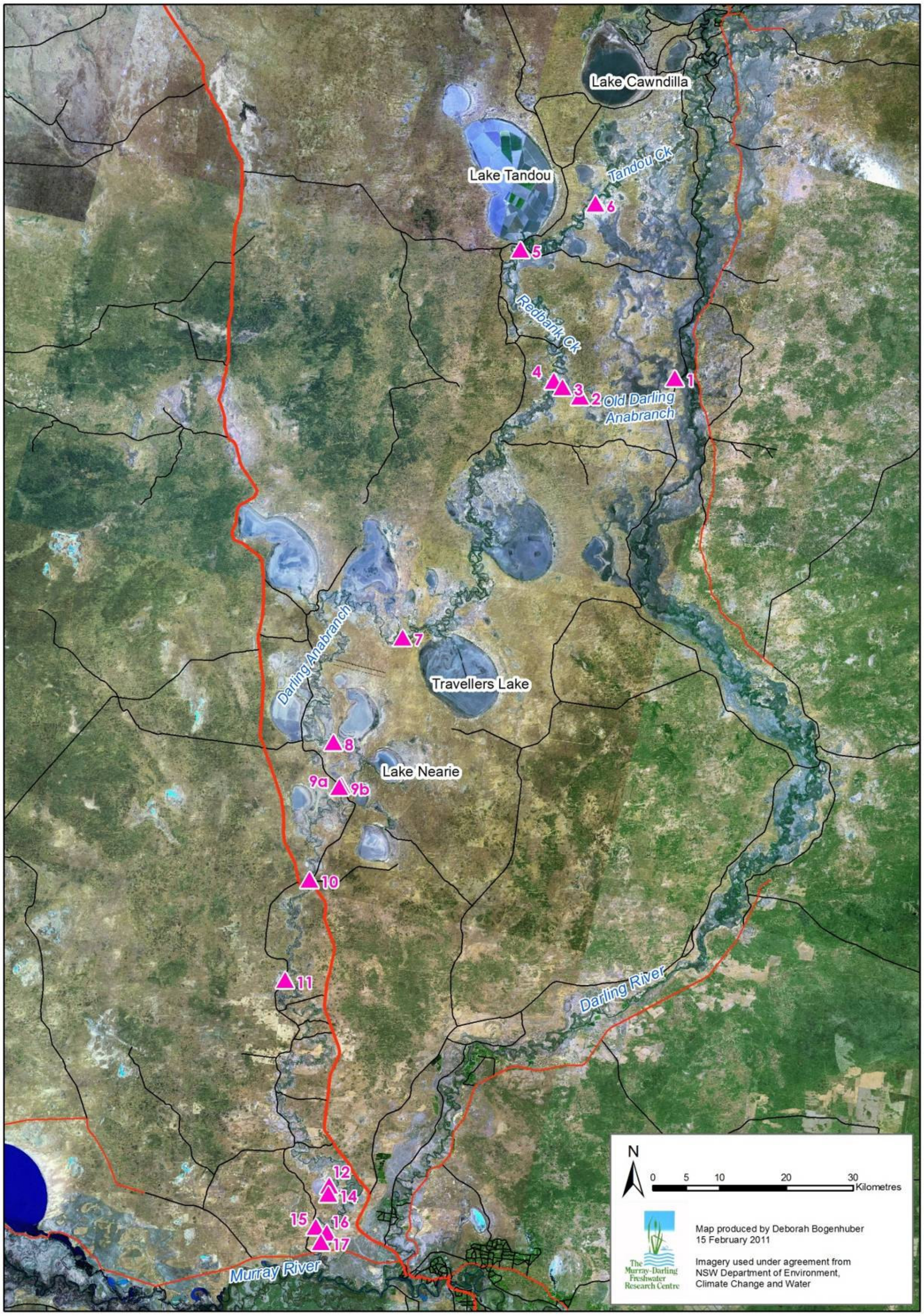


Figure 1.1. The Darling Anabranch system showing monitoring sites 1 to 17.

1.2.1. Hydrology

Flood events in the Darling River typically originate from monsoonal summer rainfall in the upper catchment, reaching the Darling Anabranch in winter/spring (Lloyd 1992). The system is characterised by high variability and intensity of flows and periods of above average and below average flooding frequency (Irish 1993). For example, the Darling River ceased flowing 48 times at Menindee between 1885 and 1960, including a no-flow period spanning 364 continuous days during the 1902/3 drought (Helman 1986 cited in Lloyd 1992) and incurred several significant flood events between 1885 and 1960 (Irish 1993).

After construction of the Menindee Lakes Scheme and prior to the Darling Anabranch Pipeline (completed in 2007), the Darling Anabranch received an annual replenishment flow of up to 50 GL $year^{-1}$ to supply the stock and domestic requirements of adjacent landholders. Approximately 3 GL of this was extracted for consumptive purposes. Replenishment flows ceased in 2002.

With construction and operation of the pipeline it was anticipated that the Darling Anabranch would be returned to an ephemeral system. The expected water savings would be utilised to generate an environmental flow of approximately 60 GL at a maximum rate of 2 GL day^{-1} approximately every two to three years (when water is available in Lake Cawndilla) that would result in an end-of-system flow. However, flows of this magnitude are not achievable due to constraints associated with the outlet regulator at Lake Cawndilla (maximum release approximately 1.8 GL day^{-1}). Flows into the Darling Anabranch are also possible from the Darling River during periods of moderate to high flow (>10 GL day^{-1}). The ability to deliver environmental flows into the Darling Anabranch (and the delivery route) is dependent upon the future management and availability of water in both the Darling River and the Menindee Lakes system.

1.2.2. Ecology

The ecology of the Darling Anabranch would have been significantly impacted by the artificial flow regime prior to construction of the pipeline. During regulation, the Darling Anabranch generally experienced poor water quality including high salinity and algal blooms (Lloyd 1992; Scholz et al. 2003). Ecological data is limited; however, there is evidence for alterations in riparian vegetation distribution, increased waterbird numbers and a decrease in the abundance and distribution of the aquatic plant *Myriophyllum verrucosum* (Lloyd 1992).

Vegetation throughout the Darling Anabranch system is subject to grazing by domestic stock and native and feral animals and many of the ephemeral lakes are subject to rotational cropping on a managed basis. Along the anabranch itself, minimal vegetation clearing has occurred (EarthTech 2004). Historically, modification of the flooding regime has posed the greatest threat to vegetation communities. With the change to an ephemeral system the biggest likely threats are inappropriate flooding regimes, poorly managed grazing and salinity.

Black Box and River Red Gum woodlands are the dominant vegetation communities along the Darling Anabranch. Surveys undertaken while the anabranch was receiving replenishment flows reported that aquatic vegetation was limited to few species of emergent and submerged macrophytes and filamentous green algae (EarthTech 2004).

The effects of regulation on fish communities, in addition to the change from an ephemeral to a permanent system, include barriers to movement, habitat alteration and changes in water quality. There is scant data on fish species in the Darling Anabranch. An electrofishing survey in December 2002 recorded only six species in the Darling Anabranch (Scholz et al. 2003). Monitoring of ecological responses to an environmental flow between October and December 2010 recorded an additional five species from aquatic surveys including Spangled perch (*Leiopotherapon unicolor*) and Murray-Darling rainbowfish (*Melanotaenia fluviatilis*) (Bogenhuber and Linklater 2011). A further five species have been reported anecdotally (Lloyd 1992) including Murray cod (*Maccullochella peelii*), Freshwater catfish (*Tandanus tandanus*) and Short-finned eel (*Anguilla australis*). Yabbies (*Cherax destructor*) are periodically abundant (Lloyd 1992).

The return to a wetting and drying regime is expected to have beneficial outcomes for the flora and fauna communities overall.

1.2.3. Archaeology and cultural heritage

People of the Barkindji language group occupied the Darling Anabranch region when the first European explorers travelled through (Balme and Hope 1990; Bonhomme Craib and Assoc. 2001, both cited in Nias 2002). Barkindji people retain a strong connection with the lower Darling region and are actively involved in looking after country through NSW National Parks and Wildlife and groups such as the Darling River Action Group.

A freshwater mussel shell midden in the Lake Nitchie lunette is the oldest archaeological site on the Darling Anabranch, aged at approximately 26 000 years old and sites at Tandou Lake have been aged at 27 000 years old (Baume and Hope 1990 cited in EarthTech 2004 and Lloyd 1992). Diprotodont bones have been reported from near Lake Nearie (Lloyd 1992).

Europeans settled the Darling Anabranch in the late 1840s (Withers 1989 cited in Nias 2002) and in many cases properties along the anabranch have been passed down the generations and are held by the same families to this day. There are at least nine listed historic items along the Darling Anabranch, in the State Heritage Register (Nias 2002).

1.3. The Darling Anabranch Adaptive Management Monitoring Plan

The Darling Anabranch Adaptive Management Monitoring Plan (DAAMMP) was developed to be consistent with The Living Murray monitoring programs, separating Condition Monitoring, Intervention Monitoring and Compliance Monitoring (Wallace et al. 2009).

Knowledge generated from the DAAMMP monitoring program is designed to inform decision-making in adaptive management of environmental flow releases in the Darling Anabranch.

The importance of the Anabranch Lakes in the Darling Anabranch system is recognised, however, monitoring of these are currently outside the scope of the DAAMMP.

1.3.1. Ecological objectives and targets

The Darling Anabranch Management Plan (Nias 2002) defines ecological objectives for the return of a wet and dry water regime to the Darling Anabranch and the removal/modification of structures restricting flow. These were used as preliminary objectives and are as follows:

- improved water quality;
- healthy vegetation with few weeds;
- stable topsoil and banks;

- lowered water table;
- reduction in exotic fish, particularly Common carp;
- reintroduction of native aquatic (including yabbies), riparian and avian fauna;
- maintenance of snags and deep holes;
- greater diversity of water plants;
- more diversity of bird species.

The overarching ecological objective for the Darling Anabranch is to:

> "*Restore a flow regime to the Darling Anabranch which closely mimics the natural flow regime so that plant and animal communities and ecological processes are largely restored*".

The ecological objectives defined by the DAAMMP (Wallace et al. 2009) are presented in terms of functional groups in Table 1.1.

Targets have not been defined for most ecological objectives due to the limited amount of data available for the Darling Anabranch.

Table 1.1. Ecological objectives for the Darling Anabranch.

Functional group	Objectives
Hydrology	Re-instate a flow regime that is representative of the natural hydrology of the Darling Anabranch
Channel geomorphology	Re-establish scouring of deep holes (refugia) within the main channel
Fish	Reduce the barriers to fish passage throughout the Darling Anabranch system
	Reinstate a diverse native fish assemblage in the Darling Anabranch
Vegetation	Maintain sustainable River Red Gum communities within the riparian zone
	Maintain sustainable Black Box communities within the riparian zone
	Maintain sustainable River Cooba communities within the riparian zone
	Maintain distribution and abundance of particulate natural organic (leaf) material
	Determine the spatial extent and hydraulic influence of River Red Gum and Black Box as invasive (increaser) species within the Darling Anabranch Channel
	Limit the extent of recognised weeds as invasive (increaser) species
	Maintain sustainable communities of flood tolerant understorey vegetation
	Maintain sustainable communities of flood dependent understorey vegetation
	Maintain sustainable communities of Lignum habitats
	Limit the extent of *Typha* as an invasive (increaser) species
Frogs	Maintain sustainable communities of the riparian frog species
Birds	Provide suitable habitat, including breeding habitat in some years, for a wide range of waterbird and -dependent species
Aquatic invertebrates	Maintain a sustainable population of Yabbies (*Cherax destructor*)
Water quality	Maintain water quality to maximise habitat value
Groundwater and soil condition	Provide conditions conducive to long-term lowering of the shallow groundwater system and subsequent reduction of soil salinity and seepage.

1.3.2. Condition monitoring

The approach of Condition Monitoring is to monitor at pre-determined, permanent sites according to a pre-determined schedule. For the DAAMMP, Condition Monitoring occurs annually for understorey and tree condition (including natural organic matter) and every two years for Lignum, *Typha* and EM31 surveys. Every three years the additional parameters of regeneration and geomorphology are monitored.

Results of Condition Monitoring provide a snapshot of community or population condition at that point in time. Regular time series data of these snapshots allow changes in condition to be observed and an assessment of whether ecological objectives are being achieved. For the DAAMMP, targets for ecological objectives have not yet been established due to a lack of existing ecological data and knowledge. Monitoring results will assist in setting targets for ecological objectives for the Darling Anabranch system.

Condition Monitoring for 2010 reports on the following components:

- Tree condition
- Natural organic matter load
- Understorey vegetation composition
- Lignum condition
- *Typha* distribution

Tree condition

Dominant tree species along the Darling Anabranch riparian zone

The information contained in this section is largely sourced from The Living Murray: Condition Monitoring Program Design for Chowilla Floodplain and the Lindsay, Mulcra and Wallpolla Islands (Wallace 2009b).

River Red Gum (Eucalyptus camaldulensis)

River Red Gum (RRG) (*Eucalyptus camaldulensis* Dehnh. Myrtaceae) woodlands dominate the riparian zone of the Darling Anabranch in areas where more permanent water occurs (e.g. deep water holes) and are particularly common at the downstream end in the Murray River Lock 9 weir pool. Where present, they generally occur as a narrow band fringing the channel.

RRGs play an important functional role within floodplain and wetland systems through their provision of carbon (leaf litter) and habitat for a range of aquatic and floodplain fauna (e.g. Briggs and Maher 1983; Briggs et al. 1997; Baldwin 1999; MDBC 2003a). The distribution of RRGs within the floodplain is greatly influenced by the magnitude and frequency of floodplain inundation events and by proximity to permanent surface or groundwater resources. For example, whilst the germination and establishment of RRGs are not completely dependent on flooding, regeneration (recruitment success) is greatly enhanced by appropriate flood regimes (i.e follow-up flooding; Bacon et al. 1993; Roberts and Marston 2000; MDBC 2001; Jensen 2008). Further, during extended periods of drought RRGs may become increasingly reliant on access to groundwater using deep tap roots (Zohar 1985; White et al. 2001). Where such resources are not available or are saline, RRGs may reduce their water requirement by shedding leaves, thereby reducing transpiration rates (e.g. Thorburn et al. 1994; Thorburn and Walker 1994; Roberts and Marston 2000; MDBC 2001). Whilst such responses by individuals to short-term water deficits are often non-lethal and reversible, little is currently known of the cumulative impact of longer dry spells on the resilience of RRGs.

Recent work along the Lower Murray River floodplain has drawn attention to reductions in the condition (*cf.* health) of mature RRGs (Lane and Associates 2003; 2005; MDBC 2003a; 2003b). These changes have been attributed to increased soil salinity associated with shallower water tables and reductions in flood frequency (Slavich et al. 1999; MDBC 2002; 2003a; 2003b; Lane and Associates 2003; 2005). It is generally accepted that unless an adequate flooding regime is reintroduced in the near future, significant loss of RRG communities on the Lower Murray River floodplain is likely to occur (MDBC 2003a).

Little is known of RRG condition along the Darling Anabranch (except anecdotal evidence), however, it is reasonable to expect the following long-term changes in distribution and regeneration under the new wetting and drying scenario (based upon RRG life history):

- an increase in RRG germination in the base of the channel between flood events;
- the persistence of RRGs in areas where they have previously drowned due to permanent inundation (e.g. near the base of the channel); and
- a decrease in recruitment along the banks due to decreased frequency and duration of available water.

Black Box (Eucalyptus largiflorens)

Black Box (BB) (*Eucalyptus largiflorens* F. Muell.) is a small to medium tree that forms open woodlands on floodplains and on the fringes of ephemeral lakes and water courses. The importance of BB communities as habitat is not well studied, however, it is known that they support ground-foraging and hollow-nesting avifauna (O'Malley and Sheldon 1990 as cited in Roberts and Marston 2000).

BB is the dominant tree species along the majority of the Darling Anabranch system. BB are less tolerant of flooding than RRGs, but can withstand longer periods without floods (Roberts and Marston 2000). They are therefore more common at higher elevations on the floodplain. A study in south-west New South Wales found that healthy BB trees occurred in areas that had flooded every four to five years, for a duration of four to six months and that trees were dying in areas where water had persisted for 12 to 18 months (Shepheard 1992 as cited in Roberts and Marston 2000). Similarly, at Nearie Lake, BB trees became water stressed when inundated for 13 months (Briggs and Townsend 1993).

Growth, flowering and germination in BB tend to occur in pulses in response to flooding. On the lower Darling, germination is most effective in the cooler months from May to October (Roberts and Marston 2000). Reductions in flood frequency are thus likely to reduce growth rates, flowering frequency (which may impact on nectar-feeding birds and mammals) and recruitment, reducing community viability (SKM and Roberts 2003). Although drought hardy and salt tolerant, recent work has drawn attention to reductions in crown condition and community viability (i.e. insufficient recruitment) of BB along the Lower Murray River floodplain (George et al. 2005; Lane and Associates 2005; Henderson et al. 2010). These changes have been attributed to increases in soil salinity associated with shallower water tables and reductions in flood frequency (e.g. Slavich et al*.* 1999; MDBC 2002).

Little is known of BB condition throughout the Darling Anabranch and it is unknown to what extent the long-term sustainability of BB communities is threatened. It is possible that the return of an ephemeral system may favour BB over RRG, particularly in areas that won't hold water for long periods.

Cooba (Acacia stenophylla)

River Cooba (RC) (*Acacia stenophylla* A.Cunn. ex Benth) is a rough barked erect or spreading shrub or small tree up to 10 m tall, generally living more than 50 years (Thomson 1987 as cited in CSIRO 2004). It is a common tree which occurs in open to dense stands on heavy clay soils close to permanent and ephemeral waterways, most commonly in association with River Red Gum and less commonly with Black Box (Cunningham et al. 1992). RC woodland is patchily distributed throughout the western part of the Murray-Darling Basin (Roberts and Marston 2000). It is considered to be an important species for restoration of riverine woodlands and floodplains owing both to its high level of salt-tolerance and its nitrogen-fixing capabilities which may be beneficial to non-legume plants in the community (Bagnall et al. 2004 as cited in CSIRO 2004). It is also highly tolerant of waterlogging (Marcar et al. 1995 as cited in CSIRO 2004).

After major floods, RC seedlings may be abundant along the flood line although survival is typically low (Cunningham et al. 1992). It has been suggested that mature RC requires flooding every two to five years to remain healthy (Carter and Nicholson 1993). Noticeably, stands of RC along the Old Darling Anabranch (sites 2 and 3) have recently died, possibly due to drought conditions (before the flow in January/February 2010 the last flow to enter the Old Darling Anabranch was between November 2000 and January 2001). Reductions in flood frequency are likely to adversely affect both recruitment and the resilience of the extant mature population.

Ecological objectives

The interim ecological objectives for long-lived woody vegetation (trees) are:

- Maintain sustainable River Red Gum communities within the riparian zone
- Maintain sustainable Black Box communities within the riparian zone
- Maintain sustainable River Cooba communities within the riparian zone

Natural Organic Matter loading

The following is largely sourced from The Darling Anabranch Adaptive Management Monitoring Plan: Condition and Intervention Monitoring Program (Wallace et al. 2009).

The release of nutrients and carbon from inundated floodplains is well documented (Baldwin and Mitchell 2000 and references therein) and it is generally considered that a substantial component of the dissolved organic material entering streams is leached from terrestrial plant material (Baldwin 1999). Soils (Nelson et al. 1996) and grazed grasslands (McTiernan et al. 2001) are also a key source of organic material in some catchments. Carbon and nutrients are essential in fuelling in-channel productivity. Terrestrial vegetation-derived carbon and nutrients is believed to be an important component in the functioning of lowland river systems (Junk et al. 1989); for example, it has been demonstrated that in low order streams, up to 99% of total energy inputs are from terrestrial inputs (Fisher and Likens 1973). The magnitude of terrestrially derived organic material (e.g. plant/leaf material) that can contribute organic carbon and nutrients to the system will be directly related to the dominant vegetation type and density, season, antecedent dry period (time since last flood) and the canopy condition of trees in the riparian zone. For example, litter loadings for BB woodland, grassland and Lignum shrublands on the Chowilla Floodplain demonstrate generally low median loadings of less than 400 g m^{-2} compared to litter loads for the RRG forests (median load of 2500 g m^{-2}). The wide range of loading in RRG zones on the Chowilla Floodplain (650 – 6100 g m^{-2}) reflect the difference in organic loading in areas with canopy condition ranging from poor to good.

For the context of Condition Monitoring, the interim objective for Particulate Natural Organic Matter (leaf litter) loading is:

- Maintain distribution and abundance of particulate natural organic material (NOM)

In a broader sense, meta-analysis of this data may be used to provide insight into the rise in water level required to generate a significant input of natural organic matter into aquatic food webs. Seasonal variation in leaf litter drop which is a natural feature of floodplain eucalypts will also influence the biomass of accumulated leaf litter that may contribute to poor water quality outcomes (e.g. blackwater events). Leaf material may also contribute to increased soil condition via increases in soil carbon and nutrient content.

Understorey vegetation

Much of the following has been modified from The Living Murray Condition Monitoring at Hattah Lakes 2009/10 (Walters et al. 2010) and The Darling Anabranch Adaptive Management Monitoring Plan: Condition and Intervention Monitoring Program (Wallace et al. 2009).

Riparian understorey strata provide habitat for many terrestrial fauna (particularly small bush birds and ground mammals); form ground cover in conjunction with litter from overstorey species, which reduces erosion and enhances soil water retention; contribute to nutrient and water cycling processes and provide organic matter to both terrestrial and aquatic food webs. The understorey communities of riparian woodlands in the Darling Anabranch region are comprised mostly of small to medium chenopods (Family Chenopodiaceae) with sparse cover of small herbs and tufted graminoids. In naturally ephemeral systems such as the Darling Anabranch, native riparian plant species have adapted to wetting and drying cycles which have a high degree of variability. The majority of floodplain understorey species in the Murray-Darling Basin are short-lived and will die when inundated for extended periods; however, flooding is often required to promote regeneration from seed and provide appropriate soil moisture for growth and recruitment (Cunningham et al. 1992; Nicol and Weedon 2006). Where this variability has been reduced through river regulation, native plants may be replaced by introduced species, particularly where grazing of native species occurs and disturbance promotes the colonisation of invasive weeds; and flood-tolerant and responsive species are likely to be replaced by drought tolerant species.

There are limited studies into vegetation dynamics and the role of the seed bank in ephemeral systems (Nicol 2004), particularly in the Darling River system. However, observations indicate that the return of wetting and drying cycles to previously regulated, ephemeral systems tends to promote flowering, seed production, germination and recruitment of native species over exotic species (MWWG research, unpublished data). Reinstating wetting and drying cycles, after a dry period, also increases the diversity and abundance of amphibious (flood tolerant and dependent) species over drought tolerant species (Henderson et al. 2010; Walters et al. 2010).

Most wetland plants, including emergent macrophytes and riparian understorey herb species, germinate best in saturated soils, most common on flood recession (Roberts and Marston 2000). A study at Menindee Lakes on germination from the seed bank found that strandlines, where receding water levels have deposited organic material, supported germination and recruitment more than surrounding soil in most cases (Nicol 2004). Nicol (2004) also found that most species germinated only when soil was exposed and not when submerged.

There is a distinct lack of data on understorey vegetation communities along the Darling Anabranch (Lloyd 1992). The investigations undertaken in the current study represent the most comprehensive recorded vegetation survey of this region. The return of an ephemeral system is likely to increase the diversity and abundance of flood tolerant and dependent understorey species.

The ecological objectives for understorey vegetation are:

- Limit the extent of recognised weeds as invasive (increaser) species
- Maintain sustainable communities of flood tolerant understorey vegetation
- Maintain sustainable communities of flood dependent understorey vegetation

Lignum condition

Lignum (*Muehlenbeckia florulenta* Meissner) is a native, woody, usually leafless, multi-stemmed perennial shrub up to 3 m high and 3 m diameter. Lignum communities are found throughout the Darling Anabranch system in clay depressions and in association with RRG and BB woodland. Lignum is recognised for its importance in providing structural habitat for aquatic biota, such as fish and invertebrates during times of flood and terrestrial animals during inundation and throughout dry periods (Young 2001). When inundated, Lignum shrublands provide breeding habitat for the Freckled Duck (*Stictonetta naevosa)*, which is known to occur along the Darling Anabranch (DEC 2005). Colonial waterbirds such as the Straw-necked Ibis (*Threskiornis spinicollis*), Australian White Ibis (*Threskiornis molucca*) and Glossy Ibis (*Plagadis falcinellus*) also utilise Lignum for breeding habitat in areas such as Hattah Lakes (Lowe 1982; Maher and Braithwaite 1992).

Lignum plants often appear lifeless, but endure dry conditions by means of a persistent rootstock, up to 3 m deep, that maintains contact with the capillary fringe of subsurface water and the topmost 0.2 m of soil (Craig et al. 1991; Chong and Walker 2005). Within two weeks of rainfall or flooding, Lignum regenerates producing a green flush of shoots, leaves and flowers (Craig et al. 1991). Lignum condition is affected by both the quantity and duration of soil moisture and is therefore highly dependent on the local flood regime in arid areas (Lynch 2006). Lignum requires flooding every 3 to 10 years (possibly more frequently in saline soils) for periods of up to 12 months and is intolerant to sustained dry periods and prolonged flooding (Craig et al. 1991).

Returning the Darling Anabranch to an ephemeral system, via environmental flow management, could be beneficial for Lignum communities if 'flow events' are managed in such a way to facilitate overbank flooding, sustaining soil moisture on the floodplain in times of increased temperature, or managed to value-add to times of high rainfall (Jensen 2008).

The ecological objective specific to Lignum along the Darling Anabranch is:

- Maintain sustainable communities of Lignum habitats

Typha distribution

Much of the following is modified from The Living Murray Condition Monitoring at Hattah Lakes 2009/10 (Walters et al. 2010).

Typha (*T. domingensis* and *T. orientalis*) is a common native macrophyte found throughout the lower Murray-Darling system. Mature *Typha* plants are erect, rhizomatous perennials that grow to 4 m and occupy riparian and wetland habitats (Sainty and Jacobs 1981). The rhizomes are extensive and branched. The inflorescence is a compact, densely formed spike of unisexual flowers (Sainty and Jacobs 1981).

Typha is capable of rapid invasion and colonisation of wetland and riparian habitat due to its specific biology and ecology (Nicol and Ganf 2000; Roberts and Marston 2000). Mature *Typha* flowers produce vast numbers of seeds that are easily dispersed by wind, water and other vectors over large distances. Germination and seedling development of *Typha* occurs in a range of conditions from moist soils to soils inundated by greater than 0.8 m of overlying water (Nicol and Ganf 2000). Once seedlings have established they grow quickly and in many cases form mono-specific stands in waters up to 2 m deep (Sainty and Jacobs 1981; Froend and McComb 1994).

Mature mono-specific stands of *Typha* are comprised of three distinct concentric zones; an actively expanding outer edge characterised by laterally colonising shoots, an inner denser mature zone characterised by reproductive shoots and taller leaf shoots, and a central core of senescent and senescing shoots (Scholz et al. 2007). *Typha* growth slows dramatically at the onset of winter, eventually ceasing in a process known as overwintering. During spring and summer above-ground growth is highest, while the greatest rhizome growth and expansion occurs after flowering in mid-summer (Roberts and Ganf 1986). It does not survive in dry conditions for longer than about four months, although the underground rhizomes can possibly survive for several years, especially if they occur in deep heavy clay (Roberts and Marston 2000). The dry period between ceasing regulated flows and the environmental and natural flows experienced in 2010 have led to a contraction of live *Typha* stands.

River regulation can affect the growth of *Typha*, documented in the Murray River weir pools (see references in Walters et al. 2010). The spread of *Typha* can be perceived as a threat to aquatic ecosystems due to its prolific growth and formation of mono-specific stands. Apart from outcompeting and displacing other plant species, it also disrupts fish movement and reduces the hydraulic capacity of floodplain channels and flood runners (Roberts and Wylks 1992; Roberts and Marston 2000). While *Typha* plays an important ecological role, providing habitat for planktivorous fish, macroinvertebrates, zooplankton and water-birds (Ogden 2000; Roberts and Marston 2000), extensive expansion of *Typha* is viewed as an imbalance.

Typha has been recorded in the Darling Anabranch in dense stands, its spread attributed to the regulated system that existed prior to construction of the pipeline (Lloyd 1992; EarthTech 2004). *Typha* distribution could reasonably be expected to remain contracted along the Darling Anabranch (except the lower reach influenced by the Murray River weir pool) under the new water regime. During Condition Monitoring between September and November 2010, dead *Typha* was noted at several of the monitoring sites for this project, prior to receiving the environmental flow. Monitoring the distribution and expansion of *Typha* will be important over the next few years to determine the effects of management on its distribution.

The interim ecological objective for *Typha* is:

- Limit the extent of *Typha* as an invasive (increaser) species

2. Methodology

2.1. Site selection and monitoring components

The DAAMMP incorporates 17 monitoring sites; one on Tandou Creek, one on Redbank Creek, three on the Old Darling Anabranch, one at the junction of the Old Darling Anabranch and Redbank Creek and the remaining 11 sites spread along the Darling Anabranch (Figure 1.1). Sites were based upon those identified in Campbell and Wallace (2009). After an initial aerial survey followed by a ground field survey, Campbell and Wallace (2009) selected 17 sites based upon spatial distribution, ease of access, as well as field notes on biological and geomorphologic characteristics. Consent for access was not able to be attained for several sites initially selected by Campbell and Wallace (2009) at the downstream end of the Darling Anabranch. Alternative sites were determined and established nearby.

Sites vary in channel morphology, dominant overstorey community and understorey vegetation composition and condition (as observed at the time of survey). Sites range from approximately 1 ha (1.26 ha) (site 7) to 15 ha (site 8) in size, depending on the distribution of the various Condition Monitoring components.

The Condition Monitoring program has been funded for three years. As part of the initial establishment between September and November 2010 the following components were assessed:

- Tree condition
- Natural Organic Matter load
- Understorey vegetation
- Lignum condition
- *Typha* distribution

The remaining components, channel geomorphology, in-channel regeneration and soil salinity will be assessed in 2011 (weather and flow dependent).

2.1.1 Limitations to component assessments

Site 1, near the upstream junction of the Old Darling Anabranch and the Darling River, was unable to be accessed between September and November 2010, due to wet weather and high flow conditions. Understorey surveys could not be completed at all elevations at all sites due to high flow conditions. Lignum condition was assessed at 10 sites, the remaining six sites did not support Lignum communities and *Typha* was observed at only three sites.

2.2. Tree condition and Natural Organic Matter load

Much of the following information is sourced from An Assessment of Tree Condition at the Pike Floodplain (South Australia) (Wallace 2009a), The Living Murray Condition Monitoring at Lindsay, Mulcra and Wallpolla Islands 2009/10 (Henderson et al. 2010, and *The Living Murray Condition Monitoring at Hattah Lakes 2009/10 (Walters et al. 2010).*

Tree condition was assessed using The Living Murray (methodology (Souter et al. 2010). This approach is consistent with that used at other floodplain sites including Chowilla Floodplain, Lindsay, Mulcra and Wallpolla Islands, Hattah Lakes and the Pike River floodplain and allows for comparisons between the Darling Anabranch and other regionally relevant floodplains. For a detailed explanation of methods see Souter et al. (2010).

2.2.1. Selection of sites

Tree condition was assessed between September and November 2010 at 16 sites along the Darling Anabranch system. A 0.25 ha quadrat (tree condition quadrat) was established at each of the 16 sites assessed along the Darling Anabranch system, with variable dimensions depending on the nature of the site. At some sites riparian trees are sparsely distributed and trees were progressively selected from outside the quadrat to reach the required 30 trees. For location of sites refer to Figure 1.1 in Section 1.

2.2.2. Tree selection

Thirty trees with diameter at breast height greater than 0.1 m were selected within each tree condition quadrat. Trees that showed no signs of visible live foliage were not included. Each tree was tagged with a unique-numbered yellow cattle tag and its position recorded with a GPS. Where riparian zones consisted of mixed species, trees from all species present were selected to be proportionally representative of the site. Species included in assessments were River Red Gum (*Eucalyptus camaldulensis*), Black Box (*Eucalyptus largiflorens*) and River Cooba (*Acacia stenophylla*).

2.2.3. Tree information

Diameter at Breast Height

The Diameter at Breast Height (DBH) of each marked tree within the site was measured and recorded (to the nearest cm) at 1.3 m above the ground using a Richter™ 10 m Fibreglass Tree Diameter Tape.

Rules for measuring DBH were:

- Measurement was made at 1.3 m above ground measured along the stem; where the tree is on a slope, 1.3 m was measured on the uphill side of the tree. Where the tree is on a lean, 1.3 m was measured on the underside of the lean.
- Where a swelling occurred at 1.3 m, two points unaffected by swellings or limbs equally spaced above and below 1.3 m were selected, measured, then averaged to give an estimate of circumference.
- The measuring tape was located at 90° to the axis of the stem at 1.3 m. Where loose bark was present at 1.3 m, it was gently cleared (firm bark was not removed) from the tree in order to provide an accurate measurement.
- Where a tree has multiple stems at 1.3 m, the DBH of each stem was recorded. The circumference of these stems were converted to area, summed to produce a "total area" and then converted to a proxy DBH (equivalent to DBH if the tree only had one primary stem).

Dominance class

Competition for resources between forest trees may affect the condition of individual trees. This parameter is more applicable to riparian 'forests' than the open riparian 'woodlands' most common along the Darling Anabranch. Nonetheless, individual trees were assigned to a dominance class according to the categories in Table 2.1.

Table 2.1. Category scale used to score tree dominance class.

Category	Description
Dominant	Tree with a crown extending above the general canopy, receiving full light from above and partly from the sides; a larger than average tree in the stand.
Co-dominant	Tree with a crown forming part of the general canopy, receiving full light from above but comparatively little from the sides.
Subdominant	Tree shorter than the previous classes, but with a crown extending into the canopy of the co-dominant trees, receiving little light from above but none from the sides.
Suppressed	Tree with a crown entirely below the canopy, receives no direct light from above or from the sides

2.2.4. Tree condition assessment

At each site the individual condition of the 30 marked trees was measured by visual assessment of two tree condition attributes: (i) crown extent and (ii) crown density. For the purposes of this assessment, the "crown" is defined as the totality of branches, twigs and leaves extending from the trunk or main stems. Assessments of crown extent and density were compared against the tree as if it were fully-foliated. As each tree is assessed individually, its 'assessable crown' is defined by its existing branching structure. This includes branches that have recently died, whilst excluding those that are long dead (i.e. have lost their side shoots). Gaps between the branching structures where foliage would not overlap in a fully-foliated tree, which are common in larger trees, were excluded from the assessable crown. A change in crown density will be noticeable prior to a change in crown extent as older leaves near the base of branches are shed prior to the younger leaves at the outer extent of the crown.

Crown extent

Crown extent is assessed as the degree to which the actual crown outline (both apical and epicormic growth) fills the assessable crown, which would be filled by a fully-foliated tree. The departure from this state is scored using the scale presented in Table 2.2. Crown extent will diminish as foliage is progressively lost from the branch tips leading to larger gaps appearing as whole branches become completely defoliated.

Crown density

Crown density is assessed as the amount of skylight blocked by the foliated portion of the crown (i.e. the higher the density, the higher the amount of skylight blocked by the crown). The assessable crown of a fully foliated tree will be close to opaque. The assessment of crown density only takes into account the foliage, not the branches. Branches are excluded as they may also block light, particularly in severely defoliated trees. Only live leaves contribute to the estimate of density (the proportion of dead leaves is estimated separately). The scale used to assess crown density is shown in Table 2.2.

The protocol uses a combination of descriptive terms and percent divisions (e.g. sparse = 11-20%). This is intended to assist assessment of condition, particularly where difficulty in defining differences at the edges of categories exists. Field data was recorded to within 5% and subsequently converted to category scores, which allows for expansion or contraction of the number of divisions (or to retrospectively analyse data using other scales) if desired.

Table 2.2. Category scale for reporting crown extent and crown density.

Score	Description	Percentage of assessable crown
0	None	0
1	Minimal	1-10
2	Sparse	11-20
3	Sparse - Medium	21-40
4	Medium	41-60
5	Medium - Major	61-80
6	Major	81-90
7	Maximum	91-100

Tree Condition Index

Tree Condition Index (TCI) scores were calculated for each site by combining the crown extent and crown density scores, with a maximum possible score of 14. Tree condition categories assigned for TCI scores are shown in Table 2.3. Categories are denoted in this document by **VERY GOOD**, **GOOD**, **STRESSED**, **POOR** and **VERY POOR**.

Table 2.3. Tree Condition Index score and condition category.

TCI score	Condition category
≥ 12	Very good
> 10 – 12	Good
> 6 – 10	Stressed
> 4 – 6	Poor
≤ 4	Very poor

2.2.5 Tree response

The ‘direction’ of a tree’s condition (i.e. whether it is improving, declining or stable in health) is assessed by gaining information from six attributes (i) new tip growth, (ii) epicormic growth, (iii) leaf die-off , (iv) reproductive extent, (v) mistletoe load and (vi) bark condition. Trees producing epicormic growth and new tip growth indicate recovery from stress and a possible improvement in condition (if suitable environmental conditions are maintained). In contrast, trees displaying leaf die off may decline in condition. Reproductive extent is considered to be a positive response variable, that is, trees with a higher abundance of reproductive material (flowers, buds and seed capsules) are responding to an improvement in environmental conditions and more likely to improve in health. Mistletoe load and bark condition are considered to be negative response variables, that is, higher mistletoe abundance and cracked bark are responses to unfavourable environmental conditions and these trees are expected to decline in health.

These response variables can be used to estimate the average trajectory (e.g. recovery or decline) of trees at a site.

New tip growth and epicormic growth

Growth of new shoots can occur either from the main trunk or major support branches of the tree (epicormic growth) or from branch tips (new tip growth). The presence and visual effect of new shoots was assessed as per the categories presented in Table 2.4. In some cases, trees may have lost their entire crown prior to responding to favourable environmental conditions. In these situations, epicormic growth may constitute the entire crown of the tree. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Leaf die-off

Unfavourable environmental conditions (e.g. lack of water, too much water) for tree growth may be evidenced by the presence of dead and/or dying leaves. Leaf die-off was assessed as the relative abundance of dead and partially dead leaves on the tree. Leaf die-off was scored according to its visible presence in the tree crown as per Table 2.4. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Table 2.4. Category scale for reporting new tip growth, epicormic growth and leaf die off (leaf die-off is recorded as negative values to reflect the decline in condition).

Score	Description	Definition
0	Absent	Effect is not visible
1	Scarce	Effect is present but not readily visible
2	Common	Effect is clearly visible
3	Abundant	Effect dominates the appearance of the tree

Extent of reproduction

Extent of reproduction of floodplain tree species may be related to environmental factors and may be indicative of tree condition. Reproductive extent was recorded as the combined relative abundance of buds, flowers and fruits. Reproductive extent was scored according to its visible presence in the tree crown as per Table 2.5. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Table 2.5. Category scale used to record the visible presence of reproductive extent within the tree crown.

Score	Description	Definition
0	Absent	Reproductive material is not visible
1	Scarce	Reproductive material is present but not readily visible
2	Common	Reproductive material is clearly visible
3	Abundant	Reproductive material dominates the tree's appearance

Mistletoe load

Mistletoes are hemiparasitic plants that obtain water and nutrients from their host. Mistletoes reduce growth in their host plant and heavy infestations may kill them. However, it should be noted that mistletoes have been recognised for their ecological importance with 217 species (66%) of the Australian arboreal nesting birds recorded as nesting in mistletoe (Cooney et al. 2006). Mistletoe load was scored according to its visible presence in the tree crown as per Table 2.6. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Table 2.6. Category scale used to record the visible presence of mistletoe load within the tree crown.

Score	Description	Definition
0	Absent	Mistletoe is not visible
1	Scarce	Mistletoe is present but not readily visible
2	Common	Mistletoe is clearly visible
3	Abundant	Mistletoe dominates the tree's appearance

Bark condition

Bark condition was assessed for River Red Gums only. The extent of cracking is rated by observing the main stem(s) of the tree as per the categories presented in Table 2.7. Very stressed trees have deep vertical cracks in the bark, generally found on the main stem which exposes the heartwood. Trees with cracked bark have generally lost all of their leaves or only have dead leaves. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Table 2.7. Categories for the assessment of bark condition for River Red Gums.

Category	Description	Definition
0	Absent	Effect is not visible (intact bark)
- 1	Scarce	Effect is present but not readily visible
- 2	Common	Effect is clearly visible
- 3	Abundant	Effect dominates the appearance of the tree

2.2.6. Site information

Site information was collected to provide extra contextual information on the condition of the assessment site. Site information may reveal localised factors contributing to tree condition such as biological infestations or localised disturbances.

Disturbance

Disturbances such as logging, grazing, ground disturbance (e.g. by feral pigs), flooding and fire can affect the condition of trees at the site. Natural and man-made disturbances were recorded where present.

Insect damage

Numerous insect species feed on the leaves of floodplain trees. Insect damage was identified by the presence of jagged, irregular shaped or skeletonised leaves, and scored according to its visible presence at the site as per Table 2.8. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Table 2.8. Category scale used to record the visible presence of insect damage within the assessment site.

Category	Description
Absent	Not visible or minor damage to some trees
Scarce	Some trees have scattered damage within the crown
Common	Most trees have significant damage within the crown
Abundant	All trees have significant damage within the crown

Other biological stressors

Other biological stressors such as disease, parasites and weed infestations can affect tree condition. Other biological stressors were scored according to their visible presence as per Table 2.9. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Table 2.9. Category scale used to record the visible presence of other biological stressors within the assessment site.

Category	Description
Absent	Not visible or minor presence within the site
Scarce	Scattered occurrence throughout the site
Common	Present throughout the majority of the site
Abundant	Present throughout the entire site

Presence of seedlings and saplings

The presence of seedlings and saplings at each site was noted whilst conducting tree condition assessments. The abundance was then recorded according to Table 2.10. Categories are denoted in this document by **ABSENT**, **SCARCE**, **COMMON** and **ABUNDANT**.

Table 2.10. Category scale used to record the abundance of seedlings and saplings within the assessment site.

Category	Description
Absent	No seedlings or saplings observed
Scarce	Less than 10 seedlings/saplings observed
Common	10-50 seedlings/saplings observed
Abundant	More than 50 seedlings/saplings observed

2.2.7. Photo points

Tree condition photo points were established at each transect to document change through time. The position of each photo point was chosen to be representative of the condition of the trees surveyed by maximising the number of transect trees captured in the image, particularly their canopy.

Photo points were marked using a wooden stake and their location recorded on a hand-held GPS unit. Where possible, photos were taken immediately following visual assessments. Metadata recorded for each photo included:

- photo identification number;
- time and date;
- direction bearing in degrees (from compass);
- GPS coordinates (in datum GDA 94);
- cloud cover (clear, patchy, overcast);
- wind (calm, gentle, strong);
- photographer and photographer's assistant's name.

All photographs were taken with a Pentax Optio W20 (7.0 megapixel) digital camera in landscape mode with image quality set to 'HQ', focus set to 'auto', zoom set to 'off/zero' and flash set to 'off'.

2.2.8. Limitations

Visual assessments of tree condition are subjective and will often vary between observers and between trees for the same observer. Observers are trained to carry out these assessments and they are always undertaken by two people, with scores averaged. Where scores are considerably different, they are discussed and adjustments are made where appropriate and mutually agreed. Despite this, it should be noted that due to the subjective nature of the assessments, a degree of inconsistency is inherent.

2.2.9. Natural Organic Matter loading

Natural Organic Matter (NOM) loading was assessed within the drip line of the first 10 trees in the tree condition quadrat at each site. All recognisable tree derived (leaf litter, twigs and bark) organic material down to the soil horizon was collected from within a pseudo-randomly selected 1 m^2 quadrat. During dry conditions material was collected and weighed to the nearest gram on site. After rain events or if leaf litter was wet or damp, material was collected and air dried before weighing. The weight of NOM was given a category as per Table 2.11. Categories are denoted in this document by **VERY LOW**, **LOW**, **MODERATE**, **HIGH** and **VERY HIGH**.

Table 2.11. Categories used to describe NOM loads (gm^{-2}).

Description	Minimum weight (g)	Maximum weight (g)
Very low	0	500
Low	501	1000
Moderate	1001	2000
High	2001	3000
Very high	>3001	

2.2.10. Statistical analysis

Visual representations of the data were produced in SigmaPlot based on average scores for the condition variables at each site. The software package PRIMER 6 (Clarke and Gorley 2006) was used to visualise patterns in the condition variables between sites using Principal Component Analysis (PCA). The site average data was normalised to account for the range in data values and scales and the assessment matrix included crown extent, crown density, new tip growth, epicormic growth, leaf die-off, DBH and NOM load. Because the variable "bark condition" only applies to River Red Gums, it was not included in the multivariate analysis. For visual clarity, response variables that are less indicative of tree condition (e.g. mistletoe and reproductive extent which may be influenced by other factors such as season and bird populations) were also excluded from the analysis.

Statistical differences in condition between sites were analysed by permutational ANOVA (PERMANOVA) utilising the PERMANOVA+ add in (Anderson et al. 2008). The factor "site" was fixed and the analysis was performed using 9999 permutations using unrestricted permutation of raw data. The condition data for individual trees was normalised to account for the range in data values and scales and a resemblance matrix created using Euclidean distance. Significant effects were accepted at $\alpha < 0.05$, with *a posteriori* pair-wise comparisons run if the main test was significant. The assessment matrix for the PERMANOVA analysis included crown extent, crown density, new tip growth, epicormic growth, leaf die-off, DBH, mistletoe and reproductive extent.

NOM was not included as this information was only collected for one third of trees assessed. As for the PCA, because the variable "bark condition" only applies to River Red Gums, it was also not included in the multivariate analysis.

2.3. Understorey vegetation

Much of the following information is adapted from The Living Murray Condition Monitoring at Lindsay, Mulcra and Wallpolla Islands 2009/10 (Henderson et al. 2010) and *The Living Murray Condition Monitoring at Lindsay, Mulcra and Wallpolla Islands 2007/08 (Henderson et al. 2008).*

This section summarises methods used to monitor community-level floodplain understorey vegetation composition along the Darling Anabranch system. In addition to understorey vegetation, Lignum (*Muehlenbeckia florulenta*) and *Typha spp*. were investigated separately. This was due to their importance to vegetation structure, habitat provision and in the case of *Typha*, the potential threat to aquatic vegetation diversity posed by its range expansion.

2.3.1. Site establishment and layout

Understorey vegetation was surveyed between September and November 2010. Quantitative vegetation surveys are based on the procedure developed by Nicol and Weedon (2006) for surveys at the Chowilla Icon site in South Australia. As such, this approach is consistent with that used at other floodplain sites including Chowilla Floodplain, Lindsay, Mulcra and Wallpolla Islands and Hattah Lakes and allows for comparisons between the Darling Anabranch and other regionally relevant floodplains.

Transects

Four replicate transects were established at each site. Transects begin in the middle of the channel and extend onto the floodplain at right angles (perpendicular) to the channel. Transects are 50 m apart, alternately extending in the opposite direction to capture both sides of the channel (Figure 2.1).

Quadrats

Quadrats were established at four elevations along each transect (Figure 2.1) using a laser level and staff. Elevation categories are as follows:

- In-channel – as close to the deepest point in the channel as possible. Where sites were flooded and deeper than approximately 1.3 m, the In-channel quadrat was established at 1.3 m depth for logistical reasons. At depths over 1.3 m aquatic plant growth decreases significantly, therefore most aquatic plants are likely to have been detected at this depth. Any aquatic plant growth below 1.3 m would be noted.
- Mid-bank – approximately half-way between the In-channel and Tree-line quadrats.
- Tree-line – approximately in line with the mature tree line, which in this program indicates a relatively consistent long-term water level. It is difficult to determine whether this is a reflection of the regulated system, or the 'natural' system pre-regulation (refer to section 2.3.7 for expansion on this).
- Floodplain – sufficiently higher than the Tree-line quadrat that it would be reasonably expected to receive floodwater only during 'out-of-channel' flood events. Refer to section 2.3.7 for discussion of this.

Each quadrat consists of 15 cells of one metre by one metre (1 m × 1 m). A wooden stake was used to permanently mark the beginning and end of each quadrat and recorded with a hand-held GPS (GDA 94 datum). In each cell, the presence of any plant species was recorded if the plant was alive and its base within the cell. The frequency of occurrence of any plant within the 15 cells provided a semi-quantitative measure of abundance. The selection of 15 cells per quadrat was deemed sufficient based on species area curves (see Nicol and Weedon 2006).

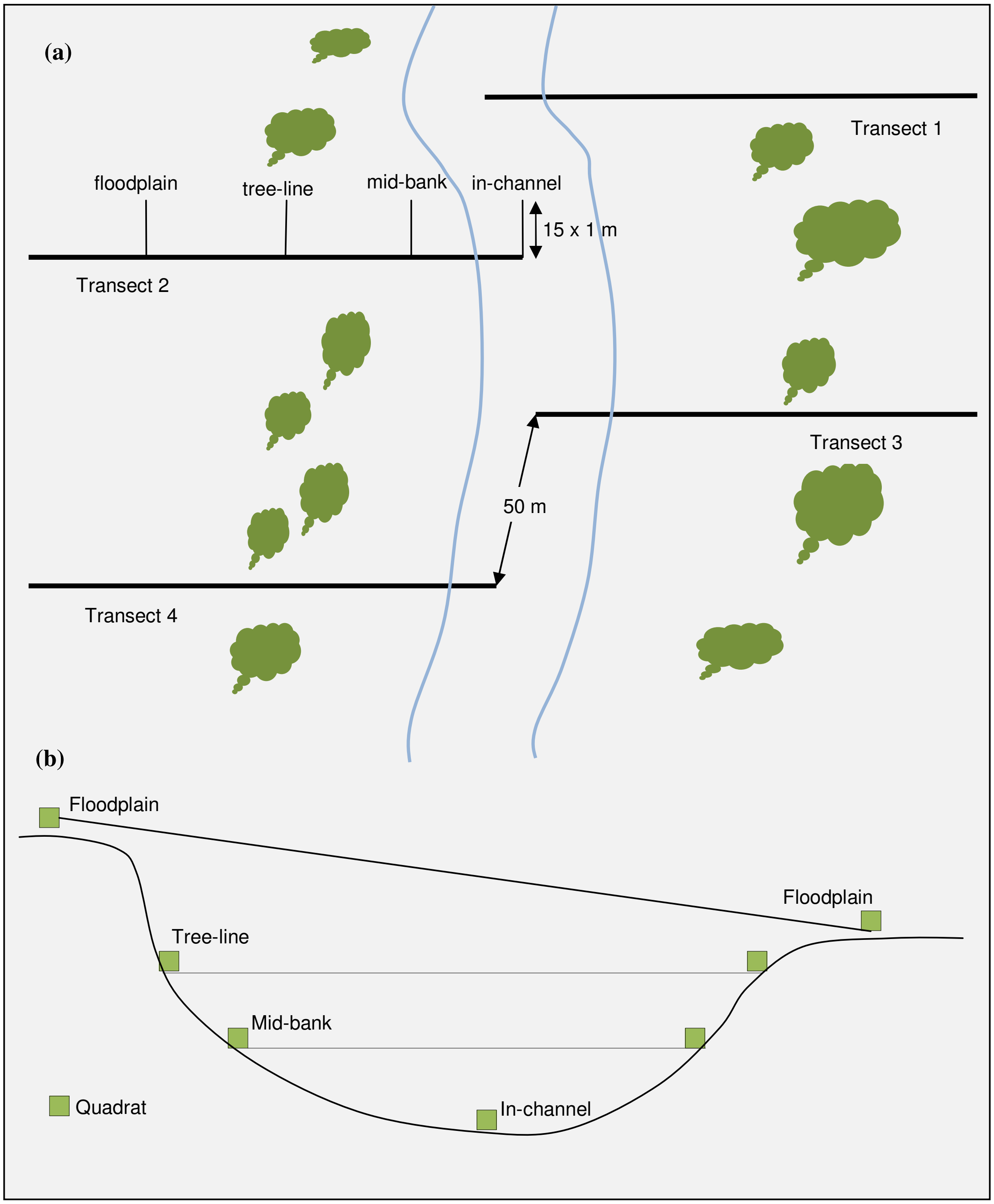


Figure 2.1. (a) Schematic diagram showing layout of understorey vegetation transects and quadrats **(b)** Example of uneven channel morphology common at many of the Darling Anabranch sites.

2.3.2. Photo points

Photo points were established at each site, taken from one of the wooden stakes used to permanently mark the quadrats. The best position was chosen on a site-by-site basis to capture the most representative photo of understorey condition.

The following information was collected from each photo point:

- date and time of photo(s);
- photographers' name(s);
- location (site, transect no., quadrat elevation, GPS location);
- bearing/direction of photo(s);
- height taken at (approx.);
- photo(s) number.

All photographs were taken with a Pentax Optio W20 (7.0 megapixel) digital camera in landscape mode with image quality set to 'HQ', focus set to 'auto', zoom set to 'off/zero' and flash set to 'off'.

2.3.3. Functional groups

The 'functional group' approach has been widely used to assist in interpreting and predicting change in plant community function and dynamics (Brock and Casanova 1997). Minor changes in species composition or inconsistencies in taxonomic resolution over time may affect the ability to detect ecologically significant changes in community structure. The use of functional groups helps detect changes in community structure based on plant responses to water regimes.

Plant species have been classified into one of 16 functional groups (Table 2.12). The classification of species is based upon that of Brock and Casanova (1997) and Reid and Quinn (2004), with the addition of the categories "LL" for leaf litter (> 50% per quadrat), "I" for inundated ground and "Uk" for unknown/unidentified species. Species not recorded by either of those studies were assigned to one of the same set of functional groups based on field observations and information in *Plants of Western New South Wales* (Cunningham et al. 1992). In some circumstances species have been classified broadly (e.g. T, instead of Tdr or Tda). This has occurred where species were identified to genus or family level only. Species unable to be identified due to lack of plant material (e.g. a highly grazed specimen or emergent seedling) were classified as "Uk". Additional categories to Brock and Casanova's (1997) and Reid and Quinn's (2004) functional groups are indicated in Table 2.12.

Table 2.12. Plant functional groups used to classify species recorded along the Darling Anabranch.

Functional group code	Functional group description
S	Submerged plants (do not tolerate drying)
F	Floating, unattached species
AT	Amphibious: fluctuation-tolerating species – emergent species (cope with fluctuations of water presence/absence by enduring the range of water conditions without major change in morphology or growth)
Ate	Species which are mostly monocotyledons (emergent plants that tolerate wetting and drying)
Atl	Species which are dicotyledons and require damp conditions (low growing plants that tolerate wetting and drying)
Atw	Amphibious (woody); flood tolerators, woody species
AR	Amphibious: fluctuation-responder species – floating species (change their growth pattern or morphology in response to the presence/absence of water)
Arf	Species which have floating leaves in their aquatic phases and also grow stranded on damp ground
Arp	Species with various growth characteristics, featuring morphological plasticity
T	Terrestrial plants
Tdr	Terrestrial: dry (terrestrial plants that typically do not tolerate flooding)
Tda	Terrestrial: damp (terrestrial plants that grow in damp places)
A*	Amphibious - species identified to family or genus level only
I*	Inundated ground
LL*	Leaf litter - quadrats with > 50% leaf litter
Uk*	Unknown – unidentified species

* Functional group categories additional to those of Brock and Casanova (1997) and Reid and Quinn (2004)

2.3.4. Data analysis

Microsoft Excel MSTM was used to generate pie graphs for visual representation of functional group data for each site. Multivariate patterns in understorey vegetation community composition and abundance were analysed both by functional groups and by species. Species and group abundances (i.e. total occurrence for each group/species summed over a quadrat of 15 cells) were firstly square root transformed to down-weight the influence of highly abundant species and retain the importance of species that occur infrequently (e.g. rare species). Some "unknown" species were also excluded from the functional group-wise analyses if the functional group could not be determined. A dummy value was added to account for cells that had no species recorded (e.g. bare ground). The Bray-Curtis resemblance measure was then used to generate both a group and a species resemblance matrix, each of which was subjected to permutational multivariate analysis of variance (PERMANOVA) (Anderson et al. 2008).

For assessment of individual sites, the PERMANOVA was based on a one-way design, with the factor Elevation fixed. For between site comparisons, the PERMANOVA was based on a two-way design, with factors Site and Elevation fixed and crossed. Significant (higher-order) interaction effects ($\alpha = 0.05$) were then followed by simple-main effect (pair-wise) tests.

Analysis was performed using 9999 permutations under a reduced model. Significant effects were accepted at $\alpha < 0.05$.

Non-metric multi-dimensional scaling (MDS) was used to visualise overall differences in community composition and abundance (group- and species-wise, as above) between sites and elevations. PERMANOVA and MDS ordinations were generated within the software package PRIMER v6 (Clarke and Gorley 2006) utilising the PERMANOVA+ add in (Anderson et al. 2008).

2.3.5. Plant names

Plants were identified using the *Flora of New South Wales Volumes 1 – 4* (Harden 2000; 2002; 1992; 1993 respectively), *Flora of Victoria Volumes 2 and 3* (Walsh and Entwisle 1994; 1996 respectively), keys and descriptions from the *Flora of New South Wales* (on-line version, http://plantnet.rbgsyd.nsw.gov.au), *Plants of Western New South Wales* (Cunningham et al. 1992) and *Waterplants in Australia* (Sainty and Jacobs 2003). Scientific plant names and common names follow *Flora of New South Wales* (on-line version, http://plantnet.rbgsyd.nsw.gov.au). Asterisks (*) have been used to identify exotic plant species.

2.3.6. Conservation significance

The conservation significance of plant species was determined by reference to listings under the Federal *Environment Protection and Biodiversity Conservation Act 1999* and the New South Wales *Threatened Species Conservation Act 1995*.

2.3.7. Limitations

Quadrat size

Using the sampling method described above, not all plant species occurring at sites will have been captured in the quadrat data. Quadrat size (the use of 15, 1 m × 1 m cells) was determined by species area curves form work done at Chowilla Floodplain in South Australia (see Nicol and Weedon 2006). However, there will be species at low abundances that do not occur in the sampled quadrats.

Season

The seasonality of plant species means that some annuals, or species that complete their life cycles in a short period of time, may not have been present at the time of survey. In addition, some plant species were identified to genus or family level only as insufficient plant material (e.g. seeds, flowers) and/or the growth stage (e.g. emergent seedling, near-dead) prevented their identification to species level. The use of functional groups ameliorates this to a large extent.

Grazing impacts

The impact of grazing may significantly influence the results of the vegetation surveys. Although control sites (e.g. grazing exclosures) could be established, there are financial and logistical constraints associated with this. Consequently, it will be important to liaise with relevant graziers to determine grazing rates at the monitoring sites and to incorporate this information into the analysis and interpretation of the data.

Lack of flood inundation modelling and channel morphology

The objective behind having quadrats at different elevations follows the methodology for floodplain understorey assessments for The Living Murray, where inundation levels are labelled *Very Often*, *Often, Sometimes, Rarely* to reflect the historical frequency of floods of specific magnitudes. Flood magnitudes are defined in The Living Murray methodology for Lindsay, Mulcra and Wallpolla Islands, however, this information is not available for the Darling Anabranch system. The Darling Anabranch quadrats may align with those established for The Living Murray quadrats at the following flood inundation levels:

- Very Often – In-channel;
- Often – Mid-bank;
- Sometimes – Tree-line; and
- Rarely – Floodplain.

Quadrat elevations were chosen based upon visual estimations in the field. Quadrat elevations were consistent between transects within the same site where possible. The methodology works well in situations where both sides of the channel exhibit even morphology. At some sites along the Darling Anabranch system however, cross-section channel morphology was uneven (see Figure 2.1b). This limited the ability at these sites to establish quadrats on either side of the channel at the same elevation, particularly for Floodplain quadrats. It is believed that all floodplain elevations at the time of sampling were "long dry" and therefore valid replicates. Following sustained high flows and above average rainfall in 2010/11 however, these may need to be reviewed prior to the 2011 Condition Monitoring surveys.

In addition, the artificial water regime in the Anabranch from the 1960s until the pipeline was constructed could have impacted upon the ability to accurately assess some of the elevations, for example, where the 'natural' tree-line occurs. Flood inundation modelling would be really helpful to determine the range of flood levels that established floodplain quadrats fall within.

2.4. Lignum

2.4.1. Plant condition

Lignum condition was assessed using the Lignum Condition Index (LCI) (Scholz et al. 2007). This approach is consistent with that used at other floodplain sites including Lindsay, Mulcra and Wallpolla Islands and Hattah Lakes and allows for comparisons between the Darling Anabranch and other regionally relevant floodplains. The LCI consists of two categorical rating scales describing (a) viability: the percentage of above ground plant biomass that is viable (i.e. not dry/dead) and (b) colour: the colour of the viable crown (Table 2.13). The LCI permits the identification of both changes in biomass (growth response) and colour (photosynthetic response) and avoids the need to observe short-term flowering and seed production events.

Ten of the 16 Darling Anabranch monitoring sites had Lignum present. At each of these 10 sites, 30 Lignum plants were selected to maximise spatial coverage and encapsulate the elevational distribution of Lignum communities along the system. Each plant was tagged with a unique number and its position recorded with a hand-held GPS unit. Lignum condition was assessed for each tagged plant between September and November 2010. Sites 5 and 6 were inundated by the environmental flow at the time of survey and sites 2 and 3 were inundated by flood waters from the Darling River. The remaining six sites were assessed before the environmental flow released from Lake Cawndilla in September 2010 had reached them.

Table 2.13. The Lignum Condition Index (LCI) used to assess Lignum plant condition.

Viability		Colour	
Score	**% Viable**	**Score**	**Colour of viable crown**
6	> 95		
5	75 < x ≤ 95	5	All green
4	50 < x ≤ 75	4	Mainly green
3	25 < x ≤ 50	3	Half green, half yellow/brown
2	5 < x ≤ 25	2	Mainly yellow/brown
1	0 < x ≤ 5	1	All yellow/brown
0	0%	0	No viable stems

2.4.2. Statistical analyses

Percent viability of stems and stem colour was used to assess Lignum condition, with the presence of flowering recorded as an additional variable. Lignum condition was assessed at 10 sites (n = 30 plants at each site) and as this is the first year of monitoring, overall baseline condition of Lignum is presented along with site comparisons. Average scores across the 30 plants at each site were graphed using SigmaPlot and data was analysed using the statistical software package PRIMER v6 utilising the PERMANOVA+ add in (Anderson et al. 2008). Differences in condition (using the variables percent viable and colour) between sites were analysed by permutational ANOVA (PERMANOVA) with the factor "site" fixed. Analysis was performed using 9999 permutations using unrestricted permutation of raw data. Significant effects were accepted at $\alpha < 0.05$, with *a posteriori* pair-wise comparisons run if the main test was significant. Differences between site average scores were visualised using multidimensional scaling (MDS) with the variables percent viable, colour and flowering displayed as vectors.

2.5. *Typha*

Live stands of *Typha* species (*T. domingensis* and *T. orientalis*) were observed at only three of the 16 monitoring sites assessed between September and November 2010. The size and location of each *Typha* stand was recorded with a hand-held GPS unit by tracking around the stand perimeter, either on foot or where water was too deep, in a canoe. The density of *Typha* within the stands was classified according to categories in Table 2.14. These categories are denoted within the document as **SPARSE**, **MEDIUM** and **DENSE**.

Table 2.14. Categories used to describe density of *Typha* plants within stands.

Category	Percentage cover of plants
Sparse	1 – 15
Medium	> 15 to 65
Dense	> 65

Maps were produced for each *Typha* stand using ArcGIS 9.3. Overlaid maps in subsequent years will allow changes in *Typha* distribution to be measured.

2.5.1. Limitations

Monitoring sites are given an arbitrary boundary, based around all components monitored in the Condition Monitoring program. *Typha* distribution is mapped within this boundary; however, it is acknowledged that stands may be continuous outside the site boundary.

No distinction is made between the two species of *Typha* likely to occur along the Darling Anabranch system. It is unknown if there is a difference in expansion rates between the two species or if they function differently in terms of flow restriction, barriers to fish movement or meeting different habitat requirements for birds and other animals. Spatial accuracy limitations are evident with the hand-held GPS units used in the field to measure the distance of some stands (± *c.* 4 m for each stand endpoint measured). It is not believed that any of these limitations will substantially alter the results.

3. Individual Site Results

The data presented in this section represents the first round of Condition Monitoring on the Darling Anabranch system; hence the level of analysis and interpretation is limited to within and between sites (no year-to-year comparisons). This section presents a summary of results for each site. For presentation and discussion of results for the Darling Anabranch system as a whole refer to section 4.

3.1. Site 1

Site location and description

Site 1 is located on Whurlie Station, on the Old Darling Anabranch, close to its offtake from the Darling River.

Site 1 was unable to be reached during the first year of Condition Monitoring due to wet weather and high flows in the Darling River and the Old Darling Anabranch.

3.2. Site 2

Site location and description

Site 2 is located on the south side of the Old Darling Anabranch on Wycot Station. The site is dominated by grey clay soils; the channel is narrow and anastomising. The dominant tree species is Black Box (BB) (*Eucalyptus largiflorens*) with River Cooba (RC) (*Acacia stenophylla*) (mostly dead) present along the edge of the channel (Figure 3.1).

Tree condition and NOM load

Species and size: All trees assessed at site 2 were BB. DBH ranged from less than 20 cm to a maximum of 105 cm (Figure 3.2a); mean DBH is 50 cm.

Tree Condition Variables: Most trees scored between 40 and 60% for both crown extent and crown density (Figure 3.2b); mean percentages are 50 and 52 respectively. The mean Tree Condition Index is 8 (**STRESSED**).

Response Variables: All trees displayed new tip growth (mean score = 1) and all but one supported epicormic growth (mean score = 1). Die-off was evident on the majority of trees (29; mean score = -1). The majority of trees (23) exhibited **SCARCE** reproduction (mean score = 1) with seven trees showing no visible signs of reproduction.

NOM load: NOM load was **LOW** for most trees (mean = 846 gm^{-2}), with two trees scoring **MODERATE** and one **HIGH** (Figure 3.3).

Lignum condition

No Lignum was recorded at site 2.

Typha distribution

No *Typha* was recorded at site 2.

Understorey

A total of 59 understorey plant species were recorded at site 2 (Table 3.1), 89% of which belong to terrestrial functional groups (FGs) and only 7% of which belong to amphibious FGs (Figure 3.4). *Tetragonia* sp. and *Atriplex eardleyae* were the most abundant native species with *Rostraria pumila** being the most abundant introduced species.

In-channel and Mid-bank quadrats were not assessed due to fast-flowing deep flood waters. Floodplain (FP) quadrats recorded a higher abundance of native and total species (42 and 45 respectively; Table 3.1) than Tree-line (TL) quadrats (32 and 36 respectively; Table 3.1). There was no significant difference in species composition between FP and TL quadrats (P = 0.0554).

Figure 3.1. Photo point for site 2 (D. Chapman, MDFRC, 3/11/2010).

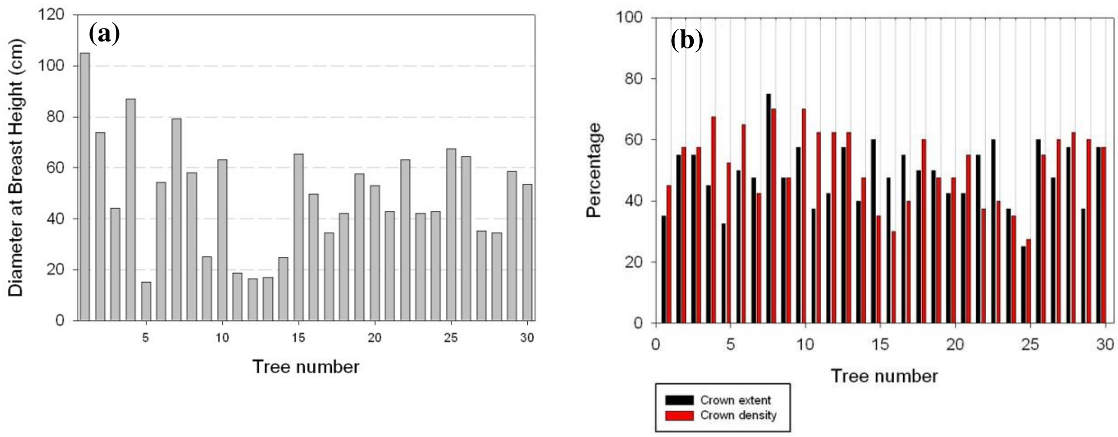
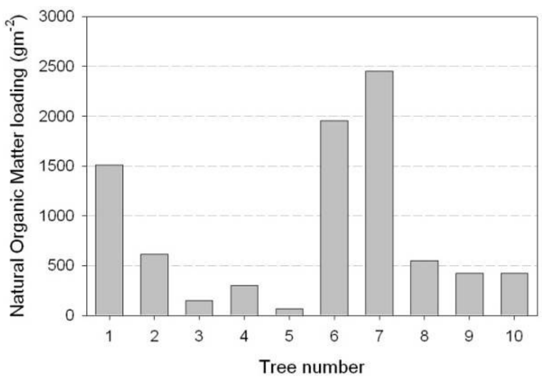


Figure 3.2. **(a)** DBH for all trees assessed at site 2. Grey bars are Black Box. **(b)** Crown extent and crown density for all trees assessed at site 2.



No Lignum
recorded at this site

Figure 3.3. NOM for all trees assessed at site 2. Grey bars are Black Box.

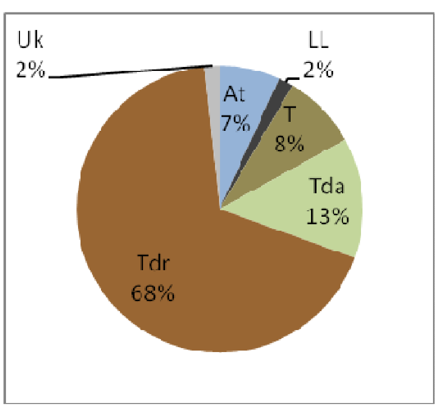


Figure 3.4. Pie chart displaying proportion of understorey plant species in broad functional groups for site 2. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; LL=Leaf litter; At=Amphibious tolerator; Uk=Unknown.

Table 3.1. Understorey plant species diversity recorded at site 2.

Elevation	Native species	Exotic species	Total species
In-channel	Not assessed		
Mid-bank	Not assessed		
Tree-line	32	4	36
Floodplain	42	3	45
Total	52	7	59

3.3. Site 3

Site location and description

Site 3 is located east of the Junction Dam on the Old Darling Anabranch on Wycot Station. The site is dominated by grey clay soils with a shallow anastomising channel. The dominant tree species is Black Box (BB) (*Eucalyptus largiflorens*) with River Cooba (RC) (*Acacia stenophylla*) (mostly dead) present along the edge of the channel (Figure 3.5).

Tree condition and NOM load

Species and size: Twenty-eight BB trees and two RC trees were assessed. DBH ranged from less than 20 cm to a maximum of 90 cm (Figure 3.6a). The mean DBH is 34 cm.

Tree Condition Variables: Most trees scored between 40 and 60% for both crown extent and crown density (Figure 3.6b); mean percentages are 55 and 51 respectively. Mean Tree Condition Index was 8.20 (**STRESSED**).

Response Variables: New tip growth was visible on 11 of the 30 trees (mean score = 1), with all trees supporting epicormic growth (mean score = 1). Die-off was evident on the majority of trees (27; mean score = -1). Reproduction was clearly visible on the majority of trees (26) (mean score = 2). Two trees clearly displayed the effects of mistletoe (mean score = -2).

NOM load: NOM load was **HIGH** to **VERY HIGH** for the majority of trees, the River Coobas scored **VERY LOW** (Figure 3.7a). Mean NOM was 2 614 gm^{-2}.

Lignum condition

Lignum condition was poor across the site, with many plants scoring 0 (Figure 3.7b). Mean Lignum viability score was 1 ($0 < x \leq 5\%$ viable) and colour score was also 1 (all yellow brown). No flowering was observed.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 43 species were recorded (Table 3.2); 83% of these belong to terrestrial functional groups (FGs) and 10% belong to amphibious FGs (Figure 3.8). *Tetragonia* sp. and *Sclerolaena muricata* var. *muricata* were the most abundant native species with *Herniaria cinerea** being the most abundant introduced species.

In-channel and Mid-bank quadrats were not assessed due to fast-flowing deep flood waters. There was no significant difference in species composition between Floodplain (FP) and Tree-line (TL) elevations (P = 0.6498).

Figure 3.5. Photo point for site 3 (D. Bogenhuber, MDFRC, 2/11/10).

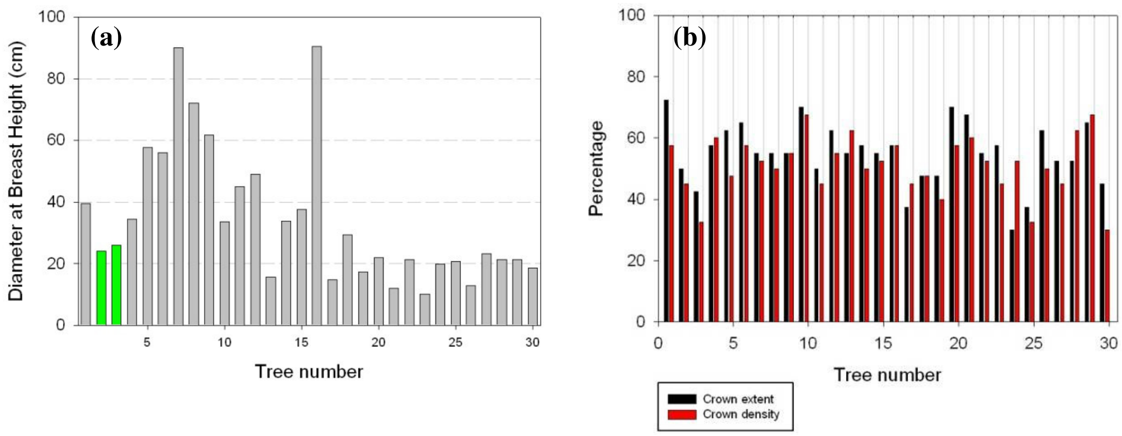


Figure 3.6. **(a)** DBH for all trees assessed at site 3. Grey is Black Box, green is River Cooba. **(b)** Crown extent and crown density for all trees assessed at site 3.

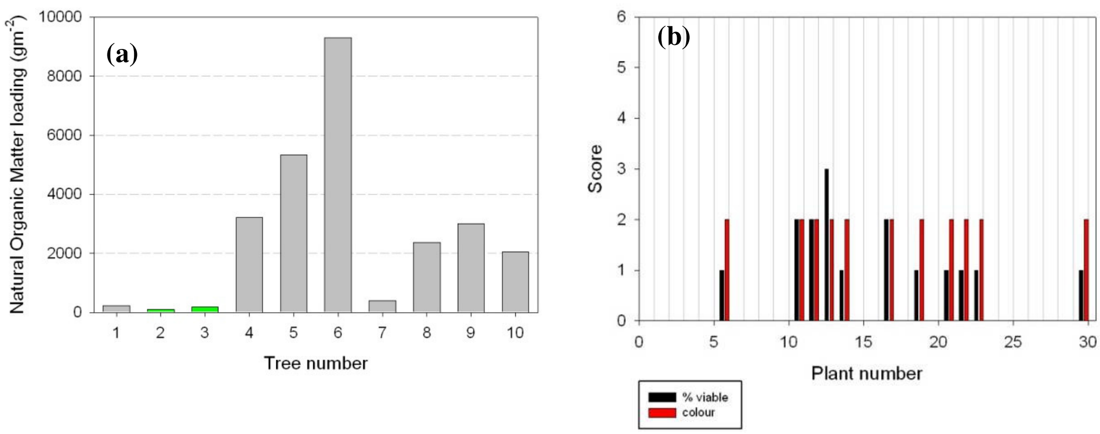


Figure 3.7. NOM for all trees assessed at site 3. Grey is Black Box, green is River Cooba. **(b)** Lignum viability and colour scores for all plants assessed at site 3.

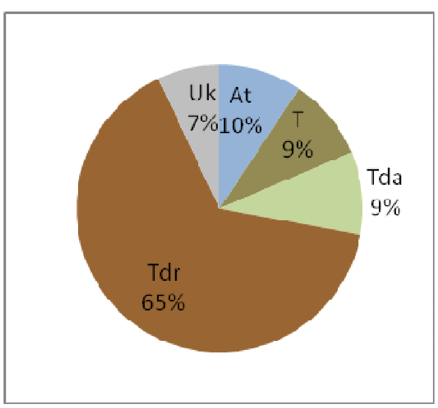


Figure 3.8. Pie chart displaying proportion of understorey plant species in broad functional groups for site 3. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Uk=Unknown.

Table 3.2. Understorey plant species diversity recorded

Elevation	Native species	Exotic species	Total species
In-channel	Not assessed		
Mid-bank	Not assessed		
Tree-line	24	4	28
Floodplain	29	5	34
Total	37	6	43

3.4. Site 4

Site location and description

Site 4 is located on Redbank Creek, upstream of Junction Dam on Wycot Station. The site is dominated by grey clay soils; the channel is wide and relatively shallow (Figure 3.9). Black Box (BB) (*Eucalyptus largiflorens*) is the dominant tree species along the channel.

Tree condition and NOM load

Species and size: All trees assessed were BB. Most trees had relatively small DBHs of less than 20 cm, the maximum DBH is 103 cm (Figure 3.10a). The mean DBH of trees is 27 cm.

Tree Condition Variables: Both crown extent and crown density varied considerably, however, was never above 80% for either variable (Figure 3.10b); mean percentages are 42 and 53 respectively. Mean Tree Condition Index was 7.57 (**STRESSED**).

Response Variables: New tip growth was visible on 16 of the 30 trees (mean score = 1); 28 trees supported epicormic growth (mean score = 1). Die-off was evident on all trees (mean score = -1). Reproduction was **SCARCE** for the majority of trees (26) (mean score = 1).

NOM load: NOM load was **VERY HIGH** for most trees (mean = 4 150 gm^{-2}) (Figure 3.11a).

Lignum condition

Lignum condition was poor across the site, with nearly one third of plants scoring 0 (Figure 3.11b). Mean percentage viability for Lignum was 1 ($0 < x \leq 5\%$ viable) and mean colour score was 1 (all yellow brown). There was evidence that plants had recently flowered.

Typha distribution

No *Typha* was recorded at site 4.

Understorey

A total of 100 species were recorded, 83% belong to terrestrial functional groups (FGs) and 12% to amphibious FGs (Figure 3.12). *Ranunculus pentandrus* var. *platycarpus* and *Poa* sp.[#] were the most abundant native species and *Medicago* sp.* and *Sisymbrium erysimoides** were the most abundant introduced species. *Marrubium vulgare** was recorded at this site and is classified as a Class 4 locally controlled weed under the *Noxious Weed Act 1993* (NSW).

Mid-bank (MB) quadrats recorded the highest number of native species (57; Table 3.3). The In-channel elevations were significantly different to all other elevations (MB, Tree-line and Floodplain) in terms of species composition (P = 0.0289, P = 0.0264 and P = 0.059 respectively). No other significant differences were observed (P ≥ 0.0551).

Figure 3.9. Photo point for site 4 (D. Bogenhuber, MDFRC, 23/9/2010).

[#] Identification to be confirmed.

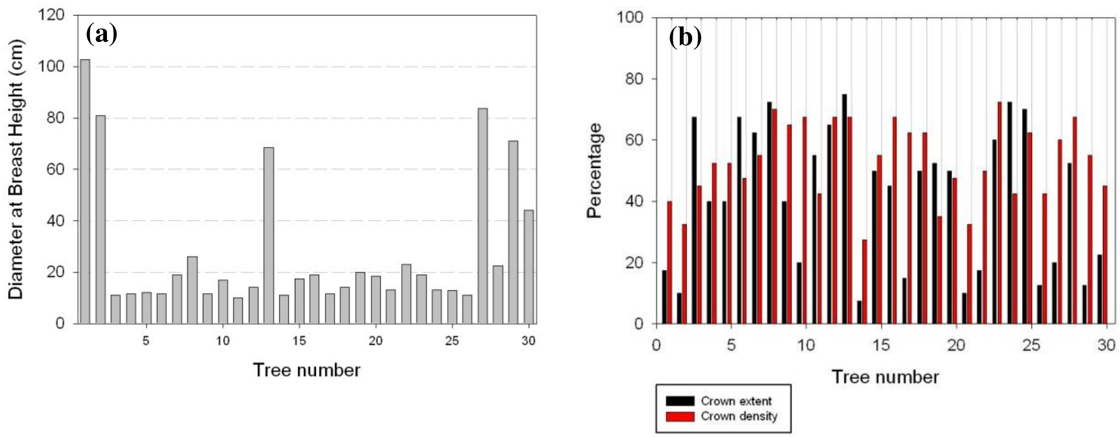


Figure 3.10. **(a)** DBH for all trees assessed at site 4. Grey bars are Black Box. **(b)** Crown extent and crown density for all trees assessed at site 4.

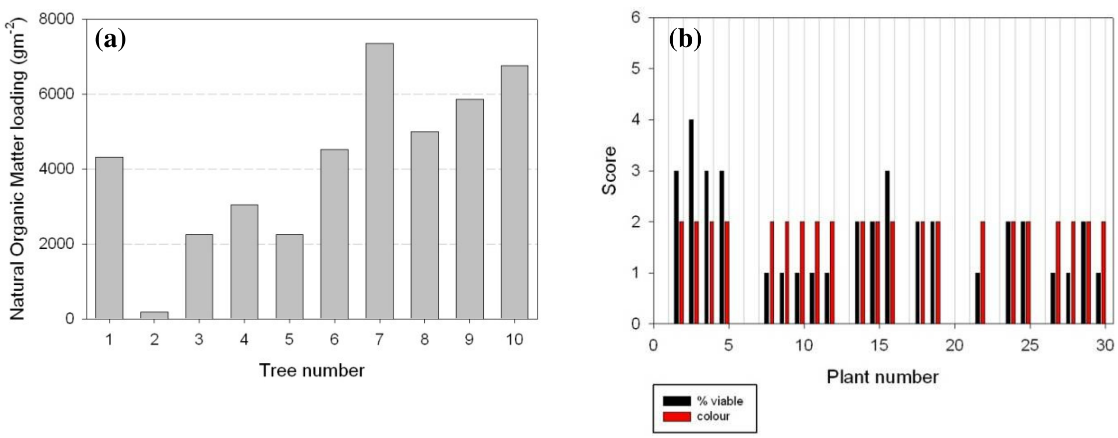


Figure 3.11. **(a)** NOM for all trees assessed at site 4. Grey bars are Black Box. **(b)** Lignum viability and colour scores for all plants assessed at site 4.

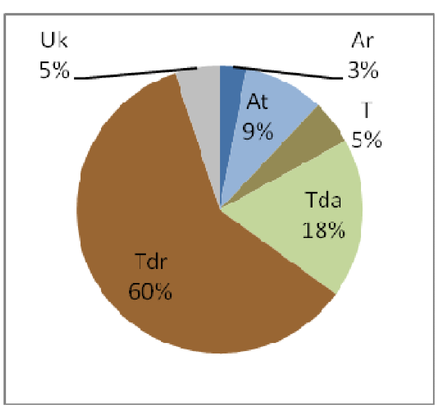


Figure 3.12. Pie chart displaying proportion of understorey plant species in broad functional groups for site 4. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Ar=Amphibious responder; Uk=Unknown.

Table 3.3. Understorey plant species diversity recorded at site 4.

Elevation	Native species	Exotic species	Total species
In-channel	23	2	25
Mid-bank	57	8	65
Tree-line	49	5	54
Floodplain	43	3	46
Total	90	10	100

3.5. Site 5

Site location and description

Site 5 is located on Redbank Creek, just downstream of Packers Crossing on Tandou Station. The site is dominated by grey clay soils and the channel is wide and flat. The main channel and flood runners were inundated at the time of surveying (Figure 3.13). Black Box (BB) (*Eucalyptus largiflorens*) and River Red Gum (RRG) (*Eucalyptus camaldulensis*) are co-dominant along the edge of the channel, with BB extending onto the floodplain.

Tree condition and NOM load

Species and size: 17 BB and 13 RRG were assessed. DBH varied across the site, with a mean of 28 cm; the maximum DBH is 67 cm (Figure 3.14a).

Tree Condition Variables: Crown extent and crown density was generally low across the site particularly for RRG (Figure 3.14b); mean percentages are 49 and 50 respectively. The mean Tree Condition Index was 7.67 (**STRESSED**).

Response Variables: New tip growth was visible on 25 trees (mean score = 1); 21 trees supported epicormic growth (mean score = 1). Die-off was evident on the majority of trees (26; mean score = -1). Reproductive extent was **SCARCE** on most trees (24) (mean score = 1).

NOM load: NOM load was mostly **VERY HIGH** (mean = 5 535 gm^{-2}), with one tree (RRG) recording over 16 000 gm^{-2} (Figure 3.15a).

Lignum condition

Lignum viability and colour scores were mostly between 2 and 4 (Figure 3.15b); mean scores were 3 for both variables ($25 < x \leq 50\%$ viable; all yellow brown). Flowering was observed.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 57 species were recorded, 91% belong to terrestrial functional groups (FGs), 3% to amphibious FGs and 2% (*Lemna* sp.) to floating FGs (Figure 3.16). *Zygophyllum ammophilum* was the most abundant native species and *Sisymbrium erysimoides** the most abundant introduced species.

The highest number of native species (36) was recorded at Floodplain elevations (Table 3.4). No species were recorded at In-channel (IC) elevations, which were inundated to approximately 1.3 m at the time of survey. There were significant differences in species composition between all elevations ($P \leq 0.0312$) except IC and Mid-bank ($P = 0.8897$).

Figure 3.13. Photo point for site 5 (D. Bogenhuber, MDFRC, 21/9/2010).

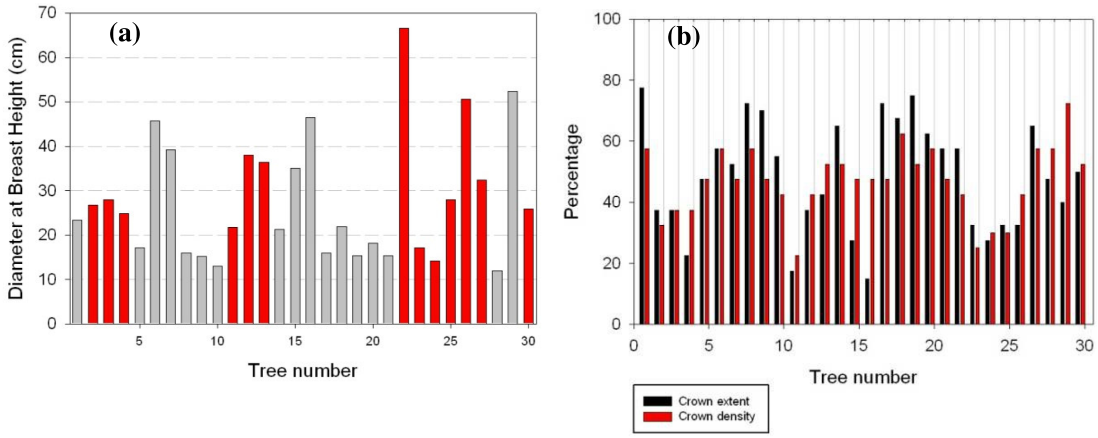


Figure 3.14. **(a)** DBH for all trees assessed at site 5. Grey is Black Box, red is River Red Gum. **(b)** Crown extent and crown density for all trees assessed at site 5.

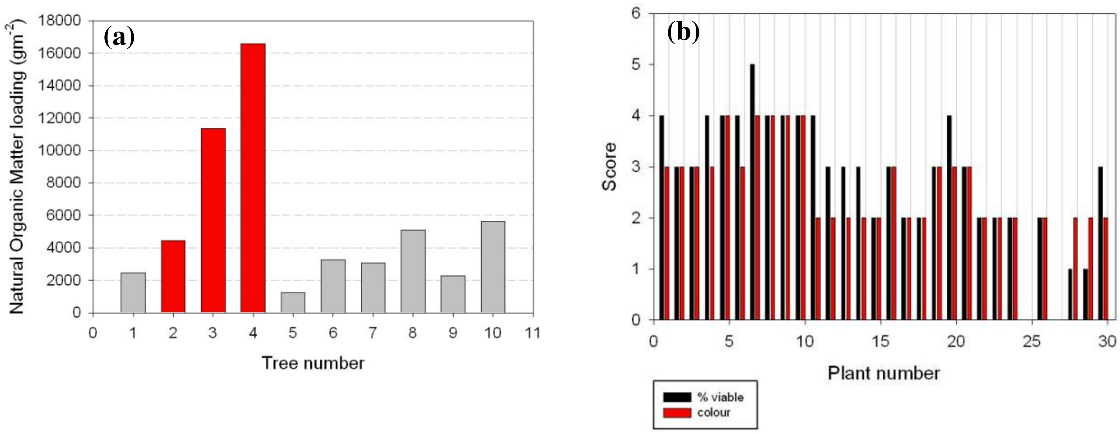


Figure 3.15. **(a)** NOM for all trees assessed at site 5. Grey is Black Box, red is River Red Gum. **(b)** Lignum viability and colour scores for all plants assessed at site 5.

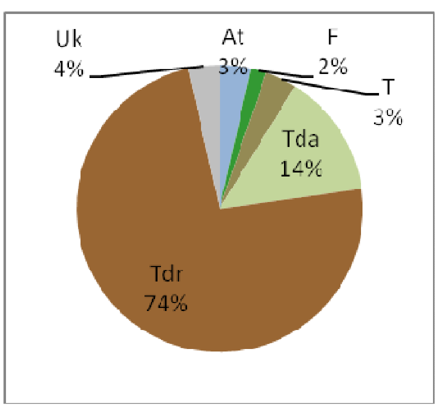


Figure 3.16. Pie chart displaying proportion of understorey plant species in broad functional groups for site 5. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; F=Floating; At=Amphibious tolerator; Uk=Unknown.

Table 3.4. Understorey plant species diversity recorded at site 5.

Elevation	Native species	Exotic species	Total species
In-channel	0	0	0
Mid-bank	4	2	6
Tree-line	27	4	31
Floodplain	36	6	42
Total	48	9	57

3.6. Site 6

Site location and description

Site 6 is located on Tandou Creek, at the Woolshed crossing on Tandou Station. The site is dominated by grey clay soils; the channel is wide and flat (Figure 3.17). The dominant tree species is Black Box (BB) (*Eucalyptus largiflorens*).

Tree condition and NOM load

Species and size: All trees assessed at site 6 were BB. Approximately two thirds had a DBH less than 20 cm (Figure 3.18a). The mean DBH is 25 cm; the maximum DBH is 70 cm.

Tree Condition Variables: Crown extent and crown density was relatively good, with most trees scoring between 60 and 80% for both variables (Figure 3.18b); mean percentages were 71 and 70 respectively. The mean Tree Condition Index was 9.90 (**STRESSED**).

Response Variables: New tip growth was visible on 11 of the 30 trees (mean score = 1); 24 trees supported epicormic growth (mean score = 1). Die-off was evident on most trees (22; mean score = -1). Reproductive extent was clearly visible on most trees (29; mean score = 2).

NOM load: NOM load was **HIGH** to **VERY HIGH** (mean = 3383 gm^{-2}) (Figure 3.19a).

Lignum condition

Plants scored very high for both viability and colour, with many receiving maximum scores (Figure 3.19b). Mean Lignum viability score was 5 ($75 < x \leq 95\%$ percentage viable) and 4 for colour (mainly green). Flowering was observed at this site.

Typha distribution

Scattered individual *Typha* plants and stands of up to 11 plants were recorded at site 6, as well as two larger 'stands' of *Typha*. Plant cover in the northern stand was 1 to 5% and 15 to 20% in the stand to the south. Figure 4.15 in section 4.6 shows *Typha* distribution at site 6.

Understorey

A total of 55 species were recorded, 93% of which belong to terrestrial functional groups (FGs) and 7% to amphibious FGs (Figure 3.20). *Calotis* sp. and *Atriplex eardleyae* were the most abundant native species and *Medicago* sp.* was the most abundant introduced species.

Only two species were recorded for In-channel (IC) and Mid-bank (MB) quadrats (*Eucalyptus largiflorens* and *Muehlenbeckia florulenta*) (Table 3.5), which were inundated to 1.3 and 0.65 m respectively at the time of survey. There were significant differences in species composition between IC and Tree-line (TL), IC and Floodplain (FP), MB and TL and MB and FP ($P \leq 0.0293$).

Figure 3.17. Photo point for site 6 (D. Bogenhuber, MDFRC, 22/9/2010).

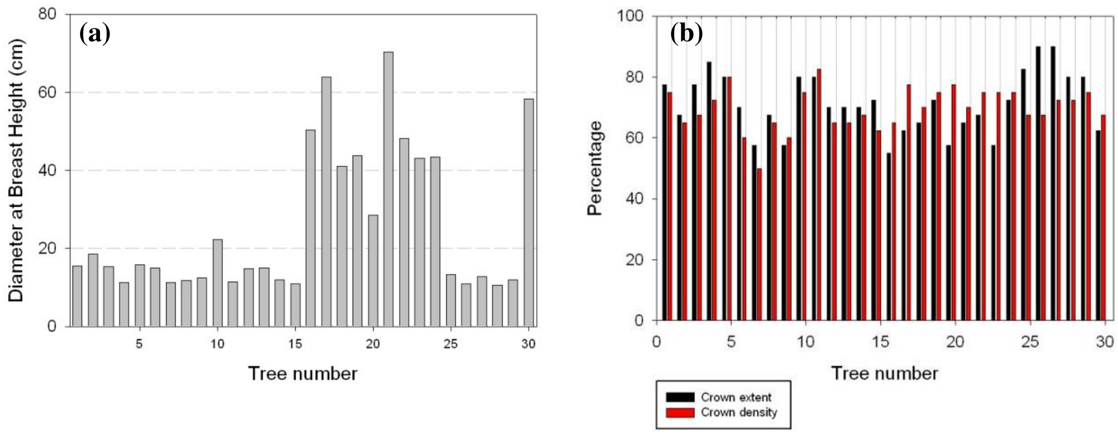


Figure 3.18. (a) DBH for all trees assessed at site 6. Grey bars are Black Box. **(b)** Crown extent and crown density for all trees assessed at site 6.

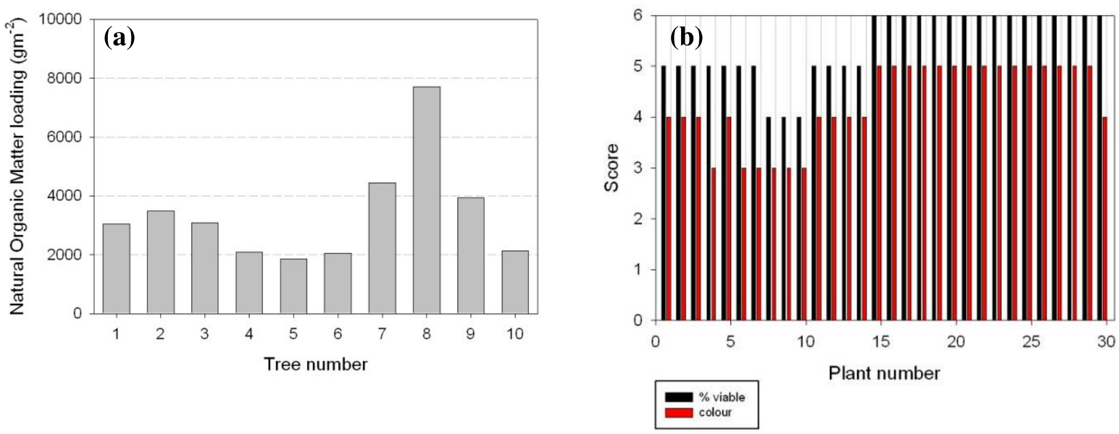


Figure 3.19. (a) NOM for all trees assessed at site 6. Grey bars are Black Box. **(b)** Lignum viability and colour scores for all plants assessed at site 6.

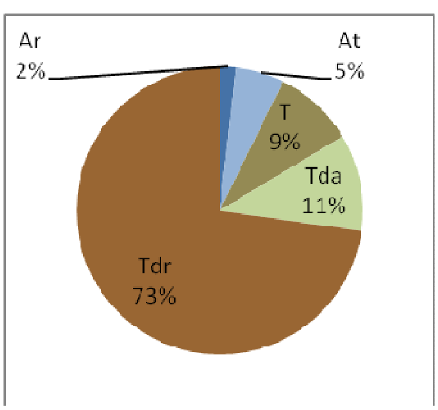


Figure 3.20. Pie chart displaying proportion of understorey plant species in broad functional groups for site 6. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Ar=Amphibious responder.

Table 3.5. Understorey plant species diversity recorded at site 6.

Elevation	Native species	Exotic species	Total species
In-channel	2	0	2
Mid-bank	2	0	2
Tree-line	38	2	40
Floodplain	33	3	36
Total	51	4	55

3.7. Site 7

Site location and description

Site 7 is located at Hunters Waterhole on Woodlands Station. The site is characterised by red sandy loam soils. The Anabranch channel is narrow and incised with deep waterholes. At the time of conducting these surveys, these sites were retaining water > 2 m deep from recent rainfall events. Black Box (BB) (*Eucalyptus largiflorens*) and River Red Gum (RRG) (*Eucalyptus camaldulensis*) occur on the steep banks (Figure 3.21).

Tree condition and NOM load

Species and size: Trees assessed consisted of 21 BB and 9 RRG. DBH varied, with no very large trees recorded (maximum DBH = 58 cm; Figure 3.22a); mean DBH is 26 cm.

Tree Condition Variables: Crown extent and crown density were mostly below 50% (Figure 3.22b); mean percentages are 41 and 42 respectively. Mean Tree Condition Index was 6.93 (**STRESSED**).

Response Variables: Both new tip and epicormic growth occurred on 29 of 30 trees, with mean scores of 2 and 1 respectively. Die-off was evident on the majority of trees (29; mean score = -1). Reproductive extent was clearly visible on most trees (28; mean score = 2).

NOM load: NOM load was **LOW** (mean = 754 gm^{-2}), RRGs recorded the highest loadings, however, these are still **MODERATE** (Figure 3.23a).

Lignum condition

No Lignum was recorded at this site.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 73 species were recorded, with 80% belonging to terrestrial functional groups (FGs), 15% belonging to amphibious FGs and 1% (*Lemna* sp.) belonging to the floating FG (Figure 3.24). *Tetragonia* sp. was the most abundant native species and *Sisymbrium erysimoides** was the most abundant introduced species.

Floodplain (FP) elevations were most abundant in both native and exotic species (35 and 9 respectively; Table 3.6). In-channel quadrats recorded only one native species (mature RRG) and were surveyed at 1.3 m depth. *Emex australis**, a Class 4 locally controlled weed under the *Noxious Weed Act 1993* (NSW) was recorded here. All pair-wise comparisons between elevations recorded significant differences in species composition ($P \leq 0.0001$).

Figure 3.21. Photo point of site 7 (D. Bogenhuber, MDFRC, 30/9/2010).

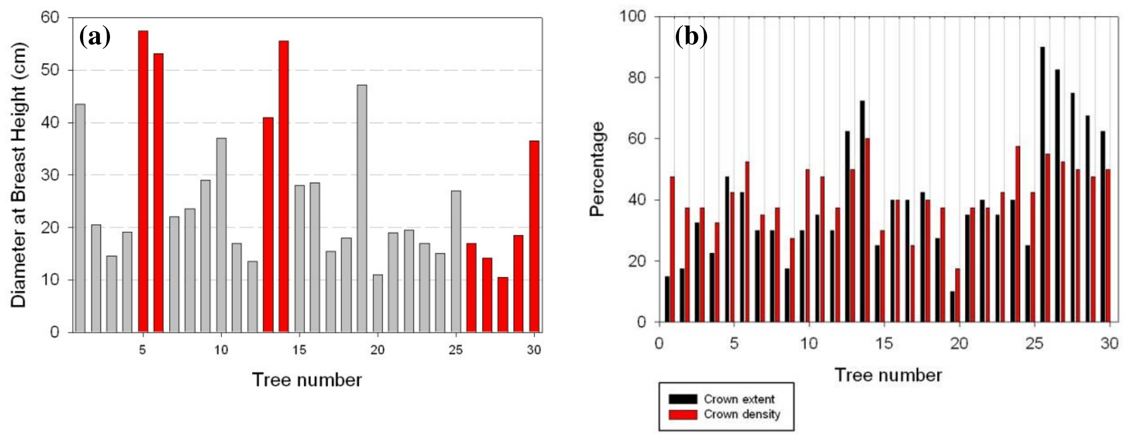
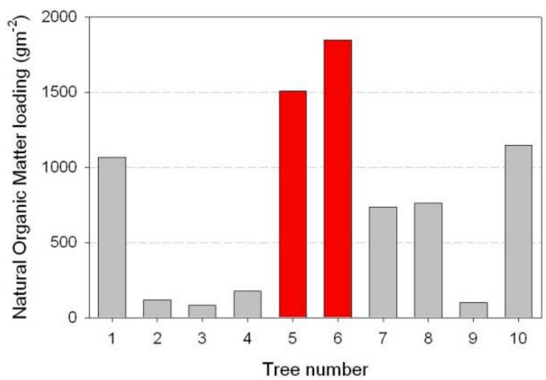


Figure 3.22. (a) DBH for all trees assessed at site 7. Grey is Black Box, red is River Red Gum. **(b)** Crown extent and crown density for all trees assessed at site 7.



No Lignum

recorded at this site

Figure 3.23. NOM for all trees assessed at site 7. Grey is Black Box, red is River Red Gum.

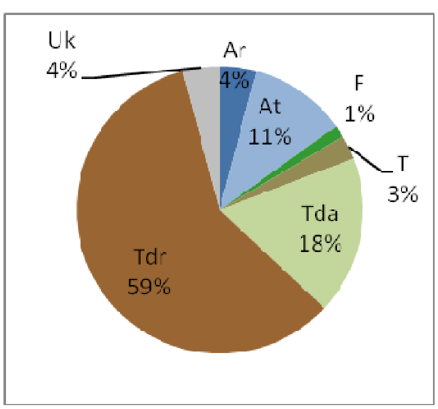


Figure 3.24. Pie chart displaying proportion of understorey plant species in broad functional groups for site 7. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; F=Floating; At=Amphibious tolerator; Ar=Amphibious responder; Uk=Unknown.

Table 3.6. Understorey plant species diversity recorded at site 7.

Elevation	Native species	Exotic species	Total species
In-channel	1	0	1
Mid-bank	29	4	33
Tree-line	31	7	38
Floodplain	35	9	44
Total	63	10	73

3.8. Site 8

Site location and description

Site 8 is located upstream of Stoney Crossing on the Darling Anabranch on Windamingle Station. It is dominated by grey clay soils; the channel is wide and flat (Figure 3.25). Water was lying on floodplain shelves, presumably runoff from localised rainfall. Black Box (BB) (*Eucalyptus largiflorens*) and River Cooba (RC) (*Acacia stenophylla*) line the channel.

Tree condition and NOM load

Species and size: Trees assessed consisted of 26 BB and 4 RC. RCs had the lowest DBH, the majority of BB were between 40 and 60 cm and the maximum DBH is 105 cm (Figure 3.26a). The mean DBH is 49 cm.

Tree Condition Variables: Crown extent and crown density varied considerably across the site, with RC scoring well for crown extent (Figure 3.26b); mean percentages were 48 and 53 respectively. The mean Tree Condition Index was 8 (**STRESSED**).

Response Variables: New tip growth was visible on 12 of the 30 trees (mean score = 1), with 21 trees supporting epicormic growth (mean score = 1). Die-off was evident on most trees (28; mean score = -1). Reproduction was clearly visible on most trees (29; mean score = 2).

NOM load: NOM load was **HIGH** to **VERY HIGH** (mean = 3763 gm^{-2}; Figure 3.27a).

Lignum condition

Lignum colour was consistent across the site, most plants scoring 2, viability ranged from 1 to 4 (Figure 3.27b). Mean viability score was 2 ($5 < x \leq 25\%$ viable) and mean colour score also 2 (mainly yellow brown). There was evidence that plants had recently flowered.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 85 species were recorded, 92% of which are in terrestrial functional groups (FGs), and 6% in amphibious FGs (Figure 3.28). *Poa* sp.[#] was the most abundant native species, with *Medicago* sp.* being the most abundant introduced species.

All except In-channel (IC) quadrats recorded relatively high native and total species richness (Table 3.7). IC quadrats recorded only seven species (all native). There were significant differences in species composition between IC and Mid-bank, IC and Tree-line and IC and Floodplain quadrats (P = 0.0.0274, P = 0.0289 and P = 0.0307, respectively).

Figure 3.25. Photo point for site 8 (D. Bogenhuber, MDFRC, 28/9/2010).

[#] Identification to be confirmed

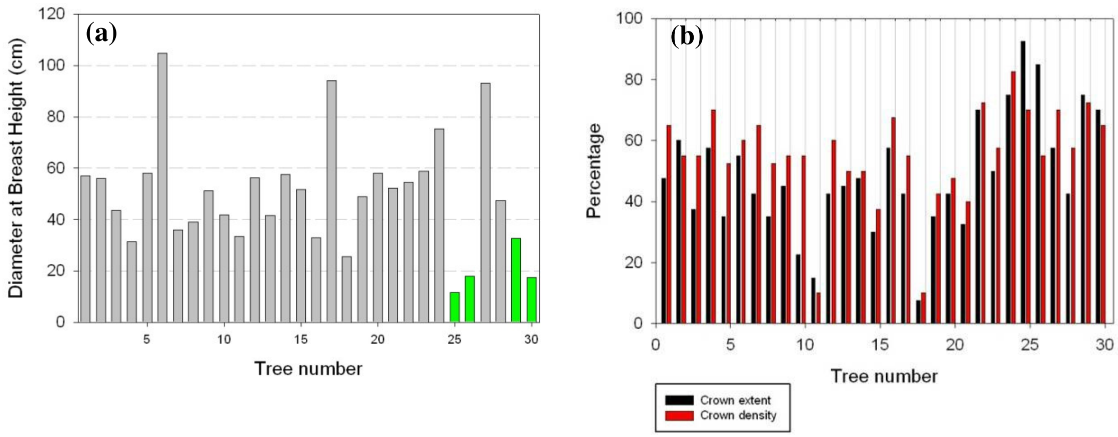


Figure 3.26. **(a)** DBH for all trees assessed at site 8. Grey is Black Box, green is River Cooba. **(b)** Crown extent and crown density for all trees assessed at site 8.

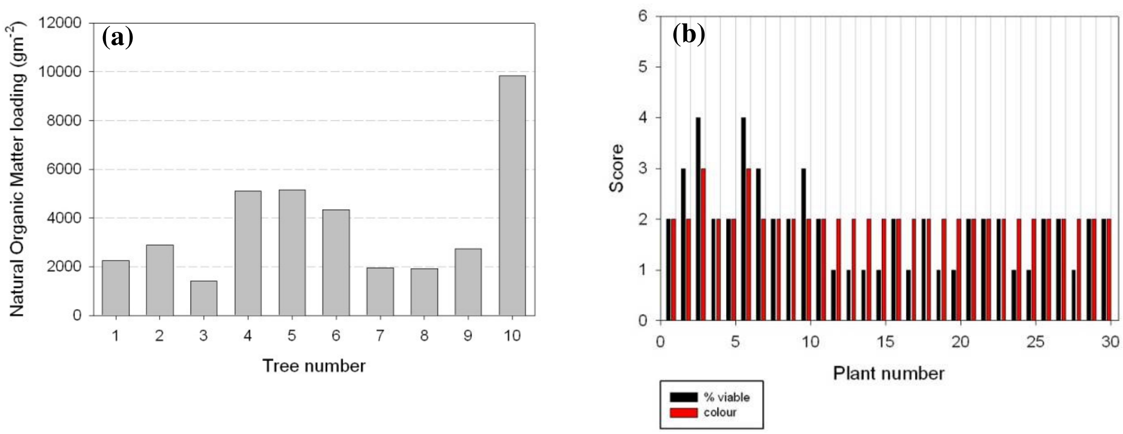


Figure 3.27. **(a)** NOM for all trees assessed at site 8. Grey bars are Black Box. **(b)** Lignum viability and colour scores for all plants assessed at site 8.

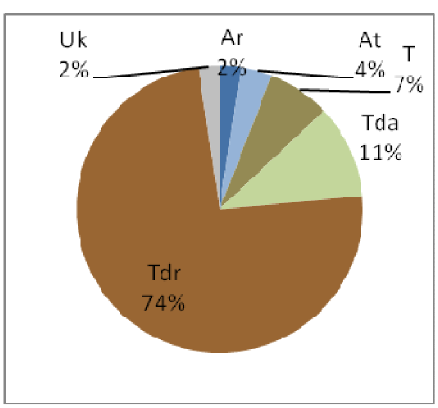


Figure 3.28. Pie chart displaying proportion of understorey plant species in broad functional groups for site 8. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Ar=Amphibious responder; Uk=Unknown.

Table 3.7. Understorey plant species diversity recorded at site 8.

Elevation	Native species	Exotic species	Total species
In-channel	7	0	7
Mid-bank	47	7	54
Tree-line	51	8	59
Floodplain	51	5	56
Total	75	10	85

3.9. Site 9a

Site location and description

Site 9a is located on the upstream side of Dam 183, Wyndham Station. The site is dominated by grey clay soils; the Anabranch channel is wide and undulating to depths > 2 m (Figure 3.29). Black Box (BB) (*Eucalyptus largiflorens*) is the dominant tree species.

Tree condition and NOM load

Species and size: All trees assessed were BB. Most trees had a DBH less than 40 cm, the maximum DBH is 107 cm (Figure 3.30a). The mean DBH is 32 cm.

Tree Condition Variables: Crown extent and crown density were fairly consistent, with crown extent slightly higher in most trees (Figure 3.30b); mean percentages are 68 and 61 respectively. The mean Tree Condition Index of assessed trees was 9.47 (**STRESSED**).

Response Variables: New tip growth was visible on 23 of the 30 trees (mean score = 1); 25 trees supported epicormic growth (mean score = 1). Die-off was evident on the majority of trees (26; mean score = -1). Reproductive extent was clearly visible on all trees (mean score = 2). Only two trees supported live mistletoe (mean score = -1).

NOM load: NOM load was **VERY HIGH** for most trees, two trees recorded **LOW** loadings (mean = 4160 gm^{-2}; Figure 3.31a).

Lignum condition

Lignum condition varied across the site with five plants appearing dead (score = 0; Figure 3.31b). Mean viability score was 2 ($5 < x \leq 25\%$ viable); mean colour score was also 2 (mainly yellow brown). There was evidence that plants had recently flowered.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 65 species were recorded, of which 94% belong to terrestrial functional groups (FGs) and 4% belong to amphibious FGs (Figure 3.32). *Enchylaena tomentosa* was the most abundant native species and *Sisymbrium erysimoides** the most abundant introduced species.

In contrast to most other sites, In-channel (IC) quadrats had the highest native species abundance (31; Table 3.8). *Marrubium vulgare** was recorded at this site and is classified as a Class 4 locally controlled weed under the *Noxious Weed Act 1993* (NSW). Significant differences in species composition were observed between IC and Tree-line and IC and Floodplain (P = 0.0269 and P = 0.0249, respectively). No other significant differences in species composition between elevations were detected (P ≥ 0.0575).

Figure 3.29. Photo point of site 9a (D. Bogenhuber, MDFRC, 24/9/2010).

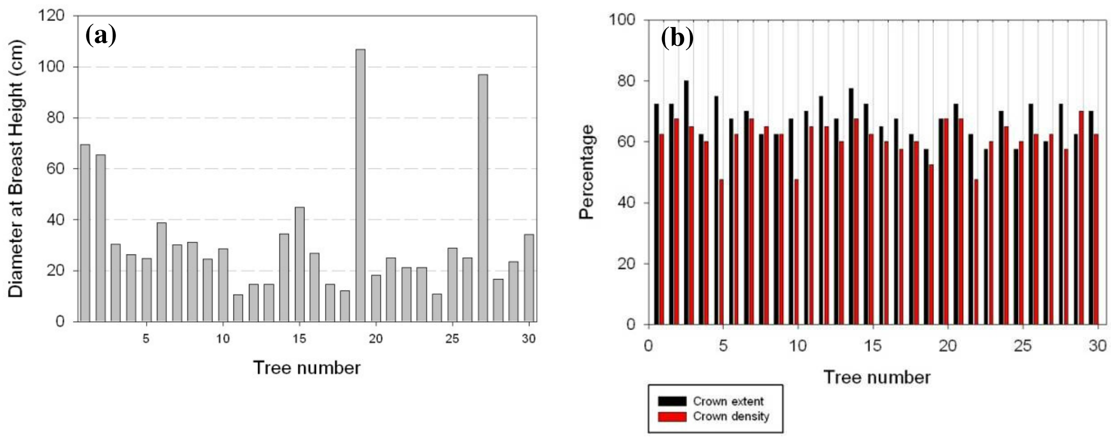


Figure 3.30. **(a)** DBH for all trees assessed at site 9a. Grey bars are Black Box. **(b)** Crown extent and crown density for all trees assessed at site 9a.

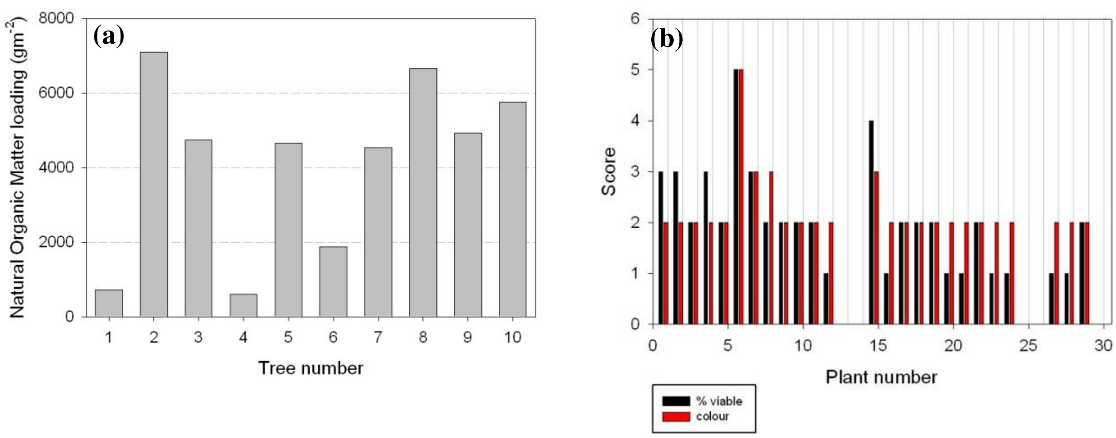


Figure 3.31. **(a)** NOM for all trees assessed at site 9a. Grey bars are Black Box. **(b)** Lignum viability and colour scores for all plants assessed at site 9a.

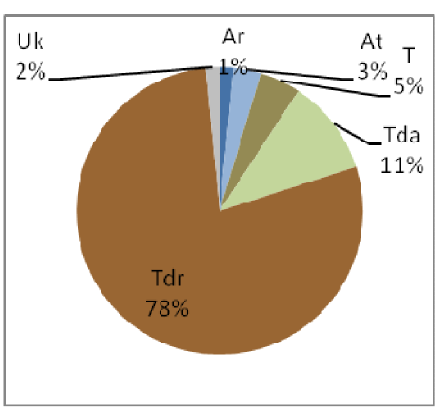


Figure 3.32. Pie chart displaying proportion of understorey plant species in broad functional groups for site 9a. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Ar=Amphibious responder; Uk=Unknown.

Table 3.8. Understorey plant species diversity recorded at site 9a.

Elevation	Native species	Exotic species	Total species
In-channel	31	7	38
Mid-bank	25	11	36
Tree-line	25	6	31
Floodplain	17	6	23
Total	52	13	65

3.10. Site 9b

Site location and description

Site 9b is located on the downstream side of Dam 183, Wyndham Station. The site is dominated by grey clay soils with fringing red sandy loam. The channel is wide and shallow (Figure 3.33) with steep banks on one side with large flood runners and waterholes. The dominant tree species is Black Box (BB) (*Eucalyptus largiflorens*).

Tree condition and NOM load

Species and size: All trees assessed were BB. Most trees were relatively small (DBH < 20 cm), with the exception of one large tree (DBH = 110 cm; Figure 3.34a); mean DBH is 22 cm.

Tree Condition Variables: Crown extent and crown density was variable across the site with most trees scoring below 70% for both variables (Figure 3.34b). Mean percentages are 49 and 52 respectively; mean Tree Condition Index was 8.17 (**STRESSED**).

Response Variables: New tip growth was visible on 29 trees (mean score = 1); 19 trees supported epicormic growth (mean score = 1). Die-off was evident on the majority of trees (25; mean score = -1). Reproductive extent was **SCARCE** on most trees (18; mean score = 1).

NOM load: NOM load was **MODERATE** (mean = 1160 gm^{-2}; Figure 3.35a).

Lignum condition

Most plants scored 3 or above for both Lignum condition variables, however, scores varied from 0 to maximum (Figure 3.35b); mean viability score was 3 ($25 < x \leq 50\%$ viable); mean colour score was 3 (all yellow brown). There was evidence that plants had recently flowered.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 67 species were recorded, with 89% belonging to terrestrial functional groups (FGs) and 8% belonging to amphibious FGs (Figure 3.36). *Enchylaena tomentosa* was the most abundant native species and *Medicago* sp.* the most abundant introduced species.

This site and site 9a were the only sites where the highest abundance of both native and total species was recorded at In-channel (IC) elevations (35 and 48 respectively, Table 3.8). Two Class 4 locally controlled weeds were recorded (*Noxious Weed Act 1993* (NSW), *Marrubium vulgare** and *Emex australis**. Significant differences in species composition were detected only between IC and Floodplain elevations (P = 0.0282).

Figure 3.33. Photo point of site 9b (D. Bogenhuber, MDFRC, 12/10/2010).

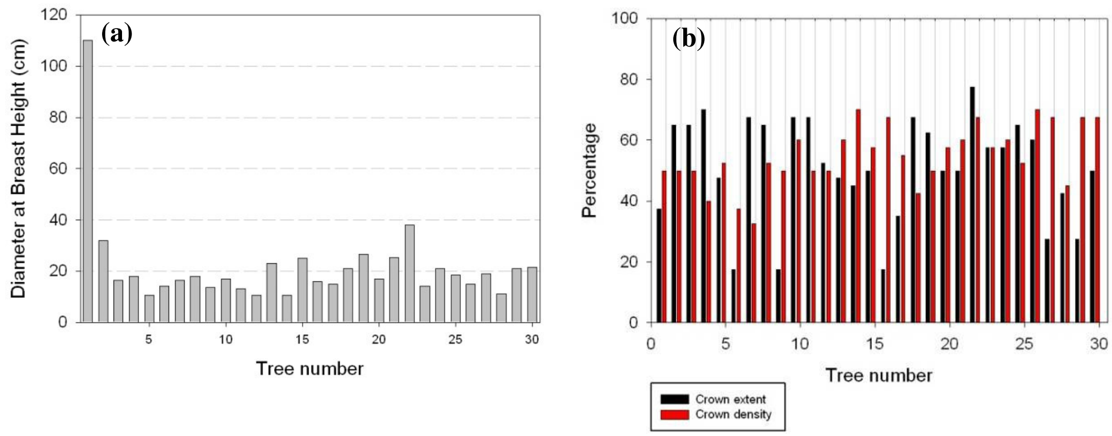


Figure 3.34. **(a)** DBH for all trees assessed at site 9b. Grey bars are Black Box. **(b)** Crown extent and crown density for all trees assessed at site 9b.

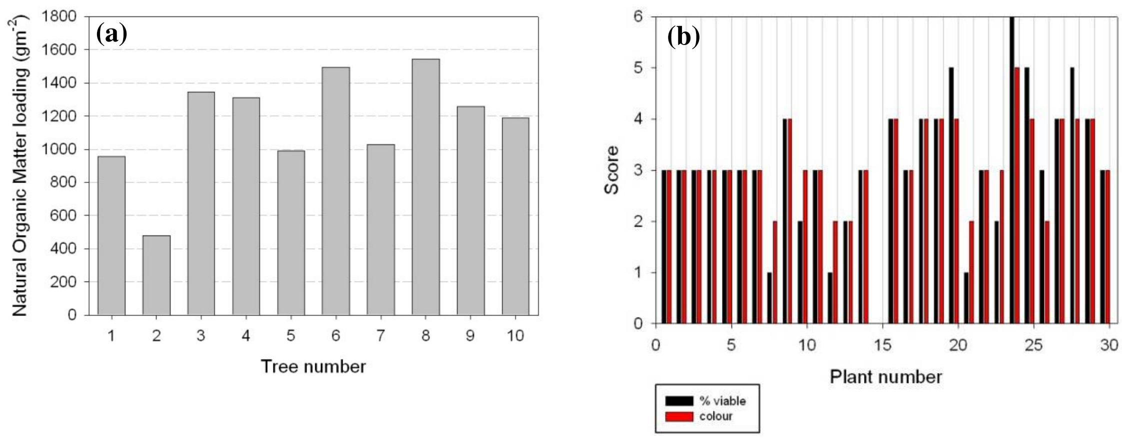


Figure 3.35. **(a)** NOM for all trees assessed at site 9b. Grey bars are Black Box. **(b)** Lignum viability and colour scores for all plants assessed at site 9b.

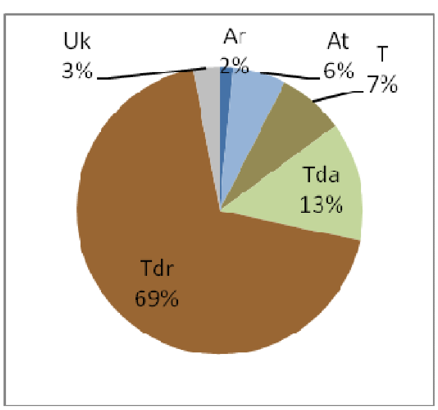


Figure 3.36. Pie chart displaying proportion of understorey plant species in broad functional groups for site 9b. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Ar=Amphibious responder; Uk=Unknown.

Table 3.9. Understorey plant species diversity recorded at site 9b.

Elevation	Native species	Exotic species	Total species
In-channel	35	13	48
Mid-bank	23	11	34
Tree-line	22	6	28
Floodplain	14	5	19
Total	52	15	67

3.11. Site 10

Site location and description

Site 10 is approximately 1 km upstream of Bunnerungee Bridge on Bunnerungee Station. The site is dominated by red sandy loam. The channel is approximately 50 m wide and shallow (Figure 3.37) with thick regeneration of River Red Gum (RRG) (*Eucalyptus camaldulensis*) in the base. Black Box (BB) (*Eucalyptus largiflorens*) and RRG occur along the edge.

Tree condition and NOM load

Species and size: Twenty-four BB and six RRG were assessed. DBH was considerably higher for RRG, recording a maximum DBH of 189 cm (Figure 3.38a). The mean DBH is 68 cm.

Tree Condition Variables: Most trees recorded > 60% for crown extent and crown density (Figure 3.38b); mean percentages are 51 and 55 respectively; mean Tree Condition Index was 9.37 (**STRESSED**).

Response Variables: New tip growth was visible on two thirds of trees (mean score = 1); 13 trees supported epicormic growth (mean score = 1). Die-off was evident on the majority of trees (19; mean score = -1). Reproductive extent was clearly visible on all trees (mean score = 2). Nine trees supported mistletoe (mean score = -1).

NOM load: NOM load was **LOW** to **MODERATE** for most trees and **VERY HIGH** for two trees (mean = 1791 gm^{-2}; Figure 3.39a).

Lignum condition

No Lignum was recorded at this site.

Typha distribution

No *Typha* was recorded at this site.

Understorey

The highest number of species was recorded at site 10 (101); 88% belong to terrestrial functional groups (FGs) and 10% to amphibious FGs (Figure 3.40). *Lachnagrostis filiformis* was the most abundant native species; *Medicago* sp.* the most abundant introduced species.

Mid-bank (MB) elevations had the greatest number of native and total species (53 and 73, respectively; Table 3.9). *Carthamus* sp.* was recorded at site 10 and may be one of the two *Carthamus** species listed under the *Noxious Weed Act 1993*. *Marrubium vulgare** and *Asphodelus fistulosus** are both Class 4 locally controlled weeds listed under the *Noxious Weed Act 1993* recorded at this site. There was a significant difference in species composition between In-channel (IC) and MB, IC and Tree-line (TL) and IC and Floodplain (FP) (P = 0.0267, P = 0.0302 and P = 0.0254, respectively).

Figure 3.37. Photo point of site 10 (D. Bogenhuber, MDFRC, 12/10/2010).

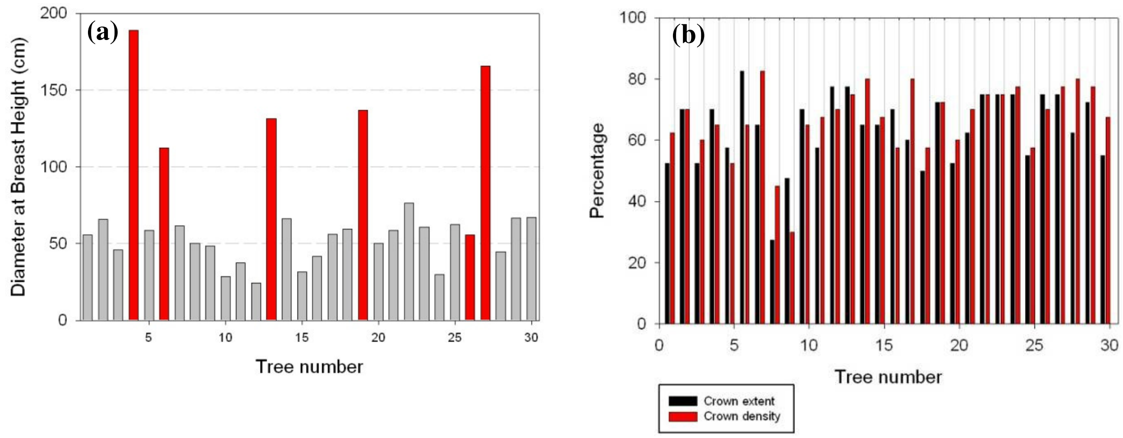
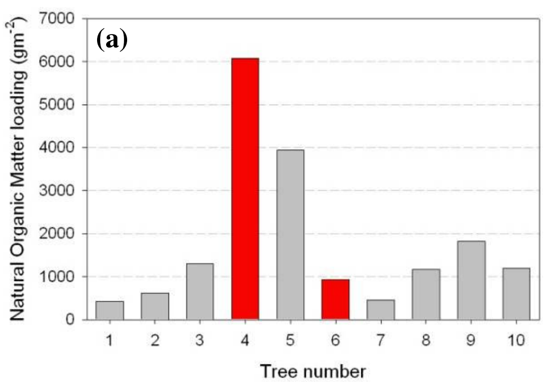


Figure 3.38. **(a)** DBH for all trees assessed at site 10. Grey is Black Box, red is River Red Gum. **(b)** Crown extent and crown density for all trees assessed at site 10.



No Lignum
recorded at this site

Figure 3.39. NOM for all trees assessed at site 10. Grey is Black Box, red is River Red Gum.

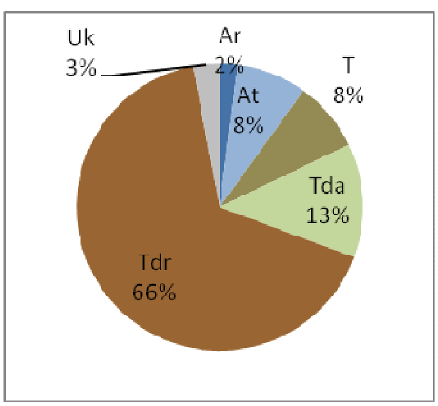


Figure 3.40. Pie chart displaying proportion of understorey plant species in broad functional groups for site 10. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Ar=Amphibious responder; Uk=Unknown.

Table 3.9. Understorey plant species diversity recorded at site 10.

Elevation	Native species	Exotic species	Total species
In-channel	17	13	30
Mid-bank	53	20	73
Tree-line	39	12	51
Floodplain	34	11	45
Total	78	23	101

3.12. Site 11

Site location and description

Site 11 is located near Lake Toora on the Darling Anabranch, Toora Station. The site is characterised by grey clay soils and steep banks. The Anabranch channel is relatively deep with a flood runner to the north-east of the main channel. The dominant tree species is Black Box (BB) (*Eucalyptus largiflorens*) (Figure 3.41).

Tree condition and NOM load

Species and size: All trees assessed were BB. DBH was generally low across the site, with one large tree recording a DBH of 208 cm (Figure 3.42a). The mean DBH of trees is 32 cm.

Tree Condition Variables: Crown extent and crown density varied considerably across the site (Figure 3.42b); mean percentages are 64 and 67 respectively. Mean Tree Condition Index was 8.93 (**STRESSED**).

Response Variables: New tip growth was clearly visible on 29 of the 30 trees (mean score = 2), with 23 trees supporting epicormic growth (mean score = 1). Die-off was evident on the majority of trees (28; mean score = -1). Reproductive extent was clearly visible in the majority of trees (27; mean score = 2).

NOM load: NOM load was **VERY LOW** to **LOW** for most quadrats, with two recording **MODERATE** loadings (mean = 782 gm^{-2}; Figure 3.43a).

Lignum condition

No Lignum was recorded at this site.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 93 species were recorded, with 90% of the total species belonging to terrestrial functional groups (FGs), 8% belonging to amphibious FGs and 1% (Family: Characeae) belonging to the submerged FG (Figure 3.44). *Enchylaena tomentosa* was the most abundant native species with *Medicago* sp.* being the most abundant introduced species.

Tree-line (TL) quadrats had the greatest number of species (52), a relatively high proportion of these (27%) were exotic (Table 3.10). The Class 4 locally controlled weed under the *Noxious Weed Act 1993* (NSW), *Marrubium vulgare**, was recorded. There were significant differences in species composition between all elevations ($P \leq 0.0309$) except Mid-bank and TL ($P = 0.1675$).

Figure 3.41. Photo point of site 11 (D. Bogenhuber, MDFRC, 20/10/2010).

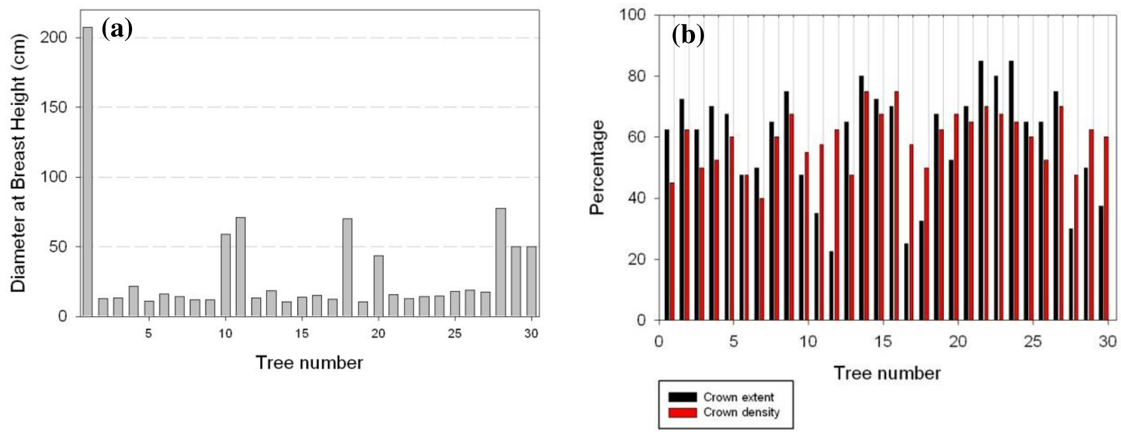
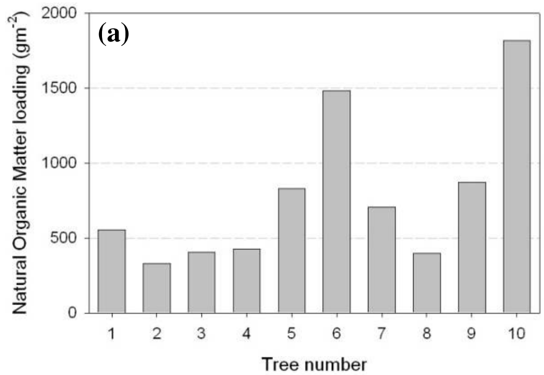


Figure 3.42. **(a)** DBH for all trees assessed at site 11. Grey bars are Black Box. **(b)** Crown extent and crown density for all trees assessed at site 11.



No Lignum

recorded at this site

Figure 3.43. NOM for all trees assessed at site 11. Grey bars are Black Box.

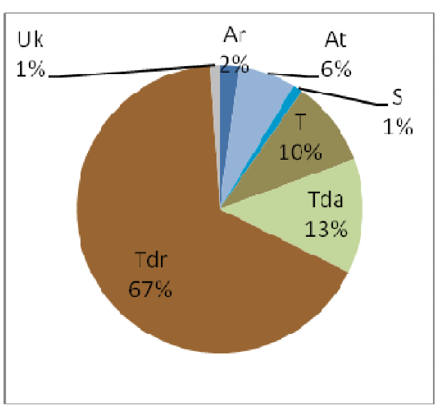


Figure 3.44. Pie chart displaying proportion of understorey plant species in broad functional groups for site 11. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; S=Submerged; At=Amphibious tolerator; Ar=Amphibious responder; Uk=Unknown.

Table 3.10. Understorey plant species diversity recorded at site 11.

Elevation	Native species	Exotic species	Total species
In-channel	20	2	22
Mid-bank	31	9	40
Tree-line	38	14	52
Floodplain	40	6	46
Total	75	18	93

3.13. Site 12

Site location and description

Site 12 is located upstream of Warra's Dam, Warrananga Station, near "The Lake". The site is dominated by grey clay soils with low lying floodplain topography. The channel is approximately 30 m wide and shallow. The overstorey consists of mixed species Black Box (BB) (*Eucalyptus largiflorens*), River Red Gum (RRG) (*Eucalyptus camaldulensis*) and River Cooba (RC) (*Acacia stenophylla*). Long-dead RRG are present within the channel, presumably drowned (Figure 3.45).

Tree Condition and NOM load

Species and size: Trees assessed consisted of 6 BB, 21 RRG and 3 RC. DBH varied considerably across the site with the largest DBHs recorded for BB (maximum = 133 cm; Figure 3.46a). Mean DBH is 51 cm.

Tree Condition Variables: Crown extent and crown density varied across the site, with one tree (RRG) recording above 80% for both variables (Figure 3.46b); mean percentages were 60 and 59 respectively; mean Tree Condition Index was 8.40 (**STRESSED**).

Response Variables: New tip growth was visible on one third of trees (mean score = 1); 21 trees supported epicormic growth (mean score = 1). Die-off was evident on all trees (mean score = -1). On the majority of trees (23) reproductive extent was clearly visible (mean score = 2).

NOM load: NOM load was **HIGH** to **VERY HIGH** for most trees (mean = 4506 gm^{-2}; Figure 3.47a).

Lignum condition

No Lignum was recorded at this site.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 71 species were recorded with 94% belonging to terrestrial functional groups (FGs) and 6% to amphibious FGs (Figure 3.48). *Enchylaena tomentosa* was the most abundant native species with *Medicago* sp.* being the most abundant introduced species.

The number of total species was highest at Floodplain elevations (49; Table 3.11). The number of exotic species was relatively high, at Mid-bank elevations almost half the species recorded were exotic (Table 3.11). There were no significant differences in species composition between elevations ($P \leq 0.0329$).

Figure 3.45. Photo point for site 12 (D. Bogenhuber, MDFRC, 20/10/2010).

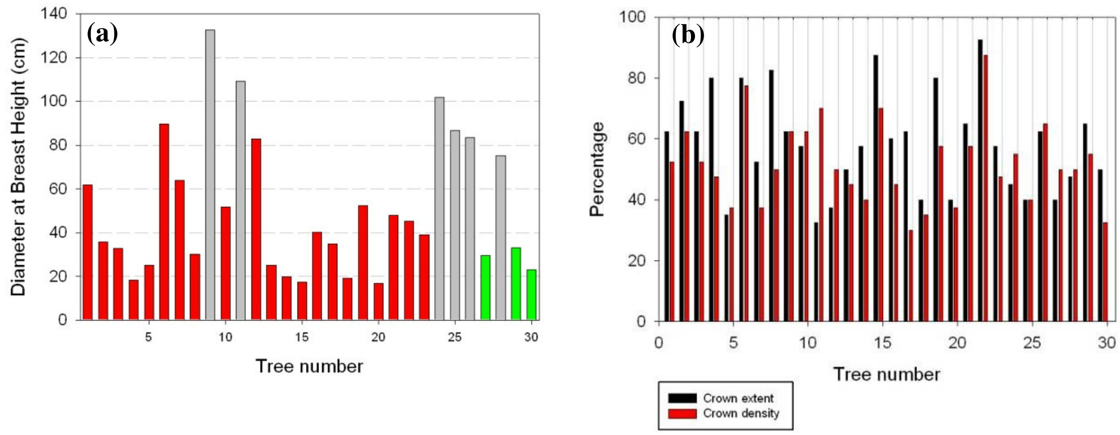
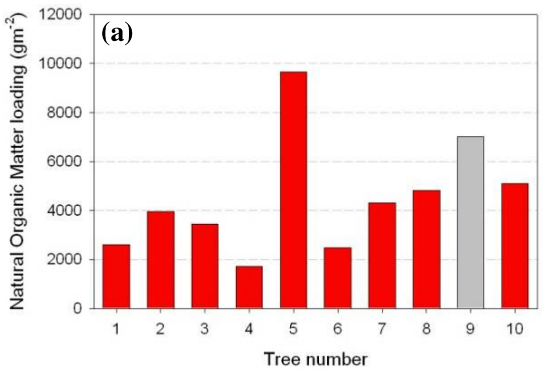


Figure 3.46. **(a)** DBH for all trees assessed at site 12. Grey is Black Box, red is River Red Gum, green is River Cooba. **(b)** Crown extent and crown density for all trees assessed at site 12.



No Lignum
recorded at this site

Figure 3.47. NOM for all trees assessed at site 12. Grey is Black Box, red is River Red Gum.

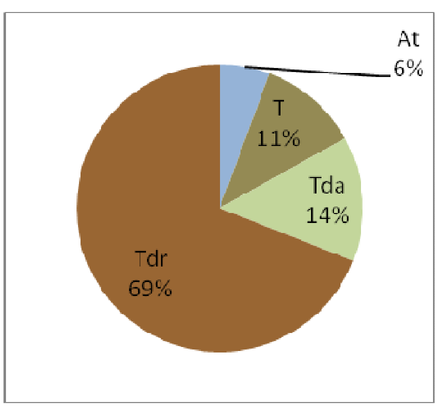


Figure 3.48. Pie chart displaying proportion of understorey plant species in broad functional groups for site 12. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator.

Table 3.11. Understorey plant species diversity recorded at site 12.

Elevation	Native species	Exotic species	Total species
In-channel	0	0	0
Mid-bank	27	13	40
Tree-line	34	12	46
Floodplain	41	8	49
Total	56	15	71

3.14. Site 14

Site location and description

Site 14 is located upstream of Oakbank Dam on Oakbank Station. The site is dominated by grey clay soils with low lying floodplain topography. Condition Monitoring was limited to the eastern bank due to access restrictions on the western bank. The channel is wide and relatively deep (Figure 3.49). The overstorey is a mixed canopy of Black Box (BB) (*Eucalyptus largiflorens*), River Red Gum (RRG) (*Eucalyptus camaldulensis*) and River Cooba (RC) (*Acacia stenophylla*).

Tree condition and NOM load

Species and size: Trees assessed consisted of 7 BB, 19 RRG and 4 RC. DBH was below 40 cm for most trees, maximum DBH (RRG) is 178 cm (Figure 3.50a). Mean DBH is 40 cm.

Tree Condition Variables: Crown extent and crown density vary considerably across the site, from below 20% to above 80% (Figure 3.50b); mean percentages are 59 and 52 respectively. The mean Tree Condition Index was 8.90 (**STRESSED**).

Response Variables: New tip growth was visible on 7 of the 30 trees (mean score = 1); 16 trees supported epicormic growth (mean score = 1). Die-off was evident on all trees (mean score = -1). On the majority of trees (22) reproduction was clearly visible (mean score = 2).

NOM load: NOM load was mostly **MODERATE** to **HIGH** (mean = 1902 gm^{-2}; Figure 3.51a).

Lignum condition

Lignum condition scores varied from 0 to 6 for viability and 0 to 4 for colour (Figure 3.51b), mean viability score was 2 ($5 < x \leq 25\%$ viable) and mean colour score also 2 (mainly yellow brown). There was evidence that plants had recently flowered.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 61 species were recorded, 92% belong to terrestrial functional groups (FGs) and 8% to amphibious FGs (Figure 3.52). *Enchylaena tomentosa* was the most abundant native species and *Mesembryanthemum nodiflorum** the most abundant introduced species.

In-channel and Mid-bank quadrats were not assessed during the September to November 2010 Condition Monitoring surveys due to high water levels. Floodplain (FP) quadrats had the highest number of native species and the lowest number of introduced species (38 and 12 respectively; Table 3.12). There was no significant difference in species composition between Tree-line and FP elevations (P = 0.0565).

Figure 3.49. Photo point of site 14 (D. Bogenhuber, MDFRC, 28/10/2010).

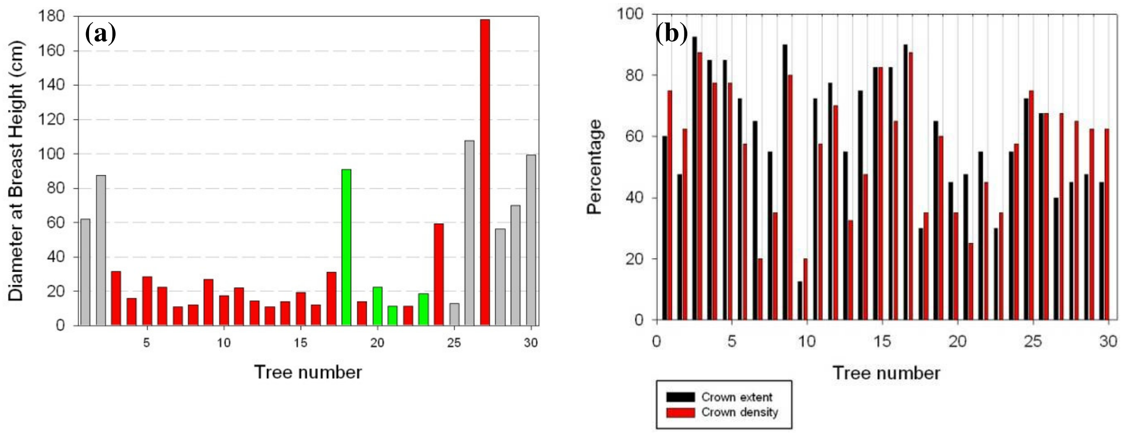


Figure 3.50. **(a)** DBH for all trees assessed at site 14. Grey is Black Box, red is River Red Gum, green is River Cooba. **(b)** Crown extent and crown density for all trees assessed at site 14.

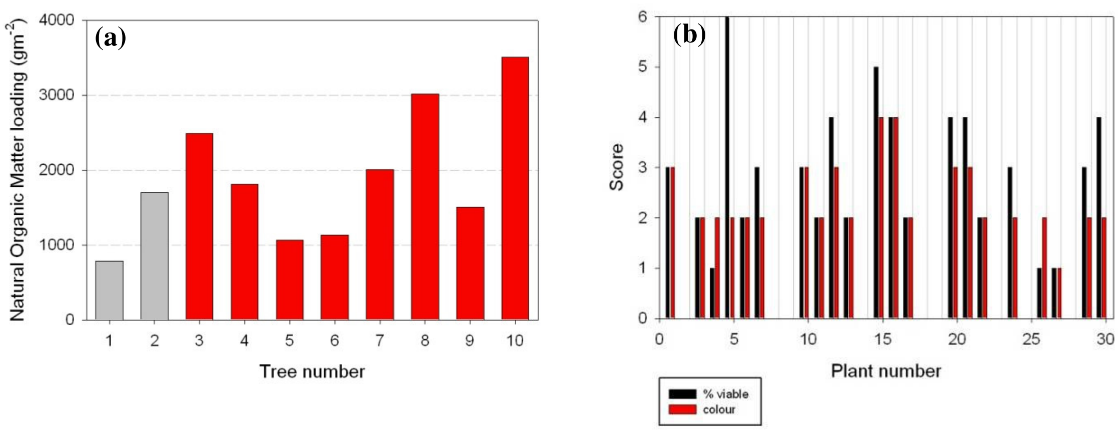


Figure 3.51. **(a)** NOM for all trees assessed at site 14. Grey is Black Box, red is River Red Gum. **(b)** Lignum viability and colour scores for all plants assessed at site 14.

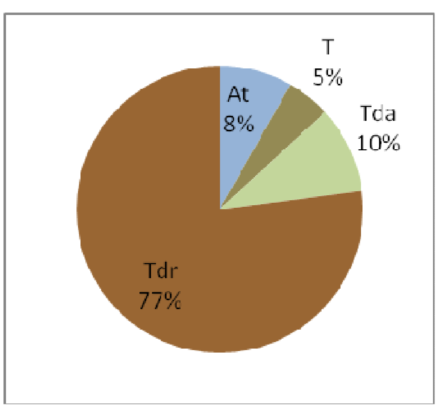


Figure 3.52. Pie chart displaying proportion of understorey plant species in broad functional groups for site 14. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator.

Table 3.12. Understorey plant species diversity recorded at site 14.

Elevation	Native species	Exotic species	Total species
In-channel	Not assessed		
Mid-bank	Not assessed		
Tree-line	31	14	45
Floodplain	38	12	50
Total	44	17	61

3.15. Site 15

Site location and description

Site 15 is approximately 1 km upstream of Oakbank Dam on 'Oakbank Bend' Station (name adopted by authors) and under the influence of the Murray River Lock 9 weir pool (Figure 3.53). Condition Monitoring was restricted to the steep eastern bank due to access restrictions on the western side. The overstorey consists of Black Box (BB) (*Eucalyptus largiflorens*), River Red Gum (RRG) (*Eucalyptus camaldulensis*) and River Cooba (RC) (*Acacia stenophylla*).

Tree condition and NOM load

Species and size: Trees assessed consisted of 6 BB, 12 RRG and 12 RC. DBH varied substantially across the site (Figure 3.54a). Mean DBH is 75 cm; maximum is 195 cm (RRG).

Tree Condition Variables: Most trees recorded 50 to 70% for crown extent and crown density (Figure 3.54b); mean scores are 62 and 58% respectively; mean Tree Condition Index was 10.23 (**GOOD**).

Response Variables: New tip growth was visible on 27 trees (mean score = 1); 21 trees supported epicormic growth (mean score = 1). Die-off was evident on all trees (mean score = -1). Reproductive extent was clearly visible on the majority of trees (27; mean score = 2). Two trees supported mistletoe (mean score = -1).

NOM load: NOM load was **MODERATE** or less for most quadrats, with one RRG recording over 12 000 gm^{-2} (**VERY HIGH**; Figure 3.55a). Mean NOM loading is 2564 gm^{-2}.

Lignum condition

No Lignum was recorded at this site.

Typha distribution

A band of *Typha* approximately 300 m long and 20 m wide was mapped along the bank (refer to section 4.6, Figure 4.12). Plants were 3 to 4 m high, in water 2 m deep. Plant density within the mapped area was about 70% and plants exhibited approximately 45% dieback.

Understorey

A total of 66 species were recorded; 91% belong to terrestrial functional groups (FGs), 8% to amphibious FGs (Figure 3.56). *Cyperus gymnocaulos* was the most abundant native species and *Medicago* sp.* the most abundant introduced species.

In-channel and Mid-bank quadrats were not assessed due to high water levels in the Lock 9 weir pool. Floodplain (FP) quadrats recorded most species (52; Table 3.13). Species composition differed significantly between Tree-line and FP quadrats (P = 0.0308).

Figure 3.53. Photo point of site 15 (D. Linklater, MDFRC, 8/11/2010).

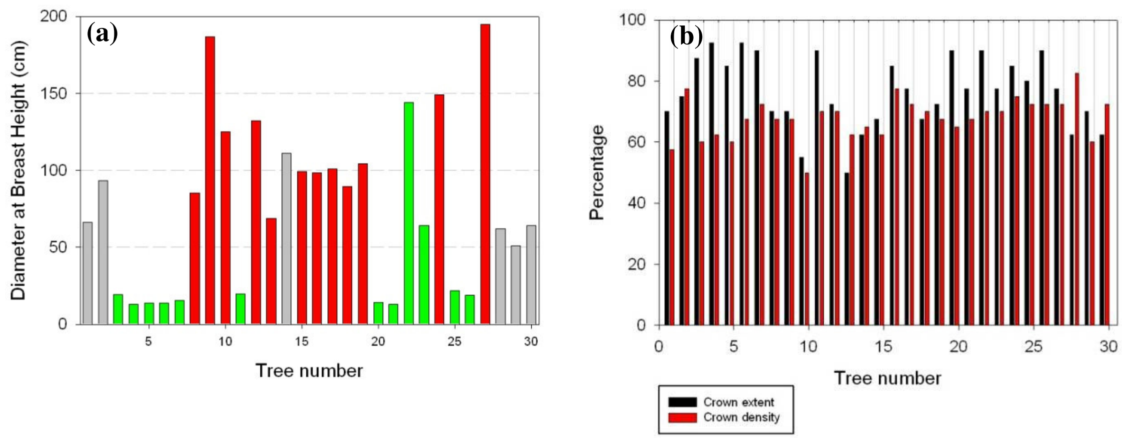
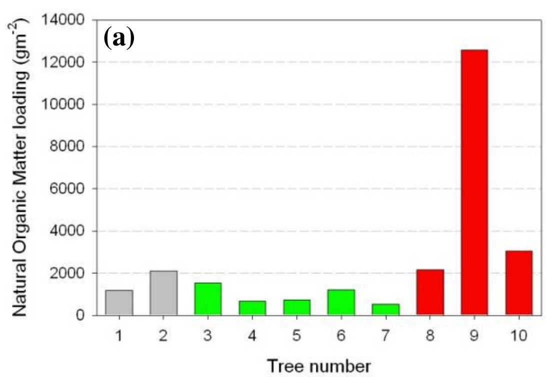


Figure 3.54. (a) DBH for all trees assessed at site 15. Grey is Black Box, red is River Red Gum, green is River Cooba. **(b)** Crown extent and crown density for all trees assessed at site 15.



No Lignum

recorded at this site

Figure 3.55. NOM for all trees assessed at site 15. Grey is Black Box, red is River Red Gum, green is River Cooba.

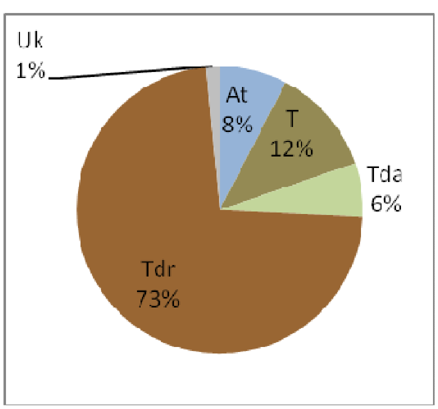


Figure 3.56. Pie chart displaying proportion of understorey plant species in broad functional groups for site 15. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator; Uk=Unknown.

Table 3.13. Understorey plant species diversity recorded at site 15.

Elevation	Native species	Exotic species	Total species
In-channel	Not assessed		
Mid-bank	Not assessed		
Tree-line	28	9	37
Floodplain	43	9	52
Total	53	13	66

3.16. Site 16

Site location and description

Site 16 is approximately 1 km downstream of Oakbank Dam on 'Oakbank Bend' Station (name adopted by authors). Condition Monitoring was carried out on the eastern bank only due to access restrictions on the western bank. The wide and deep channel is under the influence of the Murray River Lock 9 weir pool (Figure 3.57). Salt-affected soils are evident. The canopy consists of Black Box (BB) (*Eucalyptus largiflorens*), River Red Gum (RRG) (*Eucalyptus camaldulensis*) and River Cooba (RC) (*Acacia stenophylla*).

Tree condition and NOM load

Species and size: Trees assessed consisted of 9 BB, 6 RRG and 15 RC. DBH of most RC was < 20 cm, maximum DBH was 161 cm (RRG; Figure 3.58a). The mean DBH is 53 cm.

Tree Condition Variables: Crown extent for RC was considerably higher than crown density (Figure 3.58b); mean crown extent and crown density overall was 77% and 68% respectively. The mean Tree Condition Index was 10.27 (**GOOD**).

Response Variables: New tip growth was clearly visible on 29 of the 30 trees (mean score = 2); 16 trees supported epicormic growth (mean score = 1). Die-off was evident on 28 trees (mean score = -1). Reproductive extent was clearly visible on the majority of trees (24, mean score = 2). One tree supported mistletoe (mean score = -1).

NOM load: NOM load was variable with a mean of 3086 gm^{-2} (**VERY HIGH**); Figure 3.59a).

Lignum condition

Most plants scored 3 or higher for both Lignum condition variables (Figure 3.59b); mean viability score was 5 ($5 < x \leq 25\%$ viable), mean colour score was 3 (all yellow brown). Flowering was observed at this site.

Typha distribution

Typha was present in four dense stands, with scattered plants (5 to 10% cover) between the stands, in a 1 m wide strip (Figure 4.13 in section 4.6). Plants were 3 to 4 m average height and exhibited 5 to 35% die-off. No flowering was observed.

Understorey

47 species were recorded (Table 3.14), 98% belong to terrestrial functional groups (FGs) and 2% to amphibious FGs (Figure 3.60). *Tetragonia* sp. was the most abundant native species, with *Hordeum* sp.* the most abundant introduced species.

In-channel, Mid-bank and Tree-line quadrats were not assessed due to high water levels in the Lock 9 weir pool. No pair-wise analysis was able to be carried out for site 16.

Figure 3.57. Photo point for site 16 (D. Bogenhuber, MDFRC, 9/11/2010).

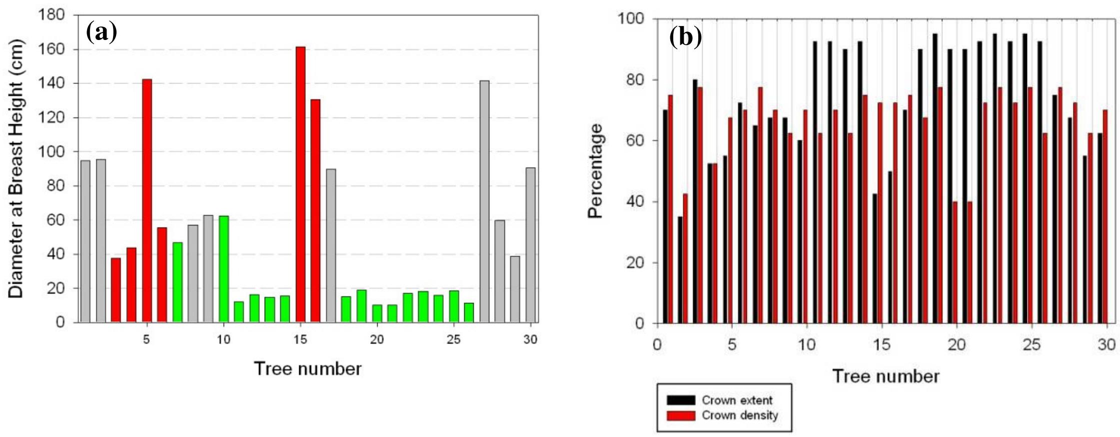


Figure 3.58. (a) DBH for all trees assessed at site 16. Grey is Black Box, red is River Red Gum, green is River Cooba. **(b)** Crown extent and crown density for all trees assessed at site 16.

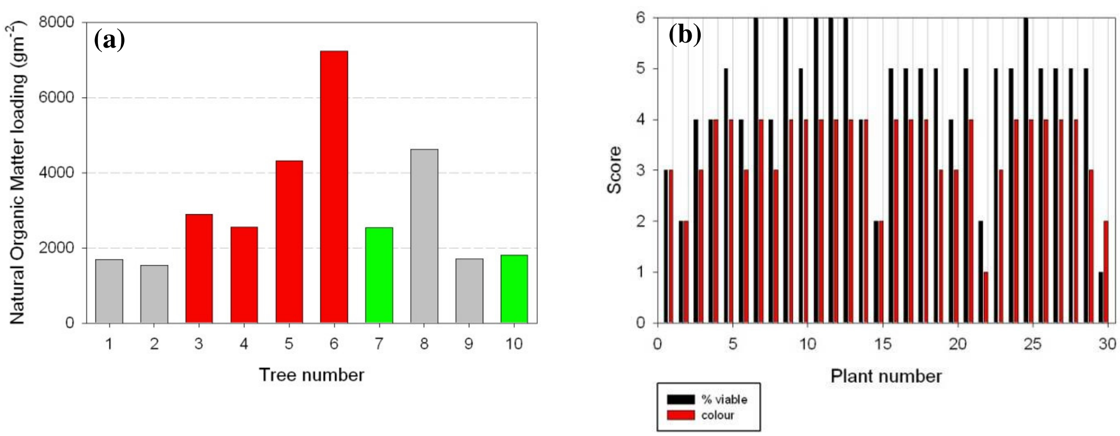


Figure 3.59. (a) NOM for all trees assessed at site 16. Grey is Black Box, red is River Red Gum, green is River Cooba. **(b)** Lignum viability and colour scores for all plants assessed at site 16.

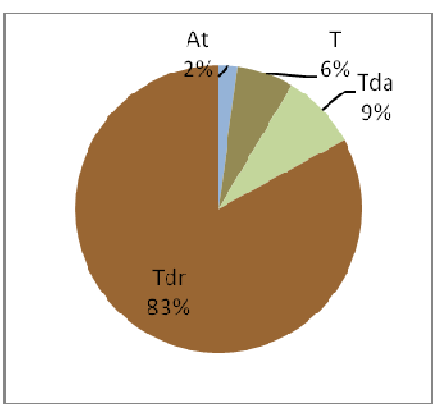


Figure 3.60. Pie chart displaying proportion of understorey plant species in broad functional groups for site 16. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator.

Table 3.14. Understorey plant species diversity recorded

Elevation	Native species	Exotic species	Total species
In-channel	Not assessed		
Mid-bank	Not assessed		
Tree-line	Not assessed		
Floodplain	39	8	47
Total	39	8	47

3.17. Site 17

Site location and description

Site 17 is downstream of Oakbank Dam on 'Oakbank Bend' Station (name adopted by authors) in the Murray River Lock 9 weir pool. Grey clay soils occur on the floodplain and red sandy loam on the steep banks. Monitoring was restricted to the eastern side of the channel. Black Box (BB) (*Eucalyptus largiflorens*) and River Red Gum (RRG) (*Eucalyptus camaldulensis*) are the dominant tree species along the edge of the channel (Figure 3.61).

Tree condition and NOM load

Species and size: Twenty-two BB and eight RRG were assessed. DBH was over 50 cm for most trees, with several very large RRG (maximum is 319 cm; Figure 3.62a). The mean DBH is 105 cm.

Tree Condition Variables: Crown extent and density was mostly <60%, mean scores were 49 and 52% respectively (Figure 3.62b); mean Tree Condition Index was 7.83 (**STRESSED**).

Response Variables: New tip growth was clearly visible on 28 trees (mean score = 2); 25 trees supported epicormic growth (mean score = 1). Die-off was evident on all trees (mean score = -1). Reproductive extent on most trees (28) was clearly visible (mean score = 2).

NOM load: NOM varied across the site with two quadrats (BB and RRG) recording over 8000 gm^{-2}, mean is 2867 gm^{-2} (**HIGH**); Figure 3.63a).

Lignum condition

Many plants recorded Lignum condition scores of 0 (Figure 3.63b); mean viability and colour scores were both 0 (0% viable; no viable stems). No flowering activity was observed.

Typha distribution

No *Typha* was recorded at this site.

Understorey

A total of 56 species were recorded, 98% belonging to terrestrial functional groups (FGs) and the remaining 2% belonging to amphibious FGs (Figure 3.64). *Poa* sp.[#] was the most abundant native species with *Medicago* sp.* being the most abundant introduced species.

In-channel, Mid-bank and Tree-line quadrats were not assessed during the September to November 2010 Condition Monitoring sampling due to the high waters experienced in the Murray River Lock 9 weir pool. Forty-nine native and seven exotic species were recorded for Floodplain quadrats (Table 3.15). No pair-wise analysis was able to be carried out for site 17.

Figure 3.61. Photo point for site 17 (D. Bogenhuber, MDFRC, 29/10/2010).

[#] Identification to be confirmed

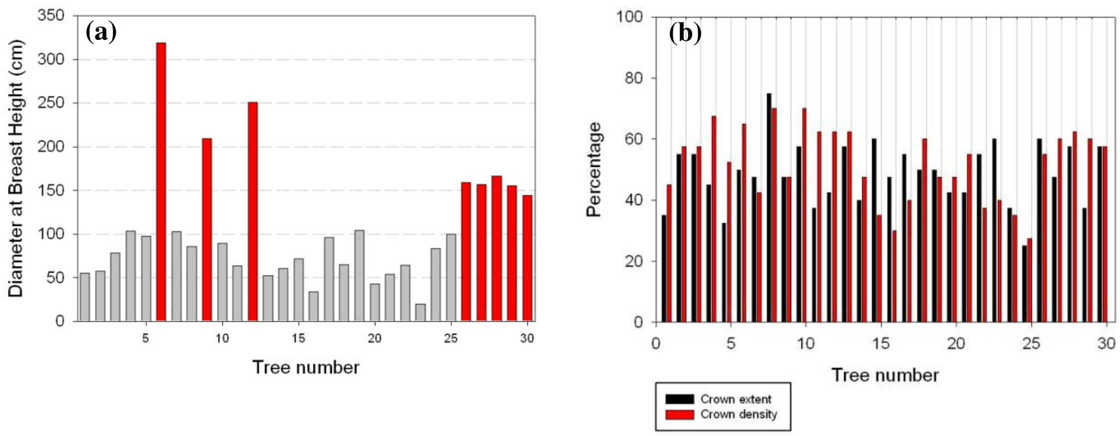


Figure 3.62. **(a)** DBH for all trees assessed at site 17. Grey is Black Box, red is River Red Gum. **(b)** Crown extent and crown density for all trees assessed at site 17.

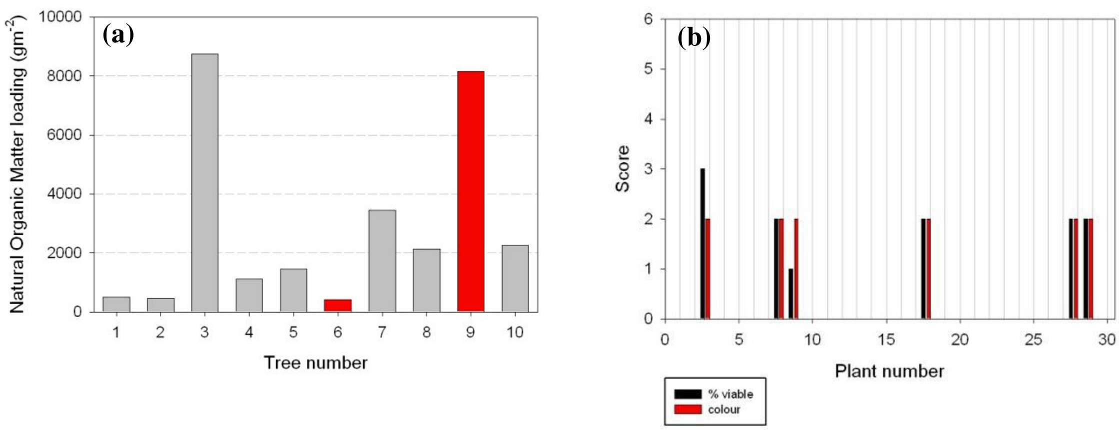


Figure 3.63. **(a)** NOM for all trees assessed at site 17. Grey is Black Box, red is River Red Gum. **(b)** Lignum viability and colour scores for all plants assessed at site 17.

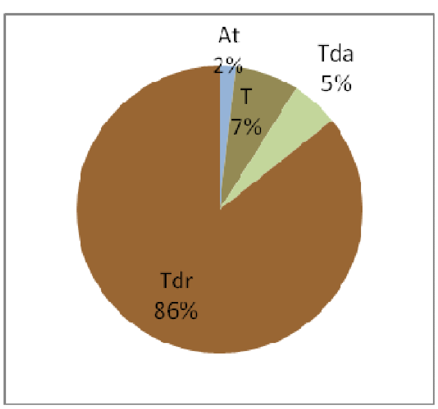


Figure 3.64 Pie chart displaying proportion of understorey plant species in broad functional groups for site 17. Tdr=Terrestrial dry; Tda=Terrestrial damp; T=Terrestrial; At=Amphibious tolerator.

Table 3.15. Understorey plant species diversity recorded at site 17.

Elevation	Native species	Exotic species	Total species
In-channel	Not assessed		
Mid-bank	Not assessed		
Tree-line	Not assessed		
Floodplain	49	7	56
Total	49	7	56

4. Overall Results and Discussion

The data presented in this section represents the first round of Condition Monitoring on the Darling Anabranch system; hence the level of analysis and interpretation is limited to within and between sites (no year-to-year comparisons). This section presents and discusses results for the Darling Anabranch system as a whole. For results of individual sites refer to section 3.

4.1. Hydrological status of sites

Sites across the Darling Anabranch varied considerably in the amount of water present during the September to November 2010 Condition Monitoring sampling. All sites except 9a and 9b had some water present at the time of survey. A summary of the hydrological situation at each site is displayed in Table 4.1.

Table 4.1. Hydrological status of sites 2 to 17 between September and November 2010.

Site	Date of survey (2010)	Water present	Source of water and timing
1	Not surveyed	Flowing and rising.	Darling River, reached site 1 late October 2010.
2	3 November	Flowing and rising, inundated to tree-line.	Darling River, reached site 2 approximately one to two weeks prior to Condition Monitoring.
3	3 November	Flowing and rising, inundated to tree-line.	Darling River, reached site 3 approximately one to two weeks prior to Condition Monitoring.
4	23 September	Shallow pools in bottom of channel only.	Remaining from localised rainfall and/or previous flow from Darling River in January/February 2010#.
5	21 September	Flowing, steady/rising, inundated to tree-line, flood runners inundated.	Lake Cawndilla, reached site 5 approximately one to two weeks prior to Condition Monitoring.
6	22 September	Flowing, steady/rising, inundated to tree-line, flood runners inundated.	Lake Cawndilla, reached site 6 approximately eight weeks prior to Condition Monitoring.
7	30 September	Deep pools (>2 m), steady?, inundated to mid-bank.	Remaining from localised rainfall and/or previous flow from Darling River in January/February 2010#.
8	29 September	Small shallow pools (approx. 0.05 m) in bottom of channel only.	Remaining from localised rainfall and/or previous flow from Darling River in January/February 2010#.
9a	24 and 28 September	Dry.	
9b	11 to 12 October	Dry.	
10	12 to 13 October; 18 to 19 October	Small shallow pools (approx. 0.15 to 0.2 m) in bottom of channel.	Remaining from localised rainfall; pools increased in depth on second visit from recent rainfall.
11	19 to 20 October	Pools up to approx. 0.4 m deep in bottom of channel.	Remaining from localised rainfall.
12	20 to 21 October	Deep pools (approx. 1 m), inundated to mid-bank.	Remaining from localised rainfall.
14	28 October and 8 November	Deep pools (>1.5 m), inundated to mid-bank.	Remaining from localised rainfall.
15	28 October and 8 November	Inundated to tree-line, rising.	In the influence of Murray River Lock 9 weir pool.
16	29 October and 9 November	Inundated to above tree-line, rising.	In the influence of Murray River Lock 9 weir pool.
17	29 October and 9 November	Inundated to above tree-line, rising.	In the influence of Murray River Lock 9 weir pool.

#Based upon flow data supplied by DECCW (flows over 10 GL day^{-1} past Weir 32 at Menindee between 28/1/2010 and 1/3/2010). This flow reached approximately 1 to 2 km short of Stoney Crossing in March/April 2010 (Angus Whyte, personal communication).

4.2. Tree condition and NOM

4.2.1. Site description

Black Box (BB) (*Eucalyptus largiflorens*) is the dominant tree species in the riparian zone within the 16 sites assessed across the Darling Anabranch system (Figure 4.1). River Red Gum (RRG) (*Eucalyptus camaldulensis*) was more prevalent at the downstream end of the Darling Anabranch, with River Cooba (RC) (*Acacia stenophylla*) also more common at downstream sites (Figure 4.1). Photo points of tree condition quadrats are displayed in Appendix A.

Disturbance was generally **SCARCE** across the sites, with the major disturbance being grazing by domestic stock and/or goats and rabbits. Other disturbances and stresses included rubbish dumping, kangaroo grazing, insect damage and soil salinity. Presence of seedlings and saplings within tree condition quadrats was generally **SCARCE** and **ABSENT** altogether from several sites. There was however, dense regeneration of eucalypts within and along the edges of the channel at several sites, notably sites 10 and 11. Monitoring changes in regeneration is a component of the DAAMMP and will be carried out when the channel is dry.

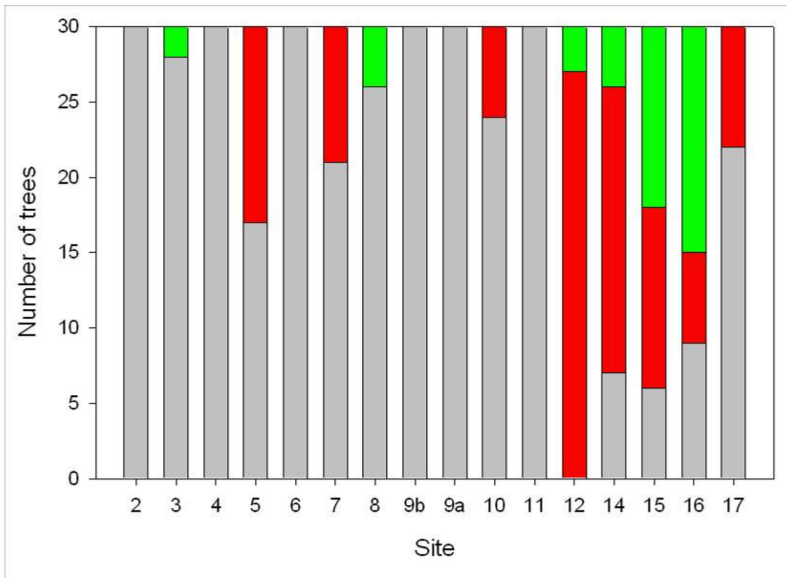


Figure 4.1. Proportion of tree species in each tree condition quadrat per site. Grey is Black Box, red is River Red Gum, green is River Cooba.

Figure 4.2 displays the mean Diameter at Breast Height (DBH) for trees at each site assessed. Site 17 recorded the largest mean DBH of 1.05 m and the largest overall DBH (RRG) of 3.19 m. The maximum recorded DBH of a RRG is approximately 5.19 m (Ogden 1978).

For the purposes of this report, definitions of 'dominant' and 'co-dominant' species are defined in Table 4.2. These definitions are used to display data across all 16 sites assessed.

Table 4.2. Definitions used for dominant and co-dominant tree species.

Category	When 2 species are present:	When 3 species are present:
Dominant	Dominant species ≥ 65% of total trees	Dominant species ≥ 50% of total trees
Co-dominant	Each species ≥ 40% of total trees	Co-dominant species make up ≥ 80% of total trees and each species is ≥ 40% of total trees

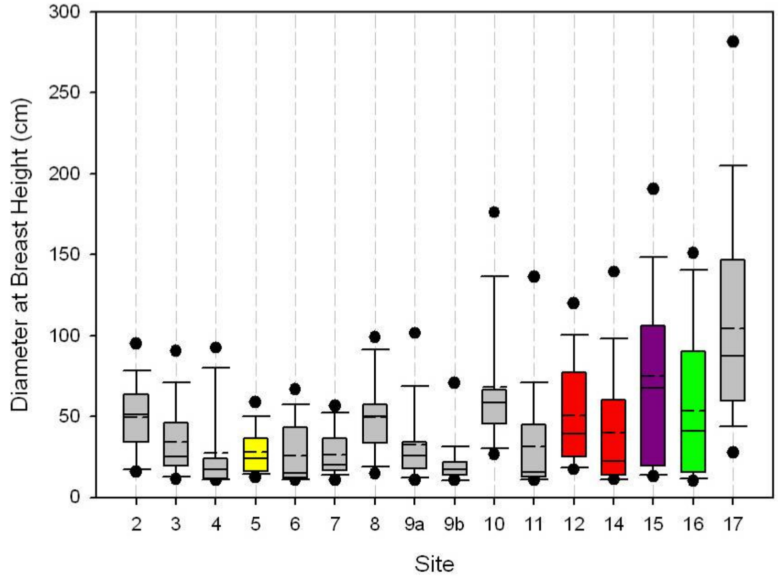


Figure 4.2. Box and whisker plot depicting mean Diameter at Breast Height for the 16 sites assessed. Boxes enclose the 25th to 75th percentiles; whiskers enclose the 10th to 90th percentiles; outliers are identified by closed circles; dashed line within box plots represents the mean and the solid line represents the median. Grey boxes are sites dominated by Black Box, yellow boxes are sites co-dominated by Black Box and River Red Gum, red boxes are sites dominated by River Red Gum, purple boxes are sites co-dominated by River Red Gum and River Cooba, green boxes are sites dominated by River Cooba.

4.2.2. Tree condition and response

Tree Condition Index (TCI) scores for sites 2 to 17 are displayed in Figure 4.3. Mean tree condition at two sites (15 and 16) is **GOOD** (categories as per Table 2.3); these sites are dominated by River Cooba or a mix of River Cooba and River Red Gum. The remaining 14 sites are all currently in **STRESSED** condition, with site 7 recording both the lowest mean and median TCI score (7 and 6.5 respectively; Figure 4.3).

Site 8 recorded the lowest TCI score for an individual tree (2; **VERY POOR** condition) and the largest range of TCI scores, from 2 to 12 (**VERY GOOD** condition). Sites 12 and 14 recorded the highest TCI scores (13; **VERY GOOD** condition) for an individual tree (Figure 4.3).

Statistical analyses were carried out to determine significant differences between sites, using both condition and response variables (refer to section 2.2.10 for further detail). Bark condition was excluded as it only applies to mature RRG. NOM was also excluded as it was recorded for only the first 10 trees within each quadrat; statistical analyses were carried out based on data for 30 trees per site. There was a significant difference between the condition of trees (based on all recorded parameters except bark condition and NOM) observed at all sites (P = 0.0001; Table B1 in Appendix B). Pair-wise comparisons between sites were conducted to further explore differences and found significant differences in tree condition between the majority of sites (Table B1 in Appendix B). Significant differences were not detected between sites 15 and 16 (P = 0.1549), site 8 and site 12 (P = 0.0929) and site 12 and 14 (P = 0.467; Table B1 in Appendix B). For further discussion of these results refer to section 4.2.5 below.

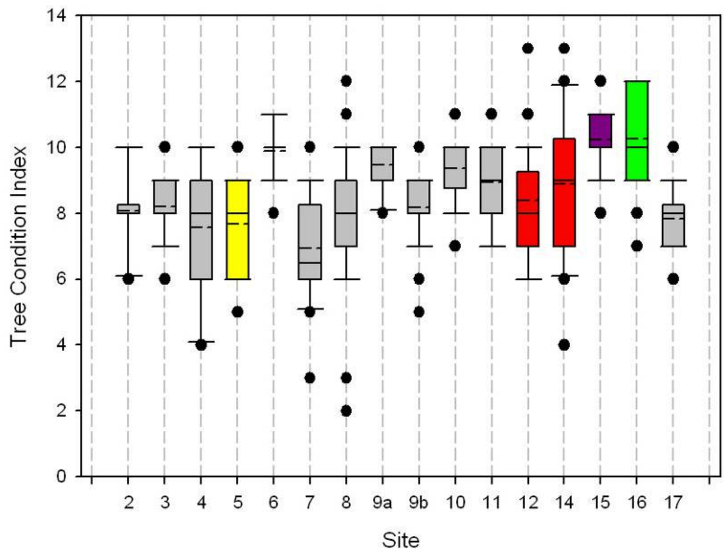


Figure 4.3. Box and whisker plot depicting Tree Condition Index (TCI) for the 16 sites assessed. Boxes enclose the 25th to 75th percentiles; whiskers enclose the 10th to 90th percentiles; outliers are identified by closed circles; dashed line within box plots represents the mean and the solid line represents the median. Grey boxes are sites dominated by Black Box, yellow boxes are sites co-dominated by Black Box and River Red Gum, red boxes are sites dominated by River Red Gum, purple boxes are sites co-dominated by River Red Gum and River Cooba, green boxes are sites dominated by River Cooba.

4.2.3. Potential trajectory

Mistletoe was observed at only five sites, where it was recorded as **SCARCE**. Reproduction was also observed at all sites, indicated by buds and flowering. The average reproductive extent scores ranged between **SCARCE** and **COMMON** at all sites except 4, 5 and 9b, where it was less than **SCARCE**.

The potential trajectory (PT) of trees, that is, whether their condition is declining, improving or stable, was calculated by combining new tip and epicormic growth scores and subtracting the leaf die-off score for each tree within a site. Bark condition has been excluded as it only applies to mature RRG; reproductive extent and mistletoe load also excluded from the PT score as they may be influenced by factors other than tree condition, such as the season and bird populations (Wallace 2009a). It is considered likely that the condition of trees that have scores for positive parameters (new tip and epicormic growth) is likely to either increase or remain stable in the short-term. Trees that have negative scores (leaf die-off) may be expected to decrease in condition, particularly if those negative scores are not accompanied by one or more positive attributes.

PT scores for sites 2 to 17 are displayed in Figure 4.4. All but one site (site 14) display positive mean scores. Site 11 (BB) had the highest mean PT score (1.93). The highest PT score (5) for an individual tree (BB) was at site 7 (Figure 4.4). River Red Gum dominated sites (12 and 14) had the lowest PT scores (0.2 and -0.13 respectively). All sites except 9a and 9b had water present (refer to Table 4.1), which could account for the mostly positive PT scores, with trees responding to recent flows in the Darling Anabranch and/or recent rainfall. It is considered that the subsequent above average rainfall in the area and sustained high flows through the system will lead to the observed positive responses resulting in an increase in tree condition, at least in the short-term.

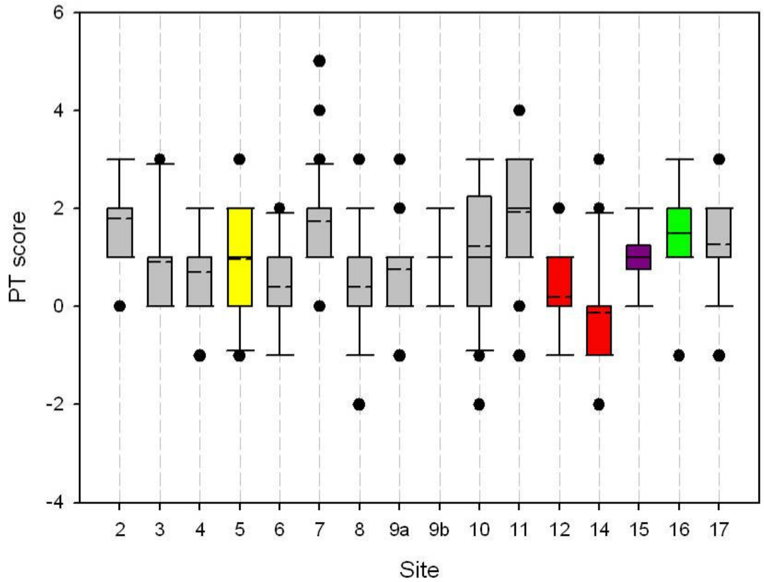


Figure 4.4. Box and whisker plot depicting Potential Trajectory (PT) for the 16 sites assessed. Boxes enclose the 25th to 75th percentiles; whiskers enclose the 10th to 90th percentiles; outliers are identified by closed circles; dashed line within box plots represents the mean and the solid line represents the median. Grey boxes are sites dominated by Black Box, yellow boxes are sites co-dominated by Black Box and River Red Gum, red boxes are sites dominated by River Red Gum, purple boxes are sites co-dominated by River Red Gum and River Cooba, green boxes are sites dominated by River Cooba.

4.2.4. NOM loading

The average Natural Organic Matter (NOM) loading was assessed for each site and is displayed in Figure 4.5. Seven sites recorded **VERY HIGH** mean NOM loading (categories as per Table 2.11), three **HIGH**, three **MODERATE** and three recorded **LOW** mean NOM loading (Figure 4.5).

NOM loading for each of the three tree species is displayed in Figure 4.6. Median NOM loading is highest for RRG and lowest for RC. However, NOM loading within sites was highly variable even for the same tree species. Data collected during the current project (Figure 4.6) exhibits the same trend as data collected from the Chowilla Floodplain (Brookes et al. 2007) and Pike River Floodplain (Wallace 2009a) in that NOM load associated with RRG is substantially higher than that associated with BB. At Pike Floodplain, Chowilla Floodplain and the Darling Anabranch, median loadings for BB are 663 gm^{-2}, 359 gm^{-2} and 1822 gm^{-2} respectively, compared to 2530 gm^{-2}, 2347 gm^{-2} and 3018 gm^{-2} for RRG. Data for NOM load associated with River Cooba does not exist from other studies. It was considerably lower than BB (median = 719 gm^{-2}; Figure 4.6). The low number of RC replicates (n = 9) makes interpretation of results for this species problematic.

It is of note that the median NOM load associated with BB in the current study is substantially higher than that recorded in the Pike and Chowilla Floodplain surveys. Compared with the Pike Floodplain, the Darling Anabranch BB dominated sites record higher Tree Condition Index scores, which could account for the higher NOM loads. Differences may also be attributed to survey timing, water availability, current status of response to water stress (shedding canopy) and grazing pressure. Further, the BB trees assessed along the Darling Anabranch were all close to the main channel, whereas a lot of those assessed at both the Pike and Chowilla Floodplains were higher on the floodplain and may have experienced a longer period without inundation.

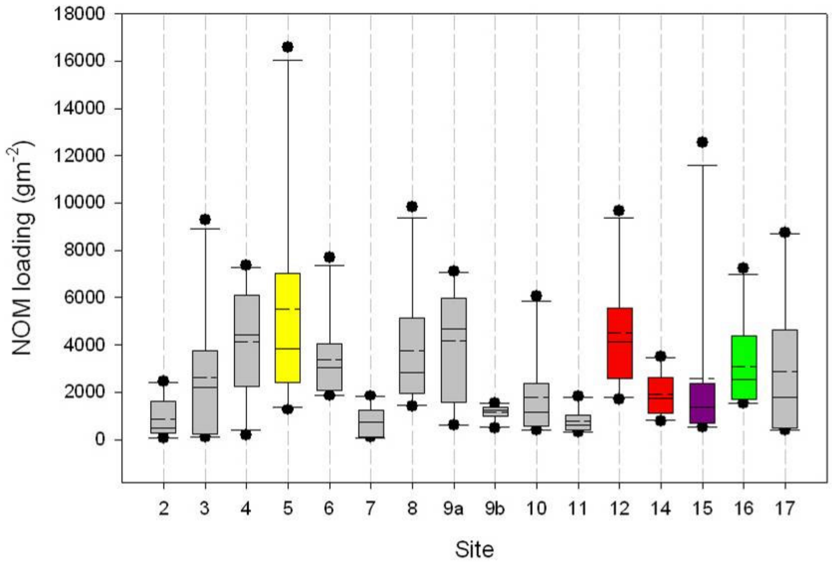


Figure 4.5. Box and whisker plot depicting Natural Organic Matter (NOM) loading for the 16 sites assessed. Boxes enclose the 25th to 75th percentiles; whiskers enclose the 10th to 90th percentiles; outliers are identified by closed circles; dashed line within box plots represents the mean and the solid line represents the median. Grey boxes are sites dominated by Black Box, yellow boxes are sites co-dominated by Black Box and River Red Gum, red boxes are sites dominated by River Red Gum, purple boxes are sites co-dominated by River Red Gum and River Cooba, green boxes are sites dominated by River Cooba.

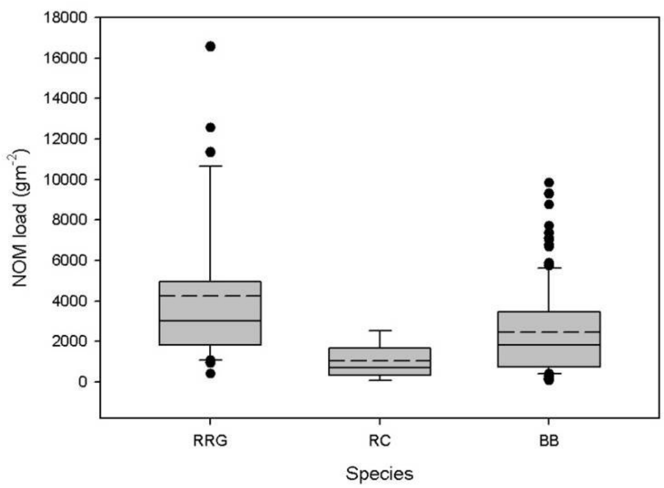


Figure 4.6. Box and whisker plot representing Natural Organic Matter (NOM) loading recorded under River Red Gum (RRG; n = 33), River Cooba (RC; n = 9) and Black Box (BB; n = 118) trees along the Darling Anabranch. Boxes enclose the 25th to 75th percentiles; whiskers enclose the 10th to 90th percentiles; outliers are identified by closed circles; dashed line within box plots represents the mean and the solid line represents the median.

The relationship between NOM load and Tree Condition Index (TCI) is displayed in Figure 4.7. The graph shows a weak relationship whereby NOM load increases with TCI score from **POOR** to **STRESSED** trees (categories as per Table 2.3), then decreases as tree condition improves (TCI scores increase). This relationship is displayed for crown extent and crown density in Figure 4.8 for the three tree species. These graphs support the relationship displayed in Figure 4.7, demonstrating that trees in **GOOD** condition that are not water stressed have relatively high NOM loadings.

Trees that are **STRESSED** are shedding leaves to manage water use (higher NOM load) and trees in **POOR** condition have probably already lost the NOM load and it has broken down and been dispersed. Broader implications are that trees in better condition (but not necessarily **VERY GOOD** condition) have greater potential to input nutrients (because of higher NOM loading), which is likely to lead to greater productivity.

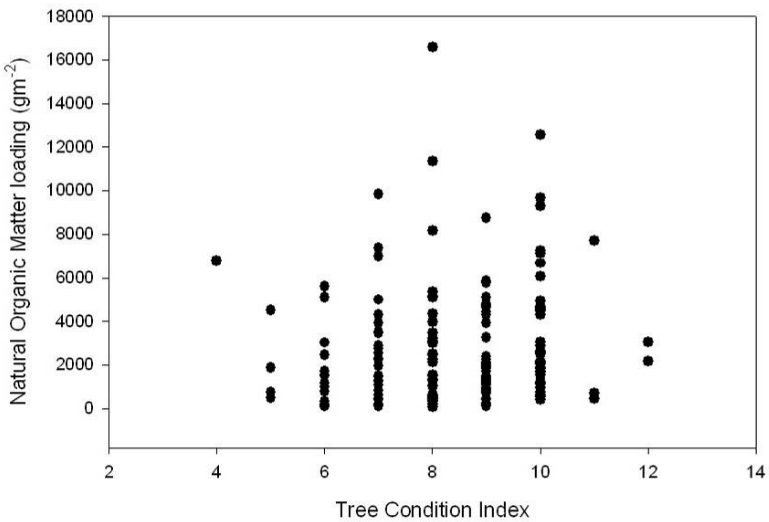


Figure 4.7. Relationship between Tree Condition Index and NOM load.

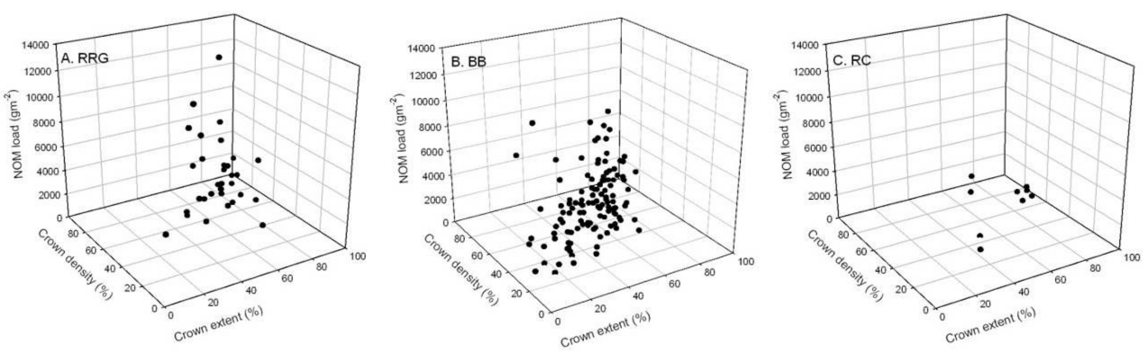


Figure 4.8. Relationship between crown extent, crown density and NOM load for [A] River Red Gum (n = 33), [B] Black Box (n = 118) and [C] River Cooba trees (n = 9).

4.2.5. Assessment of combined parameters

Principle Component Analysis (PCA) was used to visually summarise the patterns in condition variables across all of the sites. This assessment is based on the mean score for each variable at the site scale. The response variables; 'bark condition', 'mistletoe load' and 'reproductive extent' were excluded from the analysis for aforementioned reasons (see section 4.2.2).

There is no clear association between sites based on dominant species, except for sites with River Cooba (Figure 4.9). These two sites, 15 and 16, are influenced by high crown extent and crown density scores which are a defining characteristic for sites 15 and 16 (Figure 4.9). There was no significant difference in tree condition between these sites (P = 0.1549; Table 4.3).

Sites 8 and 12, and sites 12 and 14 are not significantly different in terms of tree condition (Table 4.3) however, their distribution within the ordination does not display this clearly (Figure 4.9). Sites 2, 7, 11 and 17 are separated from the remaining sites and from one another (Figure 4.9). DBH may be a defining character for site 17, which recorded the highest mean, median and individual DBH (Figure 4.2).

Sites 2, 7 and 11 have the highest Potential Trajectory (PT) scores (Figure 4.4); which are calculated using the variables; epicormic growth, new tip growth and leaf die-off. These variables may be influencing their distribution within the ordination, particularly sites 2 and 11, which are in-between leaf die-off and new tip growth and not heavily influenced by epicormic growth. The distribution of site 7 in the ordination appears to be strongly influenced by epicormic growth, however, the data does not support this (epicormic growth scores are between 0 and 2 with a mean of 1.65). Rather, the distribution of site 7 within the ordination is likely to be influenced by crown extent and crown density. The direction and length of the vectors demonstrates the relative influence of the vector on the distribution of sites. The lack of influence of crown extent and crown density on the distribution of site 7 is supported by the data which shows that site 7 recorded the lowest mean and median Tree Condition Index score (see Figure 4.3).

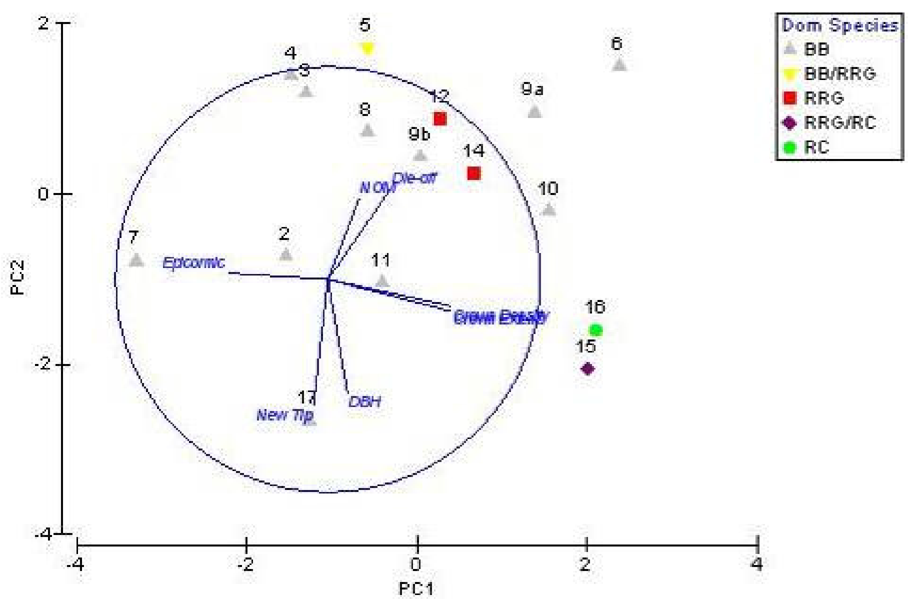


Figure 4.9. Principal Component Analysis (PCA) comparing average tree condition scores across sites.

4.3. Recruitment and tree community status

Recruitment of canopy tree species on the floodplain is a necessary process to sustain riparian overstorey communities. In systems such as the Darling Anabranch that are highly variable in terms of 'wet' and 'dry' conditions (i.e. flood and drought periods), recruitment events are likely to occur patchily over space and time. Several studies (e.g. George et al. 2005; Wallace 2010) have shown recruitment of eucalypt species on the lower River Murray floodplain to be insufficient for long-term population viability, particularly in the case of Black Box (BB).

For both BB and River Red Gum (RRG), seedling establishment primarily occurs as a result of floods (George et al. 2005). George (2004, cited in Jensen et al. 2008) suggested that above average rainfall following a flood is necessary for successful recruitment. Jensen et al. (2008) presents a case for the reverse – rainfall followed by a flood – provided timing matches peak seed release times. Conditions in the Darling Anabranch from September 2010 until the time of writing (March 2011) are conducive to the establishment of RRG and BB seedlings, according to the literature. The expansion of the DAAMMP Condition Monitoring to include the collection of recruitment data would provide evidence to support or disprove this hypothesis. It would also provide data to inform progress towards ecological objectives. Although no targets have yet been set, all objectives for trees refer to sustainable populations. Populations cannot be sustainable without adequate recruitment.

Further, the collection of stand condition information (tree density and live basal area) would enable an analysis of long-term viability of the Darling Anabranch riparian tree community. It would also enable landscape-scale modelling of tree condition using remote sensing, which has been carried out for The Living Murray Icon sites and proven to be an effective technique for accurately mapping stand condition across a major river system (Cunningham et al. 2009).

4.4. Understorey

4.4.1. Plant species and functional groups

In total 209 plant species were recorded from the 16 sites surveyed along the Darling Anabranch system between September and November 2010 (refer to Appendix C for species list). One hundred and fifty seven species are native (75%) and 52 are exotic (25%). No listed threatened species were recorded. Four exotic species are listed as Class 4 weeds under the *Noxious Weed Act 1993* (NSW) (Table 4.3). *Carthamus* sp., identified to genus level, is included as it is likely to be one of the two *Carthamus* species listed as Class 4 weeds.

Plant species were recorded from 46 families, with Chenopodiaceae and Asteraceae the most dominant in terms of number of species (Table 4.4). Chenopodiaceae was the most dominant family in terms of abundance, where abundance is a measure of the presence of a species in a 1 m× 1 m cell (i.e. a maximum abundance of 15 per quadrat) (Table 4.4).

The highest number of species was recorded at floodplain elevations (137); 122 species were recorded from Tree-line elevations, 120 from Mid-bank elevations and 75 from In-channel elevations. The three most abundant species recorded were *Medicago* spp. (at least 3 species, 1027 records), *Enchylaena tomentosa* (Ruby Saltbush, 903 records) and an unidentified species of Poaceae (763 records). The majority of species (approximately 75%) were recorded less than 50 times and more than half were recorded less than 20 times.

Table 4.3. Class 4 weeds listed under the *Noxious Weed Act 1993* (NSW) recorded along the Darling Anabranch.

Species name	Common name	Family	Sites recorded	Abundance*
*Asphodelus fistulosus**	Onion Weed	Asphodelaceae	10	33
Carthamus sp.*	Thistle	Asteraceae	10	1
*Emex australis**	Spiny Emex	Polygonaceae	7, 9b	5
*Marrubium vulgare**	White Horehound	Lamiaceae	4, 9a, 9b, 10, 11	31

*Abundance is based upon a maximum of 15 records per species per quadrat

Table 4.4. Number of species and total abundance by family recorded at Darling Anabranch sites between September and November 2010.

Family	Number of species	Abundance*	Family	Number of species	Abundance*
Aizoaceae	5	924	Lemnaceae	1	56
Amaranthaceae	1	15	Lythraceae	1	12
Apiaceae	1	36	Malvaceae	4	104
Asphodelaceae	2	110	Marsiliaceae	1	99
Asteraceae	41	1793	Myriophyllaceae	1	29
Boraginaceae	3	45	Myrsinaceae	1	2
Brassicaceae	6	735	Myrtaceae	2	132
Callitrichaceae	1	2	Nyctaginaceae	1	41
Campanulaceae	1	11	Onagraceae	1	2
Caryophyllaceae	4	292	Oxalidaceae	1	6
Charophyceae	1	1	Phyllanthaceae	1	7
Chenopodiaceae	43	4591	Plantaginaceae	3	172
Convolvulaceae	3	66	Plumbaginaceae	1	11
Crassulaceae	2	324	Poaceae	20	1773
Cucurbitaceae	1	10	Polygonaceae	6	148
Cyperaceae	2	109	Portulacaceae	1	62
Euphorbiaceae	1	175	Proteaceae	1	1
Fabaceae-Faboideae	7	1158	Ranunculaceae	2	245
Fabaceae-Mimosaceae	2	61	Scrophulariaceae	3	66
Geraniaceae	1	1	Solanaceae	5	99
Goodeniaceae	3	128	Urticaceae	1	37
Juncaceae	1	16	Verbenaceae	1	26
Lamiaceae	3	97	Zygophyllaceae	3	66

*Abundance is based upon a maximum of 15 records per species per quadrat

Table 4.5 provides a summary of the number of plant species (indigenous and exotic) recorded at each site and proportion of native to exotic species at each site. There is a relatively high proportion of exotic species overall (25%). In comparison, understorey surveys at Lindsay, Mulcra and Wallpolla Islands and Hattah Lakes in 2010 recorded the proportion of exotic species as 9-13% and 11-15% respectively (Henderson et al. 2010; Walters et al. 2010). It is important to note however, that the mean and median proportion of exotics at the individual site level is 16.6% and 16.5% respectively. Furthermore, 67% (35) of these exotic species were recorded less than 20 times, indicating that most exotic species recorded are not generally widespread across the Darling Anabranch. This could be a reflection of the long-dry conditions experienced throughout the region over the past decade or more. Subsequent Condition Monitoring surveys will detect changes in weed abundance in relation to water regime. It is expected that current conditions of high rainfall and high flows in the Darling Anabranch will result in an expansion of exotic species cover. One of the ecological objectives for understorey vegetation is to “limit the extent of recognised weeds as invasive species”. Targets for this objective should consider a series of benchmarks for exotic species abundance under different water regime scenarios.

Table 4.5. Number and relative proportion of indigenous and exotic plant species at Darling Anabranch sites recorded between September and November 2010.

Site	Native species		Exotic species		Total
	diversity	% of total	diversity	% of total	
2	52	88	7	12	59
3	37	86	6	14	43
4	90	90	10	10	100
5	48	84	9	16	57
6	51	93	4	7	55
7	63	86	10	14	73
8	75	88	10	12	85
9a	52	80	13	20	65
9b	52	78	15	22	67
10	78	77	23	23	101
11	75	81	18	19	93
12	56	79	15	21	71
14	44	72	17	28	61
15	53	80	13	20	66
16	39	83	8	17	47
17	49	88	7	12	56
All sites	157	75	52	25	209

The proportion of species in each functional group is displayed in Figure 4.10. The vast majority of species (at least 87%) belong to terrestrial functional groups (FGs) (Figure 4.10) (refer to section 2.33 for explanation of functional groups). This reflects the ‘long-dry’ period preceding Condition Monitoring. With the reinstatement of a wetting and drying regime it is anticipated that the proportion of species in the terrestrial dry (Tdr) FG would decrease and the proportion of species in the amphibious (A) FGs would increase. If Condition Monitoring happens to coincide with periods of inundation, it is anticipated that there would then be an increase in the proportion of species in floating (F) and submerged (S) FGs.

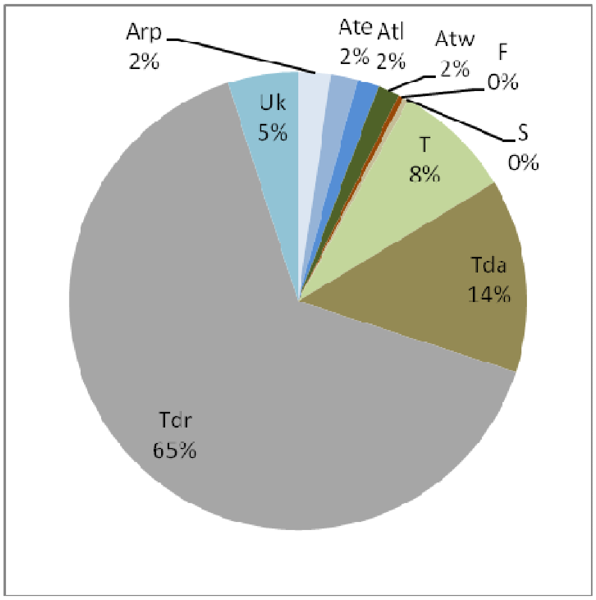


Figure 4.10. Pie chart displaying proportion of total understorey species recorded for each functional group. Tdr = terrestrial dry, Tda = terrestrial damp, T = terrestrial, S = submerged, F = floating, Atw = amphibious tolerator woody, Atl = amphibious tolerator dicotyledons, Ate = amphibious tolerator monocotyledons, Arp = amphibious responder plastic, Uk = unknown.

4.4.2. Site results and photo points

Species recorded at each site are indicated in the species list (Appendix C). Photo points for each site are displayed in Appendix D. Comparison of these from year to year will provide a rapid visual assessment of broad changes in understorey vegetation.

4.4.3. Results and discussion of understorey data analysis

Species were grouped into functional groups (FGs) for comparison between sites and between elevations (refer to section 2.3.3 for more detail of FGs). Multivariate analysis was carried out for both species and FGs. Results from all analyses returned the same significant differences for species and FGs. The use of FGs is a robust way of detecting meaningful ecological trends in community composition in relation to flow regime (and to some extent rainfall). Results are therefore discussed in terms of FGs only.

Site-quadrat interaction

There was a significant difference in FG composition for the site × quadrat interaction term ($P = 0.0001$; two-way analysis with site and quadrat as fixed factors). This significant result was explored with pair-wise comparisons between sites for each of the quadrat elevations and between elevations for each site; results are summarised in Appendix E.

There were many similarities among sites for In-channel, Tree-line and Floodplain quadrats. The dominance of terrestrial species at Floodplain and Tree-line quadrat elevations most likely explain the similarities in FG composition among the majority of sites. This is demonstrated visually in Figure 4.11. FG composition of In-channel quadrats is similar among sites that were inundated at the time of survey (dominated by amphibious species), with the remaining sites that were dry at the time of survey showing similarities (dominated by terrestrial species). The FG composition of Mid-bank quadrats was significantly different between most sites, except sites and 5 and 6 ($P = 0.1422$) and sites 9a and 9b ($P = 0.1894$).

Figure 4.11 displays these differences in the scattered distribution of Mid-bank quadrats. This is likely to be because of differences in the hydrological situation between sites at the time of survey, which are most evident at Mid-bank elevations. Conditions at the Mid-bank elevation quadrats included long-term inundated (e.g. site 17), short-term inundated (e.g. sites 5 and 6), recently inundated and soil still damp (e.g. site 4) and long-dry (e.g. sites 9a and 9b). Within most sites there was a significant difference between In-channel quadrats and all other elevations. This reflects the hydrological situation at the time of survey where In-channel quadrats at most sites were inundated and dominated by amphibious and aquatic species, whereas other elevations were dominated by terrestrial species. Figure 4.11 displays this difference, with most In-channel quadrats clearly separated from other quadrat elevations. Sites 7 and 12 were the only sites with significant differences between all elevations.

Sites

Comparing sites overall, that is, averaging FG abundances across quadrats, there was a significant difference in FG assemblages between sites ($P = 0.0001$; one-way PERMANOVA with site as a factor). Further exploration showed significant differences in FG composition between most sites except between sites 8 and 16 and sites 16 and 17 (Table 4.6). Sites 16 and 17 are both within the Murray River Lock 9 weir pool and due to high water levels at the time of survey were only surveyed at Floodplain elevations. Their similarity is therefore not surprising. The similarity between sites 8 and 16, although fairly weak ($P = 0.0611$), is difficult to explain. Site 8 was mostly dry at the time of this survey and dominated by terrestrial species (92%); site 16 was also dominated by terrestrial species (98%), however, this is common across most sites that were nonetheless found to be significantly different from one another. Future years' results will be of interest to see whether the FG composition continues to be not significantly different between sites 8 and 16.

Table 4.6. Pair-wise comparisons between sites based on Functional Groups.

Site	is significantly different to:	P value	but is not significantly different to:	P value
2	All sites	P ≤ 0.0042		
3	All sites	P ≤ 0.0025		
4	All sites	P ≤ 0.009		
5	All sites	P ≤ 0.0111		
6	All sites	P ≤ 0.0448		
7	All sites	P ≤ 0.0214		
8	Sites 2,3,4,5,6,7,9a,9b,10,11,12,14,15,17	P ≤ 0.0432	Site 16	P = 0.0611
9a	All sites	P ≤ 0.0023		
9b	All sites	P ≤ 0.0023		
10	All sites	P ≤ 0.0016		
11	All sites	P ≤ 0.0219		
12	All sites	P ≤ 0.025		
14	All sites	P ≤ 0.0081		
15	All sites	P ≤ 0.0091		
16	Sites 2,3,4,5,6,7,9a,9b,10,11,12,14,15	P ≤ 0.025	Sites 8,17	P ≥ 0.0611
17	Sites 2,3,4,5,6,7,8,9a,9b,10,11,12,14,15	P ≤ 0.0432	Site 16	P = 0.2043

Quadrat elevations

Comparing quadrats overall, that is, averaging FG abundances across sites, there was a significant difference between quadrat elevations for FG composition ($P = 0.0001$; one-way PERMANOVA with quadrat as a factor). Further exploration using pair-wise tests showed significant differences between all quadrat elevations (Table 4.7). This result validates the methodology of collecting understorey species information from the four different chosen elevations, both to be representative of a site as a whole and also to understand the effects of changing water regimes on the plant understorey community at different elevations within the channel and on the floodplain.

Table 4.7. Pair-wise comparisons between quadrat elevations based on Functional Groups.

Quadrat elevation	is significantly different to:	P value
In-channel	All quadrat elevations	$P \leq 0.0001$
Mid-bank	All quadrat elevations	$P \leq 0.0002$
Tree-line	All quadrat elevations	$P \leq 0.0012$
Floodplain	All quadrat elevations	$P \leq 0.0012$

Multi-dimensional Scaling (MDS) was used to visually summarise the patterns in FG composition across all sites and elevations. Figure 4.11 displays a comparison of quadrat elevations based on FG composition. The distribution of Tree-line and Floodplain quadrats within the ordination is influenced by the dominance of terrestrial FGs (T, Tda and Tdr) recorded at these elevations. The direction and length of the vectors demonstrates the relative influence of the vector on the distribution of quadrats. The influence of inundation and aquatic and amphibious FGs is apparent for most In-channel quadrats. The spread of Mid-bank and to a lesser extent, In-channel quadrats, can be explained by differences in recent watering history of sites (see Table 4.1), which affected these elevations in particular. For example, sites 2, 3, 5 and 6 were inundated by flows at these elevations (with the flow source also different – see Table 4.1); sites 7, 12 and 14 were inundated at these elevations by standing pools and at sites 15 to 17 these elevations are permanently inundated by the Murray River Lock 9 weir pool.

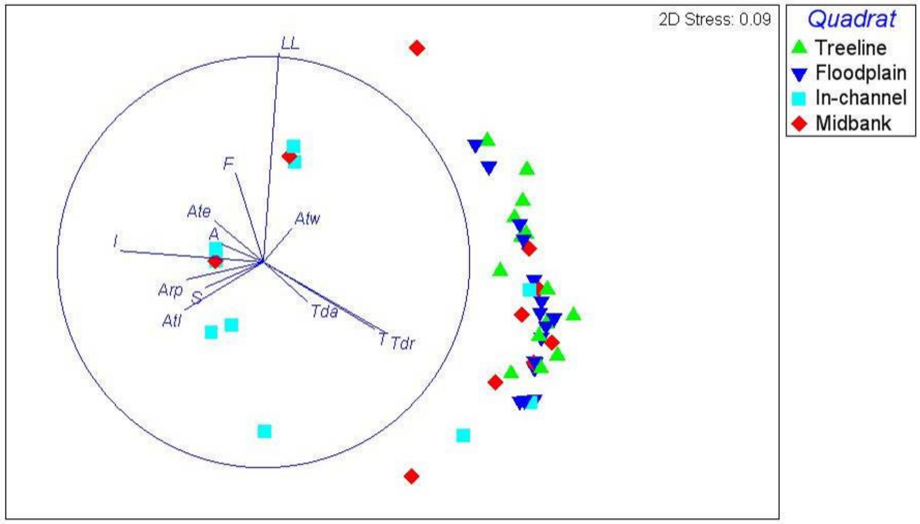


Figure 4.11. MDS plot of functional group composition across all sites, displayed by quadrat elevation. Tdr = terrestrial dry, Tda = terrestrial damp, T = terrestrial, S = submerged, F = floating, Atw = amphibious tolerator woody, Atl = amphibious tolerator dicotyledons, Ate = amphibious tolerator monocotyledons, Arp = amphibious responder plastic, I = inundated, LL = leaf litter.

4.4.4. Limitations

A discussion of some of the limitations raised in the methods section (section 2.3.7) is warranted here, due to the potential of these to confound comparisons between sites and in the future, between years.

Disturbance

Grazing by domestic stock and feral animals (particularly rabbits) is widely accepted as a major disturbance to understorey vegetation. All the sites established for the DAAMMP Condition Monitoring are subject to grazing by domestic stock and feral animals. It is not the intent of this Condition Monitoring program to assess the impact of grazing on understorey vegetation; however, the ability to interpret results over time may be inhibited by the influence of grazing. At the time of survey for example, site 9b had recently been grazed by sheep under a rotational grazing regime and is managed in such a way that domestic stock would not be expected to return to this site for some time (Angus Whyte, pers. comm.). Under this management regime, understorey vegetation would be expected to increase in species diversity and abundance until domestic stock were rotated into this paddock again, at which point species diversity and abundance would be expected to decline. Interpretation of results over time will therefore need to be in the context of stock grazing regimes. Consideration should be given to establishing grazing exclusion plots for future monitoring of the Darling Anabranch.

Lack of flood inundation modelling data

Condition Monitoring programs for The Living Murray Icon sites have based floodplain understorey quadrat elevations on frequency of inundation, from “very often” to “rarely” (Wallace 2009b). Sites are overlaid on spatial flood inundation modelling data to determine the position of quadrats. This data is lacking for the Darling Anabranch system and therefore quadrat elevations have been allocated on visual assessments. For example, “Tree-line” quadrats are placed at the elevation of the majority of ‘mature’ trees at a site and assumed to be inundated at a flood frequency of “sometimes” (defined in TLM monitoring as between 1 in 5 and 1 in 13 years).

The Darling Anabranch system has undergone significant changes in water regime since European settlement in the mid 1800s and it is difficult to determine which hydrological regime the distribution of vegetation represents. At site 12 for example, there are long-dead River Red Gums (RRGs) close to the base of the channel, their distribution presumably a reflection of the water regime prior to the Menindee Lakes Scheme, having been drowned as a result of the regulation. The distribution of younger RRG (DBH < 0.6 m) higher up the banks indicate the consistent long-term water levels experienced in the regulated system, whereas the large Black Box (BB) at a similar height on the bank reflects the pre-regulated system, where long-term consistent water levels would have been much lower.

The overarching ecological objective for the Darling Anabranch is to "Restore a flow regime to the Darling Anabranch which closely mimics the natural flow regime …". The "natural" flow regime is based upon annual flows in the Darling River between 1892 and 1998 (Nias 2002). The assumption is that the current distribution of long-lived vegetation is a product of this period, referred to for the purposes of the DAAMMP as 'natural'. This is based on the maximum longevity of RRG and BB in the Lower Murray which has been recorded as approximately 200 years (Ogden 1978; George et al. 2005).

Uneven channel morphology in the Darling Anabranch adds complexity to the selection of elevations that represent a particular flood inundation frequency. In some cases (e.g. at site 7) transects were placed on the same, high, side of the channel. At other sites (e.g. site 9b), Floodplain quadrats were established at inconsistent elevations due to substantial differences in morphology on either side of the bank. At the time of surveying, all Floodplain quadrat elevations were 'long-dry' (personal observation) and therefore comparable. Since the September to November 2010 Condition Monitoring period, however, it is possible that some Floodplain elevation quadrats have been inundated and some have remained dry. Further, of those that may have been inundated, there may be differences in inundation duration. In such a situation, Floodplain quadrat elevations would require review in subsequent years of surveying and may need to be placed on the same side of the channel. The availability of spatial elevation data and inundation modelling would add confidence to the placement of understorey vegetation quadrats.

4.5. Lignum

A Lignum Condition Index (LCI) score was calculated for all Lignum plants assessed, by summing the scores for percent viability and colour, with a maximum possible score of 11. Categories attributed to LCI scores are described as per Table 4.8. These categories are denoted in this document by **POOR**, **STRESSED** and **GOOD**. It is important to note that the LCI is a visual above-ground assessment of the plant that indicates the level of stress experienced at the time of survey. Although plants may appear dead (LCI score of 0) they may still be able to respond to favourable conditions from underground resources. Lignum condition varied considerably along the Darling Anabranch, as shown in Figure 4.12. Over half the sites fall into the **POOR** category, three sites have a mean LCI in the **STRESSED** category and only one (site 6) is considered in **GOOD** condition. Photo points for Lignum sites are displayed in Appendix F.

Table 4.8. Categories used to describe Lignum Condition Index (LCI) scores.

LCI score	Description
0-4	Poor
>4 to 8	Stressed
>8	Good

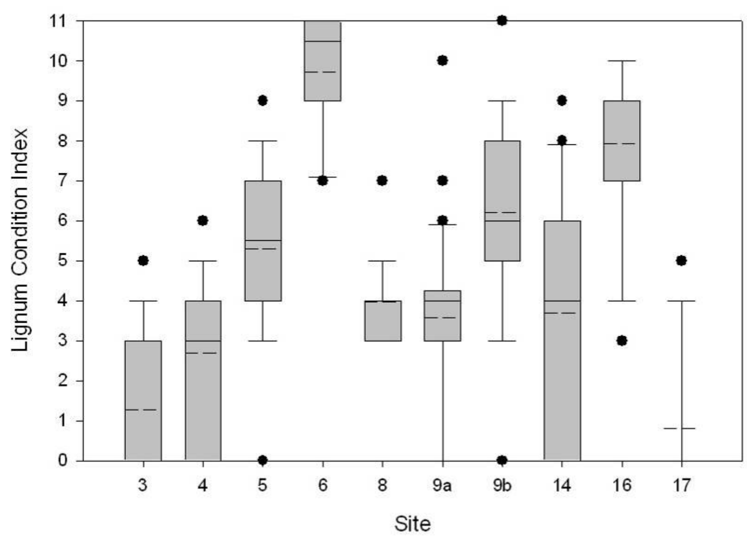


Figure 4.12. Box and whisker plots displaying the Lignum Condition Index for Lignum monitoring sites. Box encloses 25th to 75th percentiles, whiskers enclose 10th to 90th percentiles, circles are outliers; solid line within box plots depicts the median and the dotted line is the mean.

The condition of plants at site 6 can be attributed to flow at Tandou Creek approximately eight weeks before the monitoring period, at which time the plants were inundated to depths of 0.2 to 1 m (Figure 4.13). The vigour and flowering of Lignum at site 6 supports Jensen's (2008) studies, which demonstrate that direct watering to Lignum plants will cause rapid responses, within two to three weeks, including the production of vigorous green shoots, new green leaves and flowers. Lignum plants at site 5 were also inundated at the time of survey, to depths of up to 1.5 m. In comparison with site 6, Lignum plants at site 5 had only received water approximately one week prior to monitoring and had not responded to the same extent as plants at site 6, recording a mean LCI score of 5.3 (**STRESSED**) (Figure 4.12).

Figure 4.13. Lignum community at site 6, Tandou Creek (D. Bogenhuber, MDFRC, 22/9/10).

Site 16 recorded a mean LCI score of 7.9, just below **GOOD** and the second highest LCI score overall (Figure 4.12). The relatively good condition of these plants could be due to a combination of factors including their proximity to a permanent water source. Plants at this site are located within 6 m of the Darling Anabranch channel, which is permanently inundated by the Murray River Lock 9 weir pool. Lignum plants secure soil moisture via means of rainfall, flooding and shallow water tables (Lynch 2006). The Lock 9 weir pool could be creating a freshwater flush zone that the Lignum plants are utilising. In addition, above average rainfall preceding the survey period (190.4 mm recorded in Wentworth from July to October 2010, 181% of long-term average (BOM 2011c) could have contributed to a positive response in Lignum. The Lignum plants are also located under a relatively dense overstorey canopy that provides shade, hence reducing soil evaporation. Site 9b recorded the largest range of LCI scores from 0 to 11 (Figure 4.12) and a relatively good mean LCI score (although falling into the **STRESSED** category) compared with other sites. These results reflect the diversity of microhabitats surveyed at this site, which includes a deep waterhole, steep banks, flood runners and benches with dense overstorey canopy (Figure 4.14).

Sites 3 and 17 scored lowest for Lignum condition, with mean LCI scores of 1.27 and 0.80 respectively (Figure 4.12). Site 3 received a flow in January/February 2010 for approximately 5 to 6 weeks and had been inundated for one week before monitoring in November 2010. Prior to these flows, however, the most recent flow experienced at site 3 was between November 2000 and January 2001. This prolonged dry period is around the maximum time between floods required for Lignum to survive (Craig et al. 1991; Rogers 2011). The Lignum plants surveyed at site 17 were in a flood runner above normal weir pool level. There is evidence of the effects of salinity at site 17 (e.g. the presence of salt-tolerant understorey species such as *Pachycornia triandra* and *Disphyma crassifolium*), which may affect Lignum condition, particularly in the absence of regular frequent flooding (Craig et al. 1991).

Condition Monitoring during subsequent years will aid in determining if the positive responses observed in Lignum plants (e.g. new green growth and flowering) lead to an improvement in Lignum community condition. Studies by Lynch (2006) and Jensen (2008) report that if soil moisture levels fall below 10%, death or wilting will occur in Lignum seeds and seedlings. With sustained ‘unregulated’ high flows and above average rainfall across the Darling Anabranch region (highest rainfall for November on record was recorded at Wentworth Post Office and highest annual rainfall on record was recorded for Willow Point and Woodlands for 2010 (BOM 2011c; 2011a; 2011b), soil moisture may have been maintained at a sufficient level for long enough to enable Lignum seedlings to establish. The over bank flooding along parts of the Darling Anabranch could lead to the establishment of new Lignum seedlings further away from the main Anabranch channel, provided that soil moisture is sustained and grazing impacts do not impede new growth. There are difficulties associated with the detection of seedlings due to the asexual nature of reproduction and regeneration from root stock, however, consideration should be given to recording Lignum seedlings within the Lignum survey area at each site in future Condition Monitoring surveys.

Figure 4.14. Photo of site 9b taken from high side of channel looking towards waterhole and across to a low bench with dense Black Box (D. Bogenhuber, MDFRC, 12/10/2010).

4.6. *Typha* distribution

Live *Typha* plants were recorded at only three of the 16 sites surveyed between September and November 2010. Two of these sites (15 and 16) are within the Murray River Lock 9 weir pool (permanently wet) and site 6 had been inundated for approximately eight weeks prior to surveying (refer to Table 4.1).

Figures 4.15 to 4.17 display the extent of *Typha* stands within sites 6, 15 and 16 respectively, in September/October 2010. No flowering was observed at any of the sites.

Scattered individual *Typha* plants and stands of up to 11 plants were recorded at site 6, as well as two larger 'stands' of *Typha*. The northern stand (stand A) was approximately 2612 m^2 and the southern stand (stand B) was approximately 807 m^2 in size. Plant density in stand A was only 1 to 5% and approximately 15 to 20% in stand B. Although plants were sparse, they were widespread across the site (Figure 4.15), suggesting that they were re-shooting from rhizomes. With the persistence of flows at this site *Typha* stands are expected to increase in density and extent.

At site 15, a band of *Typha* approximately 300 m long and 20 m wide was mapped along the bank, covering a total area of approximately 3351 m^2 (Figure 4.16). Plants were 3-4 m high, in water 2 m deep. Plant density within the mapped area was about 70% and plants exhibited approximately 45% die-back. The stand continued along the bank south of the site boundary. *Typha* also occupied the opposite side of the channel but was not included in site 15 due to access restrictions.

Typha was present at site 16, downstream of Oakbank Dam, in a 1 m wide strip, which continues upstream of the site boundary and extends across Oakbank Dam (Figure 4.17). The total area of this stand is approximately 1241 m^2. Plant cover was sparse (5 to 10% cover), except for four small stands ranging in size from 40 to approximately 110 m^2 (Figure 4.13). Cover in these stands was approximately 70%.

Figure 4.15. Distribution of *Typha* at site 6, Tandou Creek, Darling Anabranch system.

Figure 4.16. Distribution of *Typha* at site 15, Darling Anabranch.

Figure 4.17. Distribution of *Typha* at site 16, Darling Anabranch.

The ability of *Typha* to grow and expand rapidly is well documented (Sainty and Jacobs 1981; Finlayson et al. 1983; Roberts and Ganf 1986; Froend and McComb 1994; Nicol and Ganf 2000). The high numbers of seeds (> 200 000) produced, with a high percentage of viability (Sainty and Jacobs 1981; Finlayson et al. 1983; Zedler et al. 1990; Froend and McComb 1994) and the ability of the species to survive short dry periods by way of rhizomes, all aid *Typha* in forming new stands and out-competing other species to create monospecific stands.

The generally stable water level in the Lock 9 weir pool provides ideal conditions for the development, growth and expansion of *Typha* at sites 15 and 16. The dense stands around Oakbank Dam suggest that the operation of this structure may also have favoured its growth (Figure 4.18). These stands are expected to remain stable or expand even further under a permanent water regime. It is possible that the current high water levels in the Murray River may place stress on the existing *Typha* stands, however, the average height of plants (3 to 4 m) means it is unlikely they will be completely drowned.

Dried rhizomes and dead above-ground material was present at several other sites (e.g. 9a and 9b). The long-dry period prior to the current flow (approximately six years) may have been long enough to kill rhizomes; the next survey of *Typha* in 2012 will confirm if this is the case or not.

Figure 4.18. *Typha* stands at Oakbank Dam, near sites 15 and 16 (D. Linklater, MDFRC, 17/11/2010).

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BOM (2011c) Monthly Rainfall Wentworth Post Office, Australian Government Bureau of Meteorology <http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_stn_num=047053>

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Appendix A. Tree condition photo points

Figure A1. Site 2 tree condition photo point (D. Linklater, MDFRC, 3/11/2010).

Figure A2. Site 3 tree condition photo point (D. Bogenhuber, MDFRC, 3/11/2010).

Figure A3. Site 4 tree condition photo point (D. Bogenhuber, MDFRC, 23/09/2010).

Figure A4. Site 5 tree condition photo point (D. Bogenhuber, MDFRC, 21/09/2010).

Figure A5. Site 6 tree condition photo point (D. Bogenhuber, MDFRC, 22/09/2010).

Figure A6. Site 7 tree condition photo point (D. Bogenhuber, MDFRC, 30/09/2010).

Figure A7. Site 8 tree condition photo point
(D. Bogenhuber, MDFRC, 29/9/2010).

Figure A8. Site 9a tree condition photo point
(D. Bogenhuber, MDFRC, 24/09/2010).

Figure A9. Site 9b tree condition photo point
(D. Bogenhuber, MDFRC, 12/10/2010).

Figure A10. Site 10 tree condition photo point
(D. Bogenhuber, MDFRC, 13/10/2010).

Figure A11. Site 11 tree condition photo point
(D. Linklater, MDFRC, 18/10/2010).

Figure A12. Site 12 tree condition photo point
(D. Bogenhuber, MDFRC, 21/10/2010).

Figure A13. Site 14 tree condition photo point (D. Linklater, MDFRC, 28/10/2010).

Figure A14. Site 15 tree condition photo point (D. Linklater, MDFRC, 28/10/2010).

Figure A15. Site 16 tree condition photo point (D. Linklater, MDFRC, 28/10/2010).

Figure A16. Site 17 tree condition photo point (D. Linklater, MDFRC, 29/10/2010).

Appendix B. Results of data analysis for tree condition

Table B1. Pair-wise comparisons between tree condition sites.

Site	is significantly different to:	P value	but is not significantly different to:	P value
2	All sites	P ≤ 0.0106		
3	All sites	P ≤ 0.0153		
4	All sites	P ≤ 0.0058		
5	All sites	P ≤ 0.0234		
6	All sites	P ≤ 0.0042		
7	All sites	P ≤ 0.0001		
8	Sites 2,3,4,5,6,7,9a,9b,10,11,14,15,16,17	P ≤ 0.0468	Site 12	P = 0.0929
9a	All sites	P ≤ 0.0042		
9b	All sites	P ≤ 0.0234		
10	All sites	P ≤ 0.0033		
11	All sites	P ≤ 0.0106		
12	Sites 2,3,4,5,6,7,9a,9b,10,11,15,16,17	P ≤ 0.0006	Sites 8 and 14	P ≥ 0.0929
14	Sites 2,3,4,5,6,7,8,9a,9b,10,11,15,16,17	P ≤ 0.0468	Site 12	P = 0.467
15	Sites 2,3,4,5,6,7,8,9a,9b,10,11,12,14,17	P ≤ 0.0002	Site 16	P = 0.1549
16	Sites 2,3,4,5,6,7,8,9a,9b,10,11,12,14,17	P ≤ 0.0023	Site 15	P = 0.1549
17	All sites	P ≤ 0.0001		

Appendix C. List of plant species recorded at the 16 Darling Anabranch Condition Monitoring sites, 2010

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
T	*Acacia* sp.		Fabaceae-Mimosaceae	x										x					
T	*Acacia* sp. seedling		Fabaceae-Mimosaceae											x					
Atw	*Acacia stenophylla* juvenile	River Cooba	Fabaceae-Mimosaceae														x		
Atw	*Acacia stenophylla* mature	River Cooba	Fabaceae-Mimosaceae	x					x								x		
Atw	*Acacia stenophylla* seedling	River Cooba	Fabaceae-Mimosaceae	x	x				x			x					x		
Tdr	*Actinobole uliginosum*	Flannel Cudweed	Asteraceae			x			x										
Tda	*Alternanthera denticulata*	Lesser Joyweed	Amaranthaceae	x		x					x	x	x						
Tdr	*Alyssum linifolium**	Flax-leaf Alyssum	Brassicaceae	x			x			x	x								
Tda	*Ammannia multiflora*	Jerry-jerry	Lythraceae			x													
Tdr	*Anagallis arvensis**	Scarlet Pimpernel	Myrsinaceae														x		
Tdr	*Asphodelus fistulosus**	Onion Weed	Asphodelaceae										x						
Tdr	*Atriplex conduplicata*		Chenopodiaceae							x					x	x			
Tdr	*Atriplex eardleyae*		Chenopodiaceae	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tdr	*Atriplex holocarpa*	Pop Saltbush	Chenopodiaceae			x	x	x	x	x	x	x	x	x		x		x	x
Tdr	*Atriplex leptocarpa*	Slender-fruit Saltbush	Chenopodiaceae	x	x	x	x	x		x	x		x	x	x	x		x	x
Tdr	*Atriplex limbata*		Chenopodiaceae			x		x		x							x		x
Tdr	*Atriplex lindleyi*		Chenopodiaceae	x	x	x	x			x	x		x		x	x	x	x	x
Tdr	*Atriplex semibaccata*	Creeping Saltbush	Chenopodiaceae				x	x				x	x	x	x	x	x	x	x
Tdr	*Atriplex* sp.	Saltbush	Chenopodiaceae			x	x	x	x	x	x	x	x	x	x	x	x		
Tdr	*Atriplex stipitata*	Mallee Saltbush	Chenopodiaceae			x				x		x	x	x					
Tdr	*Atriplex sturtii*		Chenopodiaceae							x									
Tdr	*Atriplex suberecta*	Sprawling Saltbush	Chenopodiaceae	x									x	x	x				

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tdr	*Atriplex versicaria* subsp. *sphaerocarpa*	Bladder Saltbush	Chenopodiaceae				x												
Tdr	*Austrodanthonia caespitosa*	Ringed Wallaby Grass	Poaceae										x						
Tdr	*Austrodanthonia setaceae*	Smallflower Wallaby Grass	Poaceae							x			x						
Tdr	*Austrostipa scabra*	Speargrass	Poaceae					x		x			x						
Tdr	*Austrostipa* sp.	Speargrass	Poaceae	x	x	x		x		x		x		x	x	x	x		x
Tdr	*Boerhavia dominii*	Tarvine	Nyctaginaceae	x								x	x	x	x	x	x	x	x
Tda	*Brachyscome basaltica* var. *gracilis*	Swamp Daisy	Asteraceae						x										
Tdr	*Brachyscome ciliaris*	Variable Daisy	Asteraceae											x					
Tdr	*Brachyscome dentata*		Asteraceae		x		x												
Tdr	*Brachyscome lineariloba*	Hard-headed Daisy	Asteraceae			x	x	x	x	x	x	x			x		x		x
Tda	*Brachyscome melanocarpa*	Black-seeded Daisy	Asteraceae			x	x	x		x	x		x	x	x	x		x	x
T	*Brachyscome* sp.	Daisy	Asteraceae													x			
Tdr	*Brassica* sp.		Brassicaceae					x											
Tdr	*Brassica tournefortii**	Meditteranean Turnip	Brassicaceae								x	x	x	x			x		
Tdr	*Bromus hordeaceus**	Soft Brome	Poaceae			x													
Tdr	*Bromus rubens*	Red Brome	Poaceae									x							
Tdr	*Bromus* sp.	Brome	Poaceae					x	x	x	x	x	x	x	x		x		x
Tda	*Bulbine alata*	Bulbine Lily	Asphodelaceae						x										
Tda	*Bulbine* sp.		Asphodelaceae	x	x	x		x	x	x				x	x	x	x	x	x
Tdr	*Calandrinia eremaea*		Portulacaceae	x		x		x	x	x								x	x
Tdr	*Calendula arvensis**	Field Marigold	Asteraceae																
Arp	*Callitriche sonderi*		Callitrichaceae						x										
Tdr	*Calocephalus sonderi*	Pale Beauty-heads	Asteraceae			x			x	x									
Tdr	*Calotis cuneifolia*	Purple Burr-daisy	Asteraceae			x													
Tdr	*Calotis hispidula*	Bogan Flea	Asteraceae			x	x	x	x	x	x	x	x	x	x			x	x

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tdr	*Calotis* sp.	Burr-daisy	Asteraceae	x		x		x	x	x	x	x	x	x	x				
Tdr	*Carrichtera annua**	Ward's Weed	Brassicaceae				x						x	x		x			
Tdr	*Carthamus* sp.*	Thistle	Asteraceae										x						
Tdr	*Centaurea melitensis**	Maltese Cockspur	Asteraceae			x					x	x							
Tdr	*Centaurea* sp.*		Asteraceae										x	x					
Atl	*Centipeda cunninghamii*	Common Sneezeweed	Asteraceae	x		x			x	x		x	x						
Atl	*Centipeda* sp.	Sneezeweed	Asteraceae						x					x					
Tdr	*Chamaesyce drummondii*	Caustic Weed	Euphorbiaceae	x		x		x		x	x	x	x	x	x	x	x	x	x
Tdr	*Chenopodium cristatum*	Crested Goosefoot	Chenopodiaceae	x		x			x		x	x		x		x	x	x	x
Tda	*Chenopodium nitrariaceum*	Nitre Goosefoot	Chenopodiaceae				x			x									
Tdr	*Chenopodium pumilio*	Small Crumbweed	Chenopodiaceae			x			x	x	x			x				x	
Tdr	*Chenopodium* sp.	Crumbweed/ Goosefoot	Chenopodiaceae		x	x	x	x	x	x	x	x	x	x					
Tdr	*Cirsium vulgare**	Spear Thistle	Asteraceae							x		x	x	x	x	x	x		
Tdr	*Convulvulus erubescens*	Blushing Bindweed	Convolvulaceae	x	x						x								
Tdr	*Convolvulus remotus*		Convolvulaceae							x	x			x		x			
Tdr	*Convolvulus* sp.	Bindweed	Convolvulaceae										x				x		x
Tdr	*Conyza bonariensis**	Flaxleaf Fleabane	Asteraceae										x						
Tda	*Craspedia* sp.	Billy-buttons	Asteraceae											x	x				
Tda	*Crassula decumbens* var. *decumbens*	Stonecrop	Crassulaceae			x													
Tda	*Crassula sp*	Stonecrop	Crassulaceae	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tda	*Cressa australis*		Convolvulaceae												x		x		
Tdr	*Cucumis myriocarpus**	Paddy Melon	Cucurbitaceae						x					x					
Ate	*Cyperus gymnocaulos*		Cyperaceae												x		x		
Tdr	*Daucus glochidiatus*	Native Carrot	Apiaceae	x	x			x	x			x	x				x		
Tdr	*Disphyma crassifolium*		Aizoaceae															x	x
Tdr	*Dissocarpus paradoxus*	Canonball Burr	Chenopodiaceae			x				x			x	x		x	x		x

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tda	*Dittrichia graveolens**	Stinkwort	Asteraceae												x				
Tdr	*Dysphania rhadinostachya* subsp. *inflata*		Chenopodiaceae			x	x												
Arp	*Eclipta platyglossa*		Asteraceae						x				x						
Tdr	*Einadia nutans*	Climbing Saltbush	Chenopodiaceae	x		x	x	x	x	x	x	x	x	x	x	x	x	x	
Tdr	*Emex australis**	Spiny Emex	Polygonaceae						x			x							
Tdr	*Enchylaena tomentosa*	Ruby Saltbush	Chenopodiaceae	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tdr	*Enneapogon gracilis*	Slender Bottle-washers	Poaceae					x											
Tdr	*Enneapogon intermedius*		Poaceae											x					
Tdr	*Enneapogon* sp.		Poaceae	x	x														
Atl	*Epaltes australis*	Spreading Nut-heads	Asteraceae	x		x			x				x	x					
Tdr	*Eragrostis dielsii*	Mallee Love-grass	Poaceae	x									x	x	x				x
T	*Eragrostis* sp.	Love-grass	Poaceae												x				
Tdr	*Erodium* sp.	Crowfoot/Storksbill	Geraniaceae											x					
Atw	*Eucalyptus camaldulensis* juvenile	River Red Gum	Myrtaceae										x			x			
Atw	*Eucalyptus camaldulensis* mature	River Red Gum	Myrtaceae						x				x		x		x		
Atw	*Eucalyptus camaldulensis* seedling	River Red Gum	Myrtaceae						x				x	x		x			
Atw	*Eucalyptus largiflorens* juvenile	Black Box	Myrtaceae		x	x		x					x			x			
Atw	*Eucalyptus largiflorens* mature	Black Box	Myrtaceae			x	x	x	x	x	x	x	x		x				
Atw	*Eucalyptus largiflorens* seedling	Black Box	Myrtaceae							x			x	x		x			
Atw	*Eucalyptus* sp. seedling		Myrtaceae		x									x	x				
Tdr	*Gazania rigens**	Treasure Flower	Asteraceae														x		
Tda	*Glinus lotoides*		Aizoaceae						x	x				x					
Tda	*Glycyrrhiza acanthocarpa*	Native Liquorice	Fabaceae-faboideae											x					
Tda	*Gnaphalium* sp. J (aff. *sphaericum)*		Asteraceae	x	x	x					x								

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tdr	*Goodenia fascicularis*		Goodeniaceae																x
Tda	*Goodenia glauca*		Goodeniaceae	x	x			x							x				
Tda	*Goodenia heteromera*		Goodeniaceae			x													
T	*Goodenia* sp.		Goodeniaceae							x						x	x	x	x
Tdr	*Hedypnois rhagodioloides**	Cretan Weed	Asteraceae											x					
Tda	*Heliotropium curassavicum**	Smooth Heliotrope	Boraginaceae												x	x			
Tda	*Heliotropium europaeum**	Potato Weed	Boraginaceae													x	x		
Tdr	*Herniaria cinerea**	Hairy Rupturewort	Caryophyllaceae		x	x			x	x	x	x	x	x	x		x	x	
Tdr	*Hordeum glaucum**	Northern Barley Grass	Poaceae								x								
Tdr	*Hordeum marinum**	Sea Barley Grass	Poaceae									x							
Tdr	*Hordeum* sp.*	Barley Grass	Poaceae	x	x				x	x	x	x	x	x	x	x	x	x	x
Tdr	*Hyalosperma glutinosum* ssp. *glutinosum*		Asteraceae											x					
Tdr	*Isoetopsis graminifolia*	Grass Cushions	Asteraceae			x	x				x				x				x
Ate	*Isolepis australiensis*		Cyperaceae			x								x					
Ate	*Juncus bufonius*	Toad Rush	Juncaceae			x													
Ate	*Juncus* sp.	Rush	Juncaceae			x													
Tda	*Lachnagrostis filiformis*		Poaceae	x		x						x	x	x					
Tdr	*Lactuca serriola**	Prickly Lettuce	Asteraceae										x	x	x	x	x		
Tdr	*Lamarckia aurea**	Goldentop	Poaceae						x			x							
F	*Lemna* sp.		Lemnaceae				x		x										
Tdr	*Lepididium pseudohyssopifolium*	Peppercress	Brassicaceae								x	x					x		
Tdr	*Lepidium* sp.	Peppercress	Brassicaceae	x	x					x		x	x				x		x
Tdr	*Limonium* sp.*	Sea Lavender	Plumbaginaceae										x	x		x		x	
Arp	*Limosella australis*	Australian Mudwort	Scrophulariaceae						x	x				x					

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tdr	*Lolium perenne**	Perennial Ryegrass	Poaceae														x		
Arp	*Ludwigia peploides*	Water Primrose	Onagraceae			x													
Tdr	*Lycium ferrocissimum**	African Boxthorn	Solanaceae														x		
Tdr	*Maireana appressa*		Chenopodiaceae																x
Tdr	*Maireana brevifolia*	Small-leaf Bluebush	Chenopodiaceae										x				x		
Tdr	*Maireana erioclada*	Rosy Bluebush	Chenopodiaceae						x						x				
Tdr	*Maireana pentatropis*	Erect Mallee Bluebush	Chenopodiaceae														x		
Tdr	*Maireana pyramidata*	Black Bluebush	Chenopodiaceae						x										
Tdr	*Maireana sclerolaenoides*		Chenopodiaceae										x			x			
Tdr	*Marieana* sp.	Bluebush	Chenopodiaceae						x	x		x	x	x	x		x		x
Tdr	*Maireana turbinata*	Satiny Bluebush	Chenopodiaceae							x			x						
Tdr	*Malacocera tricornis*	Soft Horns	Chenopodiaceae							x					x	x		x	x
Tdr	*Malva parviflora**	Small-flowered Mallow	Malvaceae			x			x										
Tdr	*Malva preissiana*	Native Hollyhock	Malvaceae						x				x						
Tdr	*Malva* sp.		Malvaceae		x	x						x				x	x		x
Tdr	*Marrubium vulgare**	White Horehound	Lamiaceae			x					x	x	x	x					
Arp	*Marsilea drummondii*	Common Nardoo	Marsiliaceae			x		x		x	x	x							
Tdr	*Medicago minima**	Woolly Burr Medic	Fabaceae-faboideae			x					x								
Tdr	*Medicago polymorpha**	Burr Medic	Fabaceae-faboideae								x								
Tdr	*Medicago praecox**	Small-leaved Burr Medic	Fabaceae-faboideae					x											
Tdr	*Medicago* sp.*	Medic	Fabaceae-faboideae		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tdr	*Melilotus indicus**	Hexham Scent	Fabaceae-faboideae		x						x	x	x		x	x			
Tdr	*Mesembryanthemum nodiflorum**	Small Ice Plant	Aizoaceae	x			x								x	x	x	x	x

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tdr	*Millotia greevesii*		Asteraceae							x					x				x
Ate	*Muehlenbeckia florulenta*	Lignum	Polygonaceae		x	x	x	x			x	x				x		x	x
Tda	*Myosurus australis*		Ranunculaceae			x			x	x			x						
Arp	*Myriophyllum* sp.	Water-milfoil	Myriophyllaceae			x							x	x					
Tdr	*Neobassia proceriflora*	Soda Bush	Chenopodiaceae	x	x	x													
Tdr	*Nicotiana occidentalis*	Native Tobacco	Solanaceae			x			x										
Tdr	*Omphalolappula concava*	Burr Stickseed	Boraginaceae								x	x							
Tdr	*Osteocarpum acropterum* var. *deminuta*		Chenopodiaceae	x		x	x	x	x	x	x		x		x	x	x	x	x
Tdr	*Oxalis radicosa*		Oxalidaceae												x				
Tdr	*Pachycornia triandra*	Desert Glasswort	Chenopodiaceae															x	x
Tdr	*Parapholis incurva**	Coast Barb Grass	Poaceae										x	x	x				
Tdr	*Phalaris minor**	Lesser Canary Grass	Poaceae													x			
Tdr	*Phalaris paradoxa**	Paradoxa Grass	Poaceae										x						
Tda	*Phyllanthus lacunarius*		Phyllanthaceae			x													
T	*Phyllanthus* sp.		Phyllanthaceae			x				x									
Tda	*Plantago coronopus* subsp. *commutata**	Buck's-horn Plantain	Plantaginaceae						x										
Tda	*Plantago cunninghamii*		Plantaginaceae				x		x										
Tda	*Plantago drummondii*		Plantaginaceae	x	x	x	x	x	x	x	x	x	x	x					
T	*Plantago* sp.		Plantaginaceae					x						x					
Tdr	*Poa* sp.		Poaceae	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Tdr	*Polygonum aviculare**	Wireweed	Polygonaceae										x						
Tda	*Polygonum plebium*	Small Knotweed	Polygonaceae			x					x	x	x	x					
Tdr	*Pseudognapalium luteoalbum*	Jersey Cudweed	Asteraceae			x			x	x			x	x					
Tdr	*Psilocaulon tenue**	Wiry Noon-flower	Aizoaceae							x			x			x	x		
Tdr	*Pycnosorus pleiocephalus*	Soft Billy Button	Asteraceae					x	x	x	x								

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tda	*Ranunculus pentandrus* var. *platycarpus*		Ranunculaceae			x	x		x	x	x	x	x	x					
T	*Ranunculus* sp.	Buttercup	Ranunculaceae			x			x					x					
Tdr	*Reichardia tingitana**	False Sowthistle	Asteraceae															x	
Tdr	*Rhagodia spinescens*	Spiny Saltbush	Chenopodiaceae			x	x		x	x	x	x	x	x	x	x	x	x	x
Tdr	*Rhodanthe corymbiflora*	Small White Sunray	Asteraceae				x												
Tdr	*Rhodanthe floribunda*	Common White Sunray	Asteraceae										x						
Tdr	*Rhodanthe moschata*		Asteraceae			x			x					x					
Tdr	*Rhodanthe pygmaea*	Pigmy Sunray	Asteraceae							x									
Tdr	*Rhodanthe stuartiana*		Asteraceae								x			x					
Tdr	*Rostraria pumila**	Roughtail	Poaceae	x	x	x	x		x	x		x	x	x	x		x		x
Atl	*Rumex crystallinus*	Shiny Dock	Polygonaceae			x													
Tda	*Rumex* sp.	Dock	Polygonaceae				x		x				x	x					
Tda	*Rumex tenax*	Shiny Dock	Polygonaceae									x	x						
Tdr	*Salsola kali* var. *kali*		Chenopodiaceae			x			x				x	x		x			
Tdr	*Schismus barbatus**	Arabian Grass	Poaceae	x		x	x	x						x					
Tdr	*Sclerolaena bicornis*	Goathead Burr	Chenopodiaceae	x		x	x	x	x	x			x	x	x	x		x	x
Tdr	*Sclerolaena bicornis* var. *bicornis*	Goathead Burr	Chenopodiaceae				x												
Tdr	*Sclerolaena brachyptera*		Chenopodiaceae	x		x	x	x		x	x		x	x	x	x	x	x	x
Tdr	*Sclerolaena calcarata*	Redburr	Chenopodiaceae	x	x	x	x	x	x	x									
Tdr	*Sclerolaena decurrens*	Green Copperburr	Chenopodiaceae			x		x						x			x	x	x
Tdr	*Sclerolaena divaricata*	Tangled Copperburr	Chenopodiaceae							x									
Tdr	*Sclerolaena intricata*	Poverty Bush	Chenopodiaceae							x	x				x	x		x	
Tdr	*Sclerolaena muricata*	Black Rolypoly	Chenopodiaceae	x	x	x		x		x	x		x	x		x		x	x
Tdr	*Sclerolaena muricata* var. *villosa*	Black Rolypoly	Chenopodiaceae					x		x					x				

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tdr	*Sclerolaena muricata* var. *muricata*	Black Rolypoly	Chenopodiaceae	x	x	x				x			x	x	x	x		x	x
Tdr	*Sclerolaena muricata* var. *semiglabra*	Black Rolypoly	Chenopodiaceae	x		x							x		x				
Tdr	*Sclerolaena obliquicuspis*	Limestone Copperburr	Chenopodiaceae										x			x	x	x	x
Tdr	*Sclerolaena patenticuspis*	Spear-fruit Copperburr	Chenopodiaceae	x		x		x	x	x	x			x					
Tdr	*Sclerolaena* sp.		Chenopodiaceae			x	x		x	x	x	x	x	x	x		x		x
Tdr	*Sclerolaena stelligera*		Chenopodiaceae	x	x	x	x	x		x			x			x		x	x
Tdr	*Sclerolaena tricuspis*	Giant Redburr	Chenopodiaceae			x	x	x							x	x		x	
Tdr	*Sclerolaena ventricosa*	Salt Copperburr	Chenopodiaceae					x		x		x							
Tda	*Senecio glossanthus*		Asteraceae				x								x				
Tdr	*Senecio runcinifolius*	Tall Groundsel	Asteraceae			x	x	x		x	x	x			x				
T	*Senecio* sp.	Groundsel	Asteraceae	x	x										x				x
Tdr	*Sida intricata*	Twiggy Sida	Malvaceae	x						x				x					
T	*Sida* sp.	Sida	Malvaceae	x	x								x				x	x	
Tdr	*Sida* species A		Malvaceae													x			
Tdr	*Silene gallica*		Caryophyllaceae								x								
T	*Silene* sp.		Caryophyllaceae	x					x	x	x	x	x	x	x		x		x
Tdr	*Sisymbrium erysimoides**	Smooth Mustard	Brassicaceae			x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tdr	*Solanum esuriale*	Quena	Solanaceae	x	x								x						
Tda	*Solanum lacunarium*	Lagoon Nightshade	Solanaceae													x		x	
Tdr	*Solanum nigrum**	Black-berry Nightshade	Solanaceae	x								x	x	x	x	x			
T	*Solanum* sp.	Nightshade	Solanaceae									x		x					
Tdr	*Sonchus oleraceus**	Common Sowthistle	Asteraceae	x			x		x	x	x	x	x	x	x	x	x		x
Tdr	*Spergularia diandra**	Lesser Sand-spurrey	Caryophyllaceae							x	x								

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Tdr	*Spergularia rubra**	Sandspurrey	Caryophyllaceae			x	x												
T	*Spergularia* sp.	Sandspurrey	Caryophyllaceae			x				x		x	x	x	x		x	x	
Tda	*Stemodia florulenta*	Blue-rod	Scrophulariaceae	x		x		x	x			x	x		x				
Tdr	*Tetragonia* sp.		Aizoaceae	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tdr	*Teucrium racemosum*	Grey Germander	Lamiaceae			x	x	x		x	x		x	x		x			
Tdr	*Tribulus terrestris**	Caltrop	Zygophyllaceae															x	x
Tdr	*Trigonella suavissima*	Coopers Clover	Fabaceae-faboideae	x			x												
Tdr	*Urtica* sp.	Nettle	Urticaceae						x		x								
Tdr	*Verbena* sp.		Verbenaceae			x								x				x	
Tda	*Verbena supina**	Trailing Verbena	Verbenaceae			x							x						
Tda	*Veronica catenata**	Pink Water Speedwell	Scrophulariaceae									x							
Tdr	*Vicia monantha* subsp. *triflora**		Fabaceae-faboideae										x						
Tdr	*Vittadinia cervicularis*		Asteraceae																x
Tdr	*Vittadinia eremaea*		Asteraceae			x								x					
Tdr	*Vittadinia gracilis*	Woolly New Holland Daisy	Asteraceae		x					x	x		x	x			x		
Tdr	*Vittadinia* sp.		Asteraceae	x	x														
Tdr	*Vittadinia sulcata*		Asteraceae									x							
Tdr	*Vulpia bromoides**	Squirrel Tail Fescue	Poaceae												x				
Tda	*Wahlenbergia fluminalis*	River Bluebell	Campanulaceae			x													
T	*Wahlenbergia* sp.	Bluebell	Campanulaceae	x	x														
Tdr	*Zygophyllum ammophilum*	Sand Twinleaf	Zygophyllaceae			x	x		x	x							x		
Tdr	*Zygophyllum iodocarpum*	Violet Twinleaf	Zygophyllaceae				x												
T			Asteraceae			x	x	x		x		x	x		x		x		x
T			Asteraceae*		x								x	x	x	x	x		
T			Brassicaceae			x													

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
S			Charophyceae											x					
T			Chenopodiaceae					x		x	x				x				
T			Fabaceae					x											
T			Lamiaceae										x						
Tdr			Malvaceae				x						x					x	
T		Unidentifiable grass	Poaceae				x	x			x	x	x	x	x		x		
T			Proteaceae														x		
Uk		Unidentified sp.		x	x	x				x	x	x	x				x		x
Uk		Unidentified #542 (same as #1056?)				x													
Uk		Unidentified #1056 (same as #542?)				x													
Uk		Unidentified #1179					x												
Uk		Unidentified #1190 (same as #1218?)				x													
Uk		Unidentified #1192				x													
Uk		Unidentified #1217							x										
Uk		Unidentified #1218 (same as #1190?)							x										
Uk		Unidentified #1263 (same as #1179 & 1510?)										x							
Tdr		Unidentified #1353 - Lamiaceae	Lamiaceae										x						
Uk		Unidentified #1371											x						
Uk		Unidentified #1401											x						
Uk		Unidentified #1510 (same as #s 1179 & 1263?)			x														
		Bare ground				x	x	x	x	x				x	x				

Functional group	Species name	Common name	Family	Site															
				2	3	4	5	6	7	8	9a	9b	10	11	12	14	15	16	17
Uk		Emergent seedling-damp			x		x		x	x				x					
Tdr		Emergent seedling-dry		x	x	x	x	x		x	x	x	x						
I		Inundated				x	x	x	x	x				x	x				
LL		Leaf litter >50%		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
			Total	**58**	**41**	**100**	**55**	**55**	**73**	**84**	**64**	**66**	**104**	**92**	**71**	**60**	**65**	**47**	**57**

* Exotic species

Appendix D. Understorey photo points

Figure D1. Site 2 understorey photo point A (D. Bogenhuber, MDFRC, 3/11/2010).

Figure D2. Site 2 understorey photo point B (D. Bogenhuber, MDFRC, 3/11/2010).

Figure D3. Site 3 understorey photo point A (D. Bogenhuber, MDFRC, 3/11/2010).

Figure D4. Site 3 understorey photo point B (D. Linklater, MDFRC, 3/11/2010).

Figure D5. Site 4 understorey photo point A (D. Bogenhuber, MDFRC, 23/09/2010).

Figure D6. Site 4 understorey photo point B (D. Bogenhuber, MDFRC, 23/09/2010).

Figure D7. Site 5 understorey photo point A (D. Bogenhuber, MDFRC, 21/09/2010).

Figure D8. Site 5 understorey photo point B (D. Bogenhuber, MDFRC, 21/09/2010).

Figure D9. Site 6 understorey photo point A (D. Bogenhuber, MDFRC, 22/09/2010).

Figure D10. Site 6 understorey photo point B (D. Bogenhuber, MDFRC, 22/09/2010).

Figure D11. Site 7 understorey photo point A (D. Bogenhuber, MDFRC, 30/09/2010).

Figure D12. Site 7 understorey photo point B (D. Linklater, MDFRC, 30/09/2010).

Figure D13. Site 8 understorey photo point A (C. Campbell, MDFRC, 29/09/2010).

Figure D14. Site 8 understorey photo point B (C. Campbell, MDFRC, 29/09/2010).

Figure D15. Site 9a understorey photo point A (D. Bogenhuber, MDFRC, 28/09/2010).

Figure D16. Site 9a understorey photo point B (D. Bogenhuber, MDFRC, 28/09/2010).

Figure D17. Site 9b understorey photo point A (D. Bogenhuber, MDFRC, 12/10/2010)

Figure D18. Site 9b understorey photo point B (D. Bogenhuber, MDFRC, 12/10/2010).

Figure D19. Site 10 understorey photo point A (D. Bogenhuber, MDFRC, 19/10/2010).

Figure D20. Site 10 understorey photo point B (D. Bogenhuber, MDFRC, 19/10/2010).

Figure D21. Site 11 understorey photo point A (D. Linklater, MDFRC, 20/10/2010).

Figure D22. Site 11 understorey photo point B (D. Linklater, MDFRC, 20/10/2010).

Figure D23. Site 12 understorey photo point A (D. Bogenhuber, MDFRC, 21/10/2010).

Figure D24. Site 12 understorey photo point B (D. Bogenhuber, MDFRC, 21/10/2010).

Figure D25. Site 14 understorey photo point A (D. Bogenhuber, MDFRC, 8/11/2010).

Figure D26. Site 14 understorey photo point B (D. Linklater, MDFRC, 8/11/2010).

Figure D27. Site 15 understorey photo point A (D. Bogenhuber, MDFRC, 8/11/2010).

Figure D28. Site 15 understorey photo point B (D. Bogenhuber, MDFRC, 8/11/2010).

Figure D29. Site 16 understorey photo point A (D. Bogenhuber, MDFRC, 9/11/2010).

Figure D30. Site 16 understorey photo point B (D. Bogenhuber, MDFRC, 9/11/2010).

Figure D31. Site 17 understorey photo point A (D. Linklater, MDFRC, 9/11/2010).

Figure D32. Site 17 understorey photo point B (D. Linklater, MDFRC, 9/11/2010).

Appendix E. Results of data analysis for understorey functional group composition

Table E1. Pair-wise comparisons between sites for In-channel quadrats based on functional groups.

Site	Significantly different	P value	Not significant	P value
2	Not assessed			
3	Not assessed			
4	Sites 7,9a,9b,10	P ≤ 0.03	Sites 5,6,8,11,12	P ≥ 0.0849
5	Sites 8,9a,9b,10,12	P ≤ 0.0553	Sites 4,6,7,11	P ≥ 0.0553
6	Sites 7,9a,9b,10	P ≤ 0.0293	Sites 4,5,8,11,12	P ≥ 0.1158
7	Sites 4,6,8,9a,9b,10,11,12	P ≤ 0.031	Site 5	P = 0.5718
8	Sites 5,7,9a,9b,10	P ≤ 0.0553	Sites 4,6,11,12	P ≥ 0.1364
9a	All sites	P ≤ 0.0316		
9b	All sites	P ≤ 0.0309		
10	All sites	P ≤ 0.0299		
11	Sites 7,9a,9b,10	P ≤ 0.0309	Sites 4,5,6,8,12	P ≥ 0.0553
12	Sites 5,7,9a,9b,10	P ≤ 0.1501	Sites 4,6,8,11	P ≥ 0.1397
14	Not assessed			
15	Not assessed			
16	Not assessed			
17	Not assessed			

Table E2. Pair-wise comparisons between sites for Mid-bank quadrats based on functional groups.

Site	Significantly different	P value	Not significant	P value
2	Not assessed			
3	Not assessed			
4	All sites	P ≤ 0.031		
5	Sites 4,7,8,9a,9b,10,11,12	P ≤ 0.0308	Site 6	P = 0.1422
6	Sites 4,7,8,9a,9b,10,11,12	P ≤ 0.0334	Site 5	P = 0.1422
7	All sites	P ≤ 0.0334		
8	All sites	P ≤ 0.0298		
9a	Sites 4,5,6,7,8,10,11,12	P ≤ 0.0334	Site 9b	P = 0.1894
9b	Sites 4,5,6,7,8,10,11,12	P ≤ 0.0308	Site 9a	P = 0.1894
10	All sites	P ≤ 0.0334		
11	All sites	P ≤ 0.031		
12	All sites	P ≤ 0.0308		
14	Not assessed			
15	Not assessed			
16	Not assessed			
17	Not assessed			

Table E3. Pair-wise comparisons between sites for Tree-line quadrats based on functional groups.

Site	Significantly different	P value	Not significant	P value
2	All sites	P ≤ 0.0301		
3	All sites	P ≤ 0.0323		
4	Sites 2,3,5,7,9a,10,11,12,14,15,16,17	P ≤ 0.0315	Sites 6,8,9b	P ≥ 0.0568
5	Sites 2,3,4,6,7,9a,9b,10,11,12,14,15,16,17	P ≤ 0.0315	Site 8	P = 0.0586
6	Sites 2,3,5,7,8,9a,10,11,12,14,15,16,17	P ≤ 0.0313	Sites 4,9b	P ≥ 0.0566
7	All sites	P ≤ 0.0323		
8	Sites 2,3,6,7,10,11,14,15,16,17	P ≤ 0.0321	Sites 4,5,9a,9b,12	P ≥ 0.0536
9a	Sites 2,3,4,5,6,7,10,11,12,14,15,16,17	P ≤ 0.0316	Sites 8,9b	P ≥ 0.0574
9b	Sites 2,3,5,7,10,11,12,14,15,16,17	P ≤ 0.0295	Sites 4,6,8,9a	P ≥ 0.0559
10	Sites 2,3,4,5,6,7,8,9a,9b,12,14,15,16,17	P ≤ 0.0316	Site 11	P = 0.06
11	Sites 2,3,4,5,6,7,8,9a,9b,12,14,15,16,17	P ≤ 0.031	Site 10	P = 0.06
12	Sites 2,3,4,5,6,7,9a,9b,10,11,14,15,16,17	P ≤ 0.0308	Site 8	P = 0.0536
14	All sites	P ≤ 0.0318		
15	All sites	P ≤ 0.0321		
16	Tree-line quadrats not sampled			
17	Tree-line quadrats not sampled			

Table E4. Pair-wise comparisons between sites for Floodplain quadrats based on functional groups.

Site	Significantly different	P value	Not significant	P value
2	All sites	P ≤ 0.0313		
3	All sites	P ≤ 0.0306		
4	Sites 2,3,7,9b,12,14,15	P ≤ 0.0526	Sites 5,6,8,9a,10,11,16,17	P ≥ 0.0563
5	Sites 2,3,7,8,9a,9b,10,11,12,14,15,16,17	P ≤ 0.0307	Sites 4,6	P ≥0.0563
6	Sites 2,3,7,8,9a,9b,10,12,14,15,16	P ≤ 0.0323	Sites 4,5,11,17	P ≥ 0.0532
7	All sites	P ≤ 0.0304		
8	Sites 2,3,5,6,7,9a,9b,10,11,14,15,16	P ≤ 0.0313	Sites 4,17	P ≥ 0.1119
9a	Sites 2,3,5,6,7,8,10,11,12,14,15,16,17	P ≤ 0.0306	Sites 4,9b	P ≥ 0.0937
9b	Sites 2,3,4,5,6,7,8,10,11,12,14,16,17	P ≤ 0.0526	Site 9a	P = 0.1158
10	Site 2,3,5,6,7,8,9a,9b,10,12,14,15,16,17	P ≤ 0.031	Sites 4,11	P ≥ 0.0563
11	Site 2,3,5,6,7,8,9a,9b,12,14,15,17	P ≤ 0.0297	Sites 4,6,10,16	P≥ 0.0536
12	All sites	P ≤ 0.0592		
14	Sites 2,3,4,5,6,7,8,9a,9b,10,11,12,15,17	P ≤ 0.0323	Site 16	P = 0.0837
15	Sites 2,3,4,5,6,7,8,9a,9b,10,11,12,14,16	P ≤ 0.0321	Site 17	P = 0.0827
16	Sites 2,3,5,6,7,8,9a,9b,10,12,15	P ≤ 0.0329	Sites 4,11,14,17	P ≥ 0.0589
17	Sites 2,3,5,6,7,9a,9b,10,11,12,14	P ≤ 0.0592	Sites 4,8,15,16	P ≥ 0.0532

Table E5. Significant pair-wise comparisons between elevations for each site based on functional groups (IC = In-channel, MB = Mid-bank, TL = Tree-line, FP = Floodplain).

Site 2. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		Not assessed	Not assessed	Not assessed
MB			Not assessed	Not assessed
TL				P = 0.0312

Site 3. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		Not assessed	Not assessed	Not assessed
MB			Not assessed	Not assessed
TL				P = 0.664

Site 4. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.0267	P = 0.03	P = 0.0551
MB			P = 0.0812	P = 0.055
TL				P = 0.7725

Site 5. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.8874	P = 0.0289	P = 0.0318
MB			P = 0.0264	P = 0.03
TL				P = 0.0294

Site 6. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.709	P = 0.0329	P = 0.0291
MB			P = 0.0282	P = 0.0298
TL				P = 0.2617

Site 7. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.0239	P = 0.0273	P = 0.0276
MB			P = 0.0277	P = 0.0286
TL				P = 0.0266

Site 8. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.0276	P = 0.0276	P = 0.029
MB			P = 0.285	P = 0.2295
TL				P = 0.395

Site 9a. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.0557	P = 0.0309	P = 0.0294
MB			P = 0.5812	P = 0.0615
TL				P = 0.3128

Site 9b. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.1926	P = 0.0809	P = 0.0311
MB			P = 0.8246	P = 0.0567
TL				P = 0.2509

Site 10. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.0286	P = 0.0276	P = 0.0277
MB			P = 0.6026	P = 0.0551
TL				P = 0.1418

Site 11. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.0307	P = 0.0292	P = 0.0284
MB			P = 0.1788	P = 0.0282
TL				P = 0.0284

Site 12. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		P = 0.0277	P = 0.0269	P = 0.0281
MB			P = 0.0287	P = 0.0278
TL				P = 0.0306

Site 14. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		Not assessed	Not assessed	Not assessed
MB			Not assessed	Not assessed
TL				P = 0.0578

Site 15. Blue = not significant; red = significant

	IC	MB	TL	FP
IC		Not assessed	Not assessed	Not assessed
MB			Not assessed	Not assessed
TL				P = 0.0303

Appendix F. Lignum photo points

Figure F1. Site 3 Lignum photo point
(D. Bogenhuber, MDFRC, 03/11/2010).

Figure F2. Site 4 Lignum photo point
(C. Campbell, MDFRC, 23/09/2010).

Figure F3. Site 5 Lignum photo point
(C. Campbell, MDFRC, 21/09/2010).

Figure F4. Site 6 Lignum photo point
(D. Bogenhuber, MDFRC, 22/09/2010).

Figure F5. Site 8 Lignum photo point
(D. Linklater, MDFRC, 29/09/2010).

Figure F6. Site 9a Lignum photo point
(D. Linklater, MDFRC, 24/09/2010).

Figure F7. Site 9b Lignum photo point
(D. Bogenhuber, MDFRC, 12/10/2010).

Figure F8. Site 14 Lignum photo point
(D. Linklater, MDFRC, 28/10/2010).

Figure F9. Site 16 Lignum photo point
(D. Linklater, MDFRC, 29/10/2010).

Figure F10. Site 17 Lignum photo point
(D. Linklater, MDFRC, 9/11/2010).