Forestry Corporation of NSW

Koondrook-Perricoota Forest
2017 Vegetation Condition Monitoring Program Review

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Koondrook-Perricoota Forest: 2017 Vegetation Condition Monitoring Program Review

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Authors:

Dr Tim Wills
GHD Pty Ltd
180 Lonsdale Street, Melbourne, Victoria, 3000
tim.wills@ghd.com

Dr Lien Sim
liensim@yahoo.com.au

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Cover photograph: Photograph of wetland at Koondrook-Perricoota Forest, 17 January 2017

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Contact us

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Forestry Corporation of NSW

121-131 Oratava Ave, West Pennant Hills, NSW, 2125

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Executive summary

Background

In mid-2016, Forestry Corporation of New South Wales (FCNSW) engaged GHD to conduct an initial review of the Vegetation Condition Monitoring Program for Koondrook-Perricoota (KP) Forest (Wills *et al.* 2016). The need for this review emerged from a recent review (between 2012 and 2015) of other Vegetation Condition Monitoring Programs under *The Living Murray* (TLM) Program. The review focused on refining monitoring objectives, selecting two vegetation condition indicators (Plant Functional Group (PFG) Species Richness for two wetland inundation phases and four treed Water Regime Classes (WRCs), and Tree Canopy Health for four treed WRCs), establishing points of reference and indices, and undertaking power and sensitivity analyses.

FCNSW has subsequently engaged GHD to undertake a further review of the monitoring program at KP Forest, with the aim of exploring additional condition indicators.

A primary output of this review is to populate the templates provided by Robinson (2014a) for incorporation into a Condition Monitoring Plan (CMP) for Koondrook-Perricoota Forest. The templates include overarching objectives (those previously set for the Forest such as the First Step Decision objectives), refined/adopted objectives, indicators, points of reference, indices and power and sensitivity analyses (where resources are available).

Approach

For this 2017 round of the program review, two indicators were selected for further investigation; Characteristic PFG Cover and Terrestrial Species Cover. Dr Lien Sim was then engaged to undertake detailed analyses of these two indicators and establish points of reference and indices using the monitoring dataset from 2010 to 2016/17. Her analysis also included sensitivity and power analyses. Two of the Koondrook-Perricoota Forest datasets were included in the analyses: wetland dataset (2010 to 2017), which includes transects at 15 semi-permanent wetlands within the Forest; and understorey dataset (2010 to 2016), which includes 60 permanently established quadrats within four WRCs: River Red Gum with Flood Dependent Understorey, River Red Gum with Flood Tolerant Understorey, Black Box Woodland and Grey Box Woodland.

For the wetland dataset, sites were assigned one of two Wetland Inundation Phase Classes (WIP) in each monitoring event: dry (no standing water but soil may still be moist) or receding (standing water present within the transect of variable depth). Further subdivision of wetland inundation phases would be useful as the program progresses, i.e. as the sample size of wetlands in different inundation phases increases.

Vegetation Condition Indicators

Characteristic PFG Cover

For each WIP and treed WRC, Characteristic PFG Cover at a site is considered ‘appropriate’ if it is on or above the PoR based on the 90th percentile of all records (wetlands) or all autumn records (understorey) since 2010.

For each WIP these values are:

- Dry phase wetlands – 24.1% cover of species from PFGs 1-5
- Receding phase wetlands – 30.7% cover of species from PFGs 1-5

For the treed (understorey) WRCs these values are:

- Red Gum with Flood Dependant Understorey – 17.5% cover of species from PFGs 3-5
- Red Gum with Flood Tolerant Understorey – 20.4% cover of species from PFGs 4-6
- Black Box Woodlands – 10% cover of species from PFGs 4-6
- Grey Box Woodlands – 12% cover of species from PFGs 4-6

Terrestrial Species Cover

For each WIP or WRC, the 'Terrestrial Species Cover Index' at a site is considered 'appropriate' if it is below the Point of Reference (PoR), based on the 90th percentile of all records (wetlands) or all autumn records (understorey) since 2010.

For the WIPs, these values are:

- Dry Phase Wetlands - proportion of terrestrial species 0.4564
- Receding Phase Wetlands- proportion of terrestrial species 0.343616.

For the treed (understorey) WRCs these values are:

- Red Gum with Flood Dependant Understorey – proportion of terrestrial species 0.741935
- Red Gum with Flood Tolerant Understorey – proportion of terrestrial species 0.795
- Black Box Woodlands proportion of terrestrial species 0.943477
- Grey Box Woodlands proportion of terrestrial species 0.974927

Power and sensitivity analyses

Power analyses determine how likely the indicators and sampling strategy are to detect change in condition at sites (wetland transects or treed WRC quadrats). Two approaches were taken (outlined in Appendix A):

- Trend analysis – for each WRC, assessment of whether there was a linear trend in index values over the six years of monitoring (i.e. overall, did index values increase or decline?)
- Year-by-year differences – for each WIP or WRC, assessment of differences in index values between pairs of consecutive sampling years/events (e.g. was the mean Characteristic PFG Cover index higher in 2011 than in 2010, etc.?)

It was not possible to run the mixed models (trend) power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

For the treed WRCs, the following trend models for the Characteristic PFG Cover indicators had sufficient power to detect change.

- Red Gum FTU MSES ±0.034, power = 0.6265178
- Grey Box MSES ±0.02, power = 0.9992650

The Red Gum FDU and Black Box Woodland WRCs had insufficient power to detect change.

The year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in all treed WRCs.

For the treed WRCs, the following trend model for the Terrestrial Species Cover indicator had sufficient power to detect change.

- Red Gum FDU MSES ±0.023, power = 0.9837447

The River Red Gum FTU and Box Woodland WRCs had insufficient power to detect change.

The year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in some WRCs.

Recommendations

Based on the work undertaken in this program review and that undertaken by Wills *et al.* (2016), we are now at a point where a sufficient number of indicators appears to have been reached to obtain a broad overview of vegetation condition across the KP icon site. In other words, the indicators of Characteristic PFG Species Richness, Characteristic PFG Cover, Terrestrial Species Cover and Tree Canopy Health, when assessed in concert with the two WIPs and the four WRCs, represent a diverse means of showing how forest, woodland and wetland condition responds to wetting and drying regimes at KP.

A method for combining the index scores from each of the 22 indicators reviewed (10 in 2016 and 12 in 2017) can now be developed so that a total score for vegetation condition at the WRC level, WIP level and whole of icon site level can be calculated each year.

This report also outlines recommendations regarding the appropriateness of the tree canopy health indicator previously used in the 2016 program review. Furthermore, recommendations are made regarding the wetland inundation phase classes and their suitability as to whether they do indeed provide an accurate representation of receding and dry phase classes. We recommend that the wetland inundation phase classes are investigated in more detail prior to developing the CMP and developing overall index scores.

Finally, we recommend that future reviews should include refinement of the PoRs and indicators proposed here, where relevant. This may be particularly relevant as the program progresses and more years of data become available for analyses, e.g. increased replication of sites in various phases of inundation.

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Abbreviations

BB	Black Box
CI	Confidence Interval (usually 95% unless stated otherwise)
CMP	Condition Monitoring Plan
DBH	Diameter at Breast Height
FCNSW	Forestry Corporation of New South Wales
FDU	Flood Dependent Understorey
FTU	Flood Tolerant Understorey
GB	Grey Box
KP	Koondrook-Perricoota
MDBA	Murray-Darling Basin Authority
MSES	Minimum Significant Effect Size
OES	Observed Effects Size
PFG	Plant Functional Group
PoR	Point of Reference
RRG	River Red Gum
TLM	The Living Murray Program
WIP / WPC	Wetland Inundation Phase / Wetland Phase Class
WRC	Water Regime Class

Definitions

Term	Working definition
Ecological objective	The stated reason for including this ecological component in the program. Comparable with *Management objective*.
Monitoring/Measurement objective	What needs to be measured, or what has been measured
Point of Reference	A value that allows *data* to be converted to an assessment of condition. May be a management target or a historical (e.g. baseline) or statistically derived value. Can move through time. Can review the PoR at any time.
Sampling Strategy	Overview of sampling methodology
Index	How the collected data are presented as a measure of Icon Site condition
Power	Explanation of size of effect that can be detected with confidence. The ability to detect change
Sensitivity	Evidence of how the Index responds to change in condition as a result of TLM operations

Water Regime Classes (WRCs)

River Red Gum (RRG) is the predominant overstorey species, occupying over 80% of Koondrook–Perricoota Forest (MDBA 2012). It usually forms pure stands, but does occur with other eucalypts on less frequently flooded sites. The health of the River Red Gum Forest depends on the flooding regime (i.e. the frequency, size, duration and timing of flooding), along with antecedent conditions. Black Box (BB) communities occur in areas prone to lower frequency, and shorter duration flooding. The Forest also supports extensive areas of Grey Box (GB) Woodland, some of which would have been flooded regularly under natural conditions (almost every year).

The following five WRCs are included in the condition monitoring program at Koondrook-Perricoota Forest, in order of decreasing water requirements:

- **Semi-permanent wetlands and waterways** (i.e. wetland transects). Wetlands require the most frequent flooding and benefit from more prolonged flooding and the persistence of water in pools and depressions (MDBA 2012)
- **River Red Gum Forests with flood dependent understorey (RRG FDU)**. River Red Gum Forest requires regular inundation to promote the flood dependent understorey (macrophytes) (MDBA 2012)
- **River Red Gum Woodlands with flood tolerant understorey (RRG FTU)**. River Red Gum Woodlands require less frequent flooding than the RRG Forests because the understorey is not flood dependent (MDBA 2012)
- **Black Box Woodland (BBW)**. Box Woodlands require little watering (MDBA 2012)

- **Grey Box Woodland (GBW)**. Proposed to have the lowest water requirements but this varies across the Forest. The lower 200 ha of Grey Box Woodland is inundated by flows of 35,000 ML/d. Under natural conditions these flows would have occurred almost every year with an average duration of more than two months (Ecological Associates 2011). At flows of 60,000 ML/d, 474 ha is inundated and would have experienced inundation events twice in ten years with average durations of less than two weeks. This suggests that some areas of Grey Box may be more tolerant of flooding than others.

The position of the five WRCs in the landscape is illustrated conceptually in Figure 1, along with the ideal flood regime for each WRC. Note that this is a very broad indication of vegetation associations, geomorphic setting and natural flood regime. As over 80% of the Forest supports River Red Gum Forests/Woodlands and these vegetation types have higher water requirements than the other woodlands, the majority of established vegetation survey sites are located within the first three WRCs.

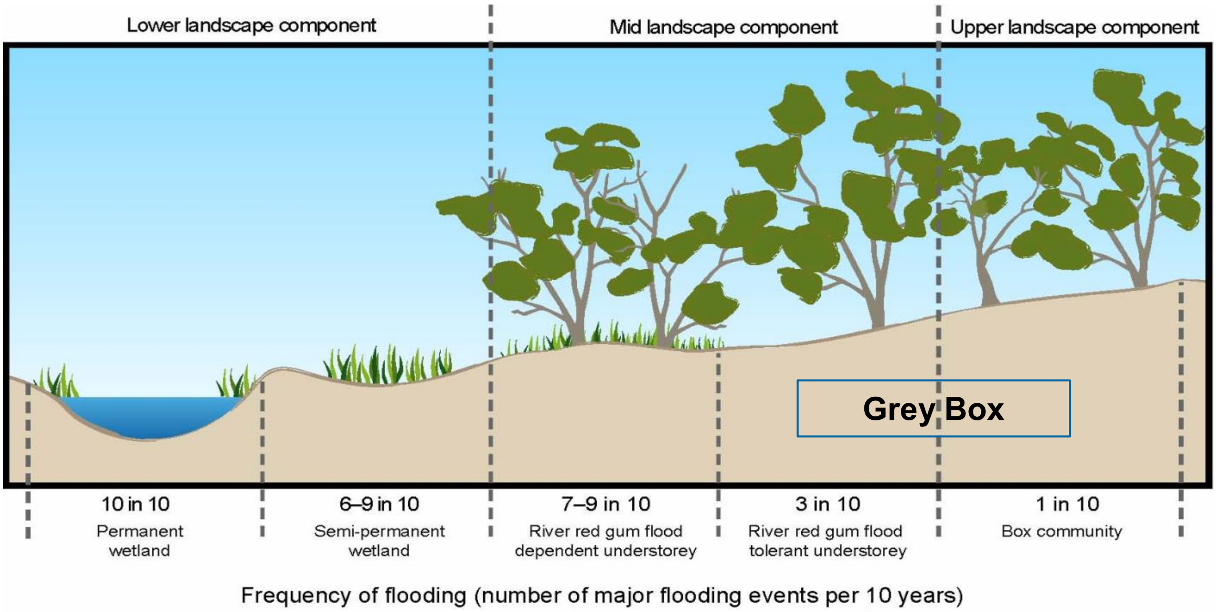

Figure 1 Water Regime Classes (vegetation associations) and ideal flood regime at Koondrook-Perricoota Forest

Source: Ecological Associates (2006) and MDBA (2012)

Plant Functional Groups (PFGs)

Table 1 Definitions of Plant Functional Groups used in the data analysis

PFG code	Abbreviation (Brock and Casanova 1997)	Plant Functional Group Name	Description
1	S (Se, Sk or Sr)	Seed/spore born aquatic flora - submerged	**Submerged** Adult plants do not survive prolonged exposure of the wetland substrate (drying) and lack perpetuating rootstocks. Seed or spores may persist in soil during dry times.
2	ARp	Rhizomatous aquatic flora	**Amphibious fluctuation – responders floating** Aerial parts of plants survive exposure of the wetland substrate (drying) for sustained periods of time. Plants survive drying by dying back to rootstocks.
3	ARf	Aquatic floaters and Semi-aquatic flora	**Amphibious fluctuation – responder's plastic** Can actively grow when substrate exposed but still moist, but may die back to rootstocks or seed during sustained dry periods.
	Atw	Perennial	**Amphibious fluctuation tolerator, woody:** Perennial woody species that require water to be present in the root zone but will germinate in shallow water or on a drying profile. Generally restricted to permanently saturated areas.
4a	ATl	Perennial mudflat flora	**Amphibious fluctuation – tolerates low growing** Perennial – maintain same general growth form during brief periods of inundation, but may dieback to rootstocks if unable to develop emergent growth during sustained inundation.
4b	ATl	Annual mudflat flora	**Amphibious fluctuation – tolerates low growing** Annual (or functionally so) – may tolerate very brief periods of shallow flooding during growth phase, but essentially short-lived plants which germinate following flood water recession and produce inundation-tolerant seed during the drying phase.
5	ATe	Floodplain flora	**Amphibious fluctuation – tolerates emergent** Rootstocks tolerate shallow inundation but plant intolerant of sustained total immersion. Recruitment and/or long-term maintenance.
6	Tda	Moisture-dependent	**Terrestrial damp** Rootstocks intolerant of more than superficial inundation, but occurring in areas of good soil moisture conditions which may be influenced by proximity to river and water seepage through soil.
7	Tdr	Terrestrial dry	**Terrestrial dry** Dry-land plants (i.e. flood intolerant and going through life cycles independently of flooding regime).
0	NA	Not-vegetated	Bare ground, litter, logs, water, etc
unknown	NA	Not assigned	Species for which there is insufficient information to assign them a PFG.

Source: AE (2011)

1. Introduction

1.1 Project context

Between 2012 and 2015, a review of the Condition Monitoring Program was completed for several of *The Living Murray* (TLM) icon sites (Robinson 2012; 2013, 2014a and 2014b). The purpose of the review was to assess whether or not condition monitoring as described in the Condition Monitoring Plans (CMP) was adequate to demonstrate change in condition over time. The monitoring plan and program for Koondrook-Perricoota Forest was not included in this review.

The review identified three key issues that needed to be resolved:

1. A need to clarify the purpose and objectives of the overall Condition Monitoring Program
2. The need for each icon site to have monitoring objectives, which in turn inform monitoring variables, indicators and targets
3. Whole of Icon site condition monitoring requires: identification of targets (e.g. based on management objectives) or, points of reference to report against

Workshops were held with agencies and service providers for some of the icon sites to refine objectives, variables, indicators and targets and identify suitable analysis techniques. Forestry Corporation of NSW (FCNSW) and the Murray-Darling Basin Authority (MDBA) have since identified the need for a similar review for the Koondrook-Perricoota Forest Vegetation Condition Monitoring Program.

In mid-2016, FCNSW engaged GHD to conduct an initial review of the Vegetation Condition Monitoring Program for Koondrook-Perricoota Forest (Wills *et al.* 2016). The review focused on refining objectives, selecting two vegetation condition indicators (PFG Species Richness for two wetland inundation phases and four treed Water Regime Classes, and Tree Canopy Health for four treed Water Regime Classes), establishing points of reference and indices, and undertaking power and sensitivity analyses.

FCNSW has subsequently engaged GHD to undertake a further review of the program at KP Forest, with the aim of exploring additional condition indicators.

1.2 Scope

The scope of this review is to:

- Review the current Vegetation Condition Monitoring Program for Koondrook-Perricoota Forest, in a similar manner to the review undertaken for Gunbower Forest in 2014 (Bennetts and Sim 2014; Robinson 2014a, 2014b) and KP Forest in 2016 (Wills *et al.* 2016)
- Focus on vegetation components of the program only
- Further populate the template (for selected objectives and indicators) provided by Robinson (2014a) for incorporation into the CMP

1.3 Purpose of this report

The purpose of this report is to summarise the findings of the review and provide recommendations to assist FCNSW in the development of the CMP for Koondrook-Perricoota Forest.

1.4 About the Condition Monitoring Program

This Project is part of the MDBA funded *The Living Murray* (TLM) Program. The Icon Site Condition Monitoring Program for Koondrook-Perricoota Forest includes monitoring of stand and tree condition (described in Forbes and Wills 2017a) and wetland and understorey condition (described in Forbes and Wills 2017b).

The purpose of the program is to survey and report on eucalypt stand and tree condition, and wetland and understorey condition at permanently established monitoring sites across KP Forest. The purpose is also to monitor temporal change in floristic composition and health, and to investigate progress toward ecological objectives and targets for KP Forest (those related to vegetation condition).

The Condition Monitoring Program commenced in 2010.[1] Condition monitoring is undertaken annually in autumn (March to May). The dataset now includes vegetation data from seven years (2010, 2012, 2013, 2014, 2015, 2016 and 2017).

In addition to the Condition Monitoring Program, additional vegetation monitoring commenced in 2014, referred to as the 'Event Monitoring Program'. The purpose of the event monitoring is to monitor the response of vegetation to specific managed watering events. Monitoring is undertaken following a watering event, upon recession of floodwaters. All monitoring sites are assessed regardless of whether they are flooded or not.

Up until 2014, the monitoring program was principally undertaken in autumn as part of the Condition Monitoring Program and therefore the program did not fully capture the diversity of flora present, i.e. additional species are likely to be present in spring or summer. To attempt to address this, more recently monitoring was undertaken in spring as well as autumn (in 2014 and 2015) and in summer (early 2017) to capture seasonal variation in species richness and vegetation cover, particularly annual introduced flora that may be present in spring but deceased by autumn. This approach was considered important given that future monitoring following a managed flood event (such as the one that occurred in spring 2014) would most likely take place in spring – early summer when vegetation response is expected to peak.

Given the variability in size (width and depth) and location of wetlands, monitoring over spring and autumn has the ability to capture different phases of the water cycle (inundation phases, e.g. wetlands are typically dry in autumn and may be inundated in spring following winter-spring floods).

There are five Water Regime Classes (WRCs) included in the Program – described in the *Definitions* section: semi-permanent wetlands, River Red Gum with Flood Dependent Understorey (FDU), River Red Gum with Flood Tolerant Understorey (FTU), Black Box Woodland and Grey Box Woodland.

The current Vegetation Condition Monitoring Program at Koondrook-Perricoota Forest is summarised in Table 2. Detailed methods are outlined in Forbes and Wills (2017a; 2017b).

Table 3 provides a summary of the number of wetland and understorey transects/quadrats included in each WRC (and proportion of monitoring program), extent (hectares) of each WRC at KP Forest, and the density of monitoring transects/quadrats within each WRC. The most number of monitoring sites are located in Red Gum with Flood Dependent Understorey, which is the dominant WRC; however, the most densely sampled WRC (number of quadrats per hectare) is Grey Box Woodland.

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[1] Monitoring at Pollack Swamp commenced in 2008

Table 2 Summary of the Koondrook-Perricoota Forest Vegetation Condition Monitoring Program

Strata	Water Regime Classes	No. sites	Data collected
Understorey (treed WRC)	Red Gum Flood Dependent Understorey (RRG FDU) Red Gum Flood Tolerant Understorey (RRG FTU) Black Box Woodland (BBW) Grey Box Woodland (GBW)	31 7 9 13 **60 total**	• Site descriptive data • Ground flora: species (PFG) & % cover • % cover bare ground, litter, coarse woody debris & water • Seedling, sapling & tree attributes • Canopy condition 20 trees • Photographs
Wetlands	Semi-permanent wetlands	**15 total**	• Site data • Ground flora: species (PFG) & % cover in zones • % cover bare ground, litter, coarse woody debris & water • Seedling, sapling & tree attributes • Photographs • Crome method (Crome 2004a; 2004b) and more recently modified Nicol & Weeden (2006) • Photographs
Stand condition	Red Gum Flood Dependent Understorey Red Gum Flood Tolerant Understorey Black Box Woodland Grey Box Woodland	16 6 2 1 **25 total**	• Site descriptive data • Plant Area Index • % Live Basal Area • Crown extent • Photographs
Tree condition	Red Gum Flood Dependent Understorey Red Gum Flood Tolerant Understorey Black Box Woodland Grey Box Woodland	16 3 1 5 **25 total**	• Crown extent & density • Bark condition • Recovery: epicormic growth, new tip growth • Decline: leaf die-off, mistletoe load • Reproduction • Tree dominance • Diameter at breast height (DBH) • Contextual information

Table 3 Number of assessments conducted in Koondrook-Perricoota Forest since monitoring commenced in 2010

Survey method	Area (ha)	2008 Spring	2010 Autumn	2011 Autumn	2013 Autumn	2014 Autumn	2014 Spring	2015 Autumn	2015 Spring	2016 Summer	2016 Autumn	2017 Summer	2017 Autumn[2]	Density of monitoring plots since 2011
Grey Box Woodland	300		9	13	13	13	13	13	13		13	13	13	1 plot per 23 Ha
Black Box Woodland	4,000		9	9	9	9	9	9	9		9	9	9	1 plot per 444 Ha
Red Gum FTU	7,000		7	7	7	7	7	7	7		7	7	7	1 plot per 1000 Ha
Red Gum FDU	19,000		30	31	31	31	31	31	31		31	30[3]	31	1 plot per 612 Ha
Semi-permanent wetlands	1,700	3	7	16	16	16	16	16	13[4]	3	16	14[5]	14[6]	1 Plot per 106 Ha
Total transects		**3**	**62**	**76**	**76**	**76**	**76**	**76**	**73**	**3**	**76**	**73**	**74**	

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[2] Autumn 2017 data were not used in this program review as the 2017 autumn data were still being collected at the time the analyses were being undertaken.
[3] One site was unable to be assessed due to water depth / inaccessibility in summer 2017
[4] Pollack Swamp transects were assessed in summer 2016 and were presented in a separate report. Data from 2008 were excluded from the data analyses because of limited sample size.
[5] One Pollack Swamp transect (PS1) was unable to be assessed due to water depth in 2017, and one (PS3) was not assessed due to being considered a pseudo-replicate following the monitoring program review in 2016, hence was considered unnecessary to assess from 2017 onwards.
[6] One site was unable to be assessed due to water depth / inaccessibility in autumn 2017

2. Approach and methods

2.1 Workshop

As part of the initial Program Review (Wills *et al.* 2016), Forestry Corporation NSW and GHD convened a workshop on 27 April 2016 in Deniliquin, NSW. Participants at the workshop included Linda Broekman (FCNSW), Kate Bennetts (Fire, Flood and Flora), Wayne Robinson (Charles Sturt University), Tim Wills (GHD) and Sjaan Bidwell (ex-GHD). Both Kate and Wayne have had previous experience with similar reviews for other TLM Icon Sites, including Gunbower Forest.

The purpose of the workshop was to:

- Summarise the Koondrook-Perricoota Forest monitoring program as it currently stands
- Learn from the reviews of other TLM icon sites, particularly Gunbower Forest, which has a similar Vegetation Monitoring Program to Koondrook-Perricoota Forest
- Agree on an approach for the review
- Consider the current ecological objectives for KP Forest and recommend improved wording or new objectives to adopt in the future
- Establish targets (Points of Reference) for each objective that allow measurement of condition at the icon site
- Identify indicators where possible
- Determine next steps in the review process

A summary of the workshop is provided in Wills *et al.* (2016, Appendix B). Participants agreed that the recent review of the Vegetation Condition Monitoring Program for Gunbower Forest provided an excellent guide for the review for Koondrook-Perricoota based on many similarities between the two icon sites and their monitoring programs, notwithstanding participants also acknowledged a number of differences.

2.2 Water Regime Classes and Wetland Inundation Phases

2.2.1 Wetland sites

For semi-permanent wetlands, Wetland Inundation Phase (WIP; otherwise referred to as Water Cycle Phase or Wetland Phase Cycle in the Monitoring Program) is important, because presence of water and time since inundation is a major driver in changes in floristic composition of wetlands (recently discussed in Bidwell and Wills (2015) and Forbes and Wills (2017b) with respect to Koondrook-Perricoota Forest).

For the purpose of this exercise, wetlands were grouped into two somewhat simplified Wetland Inundation Phases:

- Receding - standing water is present and water is of variable depth
- Dry - no standing water but soil may still be moist

In future, further subdivision of these categories would be useful.[7]

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[7] For example, the floristic composition of a wetland is likely to change through the following four phases of the water cycle:

1. Deeply inundated phase - water present > 50 cm deep in parts of the wetland transect

2.2.2 Understorey sites

The following four WRCs are included in the condition monitoring program at Koondrook-Perricoota Forest, in order of decreasing water requirements as defined in the *Definitions* section:

- River Red Gum Forests with flood dependent understorey (RRG FDU)
- River Red Gum Woodlands with flood tolerant understorey (RRG FTU)
- Black Box Woodland (BBW)
- Grey Box Woodland (GBW)

2.3 Priority indicators

Workshop participants identified five indicators considered useful in measuring condition of wetlands, as outlined in Table 4. At the workshop, four of the five indicators were also considered important for measuring condition of an example treed WRC, i.e. River Red Gum with Flood Dependent Understorey (Table 5). Tree Canopy Health was also considered an important indicator for all treed WRCs.

Following the workshop, two of the priority indicators were selected for further investigation: Plant Functional Group (PFG) Species Richness and Tree Canopy Health (Wills *et al.* 2016). PFG Species Richness was selected as it has been shown to be responsive to watering at the nearby Gunbower Forest, and is likely to act as a strong indicator of condition in both wetlands and treed WRCs, being responsive not only to flooding but also the specific water cycle inundation phase Tree Canopy Health was selected as it provides an alternative and complementary measure of site condition, it is known to be affected by flooding and water availability in floodplain ecosystems, and is a relevant indicator for all four treed WRCs at Koondrook-Perricoota Forest.

The two indicators were expanded into the following ten indicators based on WRC and Wetland Inundation Phase (for wetlands):

- PFG Species Richness Dry Phase Wetlands
- PFG Species Richness Receding Phase Wetlands
- PFG Species Richness Red Gum FDU
- PFG Species Richness Red Gum FTU
- PFG Species Richness Black Box Woodland
- PFG Species Richness Grey Box Woodland
- Tree Canopy Health Red Gum FDU
- Tree Canopy Health Red Gum FTU
- Tree Canopy Health Black Box Woodland
- Tree Canopy Health Grey Box Woodland

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2. Shallowly inundated and receding phase; water present but < 50 cm deep
3. Drying phase - no standing water, but soil moist (evidence of recent inundation)
4. Dry phase - no standing water and soil dry (no evidence of recent inundation)

In 2017 (current review), two additional priority indicators were selected for further investigation: Plant Functional Group (PFG) Cover (i.e. *appropriate cover of native species in characteristic PFGs*) and Terrestrial Species Cover (i.e. *proportion of total cover comprising terrestrial dry (native and introduced) species*). PFG Cover was selected as it is likely to act as a strong indicator of condition in both wetlands and treed WRCs, being responsive not only to flooding but also the specific water cycle inundation phase. Terrestrial Species Cover was selected as terrestrial dry species are known to invade wetlands and flood-dependent understorey vegetation at KP and are therefore considered an important indicator of poor condition.

These two indicators were expanded into the following 12 indicators based on WRC and Wetland Inundation Phase (for wetlands):

- PFG Cover Dry Phase Wetlands
- PFG Cover Receding Phase Wetlands
- PFG Cover Red Gum FDU
- PFG Cover Red Gum FTU
- PFG Cover Black Box Woodland
- PFG Cover Grey Box Woodland
- Terrestrial Species Cover Dry Phase Wetlands
- Terrestrial Species Cover Receding Phase Wetlands
- Terrestrial Species Cover Red Gum FDU
- Terrestrial Species Cover Red Gum FTU
- Terrestrial Species Cover Black Box Woodland
- Terrestrial Species Cover Grey Box Woodland

A summary of the 22 indicators assessed during both program reviews is provided in Table 6.

Table 4 Suggested indicators for measuring health of wetland sites at Koondrook-Perricoota Forest (workshop output)

Indicator	Description and rationale	Potential PoR
Appropriate native species richness in PFGs characteristic of semi-permanent wetlands (i.e. PFGs 1-5) Used in Wills *et al.* (2016)	• During and following flood, the number of aquatic and amphibious species will increase in a healthy wetland. • PFGs are closely linked to water cycle phase. Expect to find different PFGs in different inundation phases. Therefore, will need to build in water cycle phase (i.e. dry / receding).	• For each water cycle phase (dry / receding), PFG species richness at a site is considered appropriate if it is on or above the PoR curve (based on the 90th percentile of residuals) for KP Forest since 2010 • Needs to be standardised for transect area, as wetland transects comprise different areas. • Likely to be more appropriate to assess success if it meets 90th percentile of residuals in for example 5 out of 10 years, as floods are not expected every year and thus cannot expect certain PFGs to be present in absence of floods.
Appropriate cover of native species in PFGs characteristic of semi-permanent wetlands (i.e. PFGs 1-5) Used in this study	• Cover also considered important along with species richness. Species richness and cover = diversity.	• Same as above but replace species richness with cover
Proportion of total cover comprising terrestrial dry (native and introduced) species (i.e. PFGs 6&7) Used in this study	• Terrestrial dry species currently invading wetlands at KP Forest and thus considered an important indicator of poor condition. • Selected cover as the indicator not species richness of the terrestrial PFGs because cover considered to have a higher potential impact than number of species, e.g. compete with wetland PFGs.	• Could use the same approach as for richness and cover as above, OR • Could set a % cover threshold as the benchmark. Or could set no increase in proportional cover as the benchmark. • This would be a reverse index, i.e. higher proportional cover, lower the score.
Number of saplings	• No increase in Red Gum saplings or reduce the number of saplings over time.	• Suggested Benchmark – start of monitoring program, year 1, 2010 or 2012 (not all wetlands assessed in 2010 so would need to use 2012, which is complicated because that year follows floods? Start year needs further investigation.
Presence of legislatively listed weeds	• Discussion around what lists to use. Agreed to use the NSW Noxious weeds list for the region. But could expand list to include advisory lists, as done at Gunbower.	• This could be a cover threshold? Currently set at 10% cover. Could lower this cover threshold to 5% or it could be presence/absence? Agreement that presence/absence was preferred. If a High Threat weed is present, then site receives a 0.

Table 5 Suggested indicators for measuring health of River Red Gum with Flood Dependent Understorey sites at Koondrook-Perricoota Forest (workshop output)

Indicator	Description and rationale	Potential PoR
Appropriate native species richness in PFGs characteristic of the WRC – RRG FDU (i.e. PFGs 3-5) Used in Wills *et al.* (2016)	• As above for wetlands but characteristic/appropriate PFGs different.	• 90th percentile of data collected to date for the WRC, with a different PoR depending on water cycle phase (dry / receding). • As above for wetlands
Appropriate cover of native species in PFGs characteristic of the WRC - RRG FDU (i.e. PFGs 3-5) Used in this study	• As above for wetlands but characteristic/appropriate PFGs different.	• 90th percentile of data collected to date for the WRC, with a different PoR depending on water cycle phase (dry / receding). • As above for wetlands
Proportion of total cover comprising terrestrial dry (native and introduced) species (i.e. PFGs 6&7) Used in this study	• As above for wetlands	• As above for wetlands
Tree canopy health Used in Wills *et al.* (2016)	• Trees considered important ecosystem service within tree WRCs such as River Red Gum FDU.	• Healthy tree is a tree with > 50% of tree canopy present (Crome score of 4 or 5 out of possible 5) • Healthy site = ≥ 80% of the 20 sampled trees healthy • Chowilla (Wallace) uses Tree Condition data – combines canopy extent and density scores to give a score out of 14 - Robinson (2014b). Investigate if this could be used.
Presence of legislatively listed weeds	• As for wetlands	• As for wetlands

Table 6 Summary of Wetland and Understorey indicators reviewed during 2016 and 2017

WRC / WIP	Indicator	Review Yr 1[a] dataset	Review Yr 2a[b] dataset	Review Yr 2b[c] dataset
Dry phase wetlands	PFG species richness	2010-16		2010-aut 17
Receding phase wetlands	PFG species richness	2010-16		2010-aut 17
RRG FDU	PFG species richness	2010-16		2010-aut 17
RRG FTU	PFG species richness	2010-16		2010-aut 17
BBW	PFG species richness	2010-16		2010-aut 17
GBW	PFG species richness	2010-16		2010-aut 17
RRG FDU	Tree canopy health	2010-16		
RRG FTU	Tree canopy health	2010-16		
BBW	Tree canopy health	2010-16		
GBW	Tree canopy health	2010-16		
Dry phase wetlands	PFG cover		2010-sum 17	
Receding phase wetlands	PFG cover		2010-sum 17	
RRG FDU	PFG cover		2010-16	
RRG FTU	PFG cover		2010-16	
BBW	PFG cover		2010-16	
GBW	PFG cover		2010-16	
Dry phase wetlands	Terrestrial species cover		2010-sum 17	
Receding phase wetlands	Terrestrial species cover		2010-sum 17	
RRG FDU	Terrestrial species cover		2010-16	
RRG FTU	Terrestrial species cover		2010-16	
BBW	Terrestrial species cover		2010-16	
GBW	Terrestrial species cover		2010-16	

Note: For the Year 2 program review dataset (i.e. current study) for RRG FDU, RRG FTU, GBW and BBW, 2010-16 data were used rather than 2010-17 data, as the 2017 autumn data were still being collected at the time the analyses were being undertaken.

Aut = autumn, Sum = summer

[a] Wills *et al.* (2016); [b] Current study; [c] In preparation (July 2017)

2.4 Datasets

Datasets included in this review:

- GHD Koondrook Perricoota Wetland Dataset 2010 to 2017.xlsx (used for the four wetland indicators)
- GHD Koondrook Perricoota Understorey Dataset 2010 to 2016.xlsx (used for the eight treed WRC indicators)

Information included in the Wetland Dataset:

- Data Index (Inventory of monitoring events)
- Site detail - site name and code, WRC, survey year and season, observers, estimated depth of flooding, evidence of fire/logging/tree falls/grazing and field notes
- Hydrology - estimated flood depth (if evidence of flooding) and inundation phase at time of sampling
- Ground flora - transect code/name, WRC, survey year and season; start and end of vegetation zone (m); species scientific/common name, PFG No./name, cover (% and m^2), origin (native/exotic), conservation status under Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and NSW Threatened Species list, weed status under NSW Noxious Weeds List and field notes
- Trees - transect code, WRC, survey year and season; start and end (m) of vegetation zone; tree stem DBH at 1.3 m, tree crown health (categories 0 to 5) (Crome 2004a; 2004b) field notes
- Saplings - transect code, WRC, survey year and season, start and end (n) of vegetation zone, sapling height (cm), tree crown health category (categories 0 to 5) and field notes
- Seedlings - transect code, WRC, survey year and season, start and end (m) of vegetation zone, seedling count and field notes
- Water depth - transect code, WRC, survey year and season, distance along transect, water depth and field notes
- Site locations - survey site, location, GPS code, reference, datum, zone, easting and northing

Information included in the Understorey Dataset:

- Data Index (Inventory of monitoring events)
- Site detail - site name, WRC, survey year and season, observers, estimated depth of flooding, vegetation condition score/category, vegetation class, evidence of fire/logging/tree falls/grazing and field notes
- Hydrology - flood depth and inundation phase during survey, likely hydrology over previous 12 months and hydrology observations
- Ground flora - quadrat No., WRC, survey year and season; species scientific/common name, PFG No./name, origin, conservation status under EPBC Act and NSW Threatened Species list, weed status under NSW Noxious Weeds List, cover (%, m^2) and field notes
- Canopy trees - quadrat No., WRC, survey year and season; tree No., species, tree crown condition category, tree tag comments and field notes
- Live (canopy) trees - quadrat No., WRC, survey year and season; tree No., species and stem DBH at 1.3 m, tree crown condition category (categories 0 to 5) and field notes
- Other trees - quadrat No., WRC, survey year and season, tree species, stem DBH at 1.3 m, tree crown condition category (categories 0 to 5) and field notes
- Saplings - quadrat No., WRC, survey year and season, sapling species, height and tree crown condition category (categories 0 to 5) and field notes
- Seedlings - quadrat No., WRC, survey year and season, seedling species and count and field notes
- Site locations - survey site, location, GPS code, reference, datum, zone, easting and northing

2.5 Data analysis

Dr Lien Sim was engaged by GHD to develop PoRs and undertake power and sensitivity analyses for each indicator. A detailed description of the methods and data analyses employed by Dr Lien Sim, including assumptions, limitations and results are outlined in Appendix A.

2.5.1 PFG cover and Terrestrial Species cover

Flora cover data were recorded in 60 understorey quadrats and at 15 wetland sites from 2010 to 2017 in Koondrook-Perricoota Forest. The understorey data were classified into four WRCs, as outlined in section 2.2.2:

- Red Gum Flood Dependent Understorey (characteristic PFGs 3-5)
- Red Gum Flood Tolerant Understorey (characteristic PFGs 4-6)
- Black Box Woodlands (characteristic PFGs 4-6)
- Grey Box Woodlands (characteristic PFGs 4-6)

Wetland data were classified into two Wetland Inundation Phase Classes (WIP – described in section 2.2.1):

- Dry phase wetlands
- Receding phase wetlands

Plant species were categorised into PFGs (based on a master list provided by Dr Michelle Casanova – see *Definitions* section for descriptions of PFGs). Plant Functional Groups considered characteristic of each WRC were proposed by AE (2011) and further refined during the workshop. Characteristic PFGs for wetlands are PFGs 1-5, while characteristic PFGs of other WRCs are listed above.

For the purposes of this refinement project, all autumn records of indigenous species from characteristic PFGs were used for understorey analyses of the four treed WRCs, and all records (spring, summer and autumn) were used for wetland analyses because these data captured different Wetland Inundation Phases.

Points of Reference

Plant Functional Group (PFG) Cover was calculated for each site and sample year, and then PoRs were determined for each treed WRC or Wetland Inundation Phase Class (wetlands). The current approach set the PoR based on the six to seven year dataset, but depending on what is most important to the project manager, it could be set based on a reference year (i.e. the 'best' year or the first year of monitoring).

For each Wetland Inundation Phase (WIP), or Red Gum and Box (forest) WRC, the 'Characteristic PFG Cover Index' at a site is considered 'appropriate' if it is on or <u>above</u> the PoR of the 90th percentile of all records (wetlands) across the 2010-2017 sampling period, or all autumn records (understorey) across the 2010-2016 sampling period.

For each WIP or WRC, the 'Terrestrial Species Cover Index' at a site is considered 'appropriate' if it is <u>below</u> the Point of Reference (PoR), based on the 90th percentile of all records (wetlands) across the 2010-2017 sampling period, or all autumn records (understorey) across the 2010-2016 sampling period.

To derive a WRC-level or Wetland Inundation Phase-level index score, the proportion of compliant sites (scoring 1) for each WRC or WIP can be calculated.

2.5.2 Power analyses

The purpose of running power analyses on indicator data is to determine how likely it is that a statistical effect (a difference in mean index values over time or differences in mean index values from sampling event to sampling event) will be detected.

Two types of power analyses were calculated as part of the testing of new condition indicators for KP data: a) linear mixed models (i.e. trend analysis), and b) calculation of Observed Effect Sizes (OES) and Confidence Intervals (CI) (i.e. year-by-year or event-by-event comparisons).

Linear mixed models

Power analyses based on linear mixed models ('trend analysis') of the indicator data using pre-specified effect sizes to determine the minimum significant detectable effect sizes (Thomas 1997). The minimum detectable effect sizes generated in these analyses are inversely related to the resulting P values, i.e. minimum detectable effects will only be smaller than observed effects if the test is significant. This approach also requires that data be robust to the assumptions of linear models.

In general, the understorey WRCs had sufficient replication to make the linear mixed modelling approach viable. Only autumn data were used, meaning that the modelling could focus on differences between years, or a straightforward trend over time.

Conversely, it was not possible to run trend analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Observed Effects Sizes and Confidence Intervals

An Observed Effect Size (OES) is an actual measure of the size of the difference (e.g. mean index values or slope/trend in index values) between two groups and whether this difference is negative or positive (Durlak 2009). Confidence Intervals (CI) for the OES provide an estimate of the range of 'plausible' effect size values expected from the wider population, given our OES (Kirby and Gerlanc 2013), and allow the level of uncertainty in the results to be quantified. The calculation of OES and CI and is considered a robust approach to *post hoc* power analysis (Thomas 1997). It is important to report OESs, regardless of whether P-values indicate a test is significant or not (Durlak 2009).

OES and CI were calculated using: a) the understorey (treed WRC) dataset for year-by-year comparisons, and b) the wetland dataset for event-by-event comparisons, for both the Characteristic PFG Cover and Terrestrial Species Cover indicators.

Since the calculation of OES and CIs that we used do not depend on normally distributed indicator data (see Kirby and Gerlanc 2013), it was considered viable to apply this process to the KP wetland dataset, to see if the differences in observed mean indicator scores between sampling events (OES) were meaningful, and whether the CIs suggested that we could be confident in these OES values. Some sampling events for Receding Wetlands were excluded from analyses, due to insufficient replication, and some of the comparisons were less meaningful since they compared between seasons within the same year (e.g. Autumn 2014 – Spring 2014), rather than between years.

2.6 Limitations of datasets

The datasets used for the analyses have a number of limitations, as outlined below:

- Unbalanced design (discussed in Section 1.4)
- Wetland transect lengths vary
- Wetland type varies, e.g. swamps, creeks, wetlands, lagoons
- Wetlands were not randomly selected, although those selected are considered representative of the wetlands within the Forest
- Poor replication in some WRCs but not the focus WRCs, e.g. River Red Gum FDU
- Wetland Inundation Phase was divided into two categories, which are a simplified version of reality
- There are gaps in the dataset (e.g. no monitoring occurred in 2012)

Despite these limitations, the datasets were of suitable quality to undertake the necessary analyses and make recommendations as to Points of Reference, and determinations regarding the power and sensitivity of the dataset.

3. Results

A detailed report by Dr Sim is provided in Appendix A outlining the results of the statistical analyses (technical workings for the following summary data). The key findings of the analyses are summarised in this chapter, including:

- Templates Part 1 and 2 for incorporation into the Koondrook-Perricoota Forest Condition Monitoring Plan
- Figures showing plot of mean index values (and 95% confidence intervals) for each WRC by sampling year

3.1 Plant Functional Group Cover

The following template (Part 1) summarises information for the Koondrook-Perricoota Forest Characteristic PFG Cover Index (Table 7). Template Part 2 outlines the process applied to determine the power and sensitivity of this index (Table 8).

Table 7 Template Part 1 – Characteristic PFG Cover Index

Characteristic	Description
Overarching Management/Ecological Objectives for Koondrook-Perricoota (currently under review)	Maintain and restore a mosaic of healthy floodplain communities (including): • 80% of permanent[8] and semi-permanent wetlands in a healthy condition • 30% of River Red Gum forest in a healthy condition
Draft refined ecological objectives for the Gunbower–Koondrook–Perricoota icon site Technical Advisory Committee (MDBC 2007)	Protect and enhance a diverse range of healthy wetlands • Protect and enhance diverse, healthy vegetation communities • Provide for successful waterbird breeding and recruitment events • Protect and enhance viable native fish communities
Proposed targets for KP	• At least 80% of wetland WRC sites in a healthy condition • At least 30% of River Red Gum WRC sites in a healthy condition • At least 90% of Grey Box WRC sites in a healthy condition
Monitoring Objective	To measure occurrence of flora species across Koondrook-Perricoota Forest

[8] Note: there are no permanent wetlands at KP Forest

Characteristic	Description
Points of Reference	For each KP WIP, PFG Cover (comprising species from characteristic PFGs) at a site is considered 'appropriate' if it is on or above the Point of Reference (PoR) based on the 90th percentile of all records regardless of season since 2010. For each KP WIP these values are: • Dry phase wetlands – 24.1% cover of species from PFGs 1-5 • Receding phase wetlands – 30.7% cover of species from PFGs 1-5 For each KP Red Gum and Box (forest) WRC, PFG Cover (comprising species from characteristic PFGs) at a site is considered 'appropriate' if it is on or above the PoR based on the 90th percentile of all autumn records since 2010. For the treed WRCs these values are: • Red Gum with Flood Dependant Understorey – 17.5% cover of species from PFGs 3-5 • Red Gum with Flood Tolerant Understorey – 20.4% cover of species from PFGs 4-6 • Black Box Woodlands – 10% cover of species from PFGs 4-6 • Grey Box Woodlands – 12% cover of species from PFGs 4-6
Sampling Strategy	Wetland sites: regular autumn vegetation monitoring and spring and summer post-event monitoring at 15 sites. Note that Pollack Swamp transects 1 and 2 are quite ecologically distinct and have been treated as separate wetlands for the purpose of these analyses. Pollack Swamp transect 3 (PS3) is a pseudoreplicate of PS2 and has been excluded from analyses. Data were categorised into two Wetland Inundation Phase Classes (Dry and Receding). Dry Phase Wetlands – no standing water present, but sediment may be moist. Receding Phase Wetlands – standing water is present (water of variable depth). Understorey sites: regular autumn vegetation monitoring at 60 randomly located quadrats. Data categorised into four treed WRCs – River Red Gums (FDU & FTU) and Box woodlands (Black & Grey).
Index	Index 1: 'Characteristic PFG Cover Index' per site by sample year Minimum score of 0, maximum score of 1.
Observed Effect Sizes and Confidence Intervals	An Observed Effect Size (OES) is an actual measure of the size of the difference (e.g. mean index values or slope/trend in index values) between two groups and whether this difference is negative or positive (Durlak 2009). Confidence Intervals for the OES give us an estimate of the range of 'plausible' effect size values we could expect from the wider population, given our OES (Kirby and Gerlanc 2013). It is important to report OESs, regardless of whether P-values indicate a test is significant or not (Durlak 2009). For the 'Characteristic PFG Cover Index', OES and confidence intervals (CIs) were calculated for year-by-year (understorey) or sampling event-by-sampling event (wetland) comparisons.

Characteristic	Description
Power[9]	The power of a test is the likelihood that a statistical effect will be detected (probability of rejecting the null hypothesis if the null is false) (Thomas 1997). Power explains the minimum size of the effect that can be detected with confidence. In this refinement project, we have investigated the *post hoc* power of linear mixed effect models to detect (for each WRC): • A change through time (trend) in mean Characteristic PFG Cover index values • Differences between mean Characteristic PFG Cover index values on subsequent sampling dates (year-by-year for understorey sites or sampling event-by-sampling event for wetland sites) The development of these models has some value because it allows us to assess whether a trend in mean index values over time is significantly different from zero or whether mean index values are significantly different between sampling events. Retrospective (*post hoc*) power analysis using observed effect sizes and variation has limitations, since there is a direct relationship between power and p-value (low p-value, significant result, high power or high p-value, non-significant result, low power). In order to avoid this, we have instead calculated power using pre-specified effect sizes and the observed variance, and determined the minimum significant detectable effect sizes (Thomas 1997). The calculation of Observed Effect Sizes[10] and Confidence Intervals (see above) is considered to be another robust form of retrospective power analysis, which allows the level of uncertainty in the results to be quantified (Thomas 1997). The following trend models for the Characteristic PFG Cover index had sufficient power to detect change. • Red Gum FTU Minimum Significant Effect Size (MSES) ±0.034, power = 0.6265178 • Grey Box MSES ±0.02, power = 0.9992650 The year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in all treed WRCs. The results are summarised in Section 3.1.1 and presented in more detail in Appendix A *Note: it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.*

[9] Explained in more detail under the heading Power analyses on page 11 of Appendix A

[10] In contrast to the Minimum Significant Effect Size calculated as part of the Power Analysis.

Table 8 Template Part 2 – Characteristic PFG Cover Index

Characteristic	Description
Explanation of Reference	**For each WIP and WRC:** The long-term database was interrogated to determine what cover of characteristic PFG species represented the top 10% of sites for each WIP or treed WRC since 2010. Cover data were expressed as % cover, which incorporates an intrinsic weighting by area. To derive points of reference: • The appropriate cover of characteristic native PFG species across the WIP or WRC was summarised. Replicates were sampling occasions across all wetland sites or quadrats • From these data, the 90th percentile value was determined For additional details see Appendix A.
Index Calculation	**For wetland WIPs and treed WRCs:** • Cover of characteristic native PFG species for each site on each sampling occasion was converted to an index using the formula • Index = Sqrt(Characteristic PFG cover) ÷ Sqrt(Point of Reference) • Correct so that any values >1 are recorded as 1 • Index lies between 0 and 1 • Characteristic PFG cover that is greater than or equal to the PoR results in an index of 1 (it is compliant), and characteristic PFG cover less than the POR results in an index of <1 (it is not compliant) • Calculate the whole of WIP/WRC score as the proportion of compliant samples in each WIP/WRC
Sensitivity	The index is scaled to represent the cover of characteristic PFG species recorded, relative to the cover recorded in the top 10% of cases (PoR for WIPs or WRCs) over the six to seven years of the monitoring program. Hence, the indicator is sensitive because when the wetlands and floodplain support a lower cover of characteristic PFG species in any year, the sampling sites will return a lower cover of characteristic PFG species, and the index will be lower.

3.1.1 Year-by-year differences models

The year-by-year differences in Characteristic PFG Cover Index data for each WRC were represented by a series of mixed effects models with site as a random factor. Figure 2 presents mean index values and 95% confidence intervals for the understorey (treed WRC) dataset.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Characteristic PFG Cover Index year-by-year (or event-by-event) difference models for each WRC are provided in Appendix A. Table 9 provides a summary of significant differences between years.

Table 9 Summary of results of the mixed effect models and power analyses (including observed effects size and confidence intervals) for Characteristic PFG Cover

Water Regime Class	Significant differences detected
Wetlands (receding and dry)	None of the event by event comparisons for WIPs resulted in a meaningful OES that we could be confident in. This process gives an insight into the level of variability inherent in wetland data, and the difficulty in generalising measures of condition across diverse groups of wetlands.
Red Gum FDU	Mean index values in three pairs of years (2010-2011, 2011-2013 and 2014-2015) were significantly different from each other, and these tests had adequate power to detect the minimum effect sizes. Differences between mean index values in the other two pairs of years (2013-2014 and 2015-2016) could not be detected (power was insufficient). The OES for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Characteristic PFG Cover index between years. In both cases, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. These results are conclusive – we are confident that there is a detectable difference between years. OESs for 2013-2014 and 2015-2016 were too small to represent a meaningful difference in the Characteristic PFG Cover index between years, and in both cases, the confidence intervals included zero so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years. The OES for 2014-2015 was larger and more likely to represent a meaningful difference in the Characteristic PFG Cover index between years. However, one confidence interval was quite close to zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. This result is inconclusive, and suggests that we might have needed a larger sample size.
Red Gum FTU	Mean index values in two pairs of years (2010-2011 and 2011-2013) were significantly different from each other, and these tests had adequate power to detect the minimum effect sizes. Differences between mean index values in the other three pairs of years (2013-2014, 2014-2015 and 2015-2016) could not be detected (power was insufficient). The OES for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Characteristic PFG Cover index between years. In both cases, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. These results are conclusive – we are confident that there is a detectable difference between years. The OES for 2015-2016 was too small to represent a meaningful difference in the Characteristic PFG Cover index between years, and the confidence intervals included zero so we don't have confidence that there was a true difference from zero in this score. The result for these years is conclusive – we are confident that there is no detectable difference between years. The OES for 2013-2014 and 2014-2015 were larger and more likely to represent a meaningful difference in the Characteristic PFG Cover index between years. However, in both cases, the confidence intervals either approached or overlapped zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.

Water Regime Class	Significant differences detected
Black Box	Four of the pairs of years were significantly different from each other, and their corresponding tests had adequate power to detect the minimum significant effect sizes. • 2010-2011 • 2011-2013 • 2013-2014 • 2014-2015 The OES for 2011-2013 was large enough to represent a meaningful difference in the Characteristic PFG Cover index between years. In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years. OES for 2015-2016 was too small to represent a meaningful difference in the Characteristic PFG Cover index between years and the CIs included zero so we don't have confidence that there was a true difference from zero in these scores. The result for these years is conclusive – we are confident that there is no detectable difference between years. The OESs for 2010-2011, 2013-2014 and 2014-2015 were large enough to represent a meaningful difference in the Characteristic PFG Cover index between years. However, in all cases, one confidence interval was quite close to zero, reducing our confidence that the actual population OESs lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.
Grey Box	Mean index values in two pairs of years (2010-2011 and 2011-2013) were significantly different from each other, and these tests had adequate power to detect the minimum significant effect sizes. Differences between mean index values in the other three pairs of years (2013-2014, 2014-2015 and 2015-2016) could not be detected. The OES for 2011-2013 was large enough to represent a meaningful difference in the Characteristic PFG Cover index between years. In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years. The OESs for 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Characteristic PFG Cover index between years, and in all cases, the confidence intervals included zero so we do not have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years. The OES for 2010-2011 was large enough to represent a meaningful difference in the Characteristic PFG Cover index between years. However, one of the Cis was very close to zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. This result is inconclusive, and suggests that we might have needed a larger sample size.

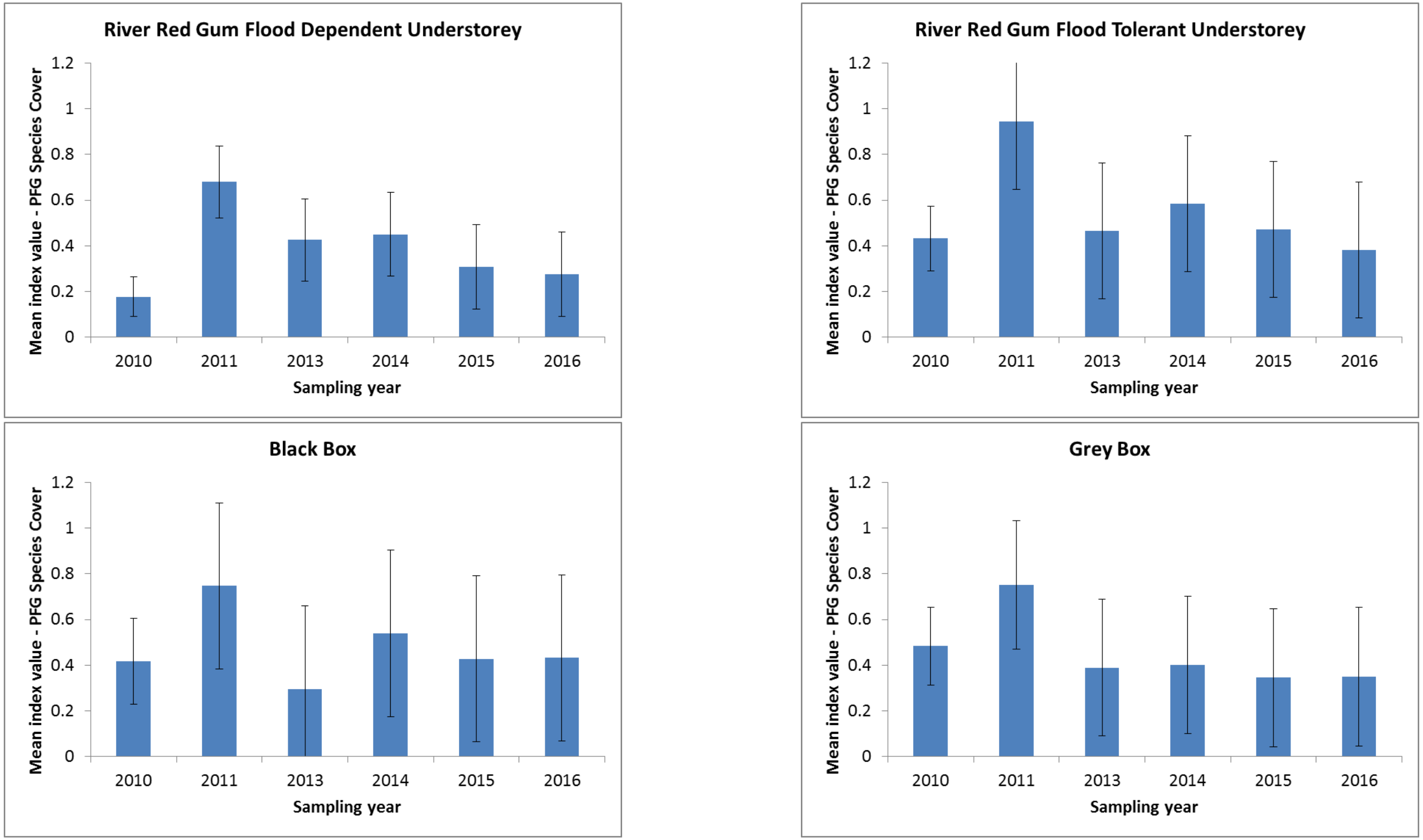

Figure 2 Plot of mean Characteristic PFG Cover index values (and 95% confidence intervals) for each WRC by sampling year

The 95% CIs indicate the variation in index scores between sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plots.

3.2 Terrestrial Species Cover

The following template (Part 1) summarises information for the Koondrook-Perricoota Forest Terrestrial Species Cover Index from the understorey sites (treed WRCs; Table 10). Template Part 2 outlines the process applied to determine the power and sensitivity of the index (Table 11).

Note that this index has a minimum of 0, indicating no dry terrestrial species cover, and a maximum of 1, indicating ≥90% dry terrestrial species cover, meaning that samples are compliant if they DO NOT exceed the PoR. This is the inverse of the other vegetation monitoring indicators applied to the Koondrook-Perricoota dataset, and means that indicator scores should not be numerically summed across indicators to provide a summary of condition. Instead, a summary of which site/dates or WIPs/WRCs are compliant can be made.

Table 10 Template Part 1 – Terrestrial Species Cover Index

Characteristic	Description
Overarching Management/Ecological Objectives for KP (currently under review)	Maintain and restore a mosaic of healthy floodplain communities (including): • 80% of permanent[11] and semi-permanent wetlands in a healthy condition • 30% of River Red Gum forest in a healthy condition
Draft refined ecological objectives for the Gunbower–Koondrook–Perricoota icon site Technical Advisory Committee (MDBC 2007)	Protect and enhance a diverse range of healthy wetlands • Protect and enhance diverse, healthy vegetation communities • Provide for successful waterbird breeding and recruitment events • Protect and enhance viable native fish communities
Proposed targets for KP	• At least 80% of wetland WRC sites in a healthy condition • At least 30% of River Red Gum WRC sites in a healthy condition • At least 90% of Grey Box WRC sites in a healthy condition
Monitoring Objective	To measure occurrence of flora species across Koondrook-Perricoota Forest
Points of Reference	For each WIP or WRC, the 'Terrestrial Species Cover Index' at a site is considered 'appropriate' if it is below the Point of Reference (PoR), based on the 90th percentile of all records (wetlands) or all autumn records (understorey) since 2010. For the WIPs, these values are: • Dry Phase Wetlands - proportion of terrestrial species 0.4564 • Receding Phase Wetlands- proportion of terrestrial species 0.343616 For the treed WRCs these values are: • Red Gum with Flood Dependant Understorey – proportion of terrestrial species 0.741935 • Red Gum with Flood Tolerant Understorey – proportion of terrestrial species 0.795 • Black Box Woodlands proportion of terrestrial species 0.943477 • Grey Box Woodlands proportion of terrestrial species 0.974927

[11] Note: there are no permanent wetlands at Koondrook-Perricoota Forest

Characteristic	Description
Sampling Strategy	Wetlands: regular autumn vegetation monitoring and spring and summer post-event monitoring at 15 sites. Note that Pollack Swamp transects 1 and 2 are quite ecologically distinct and have been treated as separate wetlands for the purpose of these analyses. Pollack Swamp transect 3 (PS3) is a pseudoreplicate of PS2 and has been excluded from analyses. Data were categorised into two Wetland Inundation Phase Classes (Dry and Receding). Dry Phase Wetlands – no standing water present, but sediment may be moist. Receding Phase Wetlands – standing water is present (water of variable depth). Understorey: regular autumn vegetation monitoring at 60 randomly located quadrats. Data were categorised into four treed WRCs – River Red Gums (FDU & FTU) and Box Woodlands (Black & Grey).
Index	Index 1: 'Terrestrial Species Cover Index' per site by sample year Minimum score of 0, maximum score of 1.
Observed Effect Sizes and Confidence Intervals	An Observed Effect Size (OES) is an actual measure of the size of the difference (e.g. mean index values or slope/trend in index values) between two groups and whether this difference is negative or positive (Durlak 2009). Confidence Intervals for the OES give us an estimate of the range of 'plausible' effect size values we could expect from the wider population, given our OES (Kirby and Gerlanc 2013). It is important to report OESs, regardless of whether P-values indicate a test is significant or not (Durlak 2009). For the 'Terrestrial Species Cover Index', OES and confidence intervals (CIs) were calculated for year-by-year (understorey) or sampling event-by-sampling event (wetland) comparisons.
Power	The power of a test is the likelihood that a statistical effect will be detected (probability of rejecting the null hypothesis if the null is false) (Thomas 1997). Power explains the minimum size of the effect that can be detected with confidence. In this refinement project, we have investigated the post hoc power of linear mixed effect models to detect (for each WRC*): • A change through time (trend) in mean 'Terrestrial Species Cover' index values • Differences between mean 'Terrestrial Species Cover' index values on subsequent sampling dates (year-by-year for understorey sites or sampling event-by-sampling event for wetland sites) The development of these models has some value because it allows us to assess whether a trend in mean index values over time is significantly different from zero or whether mean index values are significantly different between sampling events. Retrospective (*post hoc*) power analysis using observed effect sizes and variation has limitations, since there is a direct relationship between power and p-value (low p-value, significant result, high power or high p-value, non-significant result, low power). In order to avoid this, we have instead calculated power using pre-specified effect sizes and the observed variance, and determined the minimum significant detectable effect sizes (Thomas 1997). The calculation of Observed Effect Sizes[12] and Confidence Intervals (see row above) is considered to be another robust form of retrospective power analysis, which allows the level of uncertainty in the results to be quantified (Thomas 1997). The following trend model for the 'Terrestrial Species Cover Index' had sufficient power to detect change. • Red Gum FDU MSES ±0.023, power = 0.9837447 The year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in Red Gum FDU, but none of the other treed WRCs. The results are summarised in Section 3.2.1 and presented in more detail in Appendix A. **Note: it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.*

[12] In contrast to the Minimum Significant Effect Size calculated as part of the Power Analysis

Table 11 Template Part 2 – Index of Tree Canopy Health

Characteristic	Description
Explanation of the Point of Reference	**For each WIP and WRC:** The long-term database was interrogated to determine what proportion of terrestrial species cover represented the top 90% of sites for each WIP or treed WRC since 2010. Cover data were expressed as % cover, which incorporates an intrinsic weighting by area. To derive points of reference: • The proportion of terrestrial species cover across the WIPC or WRC was summarised. Replicates were sampling occasions across all wetland sites or quadrats. • From these data, the 90th percentile value was determined For additional details see Appendix A.
Sensitivity	The index is scaled to represent the Terrestrial Species Cover recorded, relative to the cover recorded in the highest 10% of cases over the 6-7 years of the monitoring program. Hence, the indicator is sensitive because when the wetlands and floodplain support a higher cover of terrestrial species in any year, the sampling sites will return a higher cover of terrestrial species, and the index will be higher. *Note that compliance for this indicator is triggered by cases that do NOT equal or exceed the PoR.*
Index Calculation	**For wetland WIPCs and treed WRCs:** • Terrestrial species cover for each site on each sampling occasion was converted to an index using the formula • Index = Sqrt(Terrestrial Species Cover) ÷ Sqrt(Point of Reference) • Correct so that any values >1 are recorded as 1 • Index lies between 0 and 1 • <u>Terrestrial Species Cover that is greater than or equal to the PoR results in an index of 1 (it is NOT compliant), and Terrestrial Species Cover less than the POR results in an index of <1 (it IS compliant)</u> • Calculate the WIP/WRC score as the proportion of compliant samples in each WIP/WRC

3.2.1 Year-by-year differences models

The year-by-year differences in Terrestrial Species Cover Index data for each WRC were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 3 for each treed WRC.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Terrestrial Species Cover Index year-by-year (or event-by-event) difference models for each WRC are provided in Appendix A. Table 12 provides a summary of significant differences between years.

Table 12 Summary of results of the mixed effect models and power analyses (including observed effects size and confidence intervals) for Terrestrial Species Cover

Water Regime Class	Significant differences detected
Wetlands (receding and dry)	None of the event by event comparisons for WIPs resulted in a meaningful OES that we could be confident in. This process gives an insight into the level of variability inherent in wetland data, and the difficulty in generalising measures of condition across diverse groups of wetlands.
Red Gum FDU	Mean index values in three pairs of years (2010-2011, 2011-2013 and 2014-2015) were significantly different from each other, and these tests had adequate power to detect the minimum significant effect sizes. Differences between mean index values in the other two pairs of years (2013-2014 and 2015-2016) could not be detected (power was insufficient). The OES for 2010-2011 was large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years. In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years. OESs for 2011-2013, 2013-2014 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years, and in all cases, the CIs included zero so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years. The OES for 2014-2015 was larger and more likely to represent a meaningful difference in the Terrestrial Species Cover Index between years. However, the confidence intervals included zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. This result is inconclusive, and suggests that we might have needed a larger sample size.
Red Gum FTU	Mean index values in 2010-2011 were significantly different from each other, and the comparison of these years had adequate power to detect the minimum significant effect size. Differences between mean index values in the other four pairs of years (2011-2013, 2013-2014, 2014-2015 and 2015-2016) could not be detected (power was insufficient). The OES for 2010-2011 was large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years. In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years. OESs for 2011-2013, 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years, and in all four cases, the CIs included zero so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

Water Regime Class	Significant differences detected
Black Box	No pairs of years were significantly different from each other, and none of the corresponding tests had adequate power to detect the minimum significant effect sizes. The OESs for 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years and the CIs included zero so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years. The OESs for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years. However, in both cases, the confidence intervals included zero, reducing our confidence that the actual population OESs lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.
Grey Box	Differences between mean index values in all pairs of years could not be detected, and these tests did not have adequate power to detect the minimum significant effect sizes. The OESs for 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years and the CIs included zero so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years. The OESs for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years. However, in both cases, the confidence intervals were either very close to or included zero, reducing our confidence that the actual population OESs lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.

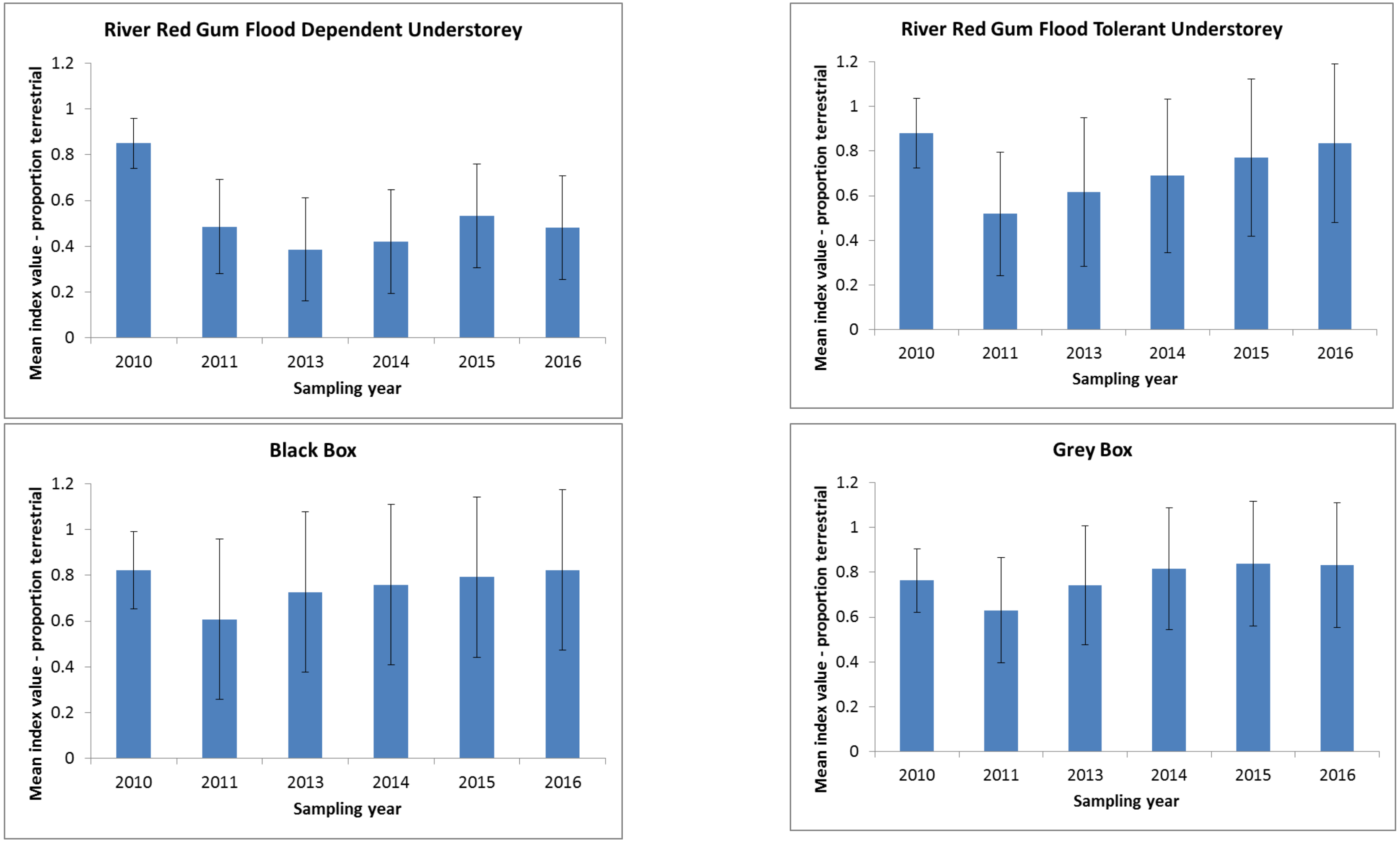

Figure 3 Plot of mean Terrestrial Species Cover index values (and 95% confidence intervals) for each WRC by sampling year

The 95% CIs indicate the variation in index scores between sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plots.

4. Conclusions and recommendations

4.1 Conclusions

4.1.1 Indicator 1: Characteristic Plant Functional Group Cover

Points of Reference

For each WIP and treed WRC, Characteristic PFG Cover at a site is considered 'appropriate' if it is on or above the PoR based on the 90th percentile of all records (wetlands) or all autumn records (understorey) since 2010.

For each WIP these values are:

- Dry phase wetlands – 24.1% cover of species from PFGs 1-5
- Receding phase wetlands – 30.7% cover of species from PFGs 1-5

For the treed (understorey) WRCs these values are:

- Red Gum with Flood Dependant Understorey – 17.5% cover of species from PFGs 3-5
- Red Gum with Flood Tolerant Understorey – 20.4% cover of species from PFGs 4-6
- Black Box Woodlands – 10% cover of species from PFGs 4-6
- Grey Box Woodlands – 12% cover of species from PFGs 4-6

Power

It was not possible to run the mixed models power analyses on the wetland indicators, since the highly unbalanced nature of the dataset, coupled with high levels of variability, made it unfeasible to run mixed models on these data.

For the treed WRCs, the following trend models for the Characteristic PFG Cover indicators had sufficient power to detect change.

- Red Gum FTU MSES ±0.034, power = 0.6265178
- Grey Box MSES ±0.02, power = 0.9992650

The Red Gum FDU and Black Box Woodland WRCs had insufficient power to detect change. While the trend model can be used for Red Gum FTU and Grey Box Woodland WRCs (based on the six-year dataset including one major flood), the year-by-year approach is likely to prove more informative, owing to the cyclical nature of cover of characteristic PFGs in response to wetting and drying regimes.

None of the event-by-event comparisons for WIPs resulted in a meaningful OES in which we could be confident. Consequently, this process gives an insight into the level of variability inherent in wetland data, and the difficulty in generalising measures of condition across diverse groups of wetlands.

In contrast, the year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in all treed WRCs (Table 13). Where the confidence intervals around the Observed Effect Size (OES) were not close to zero, it suggested that the actual population OES lay far enough from zero to be biologically significant, and the OES was large enough to represent a meaningful difference in the Characteristic PFG Cover index between years. These years are represented in bold in Table 13. These results are conclusive, i.e. we are confident that there is a detectable difference between years, with the Characteristic PFG Cover indicator increasing from 2010 to 2011 in the RRG WRCs (following flooding of the forest), and then decreasing from 2011 to 2013 in all RRG and Box WRCs (as the forest returned to a dry state). The OESs for at least two WRCs in 2010-2011, 2013-2014 and 2014-2015 (all marked with an asterisk in Table 13) probably represented a meaningful difference in the Characteristic PFG Cover index between years. However, in each instance, one confidence interval was close to zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. Consequently, these results are inconclusive, and suggest that a larger sample size may be needed. Finally, the OES for cells marked 'NE' (i.e. no effect) in Table 13 was too small to represent a meaningful difference in the Characteristic PFG Cover index between years and the confidence intervals included zero so we have no confidence that there was a true difference from zero in these scores. Consequently, the results for these years are conclusive, i.e. we are confident that there is no detectable difference between years. This lack of change was most pronounced in 2015-2016, where all WRCs exhibited no change.

Table 13 Year-by-year comparisons with sufficient power to detect change for the Characteristic PFG Cover Indicator in treed WRCs

	2010-11	2011-13	2013-14	2014-15	2015-16
RRG FDU	**Yes (+)**	**Yes (-)**	NE	Yes#	NE
RRG FTU	**Yes (+)**	**Yes (-)**	Yes*	Yes*	NE
Black Box	Yes#	**Yes (-)**	Yes#	Yes#	NE
Grey Box	Yes#	**Yes (-)**	NE	NE	NE

NE: no effect; + positive effect; - negative effect; * possible effect but inconclusive evidence

Significant effect ($p<0.05$); however, OES too small to represent a meaningful difference in Terrestrial Species Cover index between years and the confidence interval included zero, so we have no confidence that there was a true difference from zero in these scores

4.1.2 Indicator 2: Terrestrial Species Cover

Points of Reference

For each WIP or WRC, the 'Terrestrial Species Cover Index' at a site is considered 'appropriate' if it is below the Point of Reference (PoR), based on the 90th percentile of all records (wetlands) or all autumn records (understorey) since 2010.

For the WIPs, these values are:

- Dry Phase Wetlands - proportion of terrestrial species 0.4564
- Receding Phase Wetlands- proportion of terrestrial species 0.343616

For the treed (understorey) WRCs these values are:

- Red Gum with Flood Dependant Understorey – proportion of terrestrial species 0.741935
- Red Gum with Flood Tolerant Understorey – proportion of terrestrial species 0.795
- Black Box Woodlands proportion of terrestrial species 0.943477
- Grey Box Woodlands proportion of terrestrial species 0.974927

Power

It was not possible to run the mixed models power analyses on the wetland indicators, since the highly unbalanced nature of the dataset, coupled with high levels of variability, made it unfeasible to run mixed models on these data.

For the treed WRCs, the following trend model for the Terrestrial Species Cover indicator had sufficient power to detect change.

- Red Gum FDU MSES ±0.023, power = 0.9837447

The River Red Gum FTU and Box Woodland WRCs had insufficient power to detect change. While the trend model can be used for Red Gum FDU (based on the six-year dataset including one major flood), the year-by-year approach is likely to prove more informative, owing to the cyclical nature of cover of characteristic PFGs in response to wetting and drying regimes.

None of the event-by-event comparisons for WIPs resulted in a meaningful OES that we could be confident in. Consequently, this process gives an insight into the level of variability inherent in wetland data, and the difficulty in generalising measures of condition across diverse groups of wetlands.

In contrast, the year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in all treed WRCs (Table 14). Where the confidence intervals around the Observed Effect Size (OES) were not close to zero, it suggested that the actual population OES lay far enough from zero to be biologically significant, and the OES was large enough to represent a meaningful difference in the Terrestrial Species Cover index between years. These years are represented in bold in Table 14. These results are conclusive, i.e. we are confident that there is a detectable difference between years, with the Terrestrial Species Cover indicator decreasing from 2010 to 2011 in River Red Gum FDU and FTU (after the forest was inundated by floodwaters). The OES for a number of WRCs in 2010-11, 2011-2013 and 2014-2015 (all marked with an asterisk in Table 14) probably represented a meaningful difference in the characteristic Terrestrial Species Cover index between years. However, in each instance, one confidence interval was close to zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. Consequently, these results are inconclusive, and suggest that a larger sample size may be needed. Finally, the OES for cells marked 'NE' (i.e. no effect) in Table 14 was too small to represent a meaningful difference in the Terrestrial Species Cover index between years and the confidence intervals included zero so we have no confidence that there was a true difference from zero in these scores. Consequently, the results for these years are conclusive, i.e. we are confident that there is no detectable difference between years.

Table 14 Year-by-year comparisons with sufficient power to detect change for the Terrestrial Species Cover Indicator in treed WRCs

	2010-11	2011-13	2013-14	2014-15	2015-16
RRG FDU	**Yes (-)**	NE	NE	Yes[#]	NE
RRG FTU	**Yes (-)**	NE	NE	NE	NE
Black Box	Yes*	Yes*	NE	NE	NE
Grey Box	Yes*	Yes*	NE	NE	NE

NE: No effect; + positive effect; - negative effect; * possible effect but inconclusive evidence

[#] Significant effect ($p<0.05$); however, OES too small to represent a meaningful difference in Terrestrial Species Cover index between years and the confidence interval included zero, so we have no confidence that there was a true difference from zero in these scores

4.2 Recommendations

Based on the work undertaken in this program review and that undertaken by Wills *et al.* (2016), we are now at a point where a sufficient number of indicators appears to have been reached to obtain a broad overview of vegetation condition across the KP icon site. In other words, the indicators of Characteristic PFG Species Richness, Characteristic PFG Cover, Terrestrial Species Cover and Tree Canopy Health, when assessed in concert with the two WIPs and the four WRCs, represent a diverse means of showing how forest, woodland and wetland condition responds to wetting and drying regimes at KP.

Developing an overall scoring method

A method for combining the index scores from each of the 22 indicators outlined in Table 6 can now be developed so that a total score for vegetation condition at the WRC level, WIP level and whole of icon site level can be calculated each year.

Wetland inundation phase – revision required?

Currently, wetlands are divided into receding and dry phases for the purpose of developing indicators as follows:

- Receding - standing water is present and water is of variable depth
- Dry - no standing water but soil may still be moist

This should be further analysed and refined if possible, as there is a degree of ambiguity in that soil in the dry phase wetlands can still be moist by definition. Sites in the 'dry' inundation phase, as defined here, are consequently likely to have a different species composition and cover to sites that are genuinely dry and have not been wet for a year or more. The problem with further separating categories of inundation phase is that replication and power to detect changes decreases. Irrespective of this, we feel that it is worth investigating to make sure that the most appropriate wetland inundation phase classes are being used as indicators.

Measuring Tree Canopy Health – alternative indicator required?

The tree canopy health indicator assessed by Wills *et al.* (2016) appeared to be unable to regularly detect change in RRG FDU and RRG FTU. This is because either canopy health was not changing over time, or the indicator was too coarse to identify subtle year-to-year variation. Prior to the 2016 flood, our view was that the indicator was too coarse, as the increments are generally 25% intervals of the original canopy present, so the score remains the same for individual trees unless they move into the next cover threshold. However, following the 2016 flood, tree canopy health responded well, with the canopy returning to a condition not seen since 2011 (Forbes and Wills 2017a). It is likely that with reanalysis of the dataset using autumn 2017 data, the PoRs would be redefined to more realistic levels, and power to detect year-to-year change would be increased. Consequently, we recommend persisting with use of the tree canopy health indicator.

Adaptive monitoring

Acknowledging that PoR can move over time as new data are collected, future reviews should include refinement of the PoRs and indicators, where relevant. This may be particularly relevant as the program progresses and more years of data are available for analyses, e.g. increased replication of sites in various phases of inundation.

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Appendices

Appendix A – Report by Dr Lien Sim July 2017

26th July | 2017

The Living Murray – Vegetation monitoring indicators for Koondrook-Perricoota 2017

Dr Lien Sim
Community Ecologist
BA, BSc(Hons), PhD (ecology)

Cape Woolamai, Victoria
Email: liensim@yahoo.com.au
Mobile: 0401 728 736
ABN 63977265373

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Overview

This report outlines the development and testing of condition monitoring indicators for autumn ground flora monitoring data (wetland and understorey) from The Living Murray Icon Site monitoring program for Koondrook-Perricoota Forest from 2010 to summer 2017. The indicators are:

- Appropriate cover of native species in characteristic PFGs for Dry Phase Wetlands.
- Appropriate cover of native species in characteristic PFGs for Receding Phase Wetlands.
- Appropriate cover of native species in characteristic PFGs for Red Gum Flood Dependent Understorey.
- Appropriate cover of native species in characteristic PFGs for Red Gum Flood Tolerant Understorey.
- Appropriate cover of native species in characteristic PFGs for Black Box Woodland.
- Appropriate cover of native species in characteristic PFGs for Grey Box Woodland.
- Proportion of total cover comprising terrestrial dry (native and introduced) species (PFG 7) for Dry Phase Wetlands.
- Proportion of total cover comprising terrestrial dry (native and introduced) species (PFG 7) for Receding Phase Wetlands.
- Proportion of total cover comprising terrestrial dry (native and introduced) species (PFG 7) for Red Gum Flood Dependent Understorey.
- Proportion of total cover comprising terrestrial dry (native and introduced) species (PFG 7) for Red Gum Flood Tolerant Understorey.
- Proportion of total cover comprising terrestrial dry (native and introduced) species (PFG 7) for Black Box Woodland.
- Proportion of total cover comprising terrestrial dry (native and introduced) species (PFG 7) for Grey Box Woodland.

Where:
PFG = Plant Functional Group
Dry Phase Wetlands = no standing water present, but sediment may be moist.
Receding Phase Wetlands = standing water is present (water of variable depth).

Sensitivity analyses were conducted on all twelve indicators, effect sizes (with confidence intervals) calculated for year-by-year data, and power analyses were also conducted on all of the understorey indicators. It was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Methods and results

CHARACTERISTIC PFG COVER INDEX (Appropriate Cover of Native Species in Characteristic PFGS)

Template Part 1 summarises information for the Koondrook-Perricoota Forest Index of Appropriate Cover of Native Species in Characteristic PFGs (henceforth referred to as the 'Characteristic PFG Cover Index'), where PFG refers to 'Plant Functional Group'. This template also includes a description of 'Observed Effect Sizes' and 'Power' which were each calculated for this index. Template Part 2 outlines the process applied to derive the index for each understorey (i.e. four treed Water Regime Classes (WRCs)) or wetland (i.e. two Wetland Inundation Phases Classes (WIPCs)) group and describes the sensitivity of the index. The templates are a key output of the current project and are formatted to be incorporated into the Icon Site condition monitoring program. The technical workings for the index are outlined in the subsequent section.

Index Templates

Template Part 1 - Characteristic PFG Cover Index

Characteristic	Description
Overarching Management/Ecological Objectives for Koondrook-Perricoota (currently under review)	Maintain and restore a mosaic of healthy floodplain communities (including): • 80% of permanent[1] and semi-permanent wetlands in a healthy condition • 30% of River Red Gum forest in a healthy condition
Draft refined ecological objectives for the Gunbower–Koondrook–Perricoota icon site developed by the Technical Advisory Committee (MDBC 2007)	Protect and enhance a diverse range of healthy wetlands • Protect and enhance diverse, healthy vegetation communities • Provide for successful waterbird breeding and recruitment events • Protect and enhance viable native fish communities
Proposed targets for KP	• At least 80% of wetland Water Regime Class (WRC) sites in a healthy condition • At least 30% of River Red Gum WRC sites in a healthy condition • At least 90% of Grey Box WRC sites in a healthy condition
Monitoring Objective	To measure occurrence of flora species across Koondrook-Perricoota Forest
Points of Reference (PoR)	For each KP Wetland Inundation Phase Class (WIPC), or Red Gum and Box (forest) WRC, the 'Characteristic PFG Cover Index' at a site is considered 'appropriate' if it is on or above the PoR of 90th percentile of all records (wetlands) or all autumn records (understorey) since 2010. For the WIPCs, these values are: • Dry Phase Wetlands – 24.1% cover of species from PFGs 1-5.

[1] Note: there are no permanent wetlands at KP

Characteristic	Description
	• Receding Phase Wetlands – 30.7% cover of species from PFGs 1-5. For the treed WRCs these values are: • Red Gum with Flood Dependent Understorey – 17.5% cover of species from PFGs 3-5. • Red Gum with Flood Tolerant Understorey – 20.4% cover of species from PFGs 4-6. • Black Box Woodlands 10% cover of species from PFGs 4-6. • Grey Box Woodlands 12% cover of species from PFGs 4-6.
Sampling Strategy	Wetlands: regular autumn vegetation monitoring and spring and summer post-event monitoring at 15 sites. Note that Pollack Swamp transects 1 and 2 are quite ecologically distinct and have been treated as separate wetlands for the purpose of these analyses. Pollack Swamp transect 3 (PS3) is a pseudoreplicate of PS2 and has been excluded from analyses. Data were categorised into two Wetland Inundation Phase Classes (Dry and Receding). Dry Phase Wetlands = no standing water present, but sediment may be moist. Receding Phase Wetlands = standing water is present (water of variable depth). Understorey: regular autumn vegetation monitoring at 60 randomly located quadrats. Data were categorised into four treed WRCs – River Red Gums (FDU & FTU) and Box Woodlands (Black & Grey).
Index	Index 1: 'Characteristic PFG Cover Index' per site by sample year Minimum score of 0, maximum score of 1.
Observed Effect Sizes and Confidence Intervals	An Observed Effect Size (OES) is an actual measure of the size of the difference (e.g. mean index values or slope/trend in index values) between two groups and whether this difference is negative or positive (Durlak 2009). Confidence Intervals for the OES give us an estimate of the range of 'plausible' effect size values we could expect from the wider population, given our OES (Kirby and Gerlanc 2013). It is important to report OESs, regardless of whether P-values indicate a test is significant or not (Durlak 2009). For the 'Characteristic PFG Cover Index', OES and confidence intervals (CIs) were calculated for year-by-year (understorey) or sampling event-by-sampling event (wetland) comparisons.
Power[2]	The power of a test is the likelihood that a statistical effect will be detected (probability of rejecting the null hypothesis if the null is

[2] **Explained in more detail under the heading Observed Effect Sizes and Confidence Intervals**
The calculation of Observed Effect Sizes and Confidence Intervals is an actual measure of the size of the differences in mean index values between pairs of subsequent years, and estimate of the range of 'plausible' OESs we would expect from the wider population (if all possible wetlands or understorey quadrats within each WIPC/WRC were sampled within the specified date range) (Table 5).

Characteristic	Description
	false) (Thomas 1997). Power explains the minimum size of the effect that can be detected with confidence. In this refinement project, we have investigated the *post hoc* power of linear mixed effect models to detect (for each WRC*): • A change through time (trend) in mean 'Characteristic PFG Cover' index values; and • Differences between mean 'Characteristic PFG Cover' index values on subsequent sampling dates (year-by-year for understorey sites or sampling event-by-sampling event for wetland sites). The development of these models has some value because it allows us to assess whether a trend in mean index values over time is significantly different from zero or whether mean index values are significantly different between sampling events. Retrospective (*post hoc*) power analysis using observed effect sizes and variation has limitations, since there is a direct relationship between power and p-value (low p-value, significant result, high power or high p-value, non-significant result, low power). In order to avoid this, we have instead calculated power using pre-specified effect sizes and the observed variance, and determined the minimum significant detectable effect sizes (Thomas 1997). The calculation of Observed Effect Sizes[3] and Confidence Intervals (see above) is considered to be another robust form of retrospective power analysis, which allows the level of uncertainty in the results to be quantified (Thomas 1997). The following trend models for the 'Characteristic PFG Cover Index' had sufficient power to detect change. • Red Gum FTU MSES ±0.034, power = 0.6265178 • Grey Box MSES ±0.02, power = 0.9992650

Table 5 Observed Effect Sizes and Confidence Intervals for the Characteristic PFG Cover Index

Observed Effect Sizes and Confidence Intervals
For each WIPC or WRC: Bootstrap Effect Sizes and CIs were calculated for pairs of subsequent years (understorey sites) or subsequent sampling occasions (wetlands), using data from 2010, 2011, 2013, 2014, 2015, 2016 and 2017 (2017 wetlands only) using package `bootES` in R. The difference in mean Characteristic PFG Cover Index values for each pair of sampling occasions (the Observed Effect Size) was calculated, and then 95% CI were calculated by locating the values at 2.5% and 97.5% in the distribution of 2000 bootstrapped samples.   An assessment was then made of whether the OES represented a meaningful difference in the Characteristic PFG Cover Index between sampling occasions (e.g. a difference of <0.1 is unlikely to be a biologically meaningful difference in index scores between dates), and the CIs were used to determine a level of confidence in the result.

Power Analyses on page 11.

[3] In contrast to the Minimum Significant Effect Size calculated as part of the Power Analysis.

Characteristic	Description
	The year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in all treed WRCs. The results are summarised in Table 11, Table 15, Table 19 and Table 23. ***Note: it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.**

Template Part 2 - 'Characteristic PFG Cover Index'

Characteristic	Description
Explanation of Reference	**For each WIPC and WRC:** The long-term database was interrogated to determine what cover of characteristic PFG species represented the top 10% of sites for each WIPC or treed WRC since 2010. Cover data were expressed as % cover, which incorporates an intrinsic weighting by area. To derive points of reference: • The appropriate cover of characteristic native PFG species across the WIPC or WRC was summarised. Replicates were sampling occasions across all wetland sites or quadrats. • From these data, the 90th percentile value was determined. See Table 3 for additional details.
Index Calculation	**For wetland WIPCs and treed WRCs:** • Cover of characteristic native PFG species for each site on each sampling occasion was converted to an index using the formula: Index = Sqrt(Characteristic PFG cover) ÷ Sqrt(Point of Reference) • Correct so that any values >1 are recorded as 1. • Index lies between 0 and 1. • Characteristic PFG cover that is greater than or equal to the PoR results in an index of 1 (it is compliant), and characteristic PFG cover less than the POR results in an index of <1 (it is not compliant). • Calculate the whole of WIPC/WRC score as the proportion of compliant samples in each WIPC/WRC.
Sensitivity	The index is scaled to represent the cover of characteristic PFG species recorded, relative to the cover recorded in the top 10% of cases (PoR for WIPCs or WRCs) over the 6 years of the monitoring program. Hence, the indicator is sensitive because when the wetlands and floodplain support a lower cover of characteristic PFG species in any year, the sampling sites will return a lower cover of characteristic PFG species, and the index will be lower.

Technical Details

Background

This component measures compliance at a sample level (each wetland or quadrat on each date) for cover of indigenous species from characteristic PFGs in the two tested Wetland Inundation Phase Classes (WIPC) and four treed WRCs.

Points of reference (PoR) were derived for each of the two WIPCs and four treed WRCs using a 'raw percentile' approach (Robinson 2013). Details are given below (under 'Index calculation' on page 9).

General Approach Taken

Characteristic PFG Species Cover was calculated for each site on each sampling occasion, and then PoRs were determined for each WIPC/WRC (see methods in Table 3). The current approach set the PoR based on the 6-7 year dataset (2010-2016 autumn data for understorey sites, and 2010-2017 all seasons for wetlands), but depending on what is most important to the project manager it could be set based on a reference year (i.e. the 'best' year or the first year of monitoring). It should be noted that due to the variable nature of these datasets, the inclusion of additional sampling occasions in the calculation of PoRs is likely to make them more robust. Methods are given below (Table 3).

To derive a whole of WIPC/WRC index score, the proportion of compliant samples (scoring 1) for each WIPC or WRC can be calculated.

Data Description

Flora species cover data (native and introduced species) were recorded at 15 wetland sites and in 60 understorey quadrats from 2010 to summer 2017 in Koondrook-Perricoota Forest. The data were classified into two WIPCs and four WRCs. Plant species were categorised into PFGs. For the purposes of this refinement project, all autumn records of indigenous species from characteristic PFGs (Table 2) were used for understorey analyses (2010-2016) and all records (spring, summer and autumn) were used for wetland analyses (2010-summer 2017).

Component Assumptions and Caveats

It should be recognised when interpreting the results that the reference list and sample data are, at best, indicative of the total native characteristic species cover supported by the forest, and are skewed towards reporting a lower than actual level of cover. Some of the reasons for these biases include:

- Suitable environmental conditions did not exist for all species in all years.
- The monitoring program is principally undertaken in autumn and therefore does not represent the full annual diversity of flora. Only autumn data were used for understorey analyses, while (less frequent) event-based monitoring of spring and summer events were also used for wetland sites.
- Data summarised for this index are limited to indigenous species from characteristic PFGs, and do not represent total species cover.
- Wetland data are highly variable due to intrinsic differences in size, condition and flooding regime between wetlands, plus the inability to sample at the same stage of inundation each year, which dramatically affects which species are recorded.

Other caveats and assumptions:

- For the analysis of wetland data, we have assumed spatial independence of sites (although sites are located close to each other and are likely to be connected when inundated).
- Understorey quadrats are uniform in size and most were randomly allocated.
- Transect lengths at individual wetlands vary slightly between years, and differ more significantly in length among wetland sites. Consequently, we would expect more species to be recorded at a larger transect. To correct for this, weighting by area has been performed by converting cover values from m^2 values to % cover.
- Due to inter-site variability, summarising wetland data into a single index value in WRCs would be likely to incorporate significant error. Instead, the wetland phase-based approach we have adopted here attempts to address some of this variability by grouping wetlands by their stage of inundation.

Index Calculation

The following three tables detail the PoRs and calculations performed to determine the Characteristic PFG Cover Index for each WIPC or WRC.

Table 1 Explanation of Point of Reference for the Characteristic PFG Cover Index

Index	Explanation of Reference
Index 1: Characteristic PFG Cover per site by sample year	For each WIPC/WRC, Characteristic PFG Cover at a site is considered 'appropriate' if it is on or above the PoR (90th Percentile of PFG Species Cover across the 2010-summer 2017 sampling period, Table 2). WIPCs analysed: • Dry Phase Wetlands • Receding Phase Wetlands WRCs analysed: • Red Gum Flood Dependent Understorey • Red Gum Flood Tolerant Understorey • Black Box Woodlands • Grey Box Woodlands

Table 2 Points of Reference for the Characteristic PFG Cover Index

WIPC/WRC	Number of records included	Characteristic PFGs	Point of Reference (90th percentile of PFG Species Cover)
Dry Phase Wetlands	75	1-5	24.7
Receding Phase Wetlands	50	1-5	30.7
Red Gum Flood Dependant Understorey	185	3-5	17.5
Red Gum Flood Tolerant Understorey	42	4-6	20.4
Black Box Woodlands	54	4-6	10
Grey Box Woodlands	74	4-6	12

Table 3 Index calculation for the Characteristic PFG Cover Index

Index Calculation
Index 1: Characteristic PFG Cover per site by sample year **For all WIPCs/WRCs:** • Summarise the cover of characteristic PFG species (Table 2) across the WIPC/WRC (wetlands or quadrats on each sampling date as replicates).

Index Calculation
• From these data, determine the 90th percentile value. • Convert species cover data to an index using the formula: Index = Sqrt(Characteristic PFG Cover) ÷ Sqrt(Point of Reference) • Correct so that any values >1 are recorded as 1. • Index lies between 0 and 1. • Characteristic PFG cover that is greater than or equal to the PoR results in an index of 1 (it is compliant), and characteristic PFG cover less than the POR results in an index of <1 (it is not compliant).

Sensitivity Analyses

Sensitivity analysis investigates how a change in the condition of the Icon Site manifests into a change in condition assessment, usually using an index (Table 4).

Table 4 Sensitivity of the Characteristic PFG Cover Index

Sensitivity
Index 1: Characteristic PFG Cover per site by sample year It was verified that for each WIPC/WRC, the Index ranged between 0 and 1 in the data set. A site with no cover of characteristic PFG species would score 0 and a site with characteristic PFG cover at or above the 90th percentile would score 1.

Observed Effect Sizes and Confidence Intervals

The calculation of Observed Effect Sizes and Confidence Intervals is an actual measure of the size of the differences in mean index values between pairs of subsequent years, and estimate of the range of 'plausible' OESs we would expect from the wider population (if all possible wetlands or understorey quadrats within each WIPC/WRC were sampled within the specified date range) (Table 5).

Table 5 Observed Effect Sizes and Confidence Intervals for the Characteristic PFG Cover Index

Observed Effect Sizes and Confidence Intervals
For each WIPC or WRC: Bootstrap[4] Effect Sizes and CIs were calculated for pairs of subsequent years (understorey sites) or subsequent sampling occasions (wetlands), using data from 2010, 2011, 2013, 2014, 2015, 2016 and 2017 (2017 wetlands only) using package `bootES` in R. The difference in mean Characteristic PFG Cover Index values for each pair of sampling occasions (the Observed Effect Size) was calculated, and then 95% CI were calculated by locating the values at 2.5% and 97.5% in the distribution of 2000 bootstrapped samples. An assessment was then made of whether the OES represented a meaningful difference in the Characteristic PFG Cover Index between sampling occasions (e.g. a difference of <0.1 is unlikely to be a biologically meaningful difference in index scores between dates), and the CIs were used to determine a level of confidence in the result.

[4] Bootstrapping is the process of repeatedly drawing random samples from the data sample in order to approximate the distribution of the actual population parameter being estimated (from Kirby and Gerlanc 2013).

Power Analyses (understorey WRCs)

Power analyses determine how likely the indicators and sampling strategy are to detect a change in condition at sites (quadrats) (Table 6). Two approaches were taken:

- Trend analysis: for each WRC, assessment of whether there was a linear trend in index values over the six years of monitoring (i.e. overall did index values increase or decline from 2010 to 2016?). What was the minimum change in index values over time (slope) that could be detected?
- Year-by-year differences: for each WRC, assessment of differences in index values between pairs of consecutive sampling years (e.g. was the mean Characteristic PFG Cover Index higher in 2011 than in 2010, etc.?). What was the minimum difference in index values between consecutive years that could be detected? *Note: the year-by-year models compare differences from one year to another at the level of each site (quadrat) and then assess whether the mean change in index score within sites is significant.*

Note: it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Table 6 Power analysis for the Characteristic PFG Cover Index

Power
For each WRC: Mixed effects models (a trend model and a series of year-by-year differences models) were fitted to existing data from autumn 2010, 2011, 2013, 2014, 2015 and 2016. The trend model assesses a linear trend through time (time as a fixed factor) whilst including the knowledge that sites were revisited through time (sites as random factor) and that the index in one year may be dependent on the index score in the previous sampled year for that site (first order autocorrelation structure). The correlation structure was included if it improved model fit to the data, where best fit was determined by model selection using Akaike Information Criterion (AICc). The choice of model used was related to the question being asked of the data. A linear model was used to examine trends in the data over time in order to address the question “Has condition at sites improved or declined overall over the 6 years of sampling?”. It is possible to fit non-linear models to this type of data, however the choice of model should be related to the question of interest. For example, are we interested in an overall increase or decline over time (over a long time series, small increases and decreases might not alter this overall trend), or do we think that condition might follow some type of cycle? Alternatively, we might decide that a trend model is more appropriate for particular restricted time periods, e.g. a period of drought leading into a period of high rainfall, in which we would expect the indicator values to increase as the vegetation responded to more favourable environmental conditions. Or we might decide that instead of a trend model, we would prefer to compare each subsequent year to a specific year, e.g. the first year of the monitoring program, or the year of highest rainfall/flooding. In the year-by-year approach below, each sampling year is compared with the subsequent sampling year. The year-by-year differences were assessed by fitting mixed models to data from pairs of subsequent sampling years whilst including the knowledge that sites were revisited through time (site as a random factor). **Note that year-by-year models do not compare the mean index score in one year (with all sites combined) against the mean for the other year, as is depicted in the figures.** The models compare differences from one year to another at the level of each site (quadrat) and then

Power
assess whether the mean change in index score within sites is significant. Hence, the 95% CIs for indices in years depicted in figures indicate the variation in index scores between sites, but do not indicate the variation in changes between years across sites. Changes in index values from one year to the next could be quite consistent between sites and hence models may be found to be significant when the means and 95% CIs in the plots may appear to suggest they should not be significant. Both sets of models assume a Gaussian (Normal) distribution, which is not ideal for the data (since index values are constrained between 0 and 1) but a Gaussian distribution will generally provide similar results to a Binomial distribution except in extreme cases where the mean of indices are near 1 or 0. Without making this assumption about the distribution, the power analysis approach taken would not have been possible. The *post hoc* power of the models to detect either a change through time (trend) or differences between subsequent years (year-by-year) were determined by simulating effect sizes without changing other parameters in the mixed effects models, such as within year variation (Option 2 as described in Thomas 1997). The procedure for power analysis is described in Gałecki and Burzykowski (2013).

Results of power analyses are presented for each WRC according to the following stages:

- Linear mixed-effects models results for:
    - Trend model – can a statistically-significant trend in the mean Characteristic PFG Cover index values over time (2010 to 2016) be detected (is the slope significantly different to zero)?
    - Year-by-year difference models – can significant differences in mean index values be detected between subsequent sampling years?
- Minimum significant effect size (at $p<0.05$) that can be detected. For example what is the smallest difference in the slope from zero (trend) or the smallest difference between means (year-by-year) that can be detected, given the sample sizes and the level of variability in the dataset.
- Actual slope recorded (trend) or difference between means recorded (year-by-year).
- As a result of the minimum significant effect size and actual recorded difference, what is the power of that test (where 0 is no power and 1 is maximum power).

Wetlands - raw data, observed effect sizes and confidence intervals

Dry Phase Wetlands

Raw Characteristic PFG Cover Index data for all Dry Phase Wetland cases, summarised by sampling occasion, is presented in

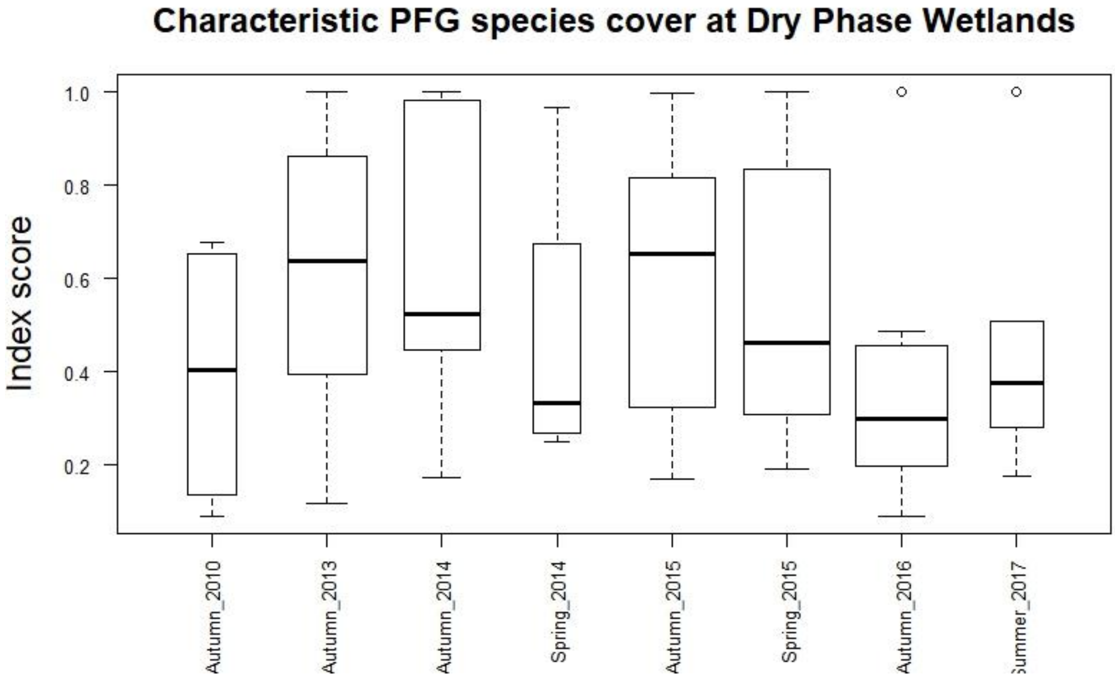

Figure 1. Boxplots are a visual representation of the spread of all data points (units) in the analysis. They show the data divided into segments of equal numbers of data points. The 'box' contains the middle 50% of data points, and the line in the middle of the box is the 'median' (the numerical value separating the top half of the dataset from the bottom half). The top 'whisker' represents the top 25% of data points, and the bottom 'whisker', the bottom 25% of data points. In some cases dots appear above or below the whiskers; these points are 'outliers': data points that are a lot higher or lower than normal.

It should be noted that there is no data point for the summer 2016 monitoring period as only the two sites at Pollacks Swamp were monitored and both were in the receding phase.

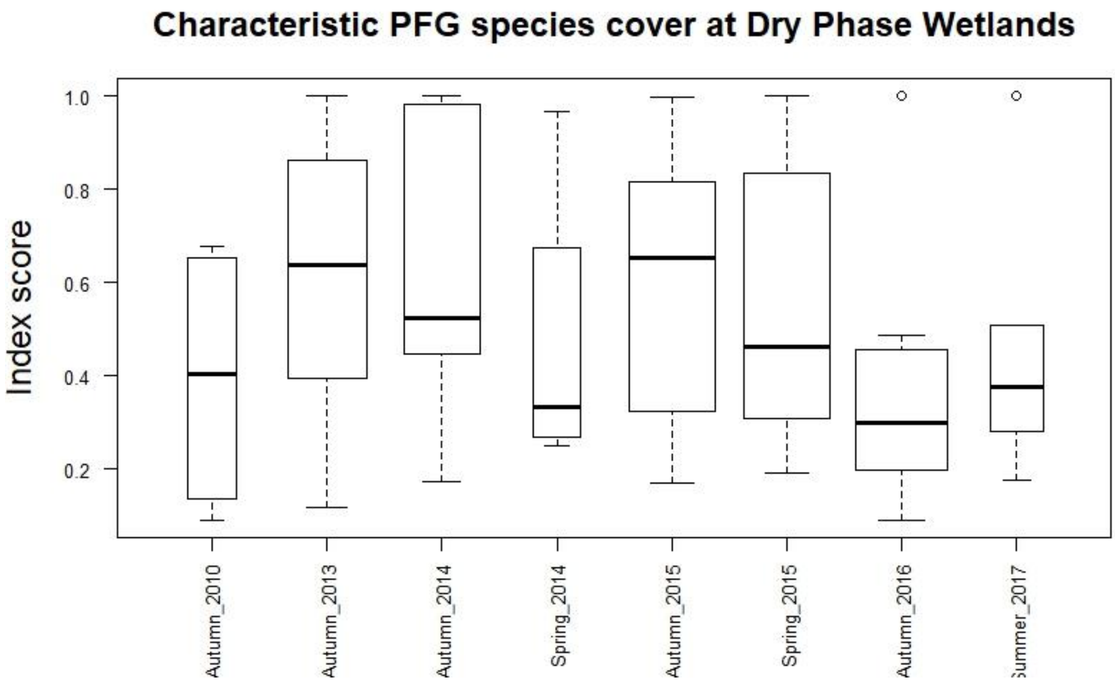

Figure 1 Boxplots of Characteristic PFG Cover Index data for Dry Phase Wetlands showing differences in the spread of values across sampling occasions. The width of each box is scaled relative to the number of samples. Note that no dry phase wetlands were recorded in 2011, and data were not collected in 2012 so these years have been omitted from the plot.

As noted earlier, it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Observed Effect Size and Confidence Intervals

Note: no data were available for Dry Phase Wetlands in 2011.

The OESs for Autumn 2010-Autumn 2013, Autumn 2014-Spring 2014, Spring 2014-Autumn 2015 and Spring 2015-Autumn 2016 were large enough to represent a meaningful difference in the characteristic PFG Cover index between years (light blue rows, Table 7). However, in all of these cases, the confidence intervals included zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.

OESs for all other pairs of sample dates were too small to represent a meaningful difference in the characteristic PFG Cover index between years, and in all cases, the CIs included zero (orange rows, Table 7) so we don't have confidence that there is a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

Table 7 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Characteristic PFG Cover Index values for Dry Phase Wetlands

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
Autumn 2010-Autumn 2013	0.3938961	0.6232761	0.229	-0.079	0.527
Autumn 2013-Autumn 2014	0.6232761	0.6122844	-0.011	-0.238	0.243
Autumn 2014-Spring 2014	0.6122844	0.4709998	-0.141	-0.414	0.243
Spring 2014-Autumn 2015	0.4709998	0.5830135	0.112	-0.265	0.385
Autumn 2015-Spring 2015	0.5830135	0.554013	-0.029	-0.240	0.191
Spring 2015-Autumn 2016	0.554013	0.3876297	-0.166	-0.367	0.053
Autumn 2016-Summer 2017	0.3876297	0.4690533	0.081	-0.202	0.374

Receding Phase Wetlands

Raw Characteristic PFG Cover Index data for all Receding Phase Wetland cases, summarised by sampling year, is presented in

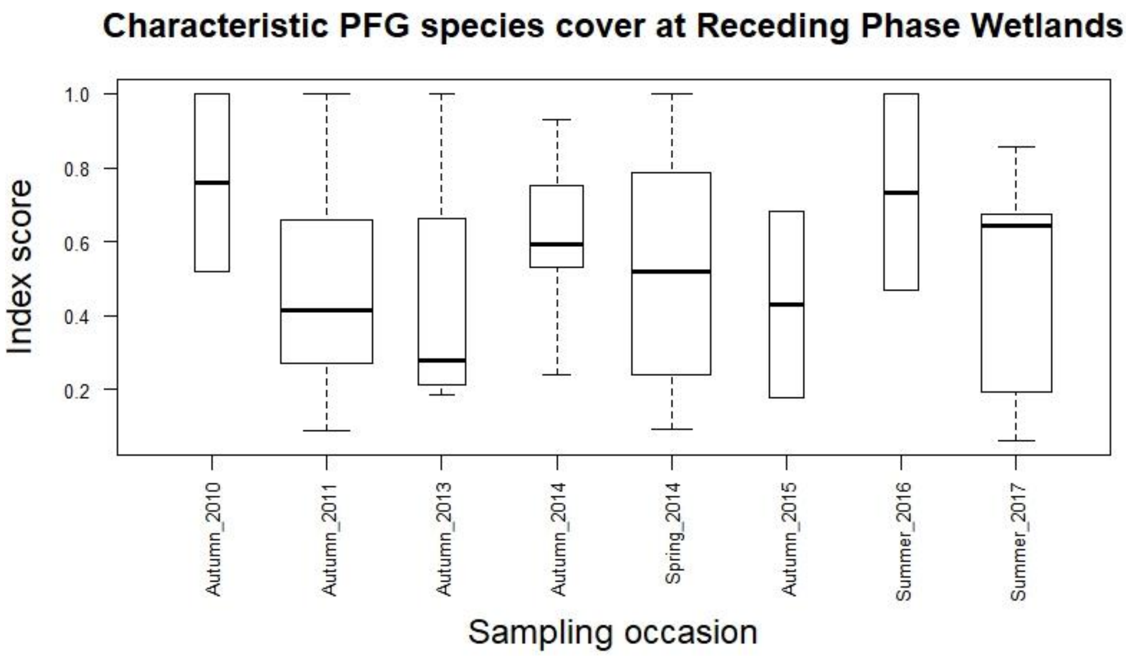

Figure 2. It should be noted that there is no data point for spring 2015, as no wetlands were in the receding phase during the spring 2015 monitoring period.

Boxplots are presented here for consistency with all other WIPCs/WRCs, however in Autumn 2010, Autumn 2015 and Summer 2016 only two samples (each) were recorded for Dry Phase Wetlands, which mean that the boxplots for these sample dates are misleading. Therefore, a dotplot has also been included to more accurately show the spread of index values across years and seasons within years (Figure 3).

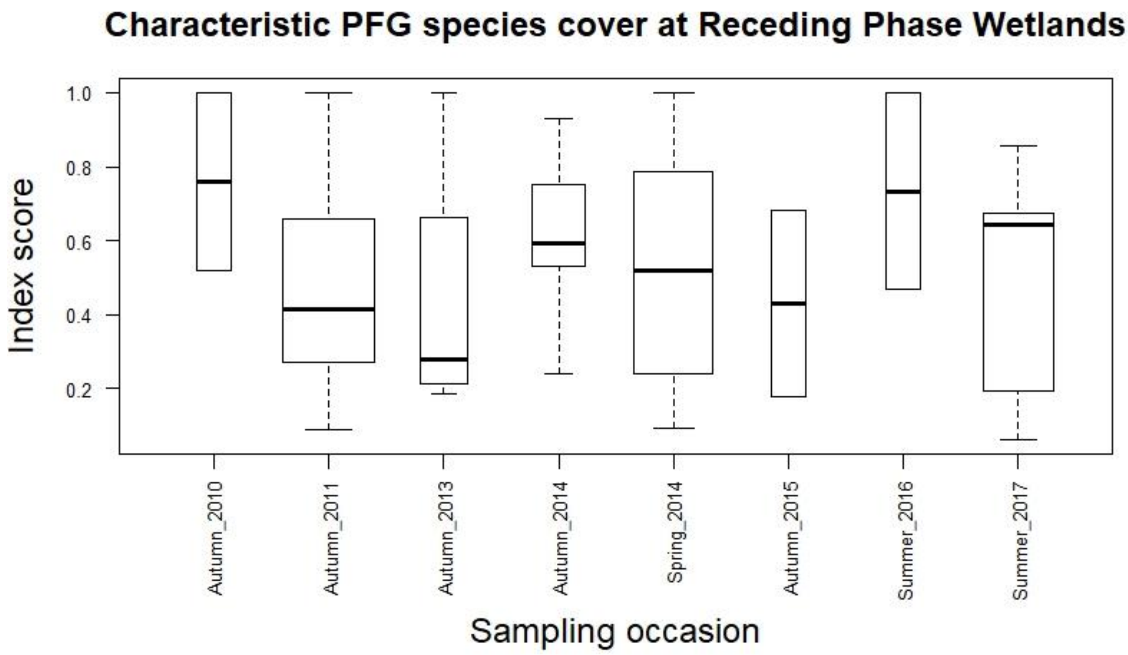

Figure 2. Boxplots of Characteristic PFG Cover Index data for Receding Phase Wetlands showing differences in the spread of values across sampling occasions. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

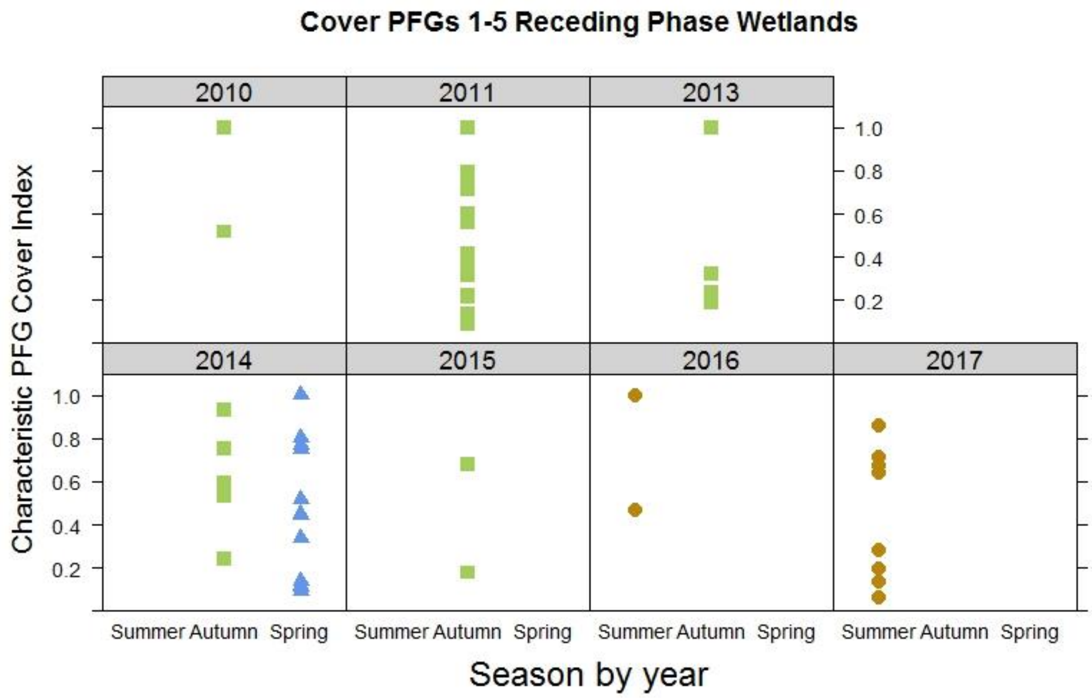

Figure 3 Dotplots of Characteristic PFG Cover Index data for Receding Phase Wetlands showing differences in the spread of values across sampling occasions. Note that data were not collected in 2012 so this year has been omitted from the plot.

As noted earlier, it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Observed Effect Size and Confidence Intervals

Note: Autumn 2010, Autumn 2015 and Summer 2016 have not been included in these calculations as only two data points were available for each of these sampling occasions for Receding Phase Wetlands.

OESs for Autumn 2011-Autumn 2013, Autumn 2014-Spring 2014 and Spring 2014- Summer 2017 were too small to represent a meaningful difference in the Characteristic PFG Cover Index between years, and in all three cases, the CIs included zero (orange rows, Table 8) so we don't have confidence that there is a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

The OES for Autumn 2013-Autumn 2014 was larger and more likely to represent a meaningful difference in the Characteristic PFG Cover Index between years (light blue row, Table 8). However, the confidence intervals included zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. This result is inconclusive, and suggests that we might have needed a larger sample size.

Table 8 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Characteristic PFG Cover Index values for Receding Phase Wetlands

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
Autumn 2011-Autumn 2013	0.4749742	0.4365223	-0.038	-0.324	0.353
Autumn 2013-Autumn 2014	0.4365223	0.6096304	0.173	-0.350	0.446
Autumn 2014-Spring 2014	0.6096304	0.5435549	-0.066	-0.351	0.204
Spring 2014- Summer 2017	0.5435549	0.4669696	-0.077	-0.334	0.190

Understorey - raw data, observed effect sizes and confidence intervals, and power analyses

<u>**Red Gum with Flood Dependent Understorey**</u>

Raw Characteristic PFG Cover Index data for all Red Gum FDU sites summarised by sampling year is presented in Figure 4.

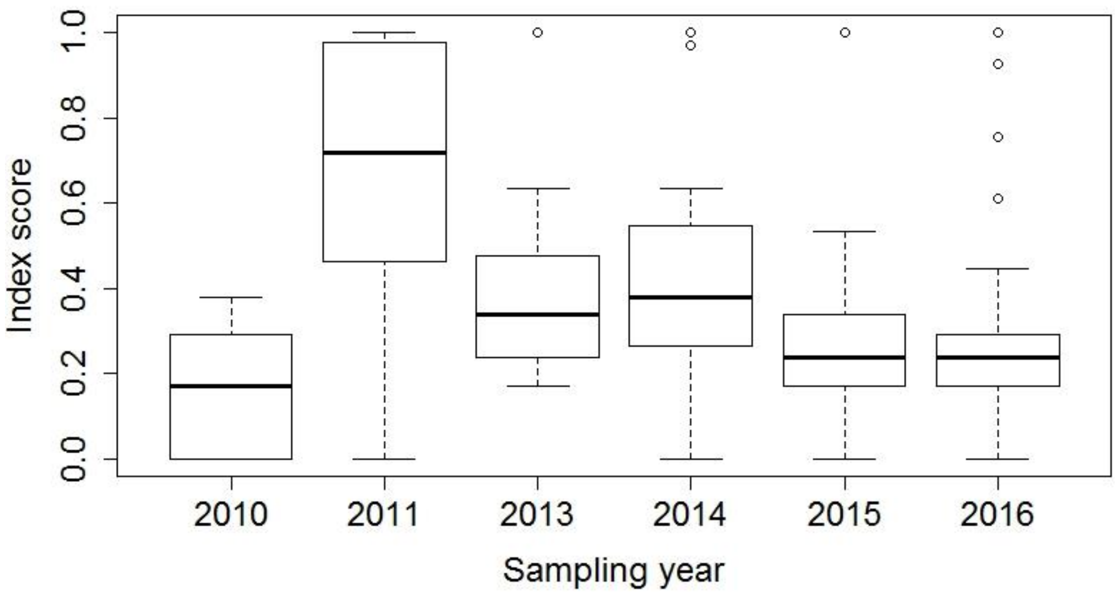

Figure 4. Boxplots of Characteristic PFG Cover Index data for Red Gum FDU showing differences in the spread of values across sampling years. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model

The linear trend in Characteristic PFG Cover Index data through time for Red Gum FDU was represented by a mixed effects model with site as a random variable (Figure 5). The negative slope (trend) in index values over time was not significantly different from zero (Table 9). Characteristic PFG Cover in Red Gum FDU did not appear to follow a clear linear trend over time. Summarising a trend over this block of 6 years has not adequately represented the fluctuations in the dataset (Figure 4, Figure 5).

Table 9. Output from the trend model for Characteristic PFG Cover Index data for Red Gum FDU. P-values in bold are significant at P<0.05.

	Value	Std. Error	DF	t-value	p-value
(Intercept)	30.429921	17.064497	153	1.783230	0.0765
Year	-0.014923	0.008476	153	-1.760569	0.0803

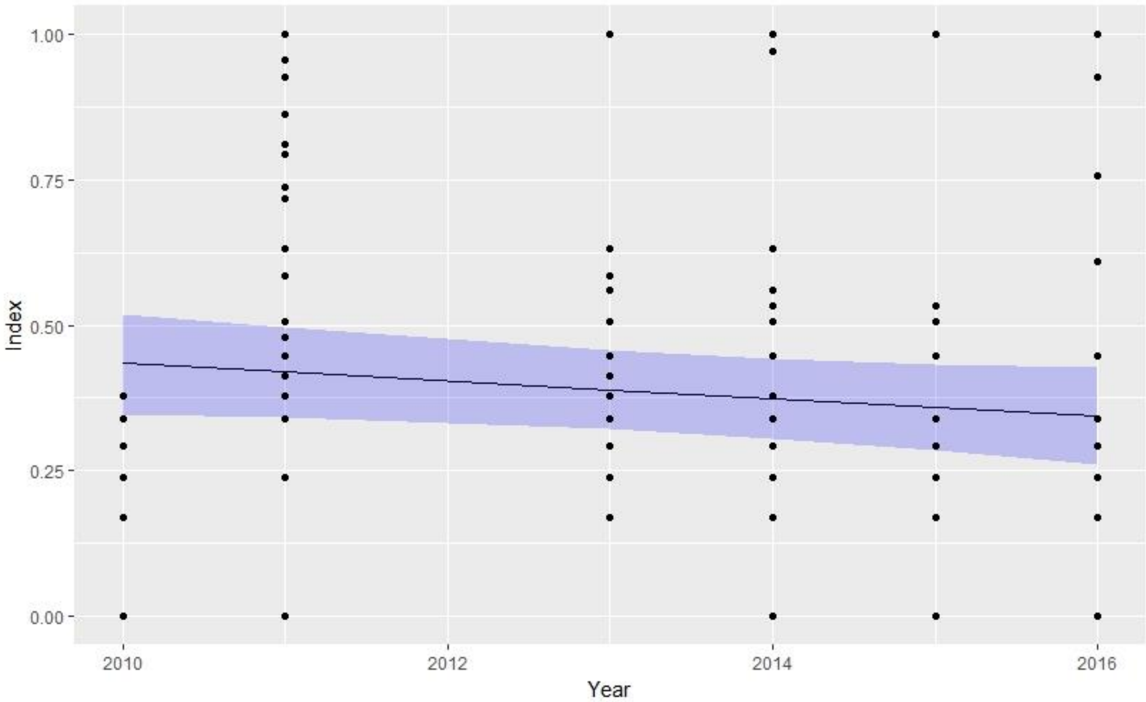

Figure 5. Plot of the fit of the linear mixed model (trend model) for Characteristic PFG Cover Index data in the Red Gum FDU WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Characteristic PFG Cover Index trend model for Red Gum FDU found that the minimum significant effect size (trend model slope) that would be significant (at P<0.05) was 0.017, and this value was larger in magnitude than the actual slope detected (-0.014923). Therefore, the power of this test was not adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 10 and Figure 6.

Table 10 Output from the power analysis for the Characteristic PFG Cover Index trend model for Red Gum FDU.

	numDF	denDF	F-value	Power
(Intercept)	1	153	127.785151	1.000000
Year	1	153	3.099604	0.4167632

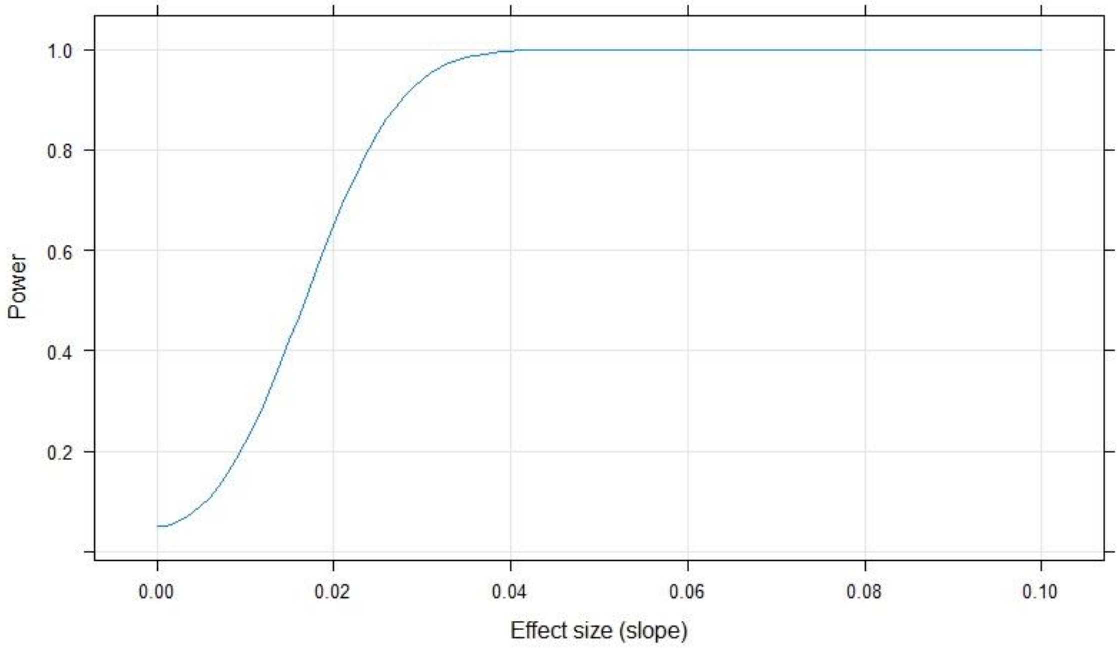

Figure 6. Power curve for the trend model using Red Gum FDU Characteristic PFG Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Characteristic PFG Cover Index data for Red Gum FDU were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 7.

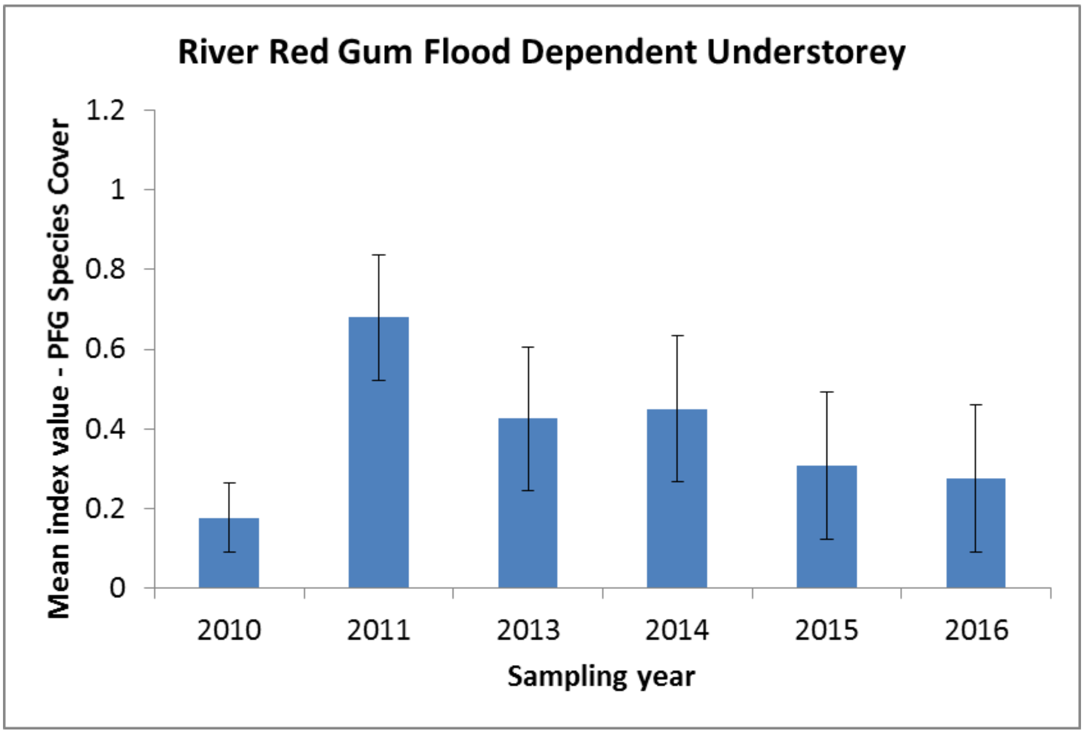

Figure 7. Plot of mean Characteristic PFG Cover Index values (and 95% confidence intervals) for Red Gum FDU by sampling year. The 95% CIs indicate the variation in index scores between

sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Characteristic PFG Cover Index year-by-year difference models for Red Gum FDU are presented in Table 11 and Figure 8. Mean index values in three pairs of years (2010-2011, 2011-2013 and 2014-2015) were significantly different from each other, and these tests had adequate power to detect the minimum significant effect sizes (Table 11). Differences between mean index values in the other two pairs of years (2013-2014 and 2015-2016) could not be detected (power was insufficient).

Table 11 Output from the year-by-year difference mixed effects models and power analyses for Characteristic PFG Cover Index data for Red Gum FDU. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	**0.5043951**	**0.05086430**	**29**	**9.916486**	**0e+00**	**1**	**0.11**
2011-2013	**-0.2529625**	**0.05325922**	**30**	**-4.749647**	**0**	**0.9957669**	**0.11**
2013-2014	0.0238053	0.02788932	30	0.853565	0.4001	0.1311714	0.06
2014-2015	**-0.1417016**	**0.03043219**	**30**	**-4.656306**	**1e-04**	**0.9945012**	**0.07**
2015-2016	-0.03285366	0.02316190	30	-1.418435	0.1664	0.2791086	0.05

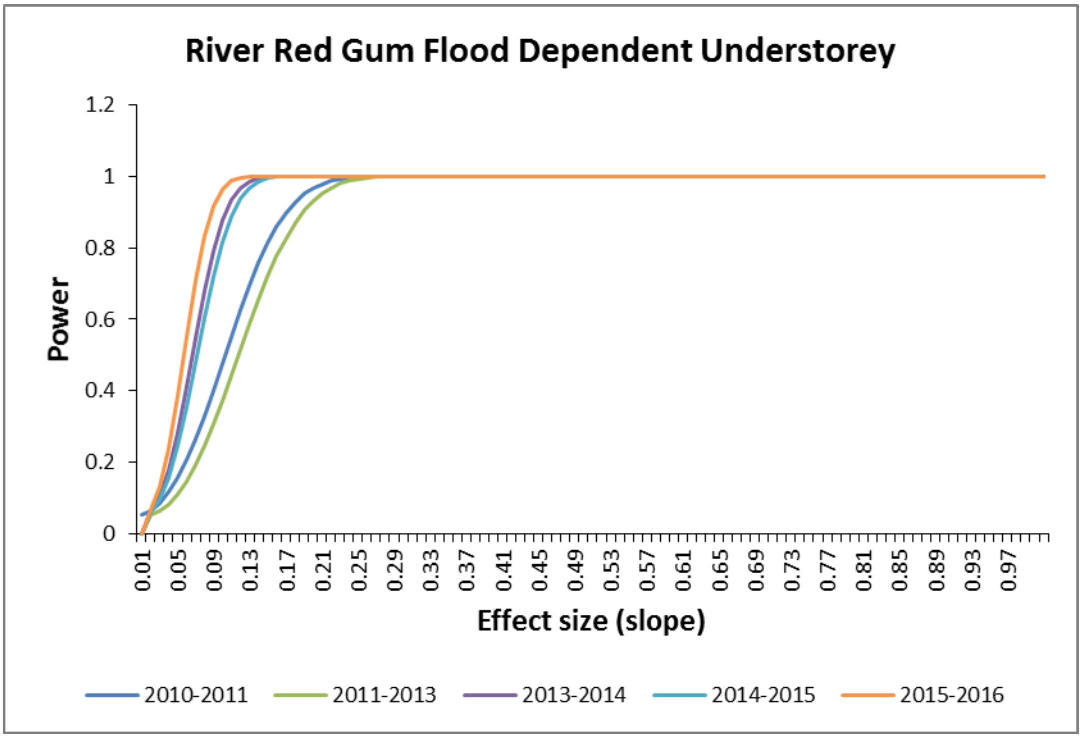

Figure 8. Power curves for year-by-year difference models using Red Gum FDU Characteristic PFG Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OES for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Characteristic PFG Cover Index between years. In both cases, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant (light green rows, Table 12). These results are conclusive – we are confident that there is a detectable difference between years.

OESs for 2013-2014 and 2015-2016 were too small to represent a meaningful difference in the Characteristic PFG Cover Index between years, and in both cases, the CIs included zero (orange rows, Table 12) so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

The OES for 2014-2015 was larger and more likely to represent a meaningful difference in the Characteristic PFG Cover Index between years (light blue row, Table 12). However, the upper confidence interval was quite close to zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. This result is inconclusive, and suggests that we might have needed a larger sample size.

Table 12 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Characteristic PFG Cover Index values for Red Gum FDU

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.1736574	0.679234	0.506	0.394	0.607
2011-2013	0.679234	0.4262714	-0.253	-0.376	-0.113
2013-2014	0.4262714	0.4500768	0.024	-0.103	0.155
2014-2015	0.4500768	0.3083752	-0.142	-0.280	-0.004
2015-2016	0.3083752	0.2755215	-0.033	-0.160	0.092

Red Gum with Flood Tolerant Understorey

Raw Characteristic PFG Cover Index data for all sites summarised by sampling year is presented in Figure 9.

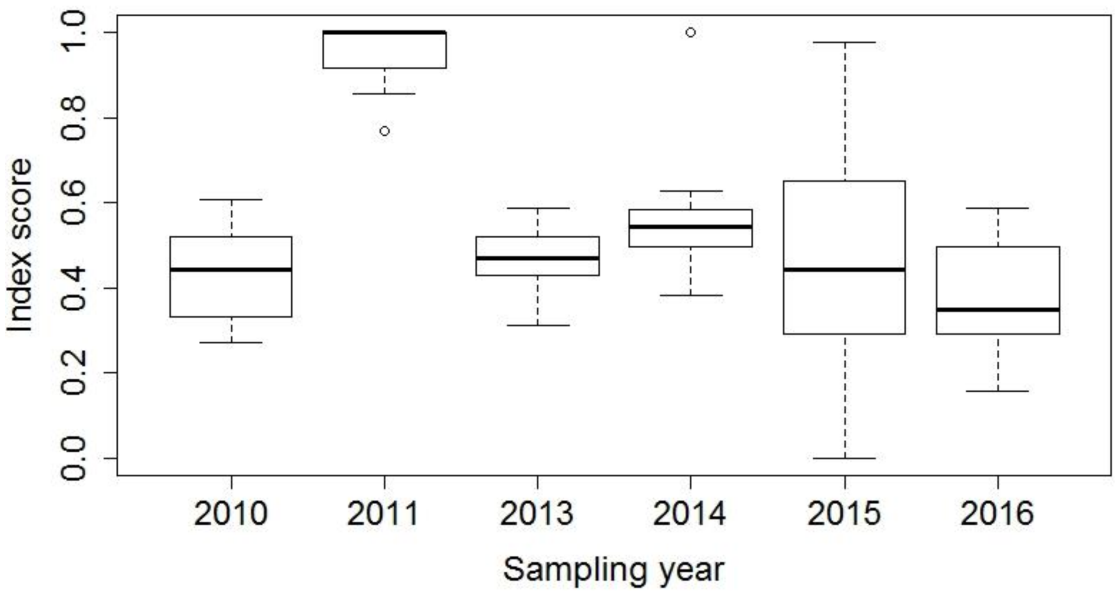

Figure 9. Boxplots of Characteristic PFG Cover Index data for Red Gum FTU showing differences in the spread of values across sampling years. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model

The linear trend in Characteristic PFG Cover Index data through time for Red Gum FTU was represented by a mixed effects model with site as a random variable (Figure 10). The slope (trend) in index values over time was significantly different from zero (Table 13). The model supports a declining linear trend in Characteristic PFG Cover in Red Gum FTU over time (Figure 10, Figure 12).

It should be noted, that despite the statistical significance of this result, the linear trend is a poor representation of the data and the trend is driven largely by results for the 2011 year (Figure 9, Figure 10). This statistically significant but not necessarily biologically significant result reflects the importance of asking the right questions of our data (e.g. do we expect changes in condition over time to be linear?), and suggests that six years may not be a long enough time period to look at a ‘trend’ in characteristic PFG cover. Nonetheless, the method we have used is sensitive enough to detect a decline in index score as seen here over this period.

Table 13 Output from the trend model for Characteristic PFG Cover Index data for Red Gum FTU. P-values in bold are significant at $P<0.05$.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	79.81359	33.74086	34	2.365488	**0.0239**
Year	-0.03937	0.01676	34	-2.349299	**0.0248**

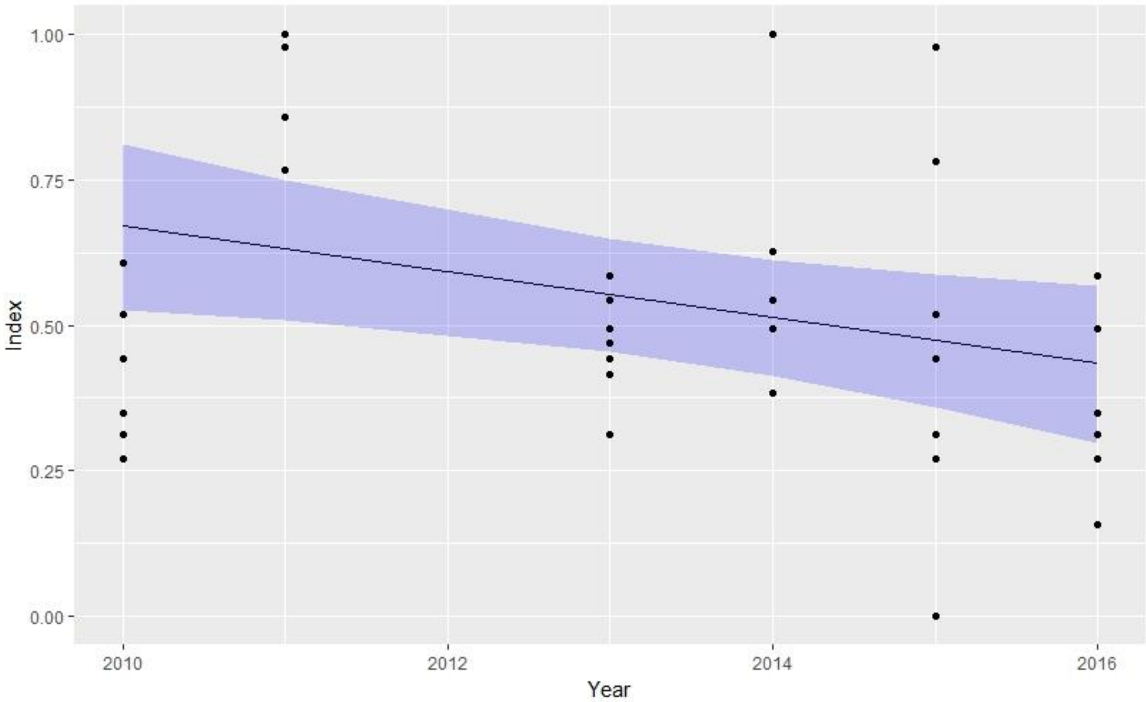

Figure 10. Plot of the fit of the linear mixed model (trend model) for Characteristic PFG Cover Index data in the Red Gum FTU WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Characteristic PFG Cover Index trend model for Red Gum FTU found that the minimum significant effect size (trend model slope) that would be significant (at P<0.05) was 0.034, and this value is smaller in magnitude than the actual slope detected (-0.03937). The power of this test was adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 14 and Figure 11.

Table 14. Output from the power analysis for the Characteristic PFG Cover Index trend model for Red Gum FTU.

	numDF	denDF	F-value	Power
(Intercept)	1	34	125.322530	1.0000000
Year	1	34	5.519204	0.6265178

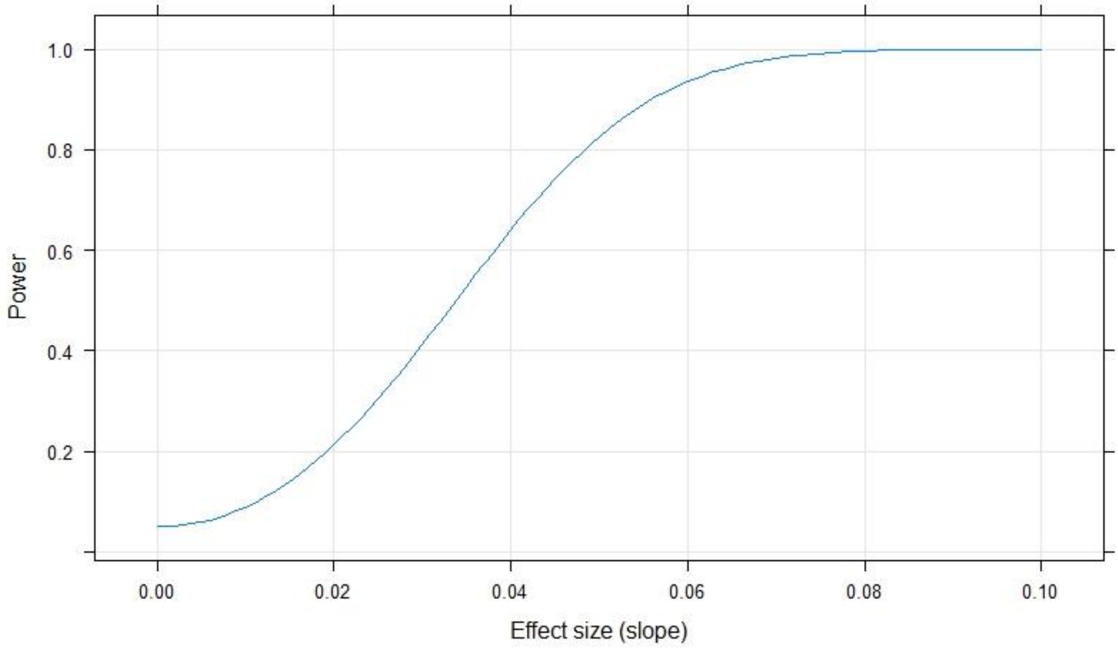

Figure 11. Power curve for the trend model using Red Gum FTU Characteristic PFG Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Red Gum FTU Characteristic PFG Cover Index data were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 12.

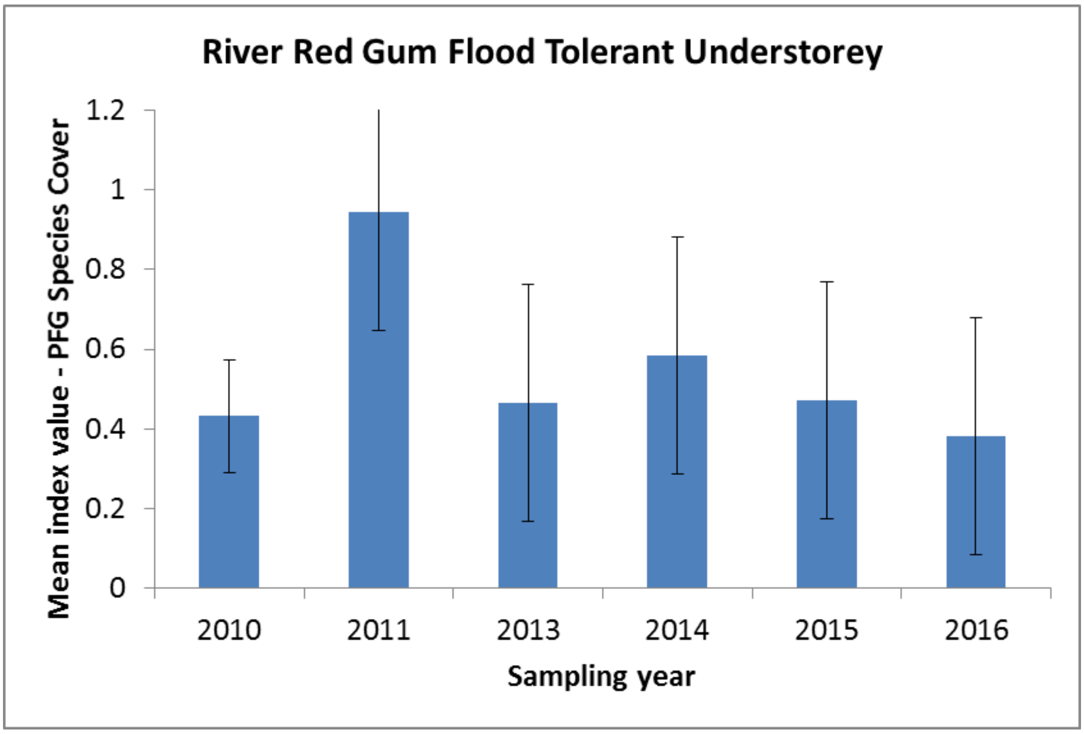

Figure 12. Plot of mean Characteristic PFG Cover Index values (and 95% confidence intervals) for Red Gum FTU by sampling year. The 95% CIs indicate the variation in index scores between

sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Characteristic PFG Cover Index year-by-year difference models for Red Gum FTU are presented in Table 15 and Figure 13. Mean index values in two pairs of years (2010-2011 and 2011-2013) were significantly different from each other, and these tests had adequate power to detect the minimum significant effect sizes. Differences between mean index values in the other three pairs of years (2013-2014, 2014-2015 and 2015-2016) could not be detected (power was insufficient).

Table 15. Output from the year-by-year difference mixed effects models and power analyses for Characteristic PFG Cover Index data for Red Gum FTU. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	**0.5114547**	**0.03096486**	**6**	**16.51726**	**0**	**1**	**0.08**
2011-2013	**-0.4770250**	**0.04638560**	**6**	**-10.28390**	**0**	**1**	**0.11**
2013-2014	0.1173616	0.05960656	6	1.968938	0.0965	0.381239	0.14
2014-2015	-0.1111019	0.1078005	6	-1.030625	0.3425	0.1410441	0.26
2015-2016	-0.0914236	0.07915068	6	-1.155057	0.2920	0.1648618	0.19

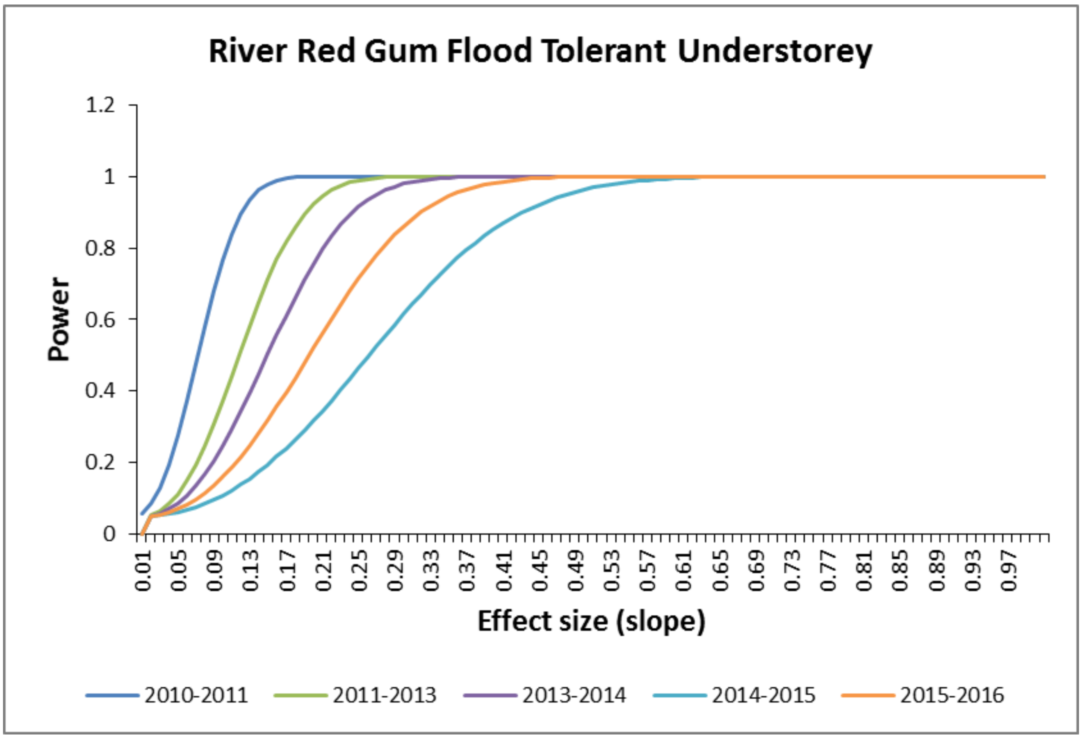

Figure 13. Power curves for year-by-year difference models using Red Gum FTU Characteristic PFG Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OES for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Characteristic PFG Cover Index between years (light green rows, Table 16). In both cases, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. These results are conclusive – we are confident that there is a detectable difference between years.

The OESs for 2013-2014 and 2014-2015 were larger and more likely to represent a meaningful difference in the Characteristic PFG Cover Index between years (light blue rows, Table 16). However, in both cases, the confidence intervals either approached or overlapped zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we may have needed larger sample sizes.

The OES for 2015-2016 was too small to represent a meaningful difference in the Characteristic PFG Cover Index between years, and the CIs included zero (orange row, Table 16) so we don't have confidence that there was a true difference from zero in this score. The result for these years is conclusive – we are confident that there is no detectable difference between years.

Table 16 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Characteristic PFG Cover Index values for Red Gum FTU

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.4317096	0.9431643	0.511	0.394	0.615
2011-2013	0.9431643	0.4661393	-0.477	-0.558	-0.378
2013-2014	0.4661393	0.5835009	0.117	0.006	0.361
2014-2015	0.5835009	0.472399	-0.111	-0.366	0.152
2015-2016	0.472399	0.3809754	-0.091	-0.351	0.133

Black Box Woodland

Raw Characteristic PFG Cover Index data for all Black Box sites summarised by sampling year is presented in Figure 14.

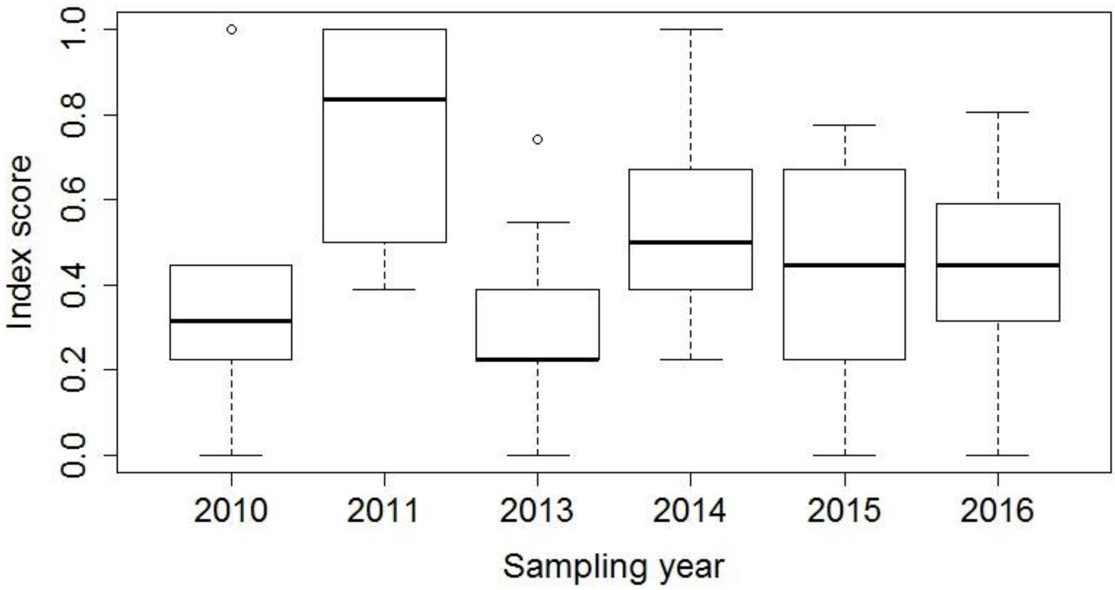

Figure 14. Boxplots of the Characteristic PFG Cover Index data for Black Box showing differences in the spread of values across sampling years. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model

The linear trend in Characteristic PFG Cover Index data through time for Black Box was represented by a mixed effects model with site as a random variable (Figure 15). The slope (trend) in index values over time was not significantly different from zero (Table 17). Characteristic PFG Cover in Black Box did not appear to follow a clear linear trend over time. Summarising a trend over this block of 6 years has not adequately represented the fluctuations in the dataset (Figure 15, Figure 17).

Table 17 Output from the trend model for Characteristic PFG Cover Index data for Black Box.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	40.19671	29.71400	44	1.352787	0.1830
Year	0.01973	-0.01476	44	-1.336762	0.1882

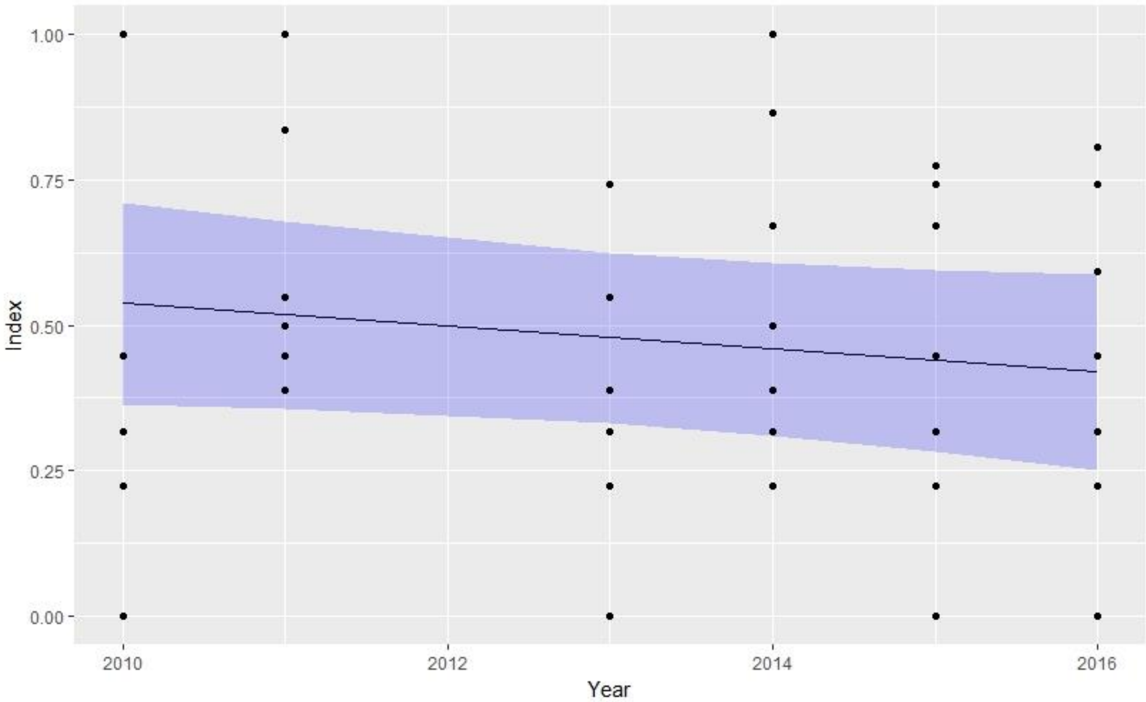

Figure 15. Plot of the fit of the linear mixed model (trend model) for Characteristic PFG Cover Index data in the Black Box WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Characteristic PFG Cover Index trend model for Black Box found that the minimum significant effect size (trend model slope) that would be significant (at P<0.05) was 0.03, and this value was larger in magnitude than the actual slope detected (0.01973). Therefore, the power of this test was not adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 18 and Figure 16.

Table 18 Output from the power analysis for the Characteristic PFG Cover Index trend model for Black Box.

	numDF	denDF	F-value	Power
(Intercept)	1	44	40.976669	0.9999913
Year	1	44	1.786933	0.2576478

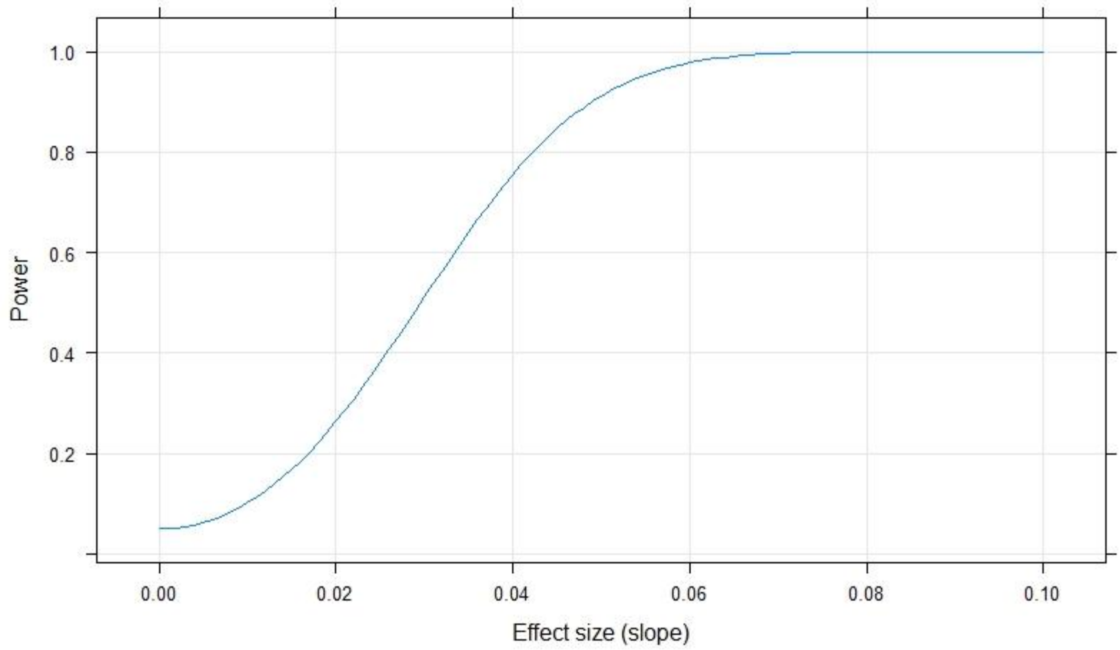

Figure 16. Power curve for the trend model using Black Box Characteristic PFG Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Black Box Characteristic PFG Cover Index data were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 17.

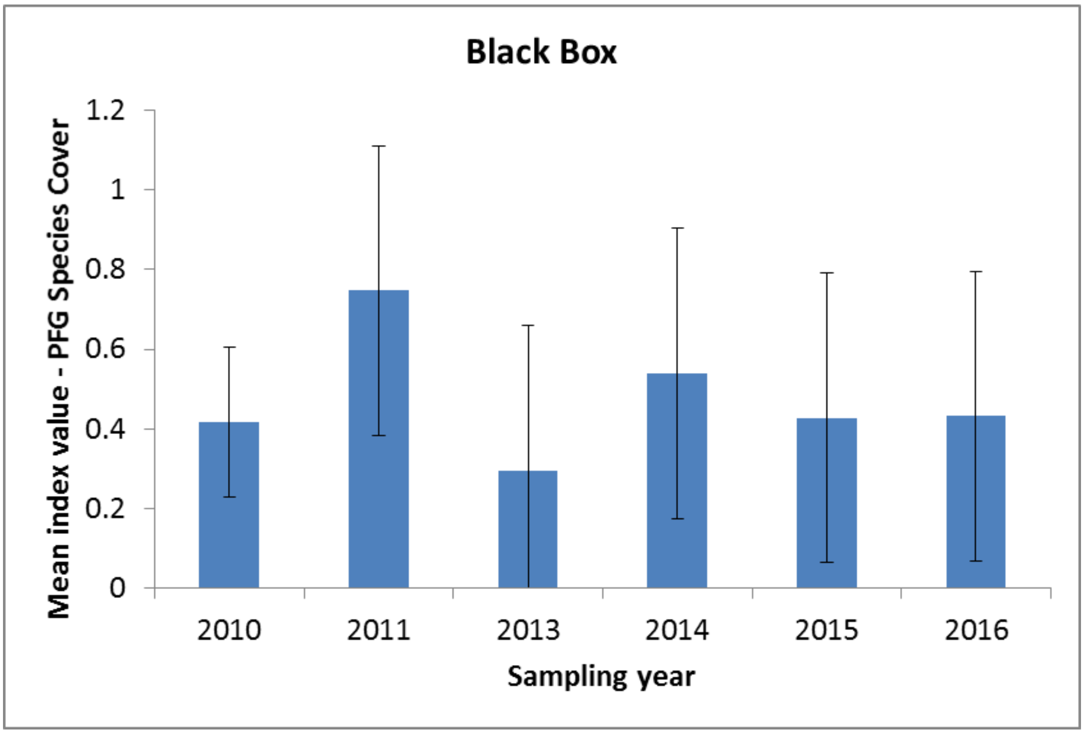

Figure 17. Plot of mean Characteristic PFG Cover Index values (and 95% confidence intervals) for Black Box by sampling year. The 95% CIs indicate the variation in index scores between sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Characteristic PFG Cover Index year-by-year difference models for Black Box are presented in Table 19 and Figure 18. Four of the five pairs of years were significantly different from each other, and their corresponding tests had adequate power to detect the minimum significant effect sizes.

Table 19 Output from the year-by-year difference mixed effects models and power analyses for Characteristic PFG Cover Index data for Black Box. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	**0.3298228**	**0.1156976**	**8**	**2.850732**	**0.0215**	**0.7051480**	**0.26**
2011-2013	**-0.4505784**	**0.07773195**	**8**	**-5.796567**	**4e-04**	**0.9988719**	**0.18**
2013-2014	**0.2430654**	**0.08086643**	**8**	**3.005763**	**0.0169**	**0.7496027**	**0.19**
2014-2015	**-0.1118191**	**0.03498218**	**8**	**-3.196458**	**0.0127**	**0.7989214**	**0.08**
2015-2016	0.0050042	0.05856749	8	0.085443	0.9340	0.05065724	0.14

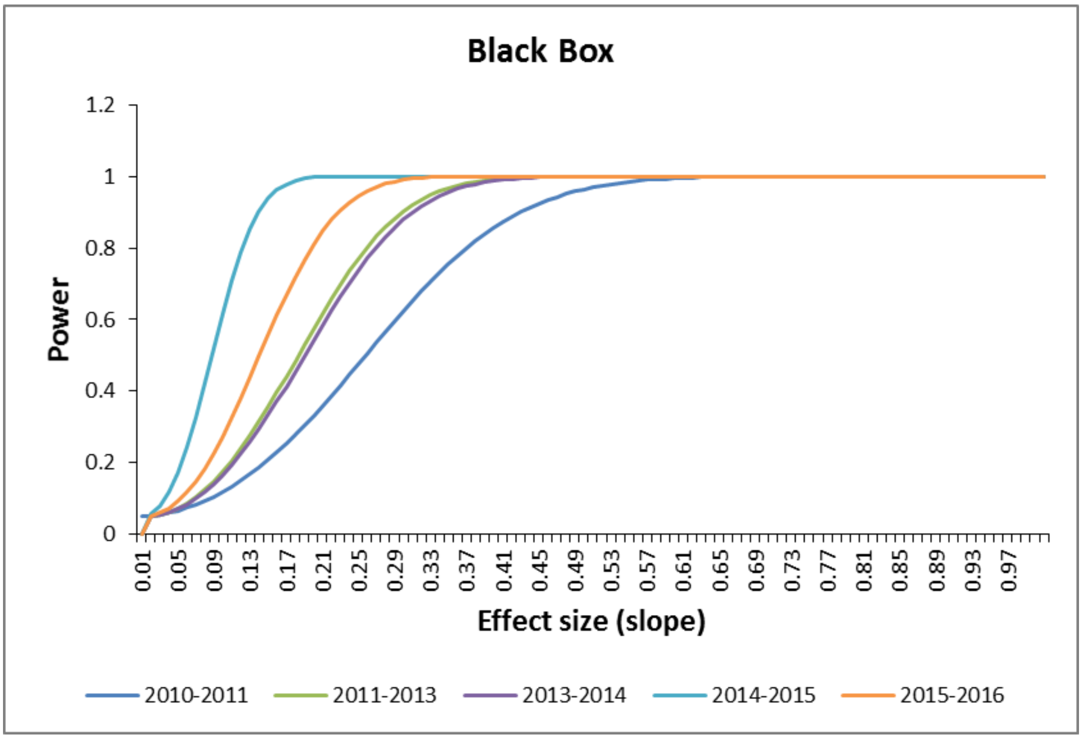

Figure 18. Power curves for year-by-year difference models using Black Box Characteristic PFG Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OES for 2011-2013 was large enough to represent a meaningful difference in the Characteristic PFG Cover Index between years (light green row, Table 20). In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years.

The OESs for 2010-2011, 2013-2014 and 2014-2015 were large enough to represent a meaningful difference in the Characteristic PFG Cover Index between years (light blue rows, Table 20). However, in all cases, one confidence interval was quite close to zero, reducing our confidence that the actual population OESs lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.

OES for 2015-2016 was too small to represent a meaningful difference in the Characteristic PFG Cover Index between years and the CIs included zero (orange row, Table 20) so we don't have confidence that there was a true difference from zero in these scores. The result for this pair of years is conclusive – we are confident that there is no detectable difference between years.

Table 20 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Characteristic PFG Cover Index values for Black Box

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.4167211	0.7465438	0.330	0.022	0.571
2011-2013	0.7465438	0.2959654	-0.451	-0.661	-0.219
2013-2014	0.2959654	0.5390308	0.243	0.014	0.436
2014-2015	0.5390308	0.4272117	-0.112	-0.348	0.097
2015-2016	0.4272117	0.4322159	0.005	-0.218	0.231

Grey Box Woodland

Raw Characteristic PFG Cover Index data for all Grey Box sites summarised by sampling year is presented in Figure 19.

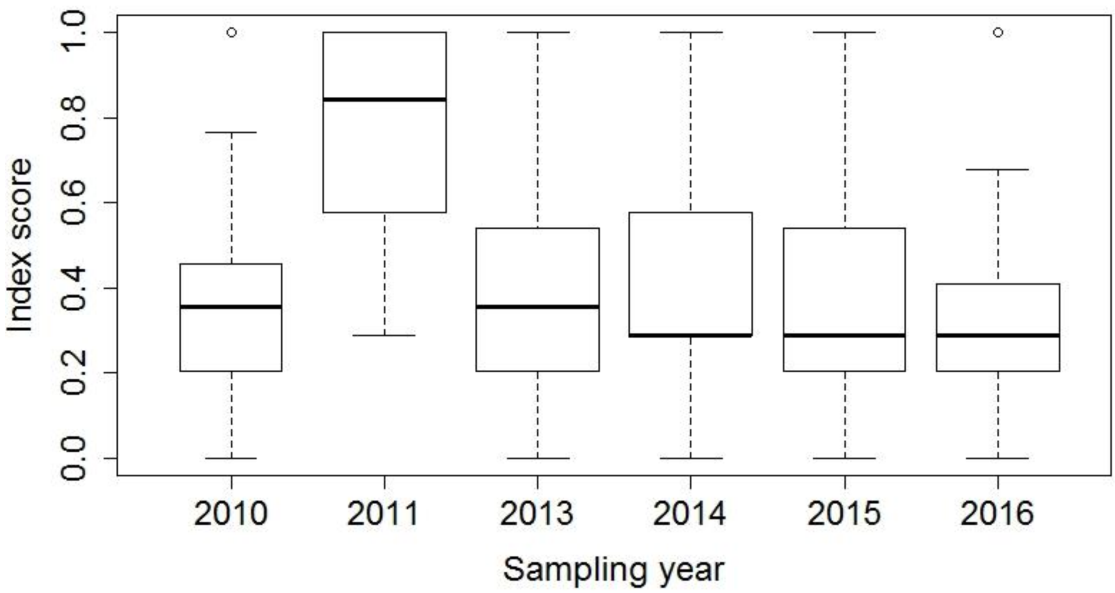

Figure 19. Boxplots of Characteristic PFG Cover Index data for Grey Box showing differences in the spread of values across sampling years. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model
The linear trend in Characteristic PFG Cover Index data through time for Grey Box was represented by a mixed effects model with site as a random variable (Figure 20). The slope (trend) in index values over time was significantly different from zero (Table 21). The model supported a declining linear trend in Characteristic PFG Cover in Red Gum FTU over time (Figure 20).

Note that as for the trend model results for Red Gum FTU (page 22) the statistical significance of this result should be interpreted with caution. Once again, the linear trend is a poor representation of the data and the trend is driven largely by the 2011 year. There were also a lower number of replicates for Grey Box than for the Red Gum sites, and a high level of variability in index scores (Figure 19, Figure 20). Additional years of data might be required to determine whether this 'trend' has biological significance. Nonetheless, the method is sensitive enough to detect a decline in index score as seen here over this period.

Table 21. Output from the trend model for Characteristic PFG Cover Index data for Grey Box.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	106.04826	20.207474	60	5.247972	0
Year	-0.05245	0.010037	60	-5.225701	0

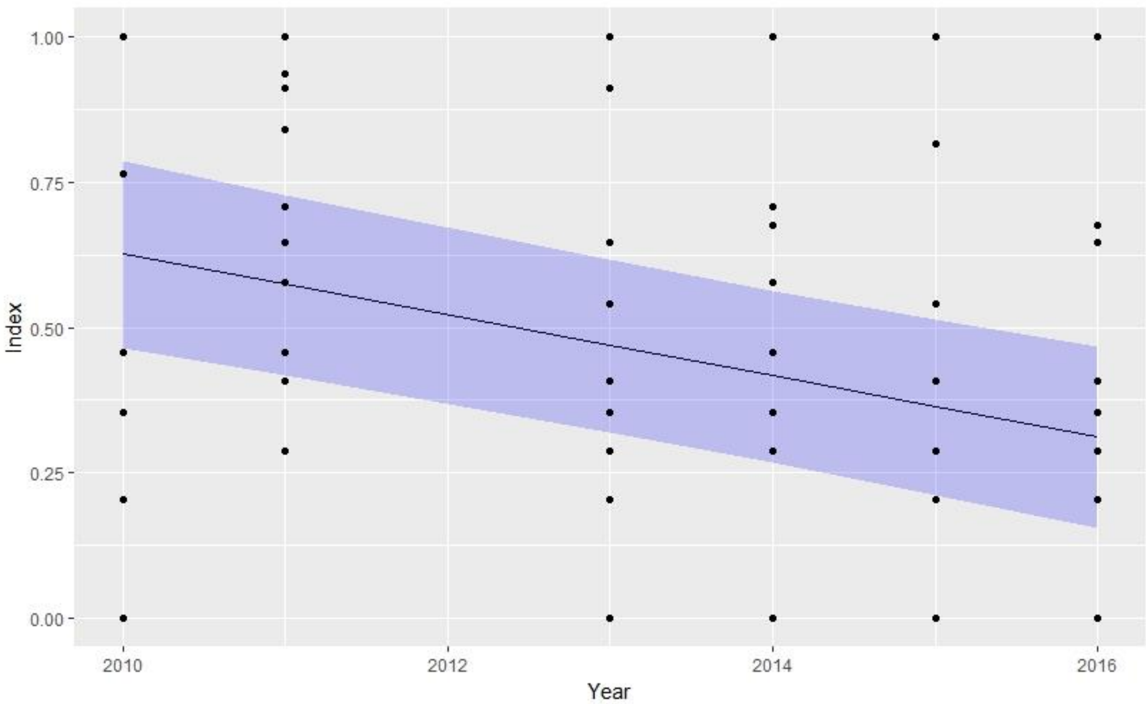

Figure 20. Plot of the fit of the linear mixed model (trend model) for Characteristic PFG Cover Index data in the Grey Box WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Characteristic PFG Cover Index trend model for Grey Box found that the minimum significant effect size (trend model slope) that would be significant (at $P<0.05$) was 0.02, and this value is smaller in magnitude than the actual slope detected (-0.05245). Therefore, the power of this test was adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 22 and Figure 21.

Table 22 Output from the power analysis for the Characteristic PFG Cover Index trend model for Grey Box.

	numDF	denDF	F-value	Power
(Intercept)	1	60	36.64586	0.9999676
Year	1	60	27.30795	0.9992650

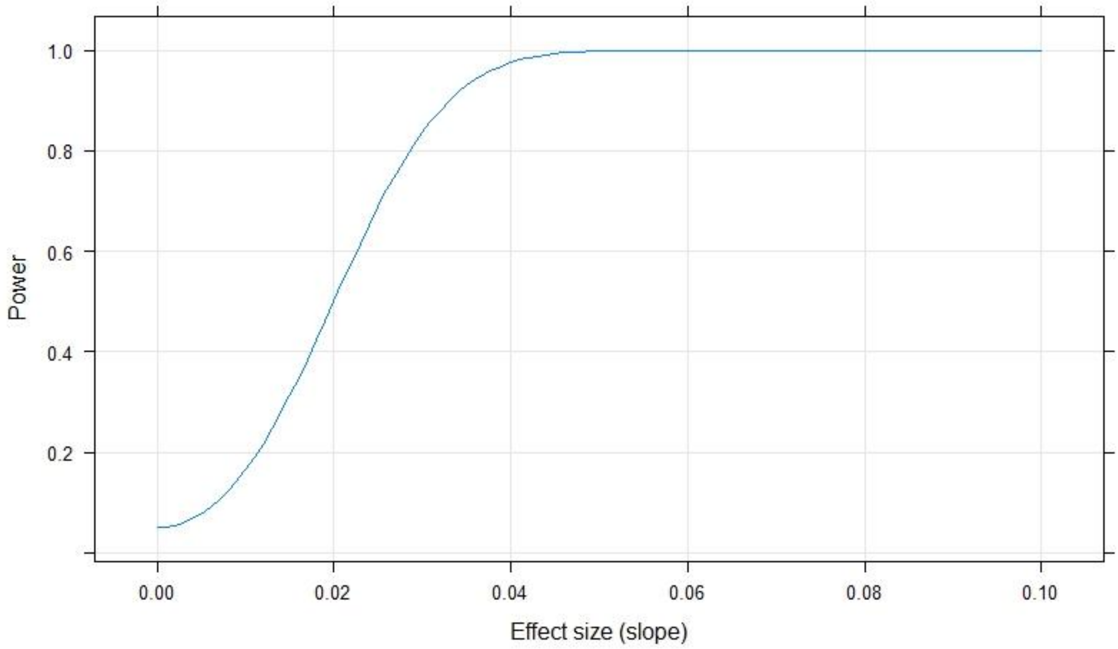

Figure 21. Power curve for the trend model using Grey Box Characteristic PFG Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Characteristic PFG Cover Index data were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 22.

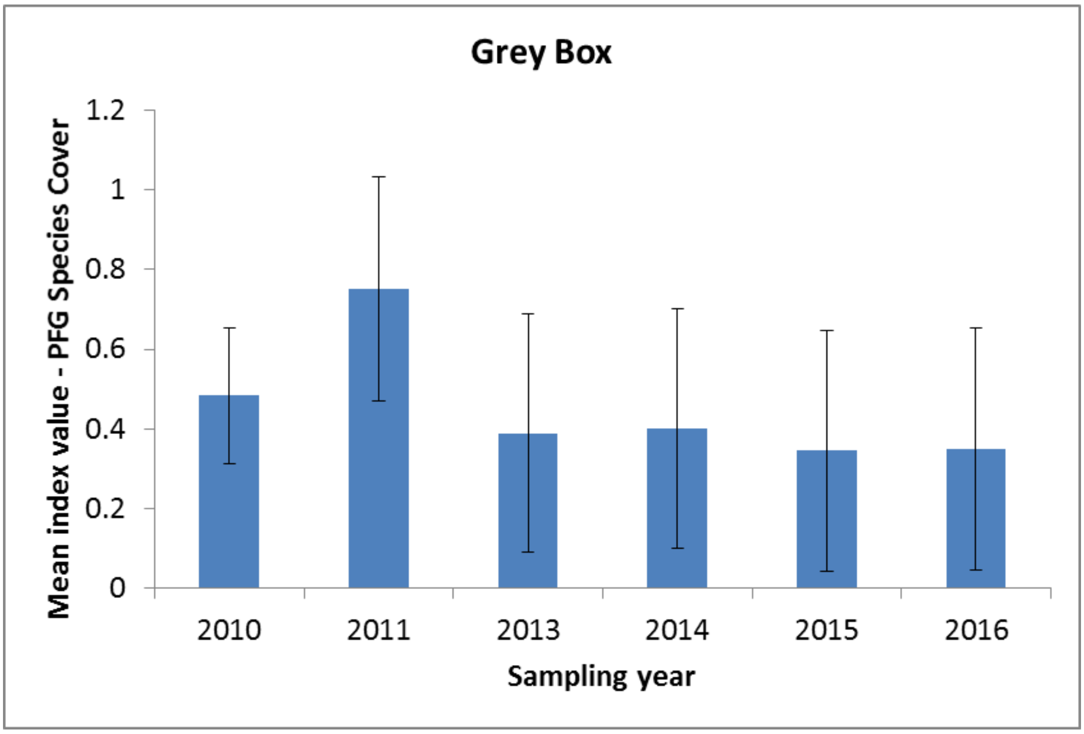

Figure 22. Plot of mean Characteristic PFG Cover Index values (and 95% confidence intervals) for Grey Box by sampling year. The 95% CIs indicate the variation in index scores between sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Characteristic PFG Cover Index year-by-year difference models for Grey Box are presented in Table 23 and Figure 23. Mean index values in two pairs of years (2010-2011 and 2011-2013) were significantly different from each other, and these tests had adequate power to detect the minimum significant effect sizes. Significant differences between mean index values in the other three pairs of years (2013-2014, 2014-2015 and 2015-2016) could not be detected.

Table 23. Output from the year-by-year difference mixed effects models and power analyses for Characteristic PFG Cover Index data for Grey Box. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	**0.2833339**	**0.07835034**	**8**	**3.616244**	**0.0068**	**0.8847311**	**0.18**
2011-2013	**-0.3625451**	**0.07570349**	**12**	**-4.789014**	**4e-04**	**0.9922189**	**0.17**
2013-2014	0.0118990	0.03155766	12	0.377056	0.7127	0.06397388	0.07
2014-2015	-0.0554026	0.04222437	12	-1.312100	0.2140	0.2269996	0.09
2015-2016	0.0037259	0.03657510	12	0.101869	0.9205	0.0510127	0.08

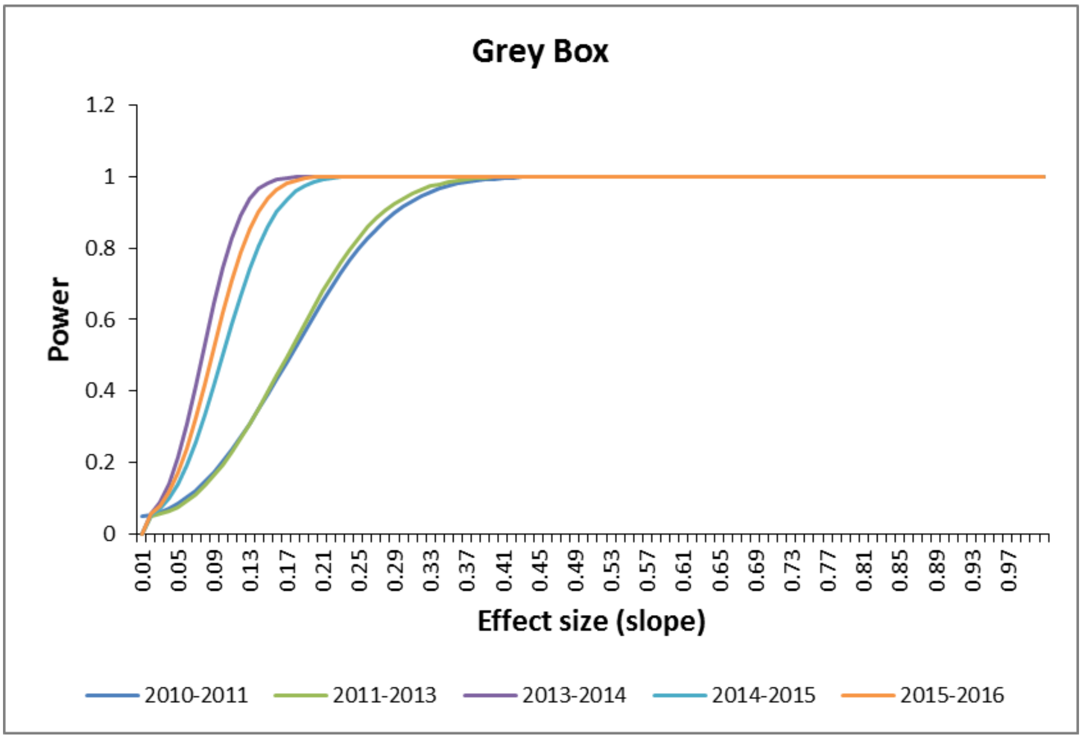

Figure 23. Power curves for year-by-year difference models using Grey Box Characteristic PFG Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OES for 2010-2011 was large enough to represent a meaningful difference in the Characteristic PFG Cover Index between years (light blue row, Table 24). However, one of the CIs was very close to zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. This result is inconclusive, and suggests that we might have needed a larger sample size.

The OES for 2011-2013 was large enough to represent a meaningful difference in the Characteristic PFG Cover Index between years (light green row, Table 24). In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. These results are conclusive – we are confident that there is a detectable difference between years.

OESs for 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Characteristic PFG Cover Index between years, and in all three cases, the CIs included zero (orange rows, Table 24) so we don’t have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

Table 24 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Characteristic PFG Cover Index values for Grey Box

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.4213321	0.7517865	0.330	0.072	0.536
2011-2013	0.7517865	0.3892414	-0.363	-0.559	-0.143
2013-2014	0.3892414	0.4011404	0.012	-0.219	0.228
2014-2015	0.4011404	0.3457378	-0.055	-0.264	0.178
2015-2016	0.3457378	0.3494636	0.004	-0.211	0.248

Characteristic PFG Cover Index Summary

The following table summarises the power and sensitivity results for the trend models (Table 25). Note that the results for year-by-year differences may be more informative for these data (Table 11, Table 15, Table 19 and Table 23).

Table 25 Power and Sensitivity Summary (trend models) for the Characteristic PFG Cover Index

WRC	Range possible	Sensitivity	Power/MSES (trend model)	Summary
Dry phase wetlands	0 to 1	✓	N/A	It was not possible to run mixed models or the associated power analyses on the wetland indicators due to the highly unbalanced nature of the dataset.
Receding phase wetlands	0 to 1	✓	N/A	
Red Gum FDU	0 to 1	✓	MSES was ± 0.017. Power was 0.4167632.	Power to detect a trend in the Red Gum FDU and Black Box Characteristic PFG cover indices was **inadequate**. The trend model averaged across year-by-year fluctuations in the species cover indices, and possible trends occurring on different time scales. **Use the year-by-year approach** to detect differences in the Characteristic PFG cover indices between years.
Black Box	0 to 1	✓	MSES was ± 0.03. Power was 0.2576478.	
Red Gum FTU	0 to 1	✓	MSES was ± 0.034. Power was 0.6265178.	Power to detect a trend in the Red Gum FTU and Grey Box Characteristic PFG cover indices was **adequate**. **The trend model can be used**, although the year-by-year approach may prove more informative. See notes in text about the limitations of using the trend models for these data.
Grey Box	0 to 1	✓	MSES was ± 0.02. Power was 0.9992650.	

TERRESTRIAL SPECIES COVER INDEX (Proportion of Total Cover Comprising Terrestrial Dry (Native and Introduced) Species)

Template Part 1 summarises information for the Koondrook-Perricoota Forest Index of Proportion of Total Cover Comprising Terrestrial Dry (Native and Introduced) Species (henceforth referred to as the 'Terrestrial Species Cover Index'). This template also includes a description of 'Observed Effect Sizes' and 'Power' which were each calculated for this index. Template Part 2 outlines the process applied to derive the index for each understorey or wetland group and describes the sensitivity of the index. The templates are a key output of the current project and are formatted to be incorporated into the Icon Site condition monitoring program. The technical workings for the index are outlined in the subsequent section.

Note that this index has a minimum of 0, indicating no dry terrestrial species cover, and a maximum of 1, indicating ≥90% dry terrestrial species cover, meaning that samples are compliant if they DO NOT exceed the PoR. This is the inverse of the other vegetation monitoring indicators applied to the Koondrook-Perricoota dataset, and means that indicator scores should not be numerically summed across indicators to provide a summary of condition. Instead, a summary of which site/dates or WIPCs/WRCs are compliant can be made.

Index Templates

Template Part 1 - Terrestrial Species Cover Index

Characteristic	Description
Overarching Management/Ecological Objectives for Koondrook-Perricoota (currently under review)	Maintain and restore a mosaic of healthy floodplain communities (including): • 80% of permanent[5] and semi-permanent wetlands in a healthy condition • 30% of River Red Gum forest in a healthy condition
Draft refined ecological objectives for the Gunbower–Koondrook–Perricoota icon site developed by the Technical Advisory Committee (MDBC 2007)	Protect and enhance a diverse range of healthy wetlands • Protect and enhance diverse, healthy vegetation communities • Provide for successful waterbird breeding and recruitment events • Protect and enhance viable native fish communities
Proposed targets for KP	• At least 80% of wetland Water Regime Class (WRC) sites in a healthy condition • At least 30% of River Red Gum WRC sites in a healthy condition • At least 90% of Grey Box WRC sites in a healthy condition
Monitoring Objective	To measure occurrence of flora species across Koondrook-Perricoota Forest
Points of Reference	For each KP WIPC or WRC, the 'Terrestrial Species Cover Index' at a site is considered 'appropriate' if it is <u>below</u> the Point of Reference (PoR), based on the 90th percentile of all records (wetlands) or all autumn records (understorey) since 2010.

[5] Note: there are no permanent wetlands at KP

Characteristic	Description
	For the WIPCs, these values are: • Dry Phase Wetlands - proportion of terrestrial species 0.4564. • Receding Phase Wetlands- proportion of terrestrial species 0.343616. For the treed WRCs these values are: • Red Gum with Flood Dependant Understorey – proportion of terrestrial species 0.741935. • Red Gum with Flood Tolerant Understorey – proportion of terrestrial species 0.795. • Black Box Woodlands proportion of terrestrial species 0.943477. • Grey Box Woodlands proportion of terrestrial species 0.974927.
Sampling Strategy	Wetlands: regular autumn vegetation monitoring and spring and summer post-event monitoring at 15 sites. Note that Pollack Swamp transects 1 and 2 are quite ecologically distinct and have been treated as separate wetlands for the purpose of these analyses. Pollack Swamp transect 3 (PS3) is a pseudoreplicate of PS2 and has been excluded from analyses. Data were categorised into two Wetland Inundation Phase Classes (Dry and Receding). Dry Phase Wetlands = no standing water present, but sediment may be moist. Receding Phase Wetlands = standing water is present (water of variable depth). Understorey: regular autumn vegetation monitoring at 60 randomly located quadrats. Data were categorised into four treed WRCs – River Red Gums (FDU & FTU) and Box Woodlands (Black & Grey).
Index	Index 1: 'Terrestrial Species Cover Index' per site by sample year Minimum score of 0, maximum score of 1.
Observed Effect Sizes and Confidence Intervals	An Observed Effect Size (OES) is an actual measure of the size of the difference (e.g. mean index values or slope/trend in index values) between two groups and whether this difference is negative or positive (Durlak 2009). Confidence Intervals for the OES give us an estimate of the range of 'plausible' effect size values we could expect from the wider population, given our OES (Kirby and Gerlanc 2013). It is important to report OESs, regardless of whether P-values indicate a test is significant or not (Durlak 2009). For the 'Terrestrial Species Cover Index', OES and confidence intervals (CIs) were calculated for year-by-year (understorey) or sampling event-by-sampling event (wetland) comparisons.
Power[6]	The power of a test is the likelihood that a statistical effect will be detected (probability of rejecting the null hypothesis if the null is

[6] **Explained in more detail under the heading Observed Effect Sizes and Confidence Intervals**
The calculation of Observed Effect Sizes and Confidence Intervals is an actual measure of the size of the differences in mean index values between pairs of subsequent years, and estimate of the

Characteristic	Description
	false) (Thomas 1997). Power explains the minimum size of the effect that can be detected with confidence. In this refinement project, we have investigated the *post hoc* power of linear mixed effect models to detect (for each WRC*): • A change through time (trend) in mean 'Terrestrial Species Cover' index values; and • Differences between mean 'Terrestrial Species Cover' index values on subsequent sampling dates (year-by-year for understorey sites or sampling event-by-sampling event for wetland sites). The development of these models has some value because it allows us to assess whether a trend in mean index values over time is significantly different from zero or whether mean index values are significantly different between sampling events. Retrospective (*post hoc*) power analysis using observed effect sizes and variation has limitations, since there is a direct relationship between power and p-value (low p-value, significant result, high power or high p-value, non-significant result, low power). In order to avoid this, we have instead calculated power using pre-specified effect sizes and the observed variance, and determined the minimum significant detectable effect sizes (Thomas 1997). The calculation of Observed Effect Sizes[7] and Confidence Intervals (see row above) is considered to be another robust form of retrospective power analysis, which allows the level of uncertainty in the results to be quantified (Thomas 1997).

range of 'plausible' OESs we would expect from the wider population (if all possible wetlands or understorey quadrats within each WIPC/WRC were sampled within the specified date range) (Table 5).

Table 5 Observed Effect Sizes and Confidence Intervals for the Characteristic PFG Cover Index

Observed Effect Sizes and Confidence Intervals
For each WIPC or WRC: Bootstrap Effect Sizes and CIs were calculated for pairs of subsequent years (understorey sites) or subsequent sampling occasions (wetlands), using data from 2010, 2011, 2013, 2014, 2015, 2016 and 2017 (2017 wetlands only) using package `bootES` in R. The difference in mean Characteristic PFG Cover Index values for each pair of sampling occasions (the Observed Effect Size) was calculated, and then 95% CI were calculated by locating the values at 2.5% and 97.5% in the distribution of 2000 bootstrapped samples. An assessment was then made of whether the OES represented a meaningful difference in the Characteristic PFG Cover Index between sampling occasions (e.g. a difference of <0.1 is unlikely to be a biologically meaningful difference in index scores between dates), and the CIs were used to determine a level of confidence in the result.

Power Analyses on page 11.

[7] In contrast to the Minimum Significant Effect Size calculated as part of the Power Analysis.

Characteristic	Description
	The following trend models for the 'Terrestrial Species Cover Index' had sufficient power to detect change. • Red Gum FDU MSES ±0.023, power = 0.9837447 The year-by-year comparison had sufficient power to detect a change for some pairs of consecutive years in Red Gum FDU, but none of the other treed WRCs. The results are summarised in Table 36. ***Note: it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.***

Template Part 2 - 'Terrestrial Species Cover Index'

Characteristic	Description
Explanation of Reference	**For each WIPC and WRC:** The long-term database was interrogated to determine what proportion of terrestrial species cover represented the top 90% of sites for each WIPC or treed WRC since 2010. Cover data were expressed as % cover, which incorporates an intrinsic weighting by area. To derive points of reference: • The proportion of terrestrial species cover across the WIPC or WRC was summarised. Replicates were sampling occasions across all wetland sites or quadrats. • From these data, the 90th percentile value was determined. See Table 28 for additional details.
Index Calculation	**For wetland WIPCs and treed WRCs:** • Terrestrial species cover for each site on each sampling occasion was converted to an index using the formula: Index = Sqrt(Terrestrial Species Cover) ÷ Sqrt(Point of Reference) • Correct so that any values >1 are recorded as 1. • Index lies between 0 and 1. • Terrestrial Species Cover that is greater than or equal to the PoR results in an index of 1 (it is NOT compliant), and Terrestrial Species Cover less than the POR results in an index of <1 (it IS compliant). • Calculate the WIPC/WRC score as the proportion of compliant samples in each WIPC/WRC~~.~~
Sensitivity	The index is scaled to represent the Terrestrial Species Cover recorded, relative to the cover recorded in the highest 10% of cases over the 6 years of the monitoring program. Hence, the indicator is sensitive because when the wetlands and floodplain support a higher cover of terrestrial species in any year, the sampling sites will return a higher cover of terrestrial species, and the index will be higher. *Note that compliance for this indicator is triggered by cases that do NOT equal or exceed the PoR.*

Technical Details

Background

This component measures compliance at a sample level (each wetland or quadrat on each date) for Terrestrial Species Cover (proportion of total cover comprising terrestrial dry (native and introduced) species, PFG 7) in the two tested WIPCs and four treed WRCs.

Points of reference (PoR) were derived for each of the WIPCs/WRCs using a 'raw percentile' approach (Robinson 2013). Details are given below (under 'Index calculation' on page 43).

General Approach Taken

Terrestrial Species Cover was calculated for each site on each sampling occasion, and then PoRs were determined for each WIPC/WRC (see methods in Table 28). The current approach set the PoR based on the 6-7 year dataset, but depending on what is most important to the project manager it could be set based on a reference year (i.e. the 'best' year or the first year of monitoring). It should be noted that due to the variable nature of these datasets, the inclusion of additional sampling occasions in the calculation of PoRs is likely to make them more robust. Methods are given below (Table 28).

To derive a whole of WIPC/WRC index score, the proportion of compliant samples (scoring <1) for each WIPC or WRC can be calculated.

Data Description

Flora species richness and cover data (native and introduced species) were recorded at 15 wetland sites and in 60 understorey quadrats from 2010 to summer 2017 in Koondrook-Perricoota Forest. The data were classified into two WIPCs and four WRCs. Plant species were categorised into PFGs. For the purposes of this refinement project, all autumn records of indigenous species from characteristic PFGs were used for understorey analyses (2010-2016) and all records (spring, summer and autumn) were used for wetland analyses (2010-summer 2017).

Component Assumptions and Caveats

It should be recognised when interpreting the results that the reference list and sample data are, at best, indicative of the total native characteristic species cover supported by the forest, and are skewed towards reporting a lower than actual level of cover. Some of the reasons for these biases include:

- Suitable environmental conditions did not exist for all species in all years.
- The monitoring program is principally undertaken in autumn and therefore does not represent the full annual diversity of flora. Only autumn data were used for understorey analyses, while (less frequent) event-based monitoring of spring and summer events were also used for wetland sites.
- Data summarised by this index is the proportion of cover of all terrestrial dry species (PFG 7) (native or exotic) relative to the cover of all species (PFGs 1-7).
- Wetland data are highly variable due to intrinsic differences in size, condition and flooding regime between wetlands, plus the inability to sample at the same stage of inundation each year, which dramatically affects which species are recorded.

Other caveats and assumptions:

- For the analysis of wetland data, we have assumed spatial independence of sites (although sites are located close to each other and are likely to be connected when inundated).
- Understorey quadrats are uniform in size and most were randomly allocated.

- Transect lengths at individual wetlands vary slightly between years, and differ more significantly in length among wetland sites. Consequently, we would expect more species to be recorded at a larger transect. The proportional nature of the data used for this indicator accounts for this.
- Due to inter-site variability, summarising wetland data into a single index value for each WRC would be likely to incorporate significant error. The wetland phase-based approach we have adopted here attempts to address some of this variability by grouping wetlands by their stage of inundation.

Index Calculation

The following three tables detail the PoRs and calculations performed to determine the Terrestrial Species Cover Index for each WIPC or WRC.

Table 26 Explanation of Point of Reference for the Terrestrial Species Cover Index

Index	Explanation of Reference
Index 1: Terrestrial Species Cover per site by sample year	For each WIPC/WRC, Terrestrial Species Cover at a site is considered ‘appropriate’ if it is <u>below</u> the PoR (90th Percentile of PFG Species Cover across the 2010-2017 sampling period, Table 6). WIPCs analysed: • Dry Phase Wetlands • Receding Phase Wetlands WRCs analysed: • Red Gum Flood Dependent Understorey • Red Gum Flood Tolerant Understorey • Black Box Woodlands • Grey Box Woodlands

Table 27 Points of Reference for the Terrestrial Species Cover Index

WIPC/WRC	Number of site_dates included	Point of Reference (90th percentile of the proportion of native + introduced dry terrestrial species)
Dry Phase Wetlands	75	0.4564
Receding Phase Wetlands	50	0.343616
Red Gum Flood Dependant Understorey	184	0.741935
Red Gum Flood Tolerant Understorey	42	0.795
Black Box Woodlands	54	0.943477
Grey Box Woodlands	74	0.974927

Table 28 Index calculation for the Terrestrial Species Cover Index

Index Calculation
For all WIPCs/WRCs: • Summarise the cover of Dry Terrestrial species across the WIPC/WRC (wetlands or quadrats on each sampling date as replicates). • From these data, determine the 90th percentile value. • Convert terrestrial species cover data to an index using the formula: Index = Sqrt(Terrestrial Species Cover) ÷ Sqrt(Point of Reference) • Correct so that any values >1 are recorded as 1. • Index lies between 0 and 1.

Index Calculation
• Terrestrial Species Cover that is greater than or equal to the PoR results in an index of 1 (it is NOT compliant), and Terrestrial Species Cover less than the POR results in an index of <1 (it IS compliant).

Sensitivity Analyses

Sensitivity analysis investigates how a change in the condition of the Icon Site manifests into a change in condition assessment, usually using an index (Table 29).

Table 29 Sensitivity of the Terrestrial Species Cover Index

Sensitivity
Index 1: Terrestrial Species Cover per site by sample year It was verified that for each WIPC/WRC, the Index ranged between 0 and 1 in the data set. A site with no cover of dry terrestrial species would score 0 and a site with Terrestrial Species Cover at or above the 90th percentile would score 1.

Observed Effect Sizes and Confidence Intervals

The calculation of Observed Effect Sizes and Confidence Intervals is an actual measure of the size of the differences in mean index values between pairs of subsequent years, and estimate of the range of 'plausible' OESs we would expect from the wider population (if all possible wetlands or understorey quadrats within each WIPC/WRC were sampled within the specified date range) (Table 30).

Table 30 Observed Effect Sizes and Confidence Intervals for the Terrestrial Species Cover Index

Observed Effect Sizes and Confidence Intervals
For each WIPC or WRC: Bootstrap[8] Effect Sizes and CIs were calculated for pairs of subsequent years (understorey sites) or subsequent sampling occasions (wetlands), using data from 2010, 2011, 2013, 2014, 2015, 2016 and 2017 (2017 wetlands only) using package `bootES` in R. The difference in mean Terrestrial Species Cover Index values for each pair of sampling occasions (the Observed Effect Size) was calculated, and then 95% CI were calculated by locating the values at 2.5% and 97.5% in the distribution of 2000 bootstrapped samples. An assessment was then made of whether the OES represented a meaningful difference in the Terrestrial Species Cover Index between dates (e.g. a difference of <0.1 is unlikely to be a biologically meaningful difference in index scores between sampling occasions), and the CIs were used to determine a level of confidence in the result.

Power Analyses (understorey WRCs)

Power analyses determine how likely the indicators and sampling strategy are to detect change in condition at sites (quadrats) (Table 31). Two approaches were taken:

- Trend analysis: for each WRC, assessment of whether there was a linear trend in index values over the six years of monitoring (i.e. overall did index values increase or decline from 2010 to 2016?). What was the minimum change in index values over time (slope) that could be detected?

[8] Bootstrapping is the process of repeatedly drawing random samples from the data sample in order to approximate the distribution of the actual population parameter being estimated (from Kirby and Gerlanc 2013).

- Year-by-year differences: for each WRC, assessment of differences in index values between pairs of consecutive sampling years (e.g. was the mean Terrestrial Species Cover Index higher in 2011 than in 2010, etc.?). What was the minimum difference in index values between consecutive years that could be detected? *Note: the year-by-year models compare differences from one year to another at the level of each site (quadrat) and then assess whether the mean change in index score within sites is significant.*

Note: it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Table 31 Power analysis of the Terrestrial Species Cover Index

Power
For each WRC: Mixed effects models (a trend model and a series of year-by-year differences models) were fitted to existing data from 2010, 2011, 2013, 2014, 2015 and 2016. The trend model assesses a linear trend through time (time as a fixed factor) whilst including the knowledge that sites were revisited through time (sites as random factor) and that the index in one year may be dependent on the index score in the previous sampled year for that site (first order autocorrelation structure). The correlation structure was included if it improved model fit to the data, where best fit was determined by model selection using Akaike Information Criterion (AICc). The choice of model used was related to the question being asked of the data. A linear model was used to examine trends in the data over time in order to address the question “Has condition at sites improved or declined overall over the 6 years of sampling?”. It is possible to fit non-linear models to this type of data, however the choice of model should be related to the question of interest. For example, are we interested in an overall increase or decline over time (over a long time series, small increases and decreases might not alter this overall trend), or do we think that condition might follow some type of cycle? Alternatively, we might decide that a trend model is more appropriate for particular restricted time periods, e.g. a period of drought leading into a period of high rainfall, in which we would expect the indicator values to increase as the vegetation responded to more favourable environmental conditions. Or we might decide that instead of a trend model, we would prefer to compare each subsequent year to a specific year, e.g. the first year of the monitoring program, or the year of highest rainfall/flooding. In the year-by-year approach below, each sampling year is compared with the subsequent sampling year. The year-by-year differences were assessed by fitting mixed models to data from pairs of subsequent sampling years whilst including the knowledge that sites were revisited through time (site as a random factor). **Note that year-by-year models do not compare the mean index score in one year (with all sites combined) against the mean for the other year, as is depicted in the figures.** The models compare differences from one year to another at the level of each site (quadrat) and then assess whether the mean change in index score within sites is significant. Hence, the 95% CIs for indices in years depicted in figures indicate the variation in index scores between sites, but do not indicate the variation in changes between years across sites. Changes in index values from one year to the next could be quite consistent between sites and hence models may be found to be significant when the means and 95% CIs in the plots may appear to suggest they should not be significant.

Power
Both sets of models assume a Gaussian (Normal) distribution, which is not ideal for the data (since index values are constrained between 0 and 1) but a Gaussian distribution will generally provide similar results to a Binomial distribution except in extreme cases where the mean of indices are near 1 or 0. Without making this assumption about the distribution, the power analysis approach taken would not have been possible. The *post hoc* power of the models to detect either a change through time (trend) or differences between subsequent years (year-by-year) were determined by simulating effect sizes without changing other parameters in the mixed effects models, such as within year variation (Option 2 as described in Thomas 1997). The procedure for power analysis is described in Gałecki and Burzykowski (2013).

Results of power analyses are presented for each WRC according to the following stages:

- Linear mixed-effects models results for:
    - Trend model – can a statistically-significant trend in the mean Terrestrial Species Cover index values over time (2010 to 2016) be detected (is the slope significantly different to zero)?
    - Year-by-year difference models – can significant differences in mean index values be detected between subsequent sampling years?
- Minimum significant effect size (at $p>0.05$) that can be detected. For example what is the smallest difference in the slope from zero (trend) or the smallest difference between means (year-by-year) that can be detected, given the sample sizes and the level of variability in the dataset.
- Actual slope recorded (trend) or difference between means recorded (year-by-year).
- As a result of the minimum significant effect size and actual recorded difference, what is the power of that test (where 0 is no power and 1 is maximum power).

Wetlands - raw data, observed effect sizes and confidence intervals

Dry Phase Wetlands

Raw Terrestrial Species Cover Index data for all Dry Phase Wetland cases, summarised by sampling occasion, is presented inFigure 24.

It should be noted that there is no data point for the summer 2016 monitoring period as only the two sites at Pollacks Swamp were monitored and both were in the receding phase.

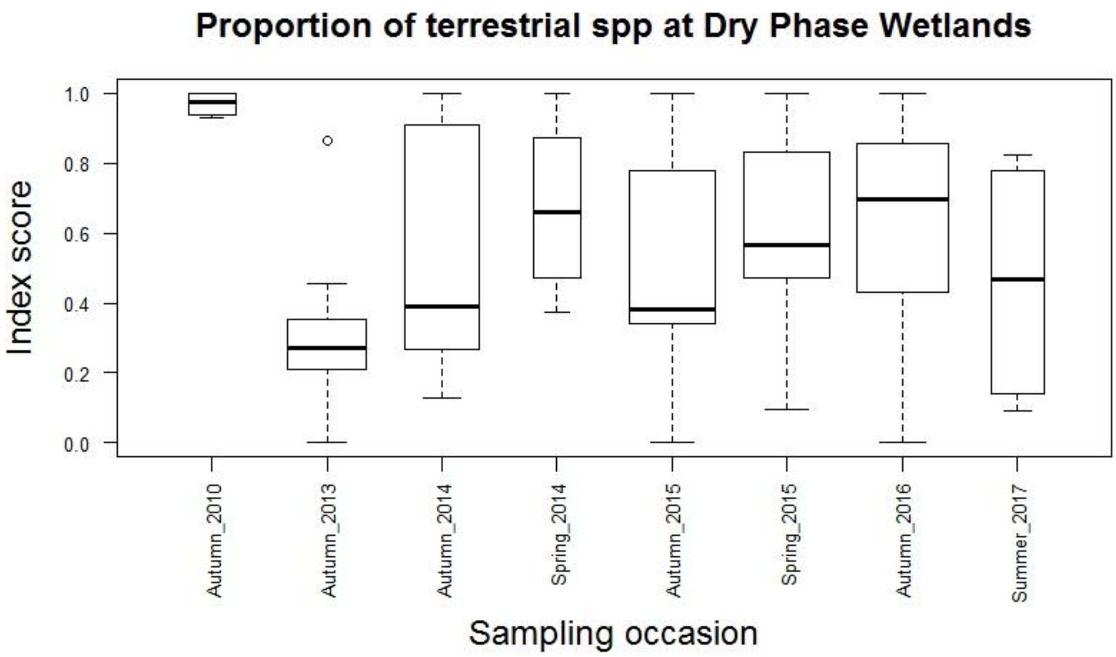

Figure 24 Boxplots of Terrestrial Species Cover Index data for Dry Phase Wetlands showing differences in the spread of values across sampling occasions. The width of each box is scaled relative to the number of samples. Note that no dry phase wetlands were recorded in 2011, and data were not collected in 2012 so these years have been omitted from the plot.

As noted earlier, it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Observed Effect Size and Confidence Intervals

Note: no data were available for Dry Phase Wetlands in 2011

The OES for Autumn 2010-Autumn 2013 was large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years (light green row, Table 7). In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years.

The OES for Spring 2015-Autumn 2016 was too small to represent a meaningful difference in the Terrestrial Species Cover index between years, and the CIs included zero (orange row, Table 7) so we don't have confidence that there is a true difference from zero in the score. The results for this year is conclusive – we are confident that there is no detectable difference between years.

The OESs for Autumn 2013-Autumn 2014, Autumn 2014-Spring 2014, Spring 2014-Autumn 2015, Autumn 2015-Spring 2015 and Autumn 2016-Summer 2017 were larger and are more likely to represent a meaningful difference in the Terrestrial Species Cover index between years (light blue rows, Table 7). However, in all cases, the confidence intervals included zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed a larger sample size.

Table 32 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Terrestrial Species Cover Index values for Dry Phase Wetlands

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
Autumn 2010-Autumn 2013	0.9701094	0.297177	-0.673	-0.778	-0.496
Autumn 2013-Autumn 2014	0.297177	0.5206377	0.223	-0.016	0.466
Autumn 2014-Spring 2014	0.5206377	0.6742901	0.154	-0.158	0.424
Spring 2014-Autumn 2015	0.6742901	0.5021586	-0.172	-0.456	0.092
Autumn 2015-Spring 2015	0.5021586	0.6237579	0.122	-0.089	0.322
Spring 2015-Autumn 2016	0.6237579	0.6440657	0.020	-0.197	0.214
Autumn 2016-Summer 2017	0.6440657	0.4607979	-0.183	-0.469	0.131

Receding Phase Wetlands

Raw Terrestrial Species Cover Index data for all Receding Phase Wetland cases, summarised by sampling year, is presented in Figure 25. It should be noted that there is no data point for spring 2015, as no wetlands were in the receding phase during the spring 2015 monitoring period.

Boxplots are presented here for consistency with all other WIPCs/WRCs, however in Autumn 2010, Autumn 2015 and Summer 2016 only two samples (each) were recorded for Dry Phase Wetlands, which mean that the boxplots for these sample dates are misleading. Therefore, a dotplot has also been included to more accurately show the spread of index values across years and seasons within years (Figure 26).

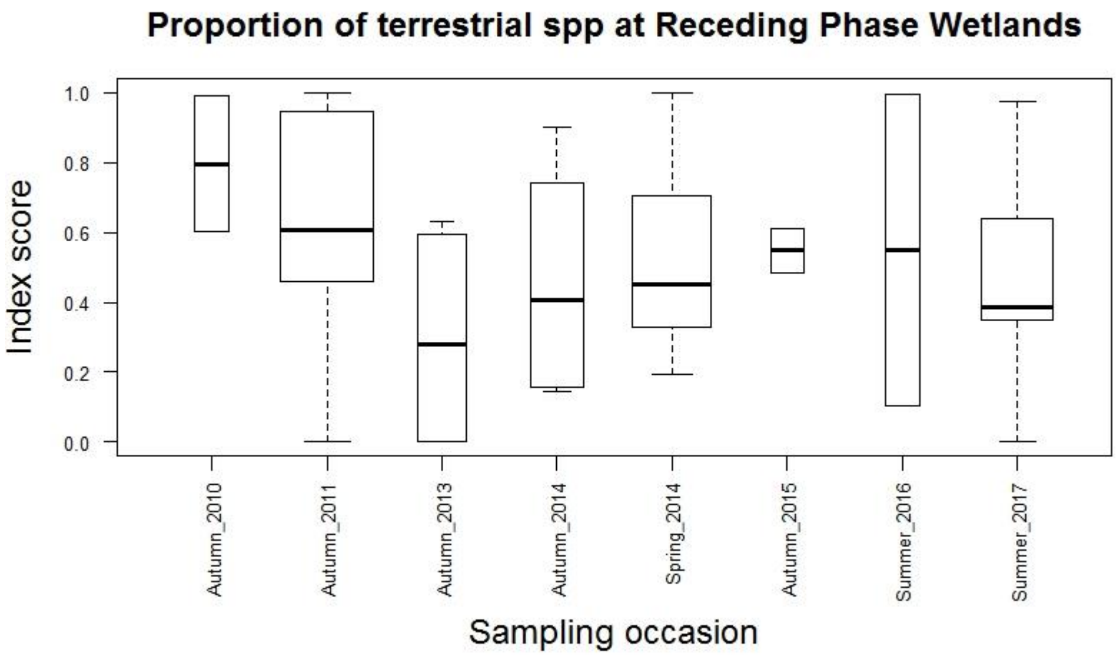

Figure 25. Boxplots of Terrestrial Species Cover Index data for Receding Phase Wetlands showing differences in the spread of values across sampling occasions. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

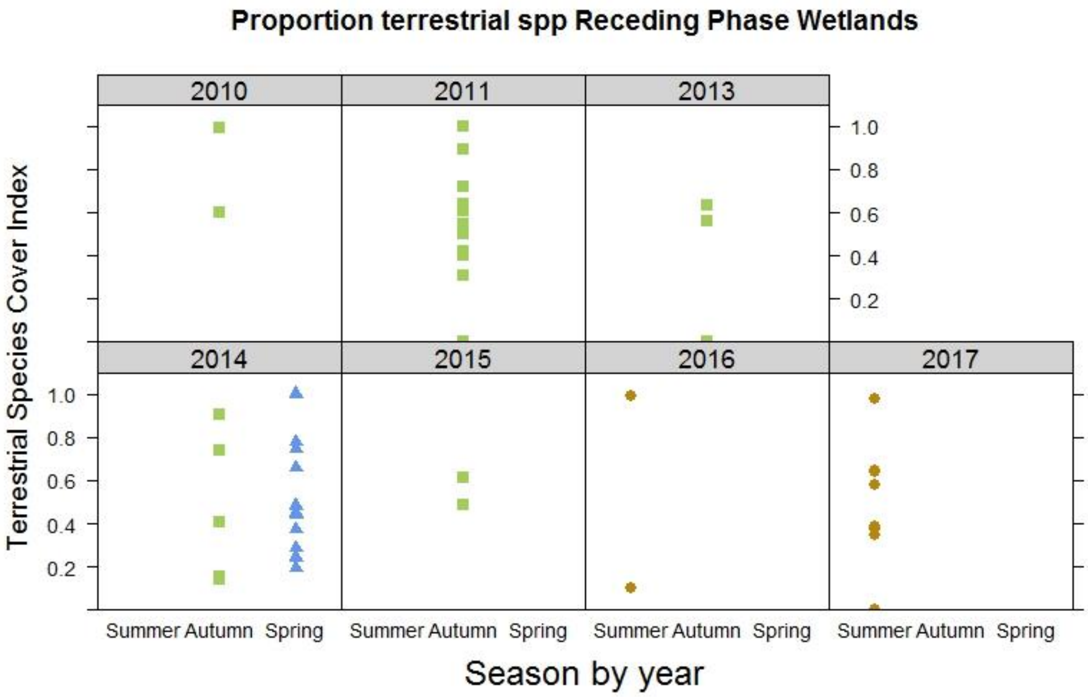

Figure 26 Dotplots of Characteristic PFG Cover Index data for Receding Phase Wetlands showing differences in the spread of values across sampling occasions. Note that data were not collected in 2012 so this year has been omitted from the plot.

As noted earlier, it was not possible to run the power analyses on the wetland indicators, since the highly unbalanced nature of the dataset (very few replicates in some date categories), coupled with high levels of variability, made it unfeasible to run mixed models on these data.

Observed Effect Size and Confidence Intervals

Note: Autumn 2010, Autumn 2015 and Summer 2016 have not been included in these calculations as only two data points were available for each of these sampling occasions for Receding Phase Wetlands.

The OESs for Autumn 2011-Autumn 2013 and Autumn 2013-Autumn 2014 were large enough to represent a meaningful difference in the Terrestrial Species Cover index between years (light blue rows, Table 33). However, in both cases, the confidence intervals were either close to or included zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed a larger sample size.

OESs for Autumn 2014-Spring 2014 and Spring 2014- Summer 2017 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years, and in both cases, the CIs included zero (orange rows, Table 33) so we don’t have confidence that there is a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

Table 33 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Terrestrial Species Cover Index values for Receding Phase Wetlands

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
Autumn 2011-Autumn 2013	0.6378036	0.2977809	-0.340	-0.672	-0.011
Autumn 2013-Autumn 2014	0.2977809	0.4707143	0.173	-0.201	0.588
Autumn 2014-Spring 2014	0.4707143	0.5147644	0.044	-0.273	0.333
Spring 2014- Summer 2017	0.5147644	0.4389837	-0.076	-0.331	0.154

Understorey - raw data, observed effect sizes and confidence intervals, and power analyses

Red Gum with Flood Dependent Understorey

Raw Terrestrial Species Cover Index data for all Red Gum FDU sites summarised by sampling year is presented in Figure 27.

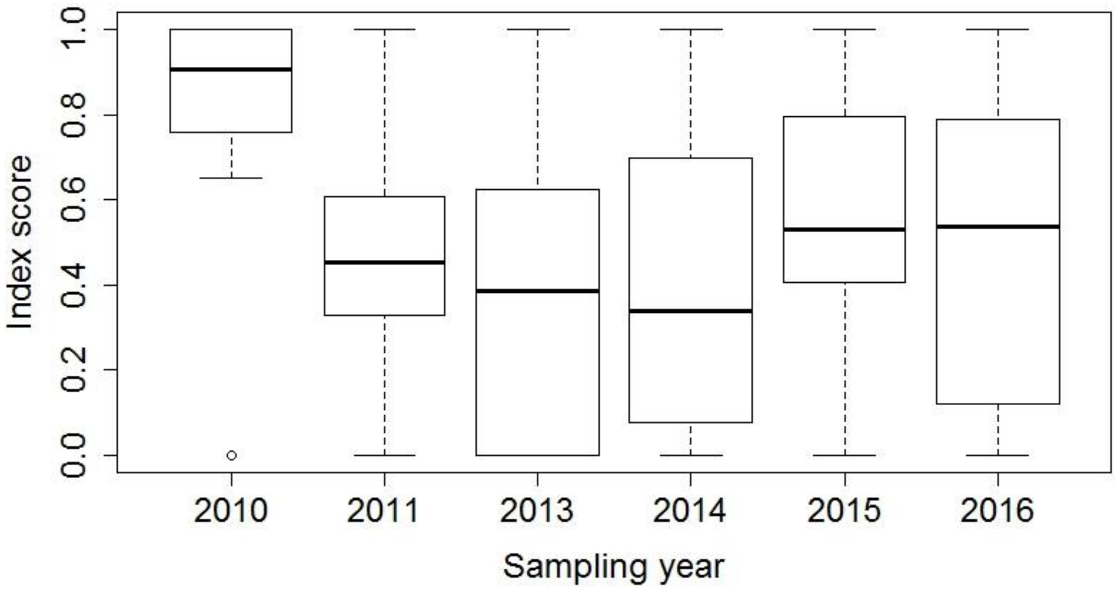

Figure 27. Boxplots of Terrestrial Species Cover Index data for Red Gum FDU showing differences in the spread of values across sampling years. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model

The linear trend in Terrestrial Species Cover Index data through time for Red Gum FDU was represented by a mixed effects model with site as a random variable and a first order correlation structure (Figure 28). The negative slope (trend) in index values over time was significantly different from zero (Table 34). The model supports a declining linear trend in Terrestrial Species Cover in Red Gum FDU over time (Figure 27, Figure 28).

Note that the statistical significance of this result should be interpreted with caution. The linear trend is a poor representation of the data and the trend is driven largely by the 2010 year. There was also a high level of variability in index scores within years (Figure 27, Figure 28). This statistically significant but not necessarily biologically significant result reflects the importance of asking the right questions of our data (e.g. do we expect changes in condition over time to be linear?), and suggests that six years may not be a long enough time period to look at a 'trend' in terrestrial species cover. Additional years of data might be required to determine whether this 'trend' has biological significance. Nonetheless, the method is sensitive enough to detect a decline in index score as was seen here over this period.

Table 34. Output from the trend model for Terrestrial Species Cover Index data for Red Gum FDU. P-values in bold are significant at P<0.05.

	Value	Std. Error	DF	t-value	p-value
(Intercept)	96.10625	23.171699	152	4.147570	**1e-04**
Year	-0.04747	0.011511	152	-4.124233	**1e-04**

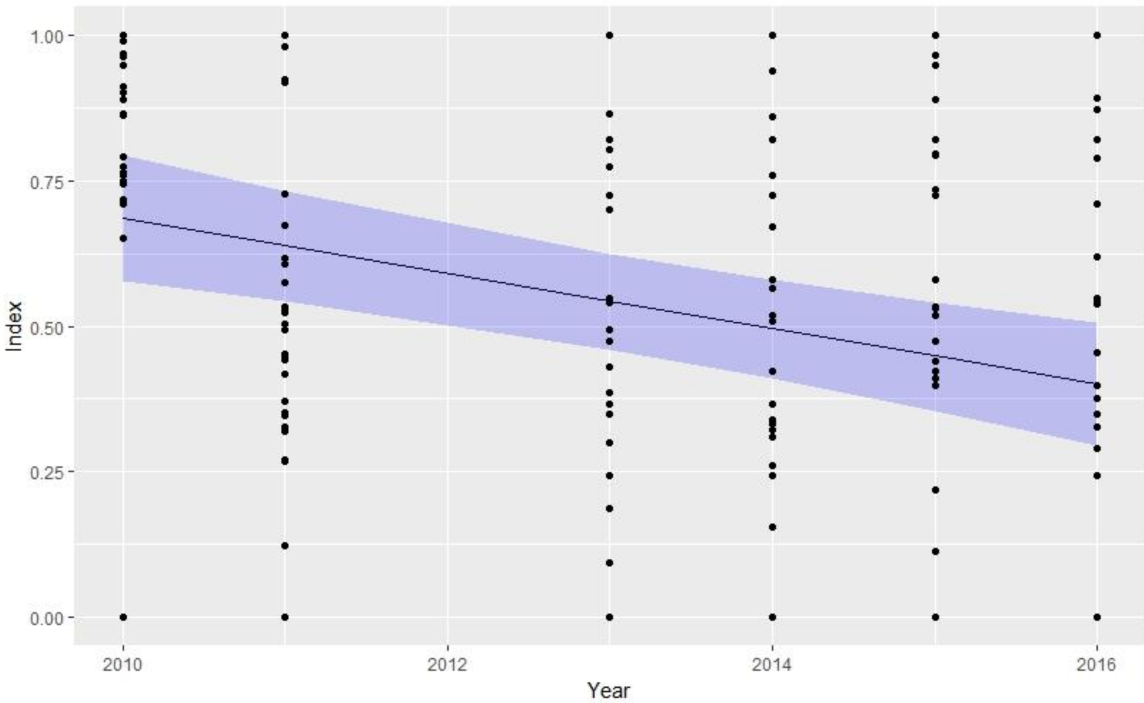

Figure 28. Plot of the fit of the linear mixed model (trend model) for Terrestrial Species Cover Index data in the Red Gum FDU WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Terrestrial Species Cover Index trend model for Red Gum FDU found that the minimum significant effect size (trend model slope) that would be significant (at P<0.05) was 0.023, and this value was smaller in magnitude than the actual slope detected (-0.04747). Therefore, the power of this test was adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 35 and Figure 29.

Table 35 Output from the power analysis for the Terrestrial Species Cover Index trend model for Red Gum FDU.

	numDF	denDF	F-value	Power
(Intercept)	1	152	169.41459	1.0000000
Year	1	152	17.00929	0.9837447

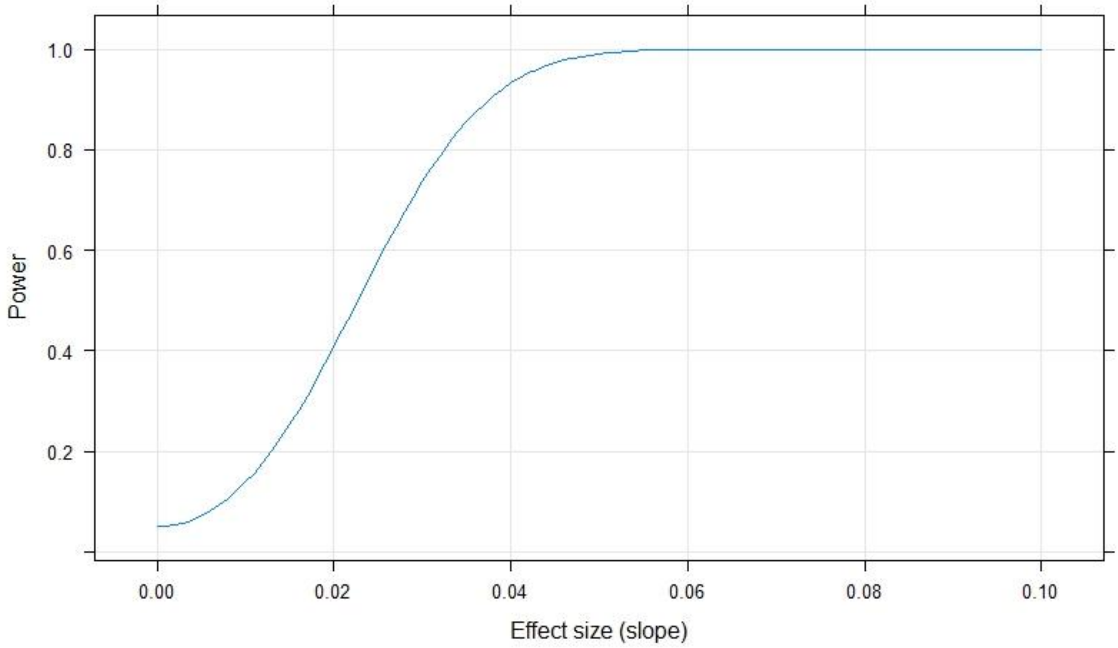

Figure 29. Power curve for the trend model using Red Gum FDU Terrestrial Species Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Terrestrial Species Cover Index data for Red Gum FDU were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 30.

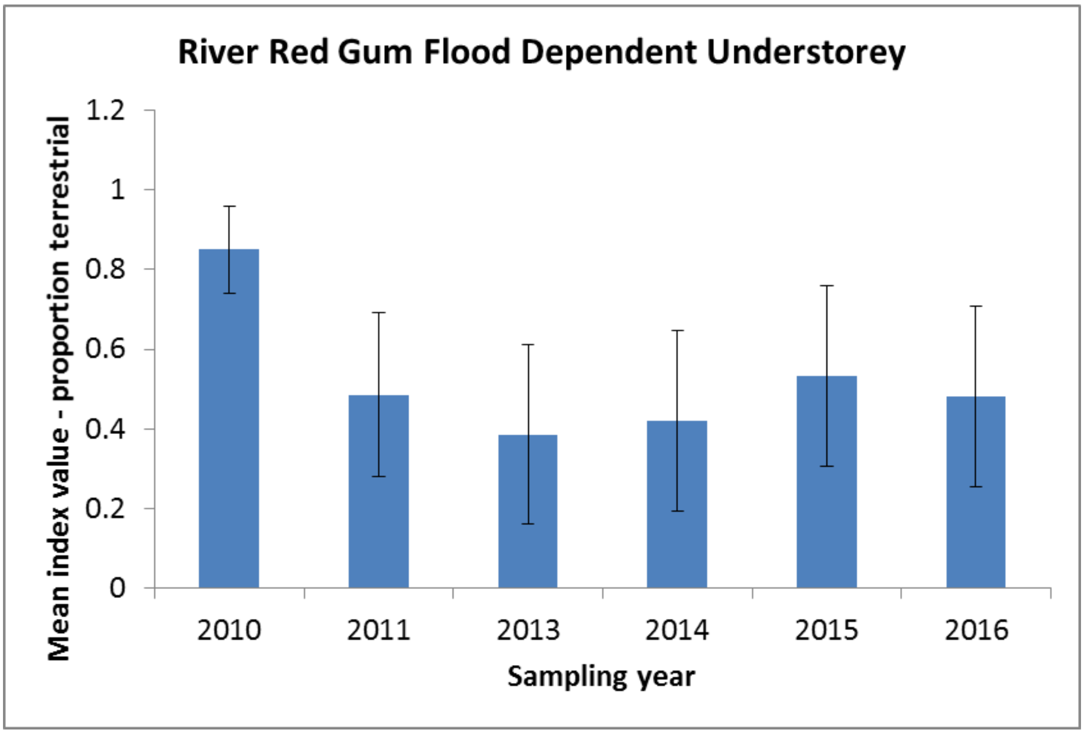

Figure 30. Plot of mean Terrestrial Species Cover Index values (and 95% confidence intervals) for Red Gum FDU by sampling year. The 95% CIs indicate the variation in index scores between

sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Terrestrial Species Cover Index year-by-year difference models for Red Gum FDU are presented in Table 36 and Figure 31. Mean index values in two pairs of years (2010-2011 and 2014-2015) were significantly different from each other, and these tests had adequate power to detect the minimum significant effect sizes (Table 36). Differences between mean index values in the other three pairs of years (2011-2013, 2013-2014 and 2015-2016) could not be detected (power was insufficient).

Table 36 Output from the year-by-year difference mixed effects models and power analyses for Terrestrial Species Cover Index data for Red Gum FDU. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	**-0.3712043**	**0.05351704**	**28**	**-6.936189**	**0**	**0.9999988**	**0.11**
2011-2013	-0.1020210	0.05364064	29	-1.901935	0.0672	0.4518795	0.11
2013-2014	0.0346777	0.04428225	30	0.783107	0.4397	0.1180243	0.09
2014-2015	**0.1112807**	**0.03842931**	**30**	**2.895725**	**0.007**	**0.8000992**	**0.08**
2015-2016	-0.0515383	0.05277182	30	-0.976625	0.3366	0.1570396	0.11

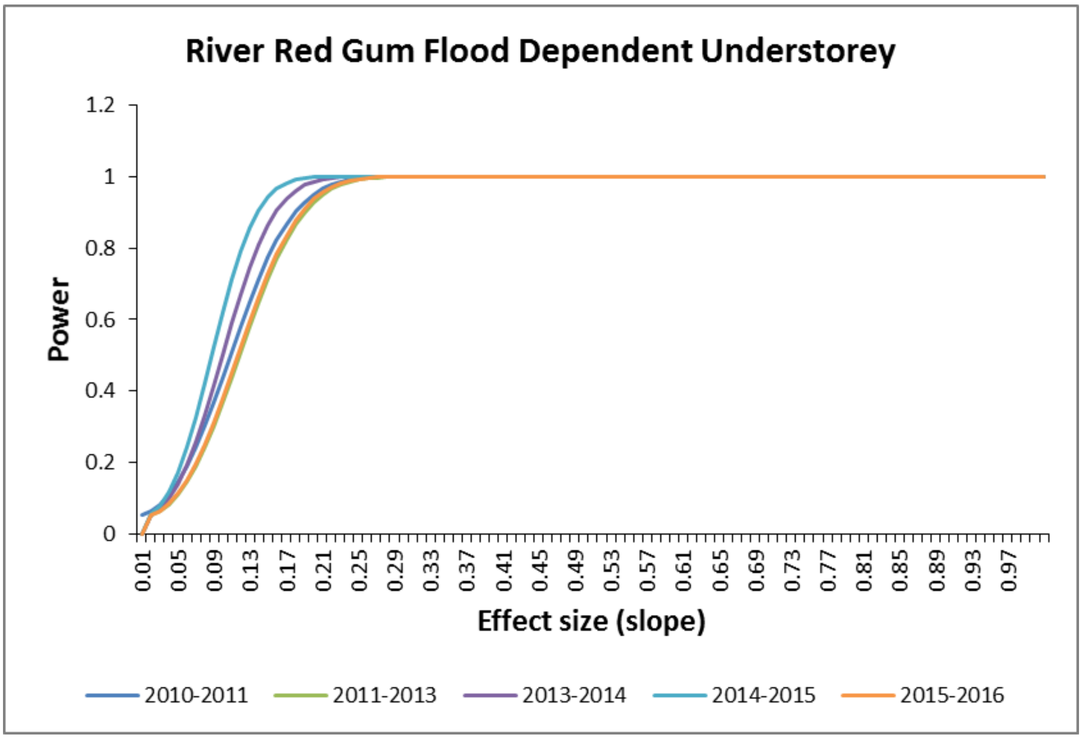

Figure 31. Power curves for year-by-year difference models using Red Gum FDU Terrestrial Species Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OES for 2010-2011 was large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years (light green row, Table 37). In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years.

OESs for 2011-2013, 2013-2014 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years, and in all cases, the CIs included zero (orange rows, Table 37) so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

The OES for 2014-2015 was larger and more likely to represent a meaningful difference in the Terrestrial Species Cover Index between years (light blue row, Table 37). However, the confidence intervals included zero, reducing our confidence that the actual population OES lay far enough from zero to be biologically significant. This result is inconclusive, and suggests that we might have needed a larger sample size.

Table 37 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Terrestrial Species Cover Index values for Red Gum FDU

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.8536351	0.4806295	-0.373	-0.482	-0.250
2011-2013	0.4806295	0.3859477	-0.095	-0.229	0.052
2013-2014	0.3859477	0.4206255	0.035	-0.126	0.205
2014-2015	0.4206255	0.5319062	0.111	-0.073	0.260
2015-2016	0.5319062	0.4803679	-0.052	-0.219	0.123

Red Gum with Flood Tolerant Understorey

Raw Terrestrial Species Cover Index data for all sites summarised by sampling year is presented in Figure 32.

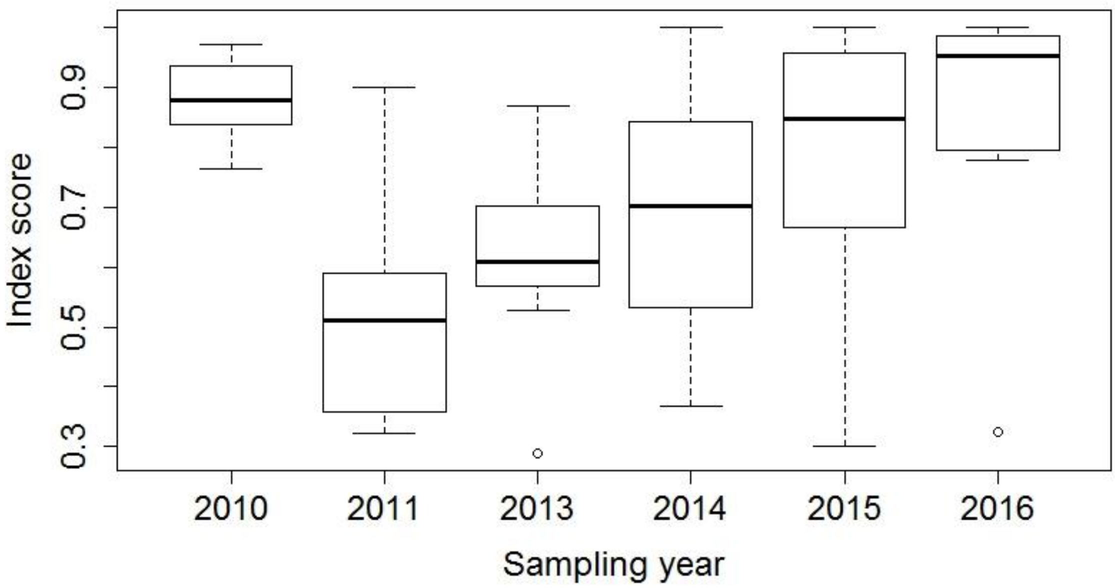

Figure 32. Boxplots of Terrestrial Species Cover Index data for Red Gum FTU showing differences in the spread of values across sampling years. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model

The linear trend in Terrestrial Species Cover Index data through time for Red Gum FTU was represented by a mixed effects model with site as a random variable (Figure 33). The slope (trend) in index values over time was not significantly different from zero (Table 38). Terrestrial Species Cover in Red Gum FTU did not appear to follow a clear linear trend over time. Summarising a trend over this block of 6 years has not adequately represented the fluctuations in the dataset (Figure 32, Figure 33).

Table 38 Output from the trend model for Terrestrial Species Cover Index data for Red Gum FTU. P-values in bold are significant at P<0.05.

	Value	Std. Error	DF	t-value	p-value
(Intercept)	-24.588688	28.034338	34	-0.8770918	0.3866
Year	0.012571	0.013925	34	0.9027056	0.3730

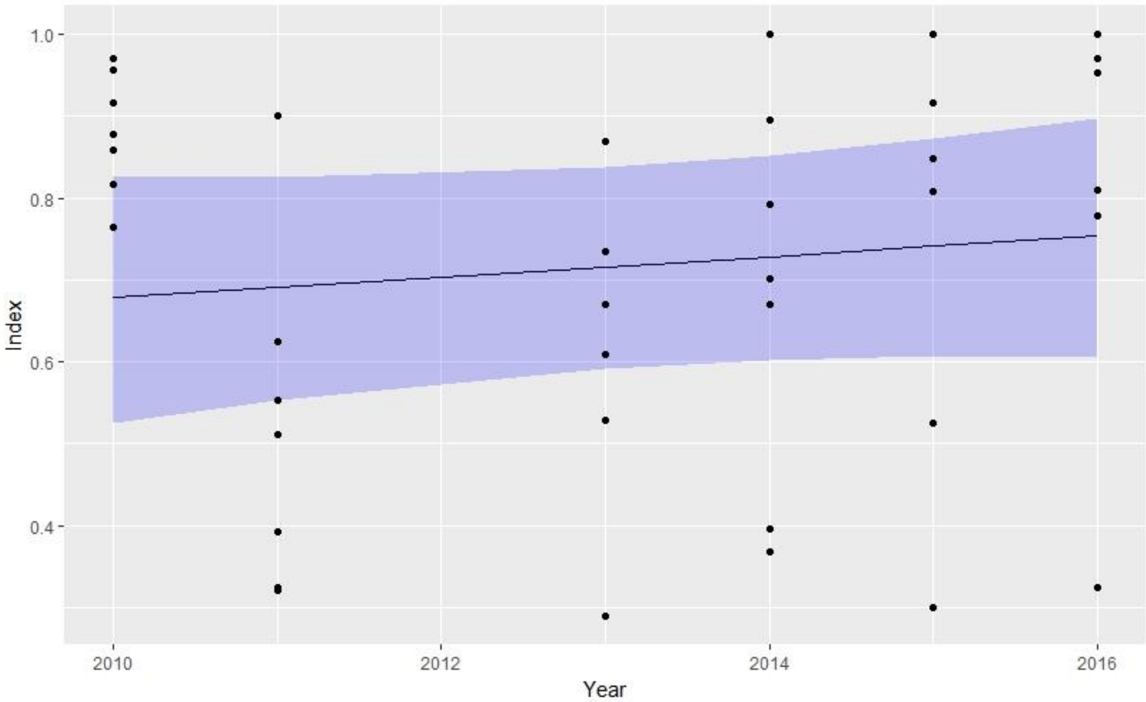

Figure 33. Plot of the fit of the linear mixed model (trend model) for Terrestrial Species Cover Index data in the Red Gum FTU WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Terrestrial Species Cover Index trend model for Red Gum FTU found that the minimum significant effect size (trend model slope) that would be significant (at P<0.05) was 0.029, and this value is larger in magnitude than the actual slope detected (0.012571). The power of this test was not adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 39 and Figure 34.

Table 39. Output from the power analysis for the Terrestrial Species Cover Index trend model for Red Gum FTU.

	numDF	denDF	F-value	Power
(Intercept)	1	34	133.4973087	1.0000000
Year	1	34	0.8148774	0.1417753

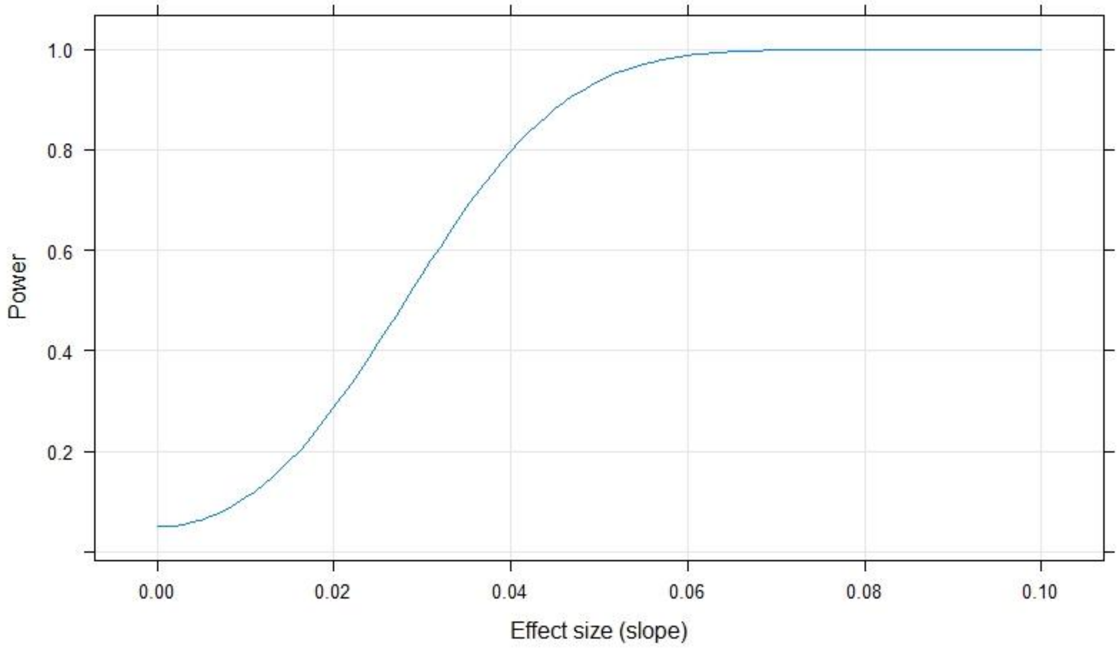

Figure 34. Power curve for the trend model using Red Gum FTU Terrestrial Species Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Red Gum FTU Terrestrial Species Cover Index data were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 35.

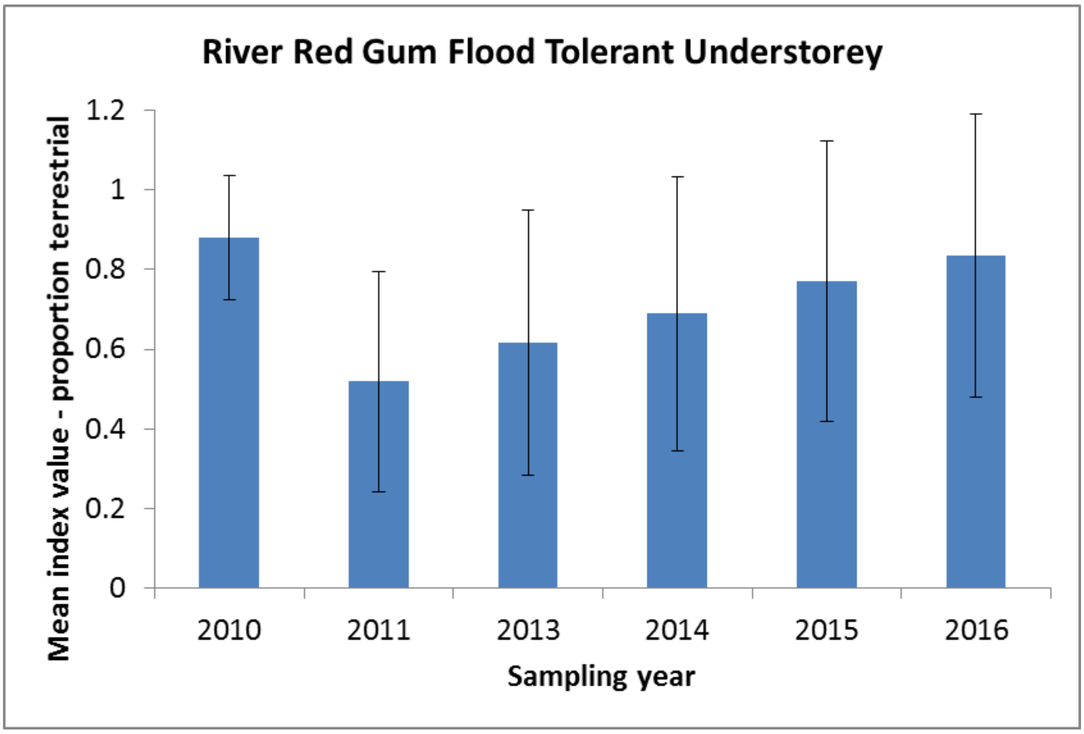

Figure 35. Plot of mean Terrestrial Species Cover Index values (and 95% confidence intervals) for Red Gum FTU by sampling year. The 95% CIs indicate the variation in index scores between

sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Terrestrial Species Cover Index year-by-year difference models for Red Gum FTU are presented in Table 40 and Figure 36. Mean index values in 2010-2011 were significantly different from each other, and the comparison of these years had adequate power to detect the minimum significant effect size. Differences between mean index values in the other four pairs of years (2011-2013, 2013-2014, 2014-2015 and 2015-2016) could not be detected (power was insufficient).

Table 40. Output from the year-by-year difference mixed effects models and power analyses for Terrestrial Species Cover Index data for Red Gum FTU. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	**-0.3615104**	**0.08229646**	**6**	**-4.392781**	**0.0046**	**0.9521193**	**0.2**
2011-2013	0.0968709	0.07966610	6	1.215961	0.2697	0.1775281	0.19
2013-2014	0.0738372	0.06651287	6	1.110119	0.3094	0.1559387	0.16
2014-2015	0.0815145	0.03962542	6	2.057127	0.0854	0.4092923	0.1
2015-2016	0.0631565	0.03508986	6	1.799849	0.1220	0.3291987	0.09

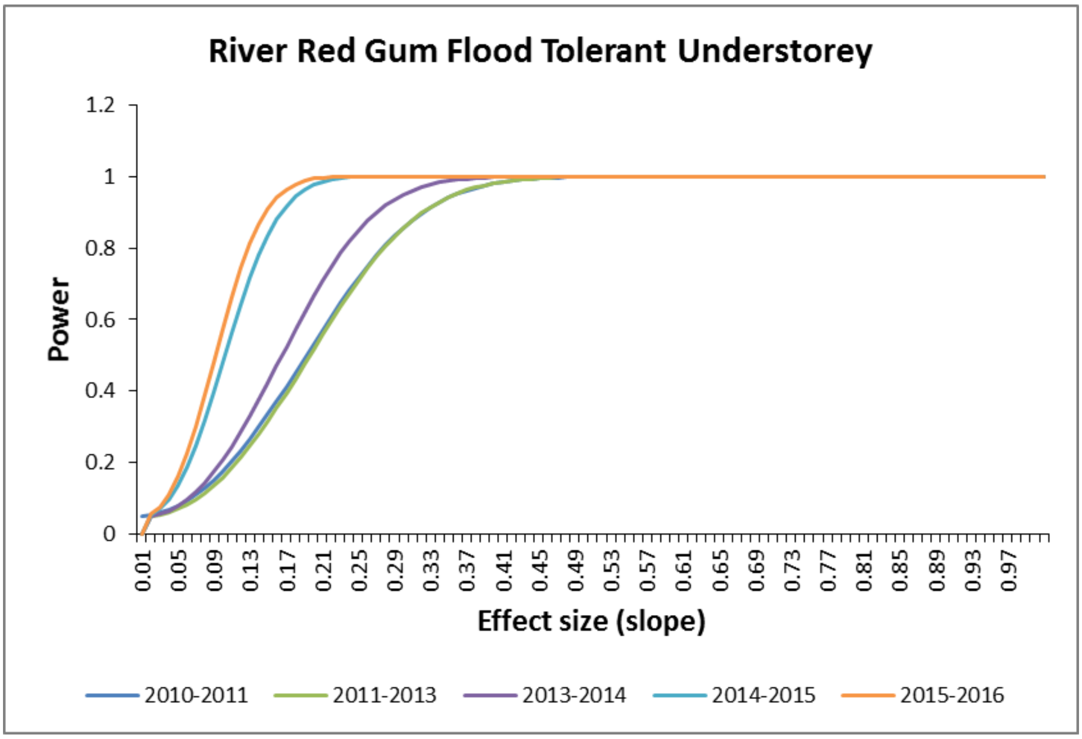

Figure 36. Power curves for year-by-year difference models using Red Gum FTU Terrestrial Species Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OES for 2010-2011 was large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years (light green row, Table 41). In this case, the confidence intervals were not close to zero and suggested that the actual population OES lay far enough from zero to be biologically significant. This result is conclusive – we are confident that there is a detectable difference between years.

OESs for 2011-2013, 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years, and in all four cases, the CIs included zero (orange rows, Table 41) so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

Table 41 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Terrestrial Species Cover Index values for Red Gum FTU

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.8800662	0.5185558	-0.362	-0.477	-0.174
2011-2013	0.5185558	0.6154267	0.097	-0.117	0.259
2013-2014	0.6154267	0.6892639	0.074	-0.121	0.275
2014-2015	0.6892639	0.7707784	0.082	-0.192	0.297
2015-2016	0.7707784	0.8339348	0.063	-0.193	0.316

Black Box Woodland

Raw Terrestrial Species Cover Index data for all Black Box sites summarised by sampling year is presented in Figure 37.

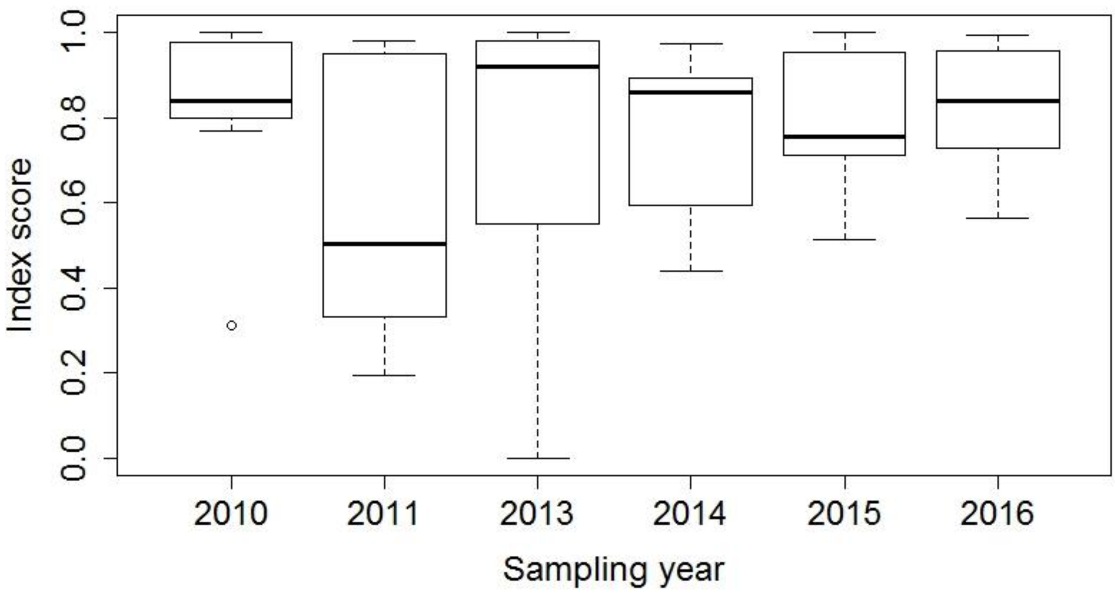

Figure 37. Boxplots of Terrestrial Species Cover Index data for Black Box showing differences in the spread of values across sampling years. The width of each box is scaled relative to the

number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model

The linear trend in Terrestrial Species Cover Index data through time for Black Box was represented by a mixed effects model with site as a random variable (Figure 38). The slope (trend) in index values over time was not significantly different from zero (Table 42). Terrestrial Species Cover in Black Box did not appear to follow a clear linear trend over time. Summarising a trend over this block of 6 years has not adequately represented the fluctuations in the dataset (Figure 37, Figure 38).

Table 42 Output from the trend model for Terrestrial Species Cover Index data for Black Box.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-27.481280	25.509552	44	-1.077294	0.2872
Year	0.014026	0.012671	44	1.106893	0.2744

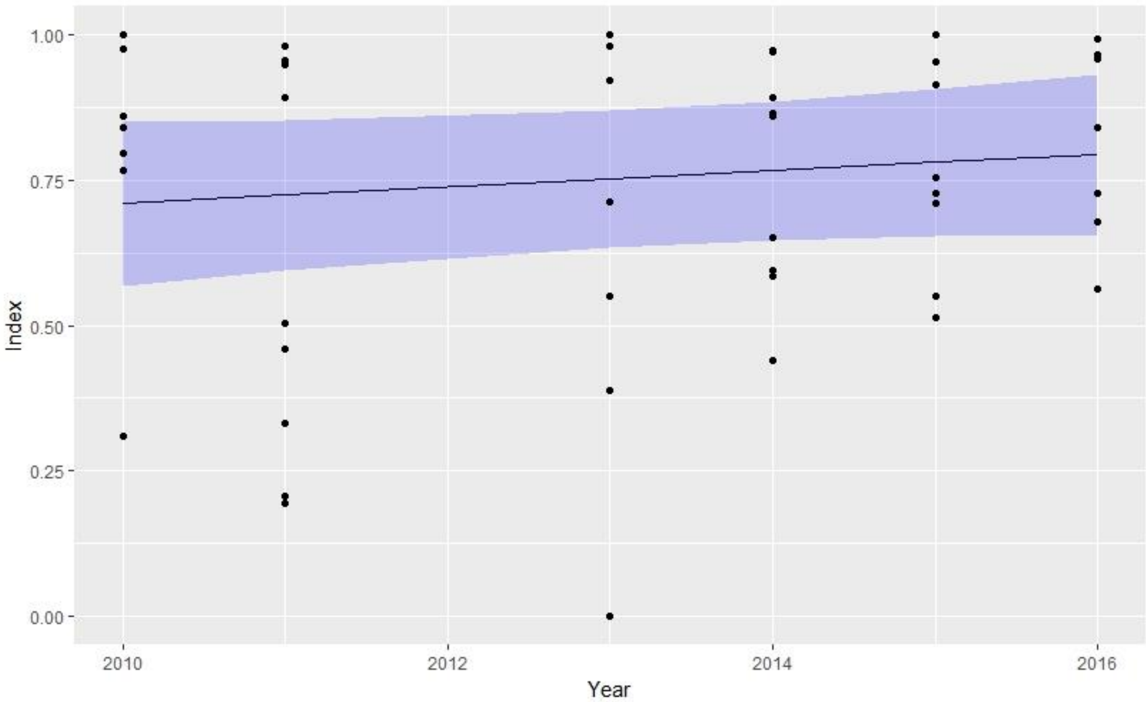

Figure 38. Plot of the fit of the linear mixed model (trend model) for Terrestrial Species Cover Index data in the Black Box WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Terrestrial Species Cover Index trend model for Black Box found that the minimum significant effect size (trend model slope) that would be significant (at $P<0.05$) was 0.026, and this value was larger in magnitude than the actual slope detected (0.014026). Therefore, the power of this test was not adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 43 and Figure 39.

Table 43 Output from the power analysis for the Terrestrial Species Cover Index trend model for Black Box.

	numDF	denDF	F-value	Power
(Intercept)	1	44	161.317777	1.0000000
Year	1	44	1.225211	0.1913816

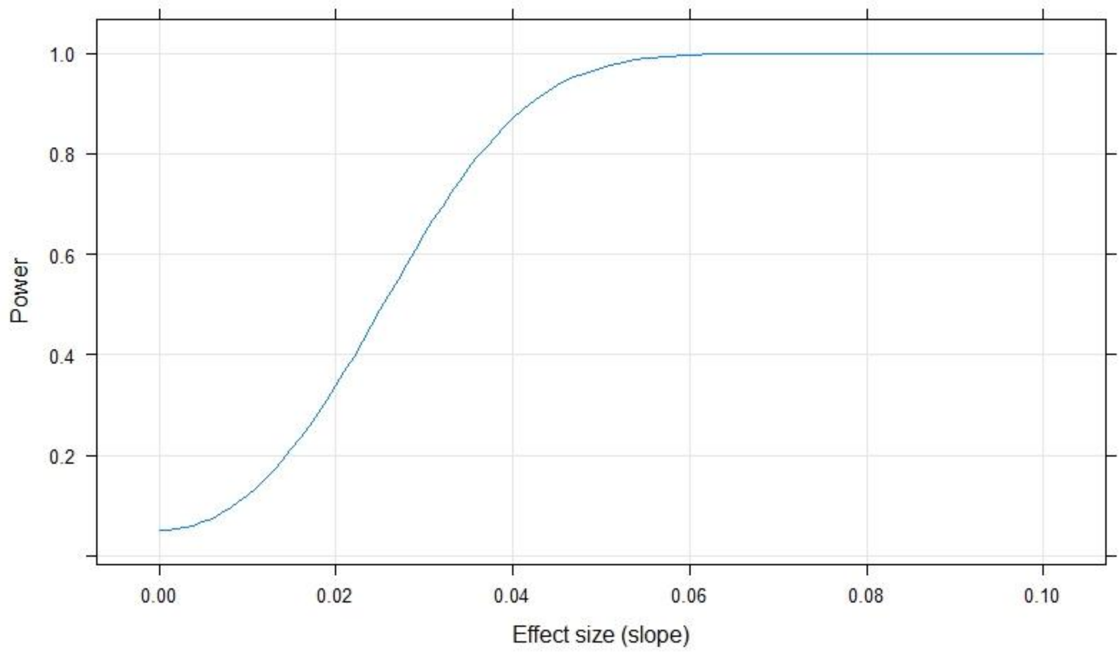

Figure 39. Power curve for the trend model using Black Box Terrestrial Species Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Black Box Terrestrial Species Cover Index data were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 40.

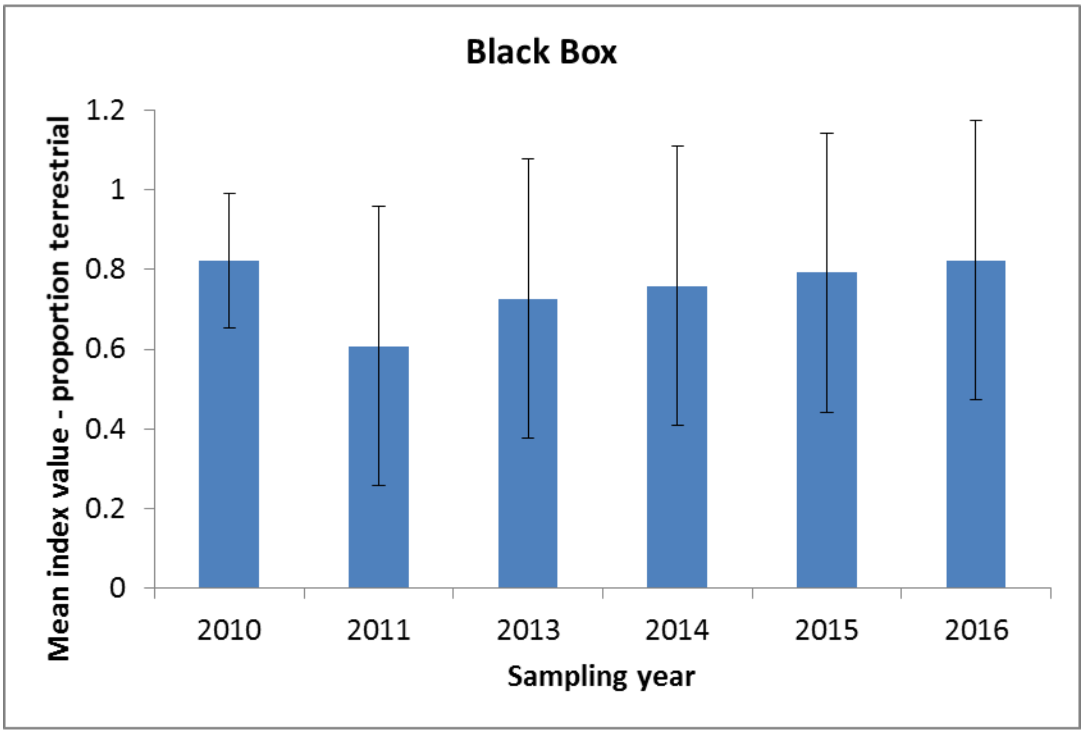

Figure 40. Plot of mean Terrestrial Species Cover Index values (and 95% confidence intervals) for Black Box by sampling year. The 95% CIs indicate the variation in index scores between

sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Terrestrial Species Cover Index year-by-year difference models for Black Box are presented in Table 44 and Figure 41. No pairs of years were significantly different from each other, and none of the corresponding tests had adequate power to detect the minimum significant effect sizes.

Table 44 Output from the year-by-year difference mixed effects models and power analyses for Terrestrial Species Cover Index data for Black Box. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	-0.2134984	0.11847265	8	-1.802090	0.1092	0.3550744	0.27
2011-2013	0.1181946	0.1080353	8	1.094037	0.3058	0.1620843	0.25
2013-2014	0.0323476	0.08748785	8	0.369738	0.7212	0.06238267	0.2
2014-2015	0.0332188	0.03201498	8	1.037603	0.3298	0.1505736	0.08
2015-2016	0.0314588	0.0408951	8	0.769255	0.4638	0.1045585	0.1

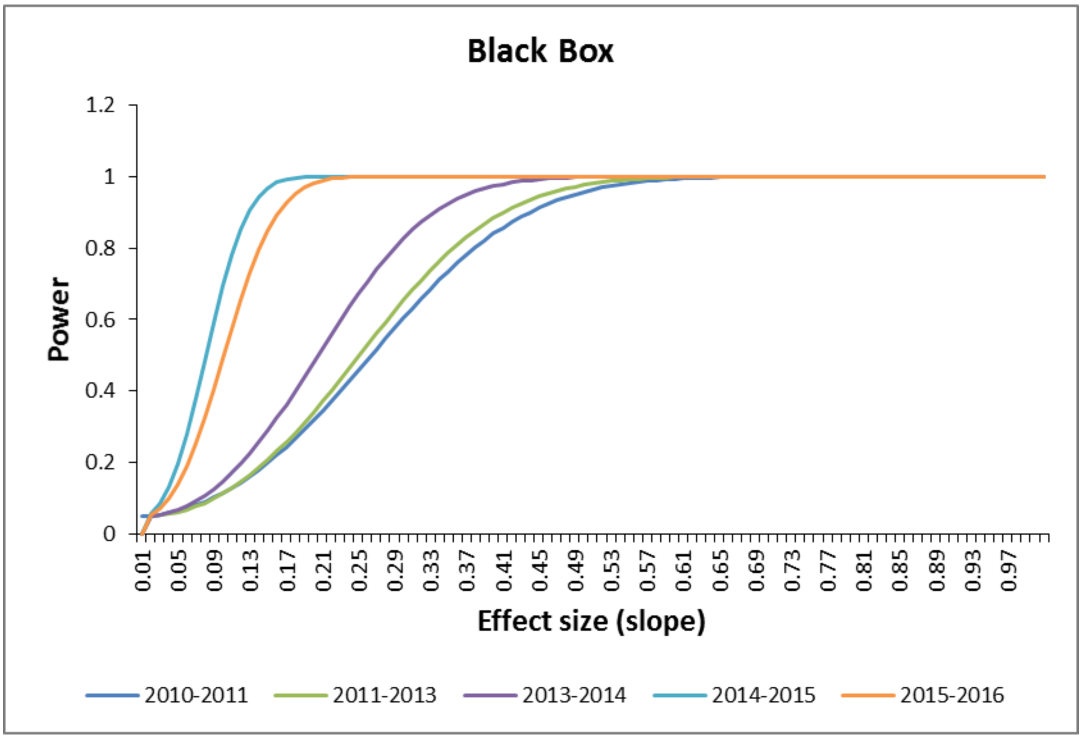

Figure 41. Power curves for year-by-year difference models using Black Box Terrestrial Species Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OESs for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years (light blue rows, Table 45). However, in both cases, the confidence intervals included zero, reducing our confidence that the actual population

OESs lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.

The OESs for 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years and the CIs included zero (orange rows, Table 45) so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

Table 45 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Terrestrial Species Cover Index values for Black Box

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.8216083	0.60811	-0.213	-0.468	0.026
2011-2013	0.60811	0.7263045	0.118	-0.210	0.386
2013-2014	0.7263045	0.7586521	0.032	-0.192	0.311
2014-2015	0.7586521	0.7918709	0.033	-0.130	0.202
2015-2016	0.7918709	0.8233297	0.031	-0.109	0.175

Grey Box Woodland

Raw Terrestrial Species Cover Index data for all Grey Box sites summarised by sampling year is presented in Figure 42.

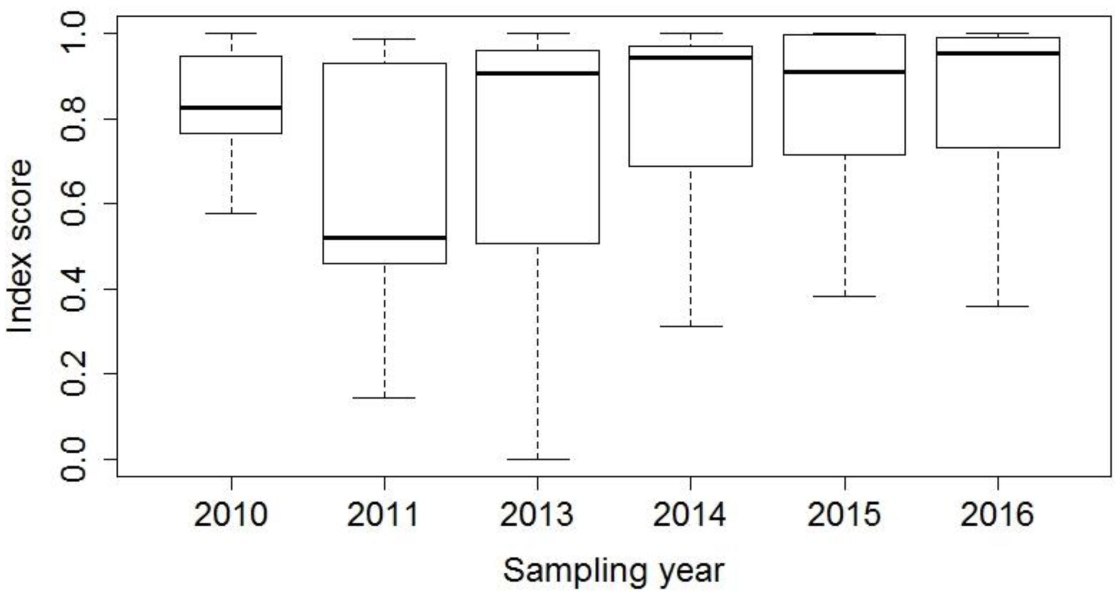

Figure 42. Boxplots of Terrestrial Species Cover Index data for Grey Box showing differences in the spread of values across sampling years. The width of each box is scaled relative to the number of samples. Note that data were not collected in 2012 so this year has been omitted from the plot.

Trend model

The linear trend in Terrestrial Species Cover Index data through time for Grey Box was represented by a mixed effects model with site as a random variable (Figure 43). The slope (trend) in index values over time was not significantly different from zero (Table 46). Terrestrial Species Cover in Grey Box did not appear to follow a linear trend over time, partly because of high variability in index values within each year. Summarising a trend over this block of 6 years has not adequately represented the fluctuations in the dataset (Figure 42, Figure 43).

Table 46. Output from the trend model for Terrestrial Species Cover Index data for Grey Box.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-42.54687	24.270676	60	-1.753015	0.0847
Year	0.02151	0.012056	60	1.784543	0.0794

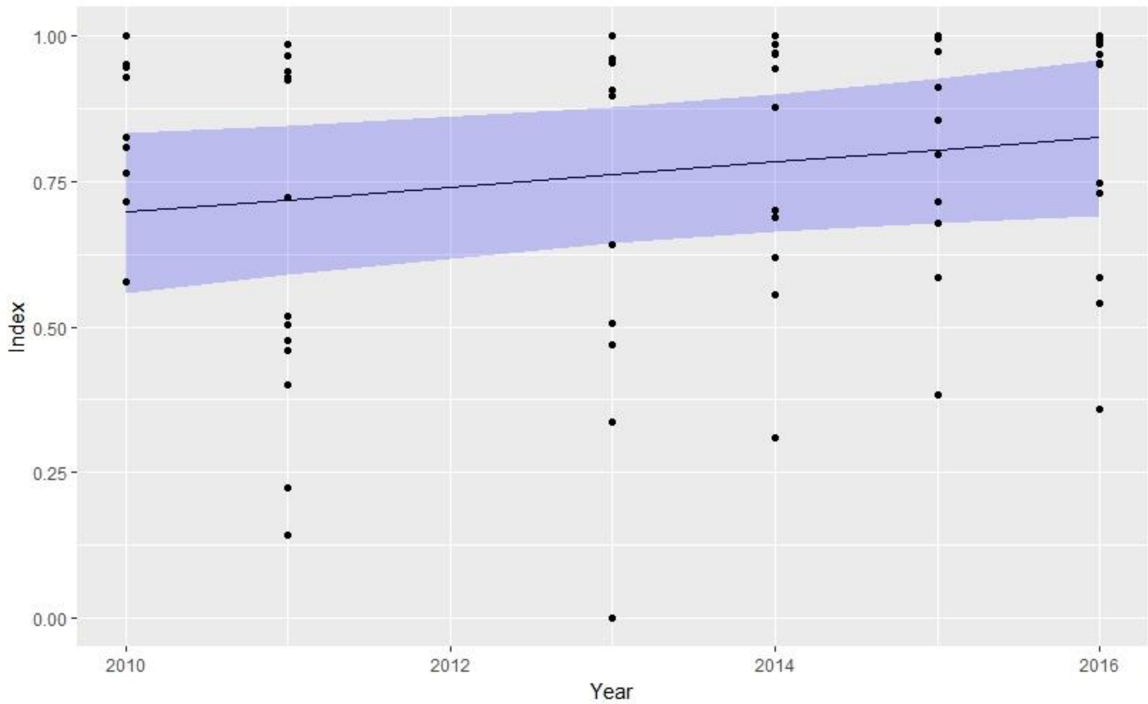

Figure 43. Plot of the fit of the linear mixed model (trend model) for Terrestrial Species Cover Index data in the Grey Box WRC. Purple shaded areas indicate the 95% confidence intervals for the trend.

A power analysis of the Terrestrial Species Cover Index trend model for Grey Box found that the minimum significant effect size (trend model slope) that would be significant (at $P<0.05$) was 0.25, and this value is larger in magnitude than the actual slope detected (0.02151). Therefore, the power of this test was not adequate to detect the actual recorded slope. Results of the power analysis are presented in Table 47 and Figure 44.

Table 47 Output from the power analysis for the Terrestrial Species Cover Index trend model for Grey Box.

	numDF	denDF	F-value	Power
(Intercept)	1	60	169.795689	1.0000000
Year	1	60	3.184592	0.4192805

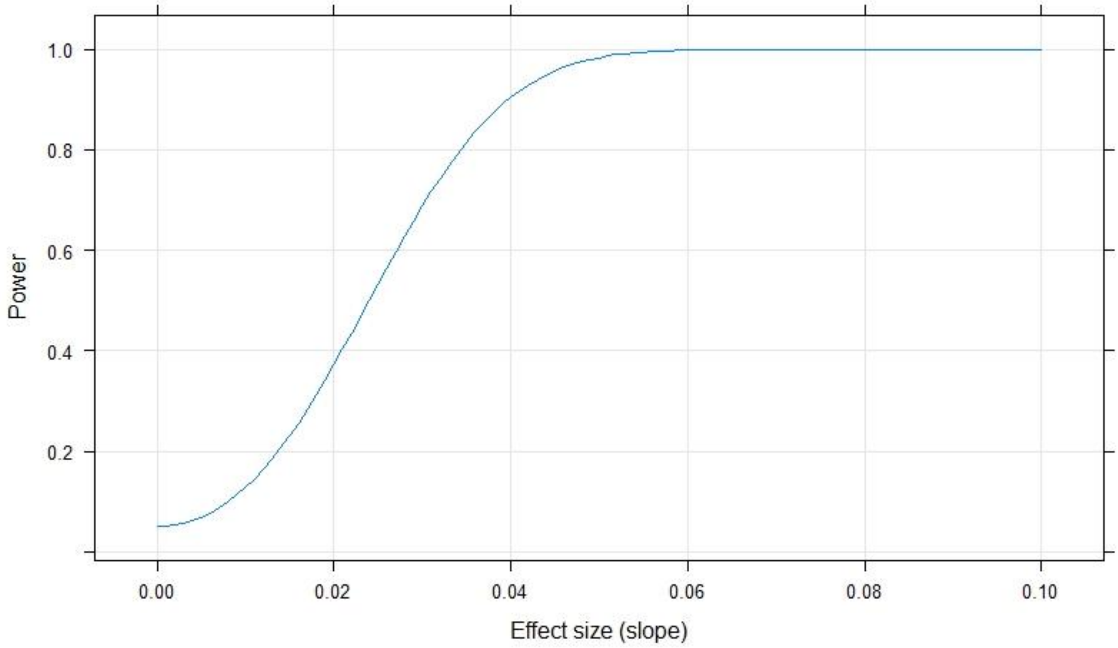

Figure 44. Power curve for the trend model using Grey Box Terrestrial Species Cover Index data and simulating effect sizes while holding other parameters from the model constant. Note that the effect size for the trend model is the slope of the fitted curve.

Year-by-year differences models

The year-by-year differences in Terrestrial Species Cover Index data were represented by a series of mixed effects models with site as a random factor. Mean index values and 95% confidence intervals are presented in Figure 45.

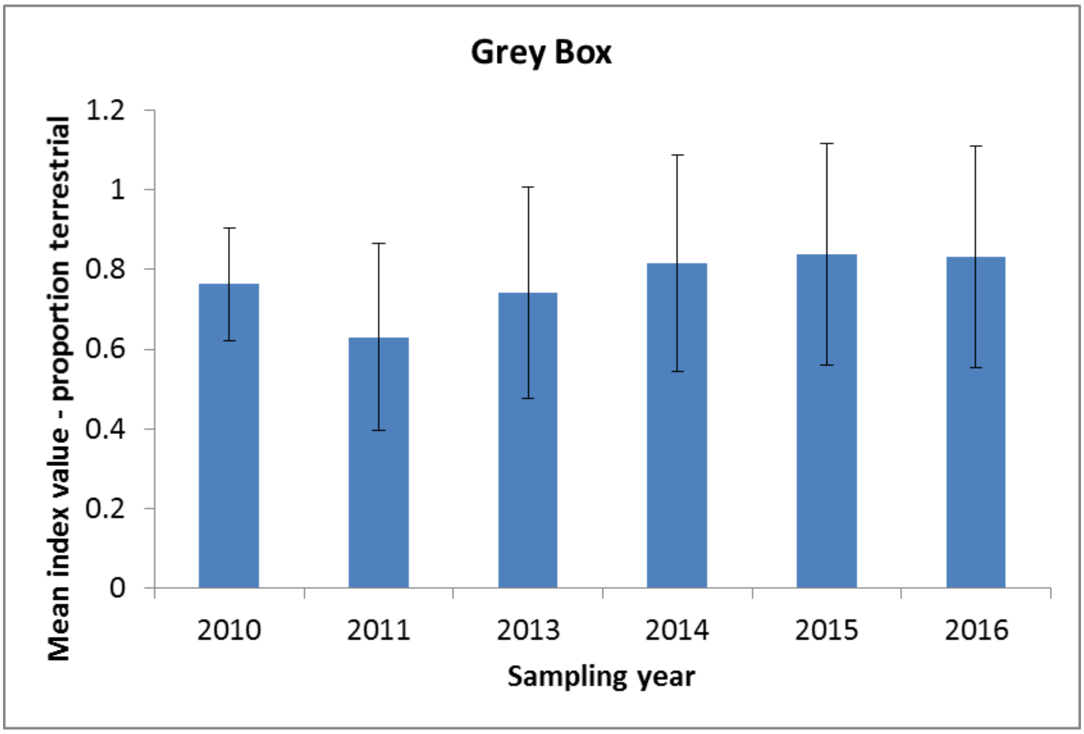

Figure 45. Plot of mean Terrestrial Species Cover Index values (and 95% confidence intervals) for Grey Box by sampling year. The 95% CIs indicate the variation in index scores between sites, but do not indicate the variation in changes between years across sites. Note that data were not collected in 2012 so this year has been omitted from the plot.

Results from the mixed effects models (comparing mean index values between subsequent sampling years) and from the corresponding power analyses (including minimum significant effect sizes) of the Terrestrial Species Cover Index year-by-year difference models for Grey Box are presented in Table 48 and Figure 46. Differences between mean index values in all pairs of years could not be detected, and these tests did not have adequate power to detect the minimum significant effect sizes.

Table 48. Output from the year-by-year difference mixed effects models and power analyses for Terrestrial Species Cover Index data for Grey Box. P-values in bold are significant at P<0.05. Bolded power and minimum significant effect size (MSES) values indicate that the power of the test was sufficient to detect the MSES.

Comparison years	Mean difference	Std.Error	DF	t-value	p-value	Power	Minimum significant effect size
2010-2011	-0.1550331	0.07505007	8	-2.06573	0.0727	0.4435529	0.17
2011-2013	0.1102058	0.05699629	12	1.933561	0.0771	0.4282121	0.13
2013-2014	0.0739310	0.04445755	12	1.662958	0.1222	0.3341201	0.1
2014-2015	0.0231098	0.01587103	12	1.456101	0.171	0.268422	0.04
2015-2016	-0.0063417	0.02179233	12	-0.291004	0.776	0.05829816	0.05

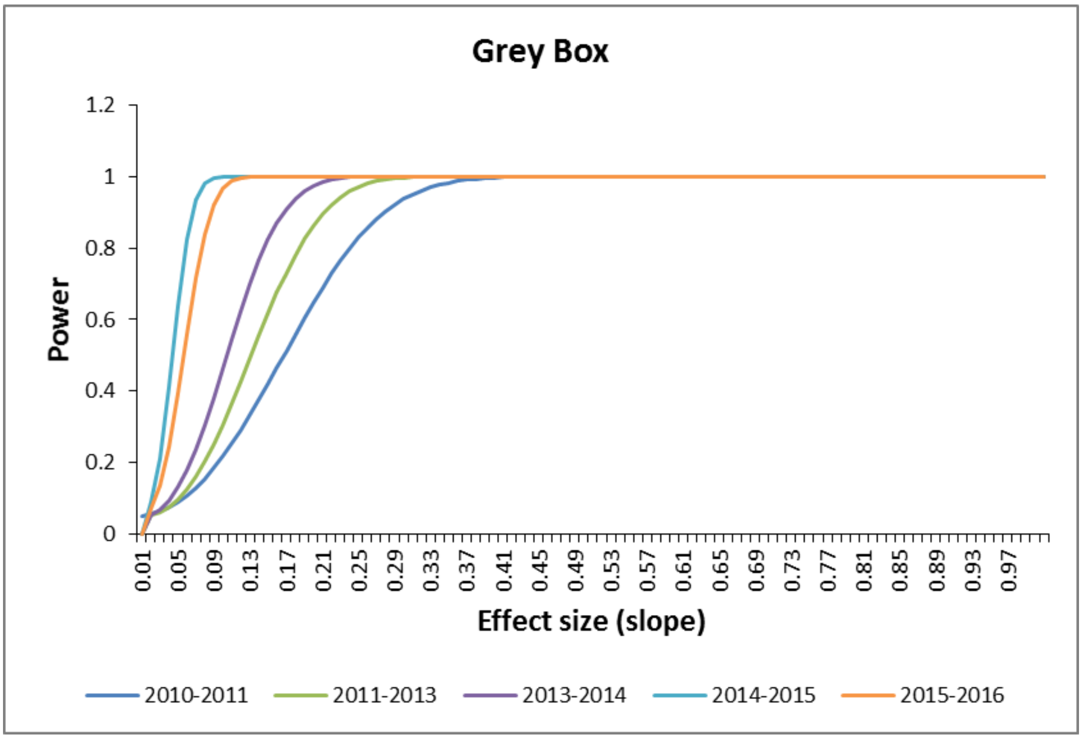

Figure 46. Power curves for year-by-year difference models using Grey Box Terrestrial Species Cover Index data. Note that effect sizes for the year-by-year models are the mean differences in the indices at sites repeated between years.

Observed Effect Size and Confidence Intervals

The OESs for 2010-2011 and 2011-2013 were large enough to represent a meaningful difference in the Terrestrial Species Cover Index between years (light blue rows, Table 49). However, in both cases, the confidence intervals were either very close to or included zero, reducing our confidence that the actual population OESs lay far enough from zero to be biologically significant. These results are inconclusive, and suggest that we might have needed larger sample sizes.

The OESs for 2013-2014, 2014-2015 and 2015-2016 were too small to represent a meaningful difference in the Terrestrial Species Cover Index between years and the CIs included zero (orange rows, Table 49) so we don't have confidence that there was a true difference from zero in these scores. The results for these years are conclusive – we are confident that there is no detectable difference between years.

Table 49 Observed Effect Sizes and 95% Confidence Intervals for year-by-year comparisons of mean Terrestrial Species Cover Index values for Grey Box

Years compared	Mean index value (first year)	Mean index value (second year)	Observed Effect Size	CI (lower)	CI (upper)
2010-2011	0.8357241	0.6304314	-0.205	-0.396	-0.036
2011-2013	0.6304314	0.7406372	0.110	-0.138	0.316
2013-2014	0.7406372	0.8145682	0.074	-0.097	0.315
2014-2015	0.8145682	0.837678	0.023	-0.127	0.174
2015-2016	0.837678	0.8313364	-0.006	-0.167	0.151

Terrestrial Species Cover Index Summary

The following table summarises the power and sensitivity results for the trend models (Table 50). Note that the results for year-by-year differences may be more informative for these data, although significant results were only found for RRG FDU and RRG FTU in the year-by-year analyses (Table 36, Table 40).

Table 50 Power and Sensitivity Summary (trend models) for the Terrestrial Species Cover Index

WRC	Range possible	Sensitivity	Power/MSES (trend model)	Summary
Dry phase wetlands	0 to 1	✓	N/A	It was not possible to run mixed models or the associated power analyses on the wetland indicators due to the highly unbalanced nature of the dataset.
Receding phase wetlands	0 to 1	✓	N/A	
Red Gum FDU	0 to 1	✓	MSES was ± 0.023. Power was 0.9837447.	Power to detect a trend in the Red Gum FDU Terrestrial Species Cover indices was **adequate**. **The trend model can be used**, although the year-by-year approach may prove more informative.
Red Gum FTU	0 to 1	✓	MSES was ± 0.029. Power was 0.1417753.	Power to detect a trend in the Red Gum FTU, Black Box and Grey Box Terrestrial Species Cover indices was **inadequate**. The trend model averaged across year-by-year fluctuations in the species cover indices, and possible trends occurring on different time scales. **Use the year-by-year approach** to detect differences in the Terrestrial Species Cover indices between years.
Black Box	0 to 1	✓	MSES was ± 0.026. Power was 0.1913816.	
Grey Box	0 to 1	✓	MSES was ± 0.025. Power was 0.4192805.	

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GHD

180 Lonsdale Street
Melbourne, Victoria 3000
T: (03) 8687 8000 F: (03) 8687 8111 E: melmail@ghd.com.au

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