Evaluation of vegetation extent and condition objectives and targets

Technical report supporting the NSW Basin Plan Matter 8 reporting 2019 to 2024

Department of Climate Change,
Energy, the Environment and Water

Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

Artist and designer Nikita Ridgeway from Aboriginal design agency Boss Lady Creative Designs created the People and Community symbol.

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Abbreviations

Term	Meaning
API	aerial photographic interpretation
BBS	Brigalow Belt South
DCCEEW	Department of Climate Change, Energy, the Environment and Water (NSW)
DPIE	Department of Planning, Industry and Environment (NSW)
DRP	Darling Riverine Plains
EWAG	environmental water advisory group
FDS	flood-dependent shrublands
FDW	flood-dependent woodland
GAMM	generalised additive mixed models
GIS	geographic information system
LTWP	long-term water plan
MDB	Murray–Darling Basin
MDB MER	Murray–Darling Basin monitoring, evaluation and reporting
ML/d	megalitres per day
NWW	non-woody wetland
PCT	plant community type
RRGF	river red gum forest
RRGW	river red gum woodland
VPP	vegetation photo pattern
WRPA	water resource planning area

Summary

The NSW Department of Climate Change, Energy, the Environment and Water manages the delivery of water for the environment in New South Wales (NSW) water resource plan areas (WRPA) of the Murray–Darling Basin (MDB), in consultation with its partners and environmental water advisory groups. Environmental water is delivered to maintain or improve the health and resilience of rivers, wetlands and adjacent floodplains. It is used to support the water requirements of a variety of animals and flood-dependent native vegetation communities that occur in some of the key wetlands of the MDB, which have, over the years, been adversely affected by river regulation.

This report evaluates how flood-dependent native vegetation communities in the Gwydir Wetlands and Macquarie Marshes of the NSW MDB are tracking against long-term water plan (LTWP) objectives. It forms part of the MDB monitoring, evaluation and reporting program (MDB MER Program). The LTWP objectives are to maintain or increase the extent, and to maintain or improve the condition/viability, of flood-dependent native vegetation communities. These include non-woody wetland (NWW) vegetation, river red gum forest (RRGF), river red gum woodland (RRGW), flood-dependent woodland (FDW, e.g. coolibah and black box), and flood-dependent shrublands (FDS, e.g. lignum and river cooba).

Long-term data (2011 to 2023) from fixed monitoring sites was used to model trends in vegetation condition (percentage cover and species richness) over time (i.e. water year, as a proxy for inundation), using a Bayesian approach. The predicted effect of estimated inundation duration (months of inundation in a water year) on vegetation percentage cover was also modelled, using data from 2017 to 2023. Where data was available, observations of flowering and fruiting for key NWW species were used to assess the maintenance of their viability.

To assess the extent of floodplain vegetation, maps were developed using aerial photographic interpretation (API) of aerial airborne digital sensor-40 imagery collected in 2022. Differences in area and vegetation types were assessed by comparing the 2022 maps to earlier vegetation maps developed using equivalent API methods at Macquarie Marshes in 2013 and the Gwydir Wetlands in 2015. Field validation surveys were undertaken in 2023 and 2024 to assess the accuracy of the preliminary 2022 vegetation maps presented in this report.

The API mapping and comparison with previous mapping found that the representation of all flood-dependent vegetation types was maintained for the Gwydir Wetlands in the period 2015 to 2022 and for the Macquarie Marshes for the period 2013 to 2022. There was also an increase in area of NWW from 2013 to 2022 at the Macquarie Marshes. Much of this increase in extent was into areas formerly mapped as terrestrial vegetation, with a smaller portion into areas of FDS.

Long-term trends suggest that vegetation condition responses were site dependent. However, there were broad trends of native species dominance over non-native species,

and native amphibious species dominance over native terrestrial species, for most vegetation communities in both the Gwydir Wetlands and Macquarie Marshes. Additionally, marsh club rush (a dominant species in the marsh-club-rush sedgeland in the Darling Riverine Plains bioregion threatened ecological community) and water couch successfully flowered and set seed in the Gwydir Wetlands between spring 2019 and autumn 2023. These observations suggest that their condition was maintained in both study areas. There was a positive relationship between cover of native amphibious species for most vegetation communities and estimated duration of inundation (number of months). This suggests that environmental flows may help meet ecological targets in core wetland areas if the required inundation durations are met.

Trends in NWWs (both study areas), RRGFs (Macquarie Marshes), and coolibah woodlands (Gwydir Wetlands), indicated that the core wetland vegetation exhibited wet and dry phases, in response to wetter and dryer stages. From this, it can be concluded that these wetlands are resilient, with an ability to regenerate after extended dry periods.

Overall, the assessment of vegetation extent and long-term condition trends suggests that LTWP objectives for flood-dependent vegetation have been met for the Gwydir Wetlands and Macquarie Marshes. Limited vegetation condition data reliability for some communities was found, along with some uncertainty in the vegetation extent mapping. However, recent wet years appear to have driven maintenance, expansion and/or improvement of extent, condition and/or viability of flood-dependent native wetland vegetation.

Ongoing investment in the NSW MDB MER Program, including the use of new and improved technologies and expansion into additional geographic areas, is needed to help better inform environmental water management decisions.

1. Introduction

The NSW Department of Climate Change, Energy, the Environment and Water (the department) delivers water for the environment in NSW water resource plan areas (WRPA) of the Murray–Darling Basin (MDB). This includes the Gwydir, Macquarie–Castlereagh, Lachlan, Murrumbidgee, NSW Murray–Lower Darling, Barwon–Darling, Intersecting Streams, Namoi and Border Rivers. The department manages a portfolio of environmental water held by the NSW Government and manages water on behalf of the Commonwealth Environmental Water Holder. This is done in consultation with representatives from other government agencies, community groups, landholders, scientists and Aboriginal organisations through environmental water advisory groups (EWAG).

Monitoring the ecological outcomes of these wetlands and other unregulated NSW wetlands (e.g. Narran Lakes) of the MDB is undertaken by the department in collaboration with partner agencies and research groups. Monitoring focuses on 4 themes: flows and connectivity, wetland vegetation, waterbirds, and other species (frogs). These themes align with expected ecological outcomes specified in the Murray–Darling Basin Authority's Basin-wide environmental watering strategy and the department's long-term water plans (LTWP) developed for each WRPA.

1.1 Flood-dependent vegetation decline

The department's long-term water plans (LTWP), which govern environmental water deliveries, have been implemented to help minimise historic declines in wetland ecosystem health across the MDB. These declines coincided largely with the start of water infrastructure development in the 1960s and 1970s. Water extraction and dam release timing have significantly altered flows at the Macquarie Marshes, resulting in a reduced area and frequency of inundation (Kingsford and Thomas 1995; Thomas et al. 2011). Additionally, there was an increase in area of terrestrial vegetation, mostly at the expense of semi-permanent non-woody wetlands (Bowen and Simpson 2010; Bino et al. 2015). Other studies have found an increase in river red gum communities at the expense of non-woody wetlands, although it is unclear if this was attributed to hydrological modification from water resource development or changing climate (Saintilan et al. 2021). The Gwydir Wetlands are understood to have been similarly affected by the development of water infrastructure as well as by historic and contemporary agricultural land-use practices (Keyte 1994; McCosker and Duggin 1993; Kingsford 2000).

1.2 Flood-dependent vegetation responses to flow regimes

Key drivers of flood-dependent vegetation community responses in the MDB include inundation duration and frequency (Thomas et al. 2010; Bino et al. 2015; Bowen 2019). While inundation frequency is relevant over longer time periods, inundation depth, duration and seasonal timing are important aspects of the annual water regimes for plants (Roberts et al. 2000). Flood-dependent vegetation communities respond to patterns of drying and wetting by exhibiting dry and wet phases, where species dominance shifts between terrestrial and aquatic or semi-aquatic species depending on the inundation regime (Figure 1). Floodplain wetland vegetation can therefore be in good condition in dry phases if the inundation regimes of the dominant species have been met but can be in poor condition in wet phases if the regime scale water requirements of the dominant species are not being met (Bowen 2019; Bowen 2020). A suitable inundation regime (frequency, duration and timing) is required to maintain wetland vegetation condition.

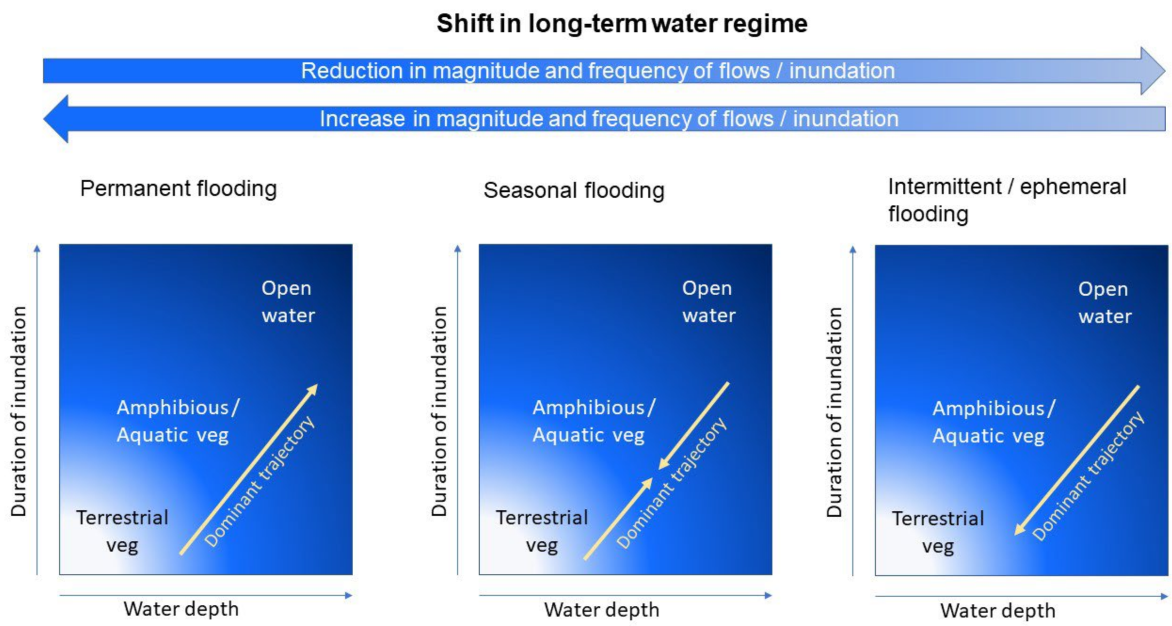

Figure 1 **Conceptual illustration of the effect of inundation regimes on inland floodplain vegetation, adapted from Sandi et al. (2015)**

1.3 Historic trends in flood-dependent vegetation responses to flow regimes

Delivery of environmental water has the potential to slow, halt or reverse longer-term declines in extent and condition of flood-dependent vegetation by establishing more natural watering regimes (Arthington et al. 2006). However, it can be challenging to understand longer-term trends in flood-dependent vegetation response to flow regimes due to the dynamic nature of the response to variable climatic conditions. For example, a recent study of river red gum and water couch communities using floristic data collected from 2014–15 to 2018–19 at the Macquarie Marshes found that these communities showed relatively healthy responses to dry and wet phases (Mason et al. 2022). However, in the same study a subset of water couch sites showed a depressed response to a flood event that occurred in 2016–17. This indicated that these sites may have remained dry for an extended period before wetter conditions returned. The study concluded that the delivery of environmental water has the potential to improve the resilience of flood-dependent vegetation communities by increasing overall flow connectivity between the river and floodplain, enabling a stronger wetland vegetation response when wet conditions return (Mason et al. 2022).

1.4 Ecological objectives for the target vegetation communities

Vegetation extent

The NSW LTWP objectives are to maintain or increase the extent of flood-dependent native vegetation communities that include non-woody wetland (NWW) vegetation, river red gum forest (RRGF), river red gum woodland (RRGW), flood-dependent woodland (FDW), and flood-dependent shrublands (FDS).

The extent of floodplain wetland vegetation communities can be difficult to assess and evaluate as it is expected healthy wetlands will expand and contract in response to patterns of wetting and drying. Assessment of floodplain wetland therefore needs to consider shorter-term fluctuations that are likely healthy responses as opposed to longer-term trends. The overall aim is to investigate and identify any longer-term losses in the extent of wetland vegetation that cannot be explained by shorter-term seasonal cycles of expansion and contraction.

Vegetation condition

The pattern of wetting and drying is an important factor influencing the composition and structure of riparian, wetland, and floodplain vegetation communities (Reid and Capon 2011; Roberts and Marston 2011). Therefore, NSW LTWPs allocate vegetation communities to hydro-ecological functional groups based on community structure and degree of flood-dependence (DPE, 2023c). The LTWP objectives relating to condition of flow-dependent native vegetation communities are to maintain the viability (successful growth, flower and seed set) of NWW vegetation and maintain or improve the condition of woody vegetation. The objectives and targets for the Gwydir Wetlands and Macquarie Marshes incorporate the following flood-dependent native vegetation communities:

- NWW vegetation
- RRGF (only in Macquarie Marshes as there are no LTWP objectives for this community in the Gwydir Wetlands)
- RRGW (only in Macquarie Marshes as there are no monitoring sites in the Gwydir Wetlands due to absence of this community in the accessible areas)
- FDW (black box and coolibah woodlands)
- FDS (lignum and river cooba).

Communities of NWW vegetation occurring in channels and RRG communities closely fringing river channels, are not reported on as no monitoring sites exist for these communities under this program.

Although not specifically included in the LTWPs, river cooba frequently co-occurs with lignum and is therefore monitored as a mixed lignum–river cooba shrubland community in this report.

Non-woody wetland vegetation

NWW vegetation includes various sedgeland, reedland, marsh and grassland wetland vegetation types that tend to occupy low-lying depressions and lower elevations on the floodplain. However, some occur in, or on the edges of, channels and waterbodies. Common characteristic species include *Juncus* spp., marsh club-rush (*Bolboschoenus fluviatilis*), water couch (*Paspalum distichum*), cumbungi (*Typha* spp.) and common reed (*Phragmites australis*). These communities are associated with alluvial clays, silts and loams, and require frequent inundation and regular wetting and drying cycles (DPE 2023e). The required inundation frequency (average recurrence interval) is estimated to be one in 1 to 2 years (DPE 2023e).

Threats to NWW communities include changes to flooding regimes (e.g. less frequent flooding), drainage of natural habitats, clearing and invasion by weeds – for example, lippia (*Phyla canescens* in PCT 53 [BioNet 2023]).

The following NWW communities were evaluated as part of this study:

- PCT 53: shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains
- PCT 204: water couch marsh grassland wetland of frequently flooded inland watercourses
- PCT 205: marsh-club-rush wetland – very tall sedgeland of inland watercourses, mainly Darling Riverine Plains Bioregion
- PCT 181: common reed – bushy groundsel aquatic tall reedland grassland wetland of inland river systems
- PCT 182: cumbungi rushland wetland of shallow semi-permanent water bodies and inland watercourses.

The extent of these PCTs has declined in NSW with more than 60% cleared (estimate from PCT descriptions [BioNet 2024]). PCT 205 encompasses the critically endangered ecological community marsh-club-rush sedgeland in the Darling Riverine Plains bioregion (NSW Environment and Heritage 2011).

Ecological objectives and targets for NWW vegetation communities are described in Table 1. Changes in vegetation cover and species richness over time have been reported as proxies for vegetation condition for this study. Data on flowering and seed set have only been reported for the Gwydir Wetlands as this data has not been collected consistently at Macquarie Marshes.

Table 1 **LTWP ecological objective and targets for NWW vegetation in the Gwydir Wetlands and Macquarie Marshes**

LTWP ecological objective	Ecological targets
NV2 – maintain or increase the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains.[1]	Over a 5-year rolling period, water couch and marsh club-rush to flower and set seed at least 2 in 5 years. Maintain the total area of NWW vegetation communities occurring within actively managed wetlands and floodplains (Gwydir Wetlands) or 2017 DPIE[2] amalgamated mapped extent (Macquarie Marshes).

1 'maintain or increase extent and maintain viability' (Gwydir Wetlands); 'maintain or increase extent and viability' (Macquarie Marshes).
2 DPIE = NSW Department of Planning, Industry and Environment.

Woody wetland vegetation

River red gum forests

RRGF are vegetation communities dominated by *Eucalyptus camaldulensis* on rivers and floodplains.

The following RRGF community was evaluated as part of this study:

- PCT 36: river red gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains bioregion.

The floristic composition of this PCT varies and is dependent on flooding regimes. It occurs in riparian zones, ox-bow lakes, cowals, on floodplains of major rivers and creeks, on cracking grey clays, loamy clays and sometimes sandy loam (BioNet 2024). RRGF are dependent on inundation, but do not need to be permanently flooded. The required inundation frequency is estimated to be one in one to three years (DPE 2023e).

Threats to this vegetation community include alterations to water regime, trampling by stock, weed invasion and clearing/fragmentation. Consequently, the extent of PCT 36 has declined in NSW, with over 50% cleared (estimate from PCT descriptions [BioNet 2024]).

The ecological objective and targets for RRGF communities are described in Table 2. Vegetation condition objectives are only reported for Macquarie Marshes, as there are no RRGF objectives in the LTWP for the Gwydir Wetlands.

Table 2 LTWP ecological objective and targets for RRGF vegetation in Macquarie Marshes

LTWP objective	Ecological targets
NV4a – maintain or increase the extent and maintain or improve the condition of RRGF on floodplains.[1]	Maintain the mapped extent[2] of RRGF communities. Over a five-year rolling period: • maintain the proportion of RRGF in moderate or good condition • no further decline in the condition of RRGF in poor or degraded condition.

1 NV4a objective only relates to the Macquarie–Castlereagh LTWP, not the Gwydir Wetlands.
2 2016 mapped extent (Gwydir Wetlands); 2017 DPIE amalgamated mapped extent (Macquarie Marshes).

River red gum woodland

RRGW vegetation is often found away from watercourses on grey cracking clays or black soils (BioNet 2024) and requires regular inundation (one in 2 to 4 years).

The following RRGW community was evaluated as part of this study:

- PCT 454: river red gum grassy chenopod open tall woodland (wetland) on floodplain clay soil of the Darling Riverine Plains Bioregion and western Brigalow Belt South Bioregion.

Threats to this PCT include clearing, grazing, weed invasion and reduced flooding. Their extent has declined drastically in NSW, with over 80% cleared (estimate from PCT descriptions [BioNet 2024]).

The ecological objective and targets for RRGW communities are shown in Table 3. Vegetation condition objectives are only reported for Macquarie Marshes as RRGW monitoring plots have not been established in the Gwydir Wetlands due to this community not being present in accessible areas.

Table 3 **LTWP ecological objective and targets for RRGW vegetation in Macquarie Marshes**

LTWP objective	Ecological targets
NV4b — maintain or increase the extent and maintain or improve the condition[1] of RRGW communities on floodplains.	Maintain the extent[2] of RRGW communities. Over a 5-year rolling period: • maintain the proportion of RRGW communities in moderate or good condition • no further decline in the condition of RRGW communities that are in poor or degraded condition. Maintain or improve the age class structure of RRGW communities at selected sites.

1 Condition is not targeted in the Gwydir Wetlands.
2 2016 mapped extent in the Gwydir Wetlands, 2017 DPIE amalgamated mapped extent in Macquarie Marshes.

Coolibah and black box flood-dependent woodlands

FDWs evaluated as part of this study were dominated by coolibah (*Eucalyptus coolabah*) and black box (*E. largiflorens*). These included:

- PCT 37: black box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion
- PCT 39: coolibah – River Cooba – lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion
- PCT 40: coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains.

The watering requirement for coolibah and black box is dependent on their community type and position on the floodplain. These requirements can vary from frequent to occasional inundation. The required inundation frequency for coolibah woodland is estimated to be one in 10 years. The required inundation frequency for black box woodland is estimated to be one in 3 to 7 years to one in 5 to 10 years (DPE 2023e).

Black box woodland occurs on floodplains near watercourses, ox-bow lakes and drainage depressions. Coolibah woodland occurs on alluvial plains and floodplains, although coolibah PCT 40 occurs on higher floodplains. Both black box and coolibah are associated with alluvial clay soils. Black box may also occur on red and brown loams (BioNet 2024).

Threats to these vegetation communities include clearing, altered water regimes, grazing, and weed invasion. Their extent has been greatly reduced in NSW, with more than 60% cleared (estimate from PCT descriptions [Bionet 2024]). All 3 PCTs are included in the NSW and Commonwealth listed endangered ecological community *Coolibah-Black Box Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga Lands Bioregions* (NSW Environment and Heritage 2012).

The ecological objective and targets for coolibah and black box woodlands are shown in Table 4.

Table 4 **LTWP ecological objective and targets for coolibah and black box woodland communities in the Gwydir Wetlands and Macquarie Marshes**

LTWP objective	Ecological targets
NV4c, d, f – maintain or increase the extent and maintain or improve the condition of black box and coolibah woodland communities on floodplains.	Maintain the extent of black box and coolibah woodland communities. Over a 5-year rolling period: • maintain the proportion of black box and coolibah woodland communities in moderate or good condition • no further decline in the condition of black box and coolibah woodland communities that are in poor or degraded condition • increase the abundance of woodland seedlings and saplings in degraded communities on the actively managed floodplains of the Gwydir Wetlands. Maintain or improve the age class structure of black box and coolibah communities at selected sites in Macquarie Marshes.

River cooba and lignum flood-dependent shrubland

FDSs evaluated as part of this study are dominated by river cooba (*Acacia stenophylla*) and lignum (*Duma florulenta*). These included:

- PCT 241: river cooba swamp wetland on the floodplains of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion
- PCT 247: lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion.

These shrublands occur in floodplain depressions and on alluvial loams and clays. Their watering requirements vary and are dependent on the dominant species of the community, plant sizes and their position on the floodplain. They require an inundation frequency of between one in 1 to 3 years to one in 7 to 10 years, as identified in the LTWPs (DPE, 2023e). River cooba and lignum can tolerate longer dry periods. However, a suitable inundation regime needs to be met to support their maintenance and regeneration (Roberts and Marston 2011).

Threats to these vegetation communities include land clearing and reduced flooding. The extent of the river cooba and lignum PCTs have greatly reduced in NSW, with more than 60% cleared (estimate from PCT descriptions [BioNet 2024]).

The ecological objectives and targets for FDS communities are shown in Table 5. In the Gwydir Wetlands and Macquarie Marshes, lignum co-occurs with river cooba and, in most instances, is the dominant species. Therefore, the data from lignum and river cooba plots were combined to assess these PCTs together.

Table 5 Flood-dependent shrubland objectives and targets in the Gwydir Wetlands and Macquarie Marshes

LTWP objective	Ecological targets
NV4e – maintain the extent and maintain or improve the condition of lignum shrubland communities on floodplains.	Maintain the extent of lignum shrubland communities.[1] Over a 5-year rolling period: • increase the proportion of lignum shrubland communities in moderate or good condition on the actively managed floodplain (maintain proportion on remaining floodplain)[2] • no further decline in the condition of lignum shrubland communities that are in poor or degraded condition.[2]

1 2016 mapped extent in the Gwydir Wetlands, 2017 DPIE amalgamated mapped extent in Macquarie Marshes.

2 Applicable to Macquarie Marshes only as condition targets have not been set for lignum shrublands of the Gwydir Wetlands.

1.5 Climate and hydrology over reporting period

The long-term vegetation condition data encompasses water years with more than 6 months of below (dry) and above average (wet) rainfall deciles (BOM, 2023). These drier and wetter phases are reflected by cumulative daily river flow volumes of below or above median, respectively, for both the Gwydir Wetlands and Macquarie Marshes (Figure 2). The first 2 wet years (2011–12 and 2012–13) were followed by a 3-year dry phase (2013–14 to 2015–16), one wet year (2016–17), another 3-year dry period (2017–18 to 2019–20) and most recently, a 3-year wet phase (2016–17 to 2022–23).

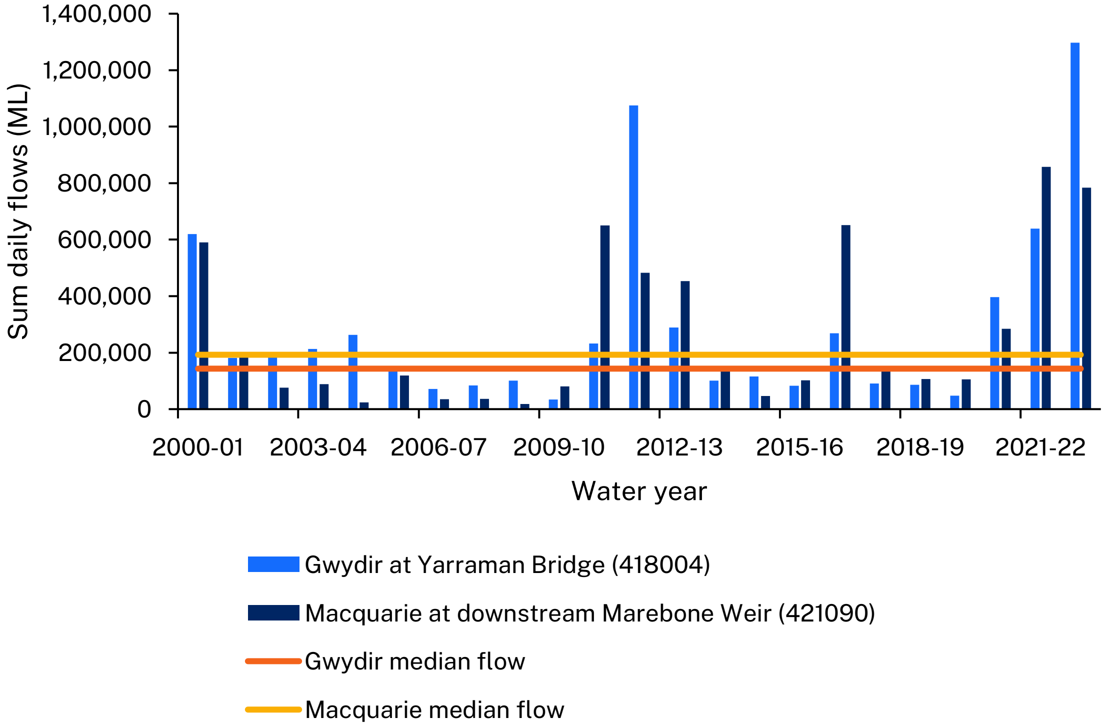

Figure 2 **Flow data downstream of Yarraman Bridge and Marebone Weir at the Gwydir Wetlands and Macquarie Marshes (BOM 2024)**

2. Methods

2.1 Wetlands monitored

Gwydir Wetlands

The Gwydir Wetlands are a complex floodplain wetland system located in the Gwydir River catchment, approximately 60 km north-west of Moree in northern NSW. The Gwydir Wetlands are inundated by major watercourses that make up the Gwydir River delta: the Gingham Watercourse, lower Gwydir Watercourse and the Mehi River–Mallowa Creek–Moomin Creek System.

The Gwydir Wetlands are listed under international migratory bird treaties. They are also recognised for their unique assemblages of wetland and floodplain plant communities. These plant communities include the endangered marsh club-rush (*Bolboschoenus fluviatilis*) sedgeland community, and coolibah (*Eucalyptus coolabah*) and black box (*Eucalyptus largiflorens*) woodland communities.

The Gwydir Wetlands State Conservation Area covers 7,400 ha. It is managed by NSW National Parks and Wildlife Service (NPWS) as part of the NSW National Park Estate. The Gwydir Wetlands also include 4 privately owned areas listed as wetlands of international importance under the Ramsar Convention in 1999 (Bowen et al. 2019a). The Ramsar site covers 823 ha and comprises 2 areas in the Gwydir Wetlands State Conservation Area, namely Old Dromana on the lower Gwydir, and Goddard's Lease on the Gingham Watercourse, and 2 further areas on the Gingham Watercourse, namely Crinolyn and Windella (Figure 3).

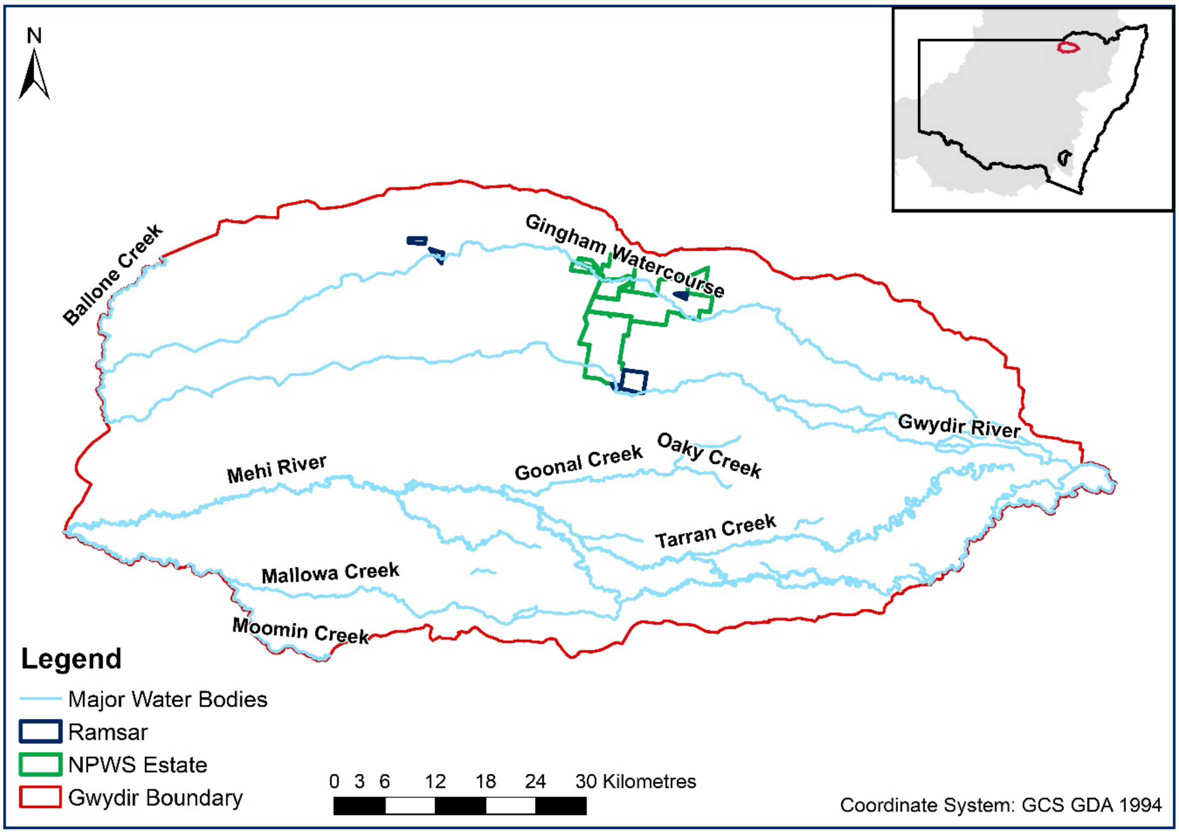

Figure 3 **Map of the Gwydir Wetlands showing major watercourses, the location of 4 Ramsar sites and areas managed by NPWS. Top right inset shows the location of the Gwydir Wetlands in relation to the MDB (shaded grey) and NSW state boundaries (black lines)**

Macquarie Marshes

Macquarie Marshes is a complex floodplain wetland system of approximately 200,000 ha (Kingsford and Thomas 1995) occurring in the lower floodplain of the Macquarie catchment, approximately 60 km north of Warren in central western NSW (Figure 4).

Macquarie Marshes is recognised nationally and internationally for its importance as waterbird habitat. At least 76 waterbird species are recorded as using the wetlands, of which 44 species use it as breeding habitat (Kingsford and Auld 2005). Macquarie Marshes is also known for its unique assemblages of wetland and floodplain plant communities. These include RRGF, RRGW and FDW communities.

Macquarie Marshes Ramsar site covers 19,850 ha (Bowen et al. 2017). It comprises Macquarie Marshes Nature Reserve (19,078 ha), and parts of the Wilgara Wetland (583 ha) and The Mole (189 ha) (Figure 4). Macquarie Marshes are also listed in the Directory of Important Wetlands (Environment Australia, 2001; Anon, 2017). Macquarie Marshes Nature Reserve is managed by the NSW NPWS as part of the NSW National Park Estate.

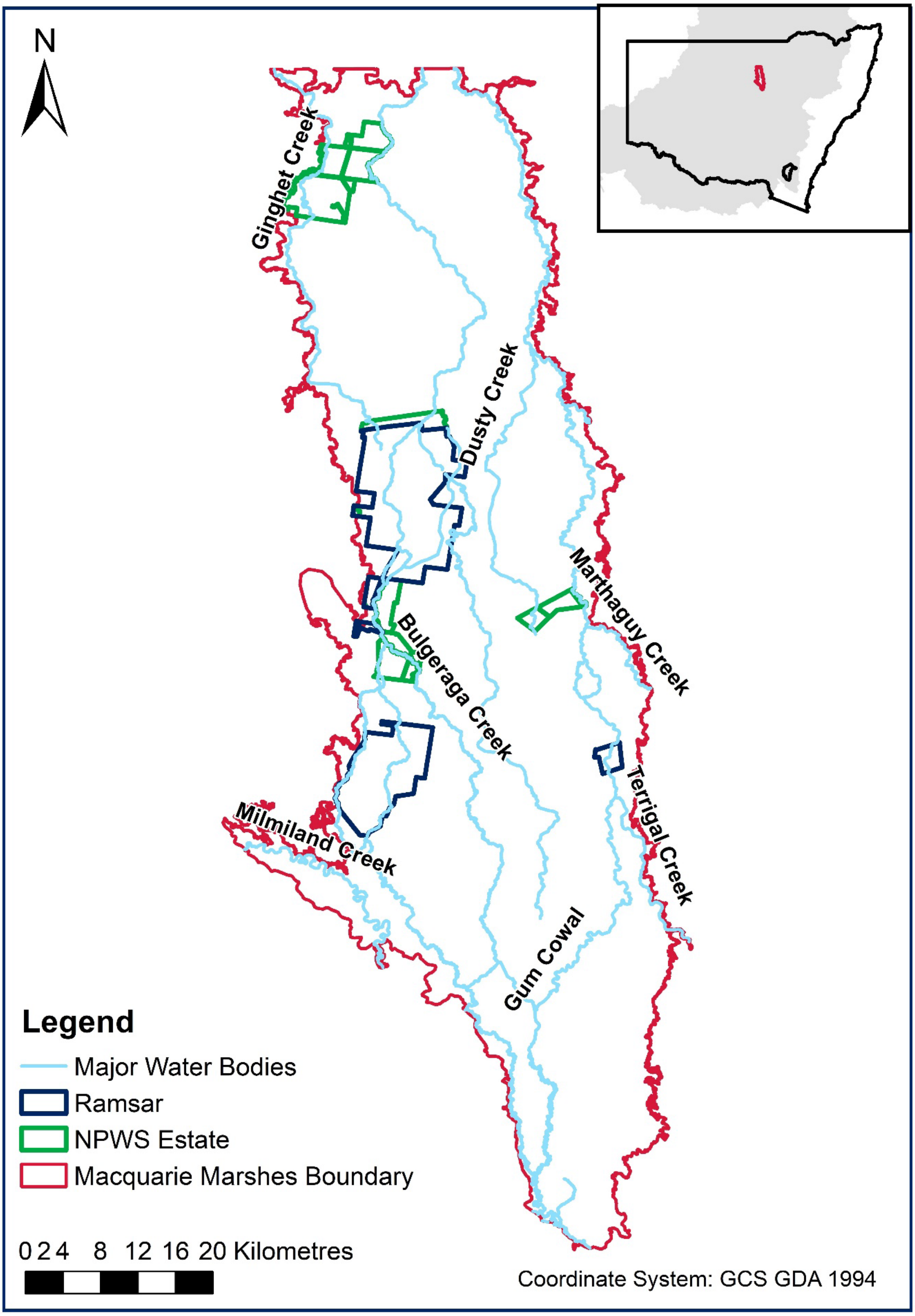

Figure 4 **Map of Macquarie Marshes showing major watercourses, the location of Ramsar sites and areas managed by NPWS. Top right inset shows the location of Macquarie Marshes in relation to the MDB (grey shaded areas) and NSW state boundaries (black lines)**

2.2 Data collection

Vegetation extent

Map development

A summary of the steps taken to develop vegetation maps is provided below. Additional details on these methods and data sources are provided at Appendix A.

To develop the 2022 maps:

- a look-up table to describe the relationship between vegetation functional groups, plant community types and vegetation LTWP targets was developed (Appendix A).
- high resolution airborne digital sensor 40 (ADS-40) imagery collected in June 2022 (Macquarie Marshes), August 2022 and January 2023 (Gwydir wetlands) was sourced for air photo interpretation.
- existing field datasets, oblique aerial images, and spatial layers depicting environmental layers (soils, inundation, elevation) were collated to inform air photo interpretation.
- a spatial layer of small polygons derived from machine-learning and delineating vegetation patches was sourced to overlay on the high-resolution ADS-40 imagery.
- all datasets were imported to ESRI ArcMap 10.8 for analysis and interpretation.
- mapping by air photo interpretation was undertaken by visually interpreting the vegetation patterns observed from the ADS-40 imagery, oblique imagery, field survey data points, and environmental layers.
- polygons from the segmentation layer were manually selected on screen and allocated to a vegetation functional class and plant community type to produce the final map layers.

Map validation field surveys

Field validation datasets were developed to assess map accuracy at the Gwydir Wetlands and Macquarie Marshes study areas.

Gwydir Wetlands

The study area for the Gwydir Wetlands was stratified using 3 sampling units:

1. vegetation class – 9 vegetation classes mapped in 2015 (Bowen et al. 2019a)
2. inundation frequency modelled from Landsat data
3. soil landscapes (OEH 2015).

A random stratified approach was used to generate a set of potential survey points in accessible areas. These included national parks, Crown land, and roadside areas. A total of 445 points were surveyed in June and July 2023. The species name and percentage cover of the 5 most dominant species in each stratum within a 20 x 20 m plot were recorded. Environmental attributes such as landscape position and soil characteristics were also recorded.

To supplement this data and to improve field data coverage across the Gwydir Wetlands, equivalent vegetation survey data was sourced from other projects. This data consisted of 220 survey points provided by Alluvium Group (Ecofutures), and 126 survey points provided by 2rog Consulting. Therefore, a total of 780 survey points were included for assessment of the Gwydir Wetlands map.

Macquarie Marshes

The study area for Macquarie Marshes was stratified using 2 sampling units:

1. vegetation class – 14 vegetation classes mapped in 2013 (Bowen et al. 2019b)
2. inundation frequency modelled from Landsat data (Heath et al. in prep).

Soil landscape mapping at the level of detail required for stratification was not available for Macquarie Marshes. A random stratified approach was used to generate a set of potential survey points within accessible areas. In November 2023 a total of 505 points were surveyed. The species name and percentage cover of the 5 most dominant species in each stratum within a 20 x 20 m plot was recorded. Environmental attributes such as landscape position and soil characteristics were also recorded.

Determining the plant community type for each field survey data point

Data was prepared for application to the map accuracy assessment process. Plant community types (PCT) were determined for all points surveyed at the Gwydir Wetlands and Macquarie Marshes using BioNet's NSW vegetation classification master list of PCTs (DPE 2022). The assignment of PCTs was based on the dominant species present and the landscape position recorded in the field. Once a PCT was assigned to each survey point, the functional group for each point was also determined using the look-up table at Appendix A.

Vegetation condition

Survey sites and timing

Native vegetation condition monitoring began in 2011 in the Gwydir Wetlands and 2008 in Macquarie Marshes. The monitoring program involved conducting floristic surveys at 52 fixed sites in the Gwydir Wetlands and 80 fixed sites in Macquarie Marshes (Table 6; Appendix B [Figure 37 and Figure 38]). Surveys took place twice a year (spring and autumn) in the Gwydir Wetlands and once a year (autumn) in Macquarie Marshes. However, not all sites were surveyed during all water years due to inaccessibility of some sites during extremely wet years (Appendix C). This study analysed results from the period during which continuous survey data were available for both the Gwydir Wetlands and Macquarie Marshes (from the 2010–11 water year onward).

Table 6 **Number of monitoring plots[1] assessed for vegetation condition trends in the Gwydir Wetlands and Macquarie Marshes and corresponding LTWP objectives**

Vegetation community	No. of plots in Gwydir Wetlands	No. of plots in Macquarie Marshes	Corresponding LTWP objective
NWW	29	33	Maintain the viability (and condition) of NWW vegetation communities occurring in wetlands and on floodplains
RRGF	0[2]	29	Maintain or improve the condition of RRGF communities on floodplains
RRGW	0	6	Maintain or improve the condition of RRGW communities on floodplains
Coolibah and black box woodlands	16	5	Maintain or improve the condition of coolibah and black box woodland communities on floodplains
FDS	7	7	Maintain or improve the condition of native shrubland communities on floodplains
Total plots	**52**	**80**	–

1 Plots included in analyses are those with at least 3 years of data collected from 2011 onwards.
2 There are no RRGF objectives in the LTWP for the Gwydir Wetlands, therefore no monitoring plots were established.

Survey method

Vegetation condition field surveys involved recording bare ground cover and floristic data (species name and percentage cover) at each site (Bowen 2016), which included:

- 20 x 20 m quadrats in non-woody and shrubland communities
- 20 x 50 m quadrats in forest and woodland communities, with nested 20 x 20 m quadrats for floristic data
- 50 m transects for impenetrable stands such as 2 marsh club-rush (*Bolboschoenus fluviatilis*) dominated sites in the Gwydir Wetlands and 6 lignum (*Duma florulenta*) dominated sites in Macquarie Marshes.

The point intercept method, which involves lowering a pole vertically to the ground at one metre intervals along the transect, was used to record the plant species or bare ground contacted by the pole. Percentage cover was calculated by dividing the number of times a species or bare ground was recorded along the transect by 50 (the total number of survey points along each transect) and multiplying by 100. During the study period, a mixture of transect and quadrat surveys were completed at one of the FDS sites, 2 RRGF sites and 2 NWW sites in Macquarie Marshes. The survey method was switched from quadrat to transect when the herbaceous layer was dominated by thick stands of cumbungi that made it difficult for the observers to traverse the site. Transect sites were treated as analogous to quadrat sites (Bowen 2016) and species richness and cover estimates from these 2 methods were pooled for analysis. This variation in methodology was considered in the data reliability assessment for NWW, RRGF and FDS.

Inundation duration

A series of inundation maps produced from cloud-free Landsat and Sentinel 2 imagery was used to count the number of months in a water year leading up to the autumn survey when a site was inundated (Thomas et al. 2015). Maps from 2016–17 to 2022–23 water years were used as this period has the most complete set of inundation data and covers climatically dry and wet periods. The derived inundation-duration data was used as a predictor in fitting models to vegetation cover.

2.3 Data analysis

Vegetation extent

Map accuracy assessment

Map accuracy was assessed by measuring agreement between the field data and the mapped values. A bootstrapping technique was used to calculate overall accuracies, kappa statistics and confidence intervals (Stehman and Czaplewski 1998; Weber and Langille 2007). Confusion matrices were also generated to assist in understanding sources of error and confusion between vegetation classes. All analyses were undertaken in R Studio 2022.02.0 with the Caret package (Kuhn 2008). For all analyses it was assumed that the collected field data was the ‘correct’ or ‘reference’ dataset and the mapped dataset was the ‘predicted’ value.

Map comparison and assessment of extent objectives

Overlay analysis undertaken in GIS software (ArcMap 10.8.2) was used to calculate area and location differences in vegetation functional groups between:

- the 2015 (Bowen et al. 2019a) map and the 2022 (current) map of the Gwydir Wetlands
- the 2013 (Bowen et al. 2019b) map and the 2022 (current) map of Macquarie Marshes.

Differences in areas and locations of vegetation communities between the 2 maps for the Gwydir Wetlands and Macquarie Marshes were interpreted taking into consideration:

- environmental context of the change – that is, wet and dry conditions at the time of imagery collection for each vegetation map
- known limitations of the mapping method, especially that of observation bias in the API method
- accuracy assessment results of the 2022 maps, which identified sources of error and confusion between mapped vegetation communities

- the nature of the change in composition and structure from one vegetation type to another, and whether this was plausible and consistent with the current understanding of how floodplain vegetation communities can change in the period between map snapshots.

Vegetation condition

Trend assessment

A Bayesian modelling approach was used to fit models to:

- vegetation condition time series data, for both cover and species richness
- assess the effect of inundation duration on vegetation cover.

This approach allowed for inferences to be drawn from the trend direction (increase or decrease) regardless of its magnitude (McBride 2019), to align with the relevant LTWP objectives for vegetation condition in terms of long-term trends. Factors considered as indicators of desirable vegetation condition include:

- dominance of native species (cover and species richness) compared with non-native species
- dominance of native amphibious species compared with native terrestrial species, except for woodlands higher on the floodplain which are less frequently inundated and are therefore dominated by terrestrial species
- increased number of years of flowering and/or seed set for marsh club-rush and water couch.

Exploratory data analyses revealed that changes in wetland vegetation cover, bare ground cover, and species richness over time and due to inundation duration were non-linear and site dependent. Therefore, this study used generalised additive mixed models (GAMM) (Hastie and Tibshirani 1986) with smoothing terms on predictor variables. This was done using the mgcv package (Wood 2004) in R programming language (R Core Team 2023). Models were fitted by Hamiltonian Monte Carlo sampling via the brms R package (Bürkner 2017) to estimate parameter trend (slopes).

Species were grouped by their provenance and native species placed into amphibious or terrestrial categories based on their wetland functional group as assigned in published lists (Campbell et al. 2014; Ling et al. 2018). Trends in vegetation cover, bare ground cover and species richness over time were modelled with water year as a fixed effect and site as a random effect. Season was also included as a fixed effect for the Gwydir Wetlands as surveys were conducted twice in a water year (spring and autumn). Effect of water year on bare ground cover in marsh club-rush transect sites in the Gwydir Wetlands was not assessed as bare ground was not recorded in the same way as for quadrat sites.

Beta family models were fitted to bare ground and vegetation cover data due to the proportional nature of the dataset (Damgaard and Irvine 2019). Where vegetation cover exceeded 100%, cover data was scaled to between zero and 99% to meet model requirements. Zero-inflated beta distribution was employed where cover data comprised many zeros. Species richness models utilised a negative binomial family due to over-dispersed count data, with zero-inflated versions applied for datasets with numerous zeros (e.g., non-native and terrestrial species). Percentage cover of the overstorey and understorey species in tree-dominated communities was analysed separately. All strata were combined for species richness models.

Weakly informative priors that ensured all models predicted realistic parameter ranges were set (Gelman et al. 2020). Each model had 4 Markov chains with 4,000 iterations and 1,000 warmup iterations. Model convergence was assessed using the Gelmann–Rubin statistic. Models with a small number of divergent transitions were re-run after adjusting adapt-delta to 0.99, maximum tree-depth to 20 and step-size to 0.001, thus ensuring a 100% model convergence.

The posterior probability of a positive trend direction (an increase in percentage cover or species richness) was calculated by summarising the proportion of posterior draws that were greater than zero. These probabilities are presented using graduated scales (Table 7) following McBride (2019) in alignment with terminology of the LTWPs. The probability and magnitude of difference in parameter estimates between native and non-native, and between native amphibious and native terrestrial species were calculated from model posterior draws using the tidybayes R package (Kay 2023).

Also analysed was the effect on understory vegetation of the number of months a site was inundated in a water year. The estimated number of months a site was inundated in a water year (leading up to autumn surveys) was included as a fixed effect. Site and water year were added as random effects to allow for the slope and intercept to vary among sites and years. Autumn vegetation survey data was used for these models as these surveys occur towards the end of a water year.

The marginal effect of inundation duration on vegetation cover was calculated to illustrate the predicted change in vegetation cover if inundation duration was increased by one month, while holding all other variables constant (Arel-Bundock 2024). Marginal effects were calculated at the levels of 0, 2, 4, 6, 8 and 10 months of flooding using the emmeans R package (Lenth 2023).

Descriptive statistics were applied to marsh club-rush and water couch flowering and seed set data due to the low number of site replicates.

Table 7 **Vegetation condition trend outcomes inferred from the probability of an increase in the average cover or species richness estimate (modified from Mastrandrea et al. 2010). Vegetation cover and species richness were determined to have (i) improved if the probability of an increase in their average was between 66% and 100%, (ii) maintained if between 33% and 66%, and (iii) declined if less than 33%**

Outcome	Probability of outcome	Status
Virtually certain	>99–100%	Improved
Extremely likely	>95–99%	Improved
Very likely	>90–95%	Improved
Likely	> 66–90%	Improved
About as likely as not	>33–66%	Maintained
Unlikely	>10–33%	Declined
Very unlikely	>5–10%	Declined
Extremely unlikely	>1–5%	Declined
Exceptionally unlikely	0–1%	Declined

2.4 Data reliability assessment

The reliability of wetland vegetation condition data was assessed using a modified version of the method developed by Battisti et al. (2014) (Appendix D [Table 12]). A score (0, 1 or 2) was assigned to each of the 6 questions relating to the method of data collection, repetition and representativeness, giving a final score ranging from 0 to 12. A final score of 0 represents 'poor' reliability while 12 represents 'excellent' data reliability.

3. Results

3.1 Vegetation extent

Results showed that all vegetation types remained represented at the Gwydir Wetlands from 2015 to 2022, and at Macquarie Marshes from 2013 to 2022.

Small differences seen in vegetation extent in the Gwydir Wetlands were likely due to observer bias in the air photo method adopted to produce both the 2015 and 2022 map snapshots of vegetation extent.

There was an increase in NWW vegetation in Macquarie Marshes. Most of this expansion in vegetation was into areas previously mapped as terrestrial vegetation, especially derived native grassland. A smaller component of this expansion was into areas previously mapped as wetland shrublands. This is interpreted as a healthy expansion of NWW vegetation following the wetter conditions from 2020 to 2022.

Gwydir Wetlands

Map of flood-dependent vegetation 2022

Figure 5 depicts the extent of flood-dependent vegetation communities at the Gwydir Wetlands, developed via the API method. Survey points included in the map accuracy assessment are also shown.

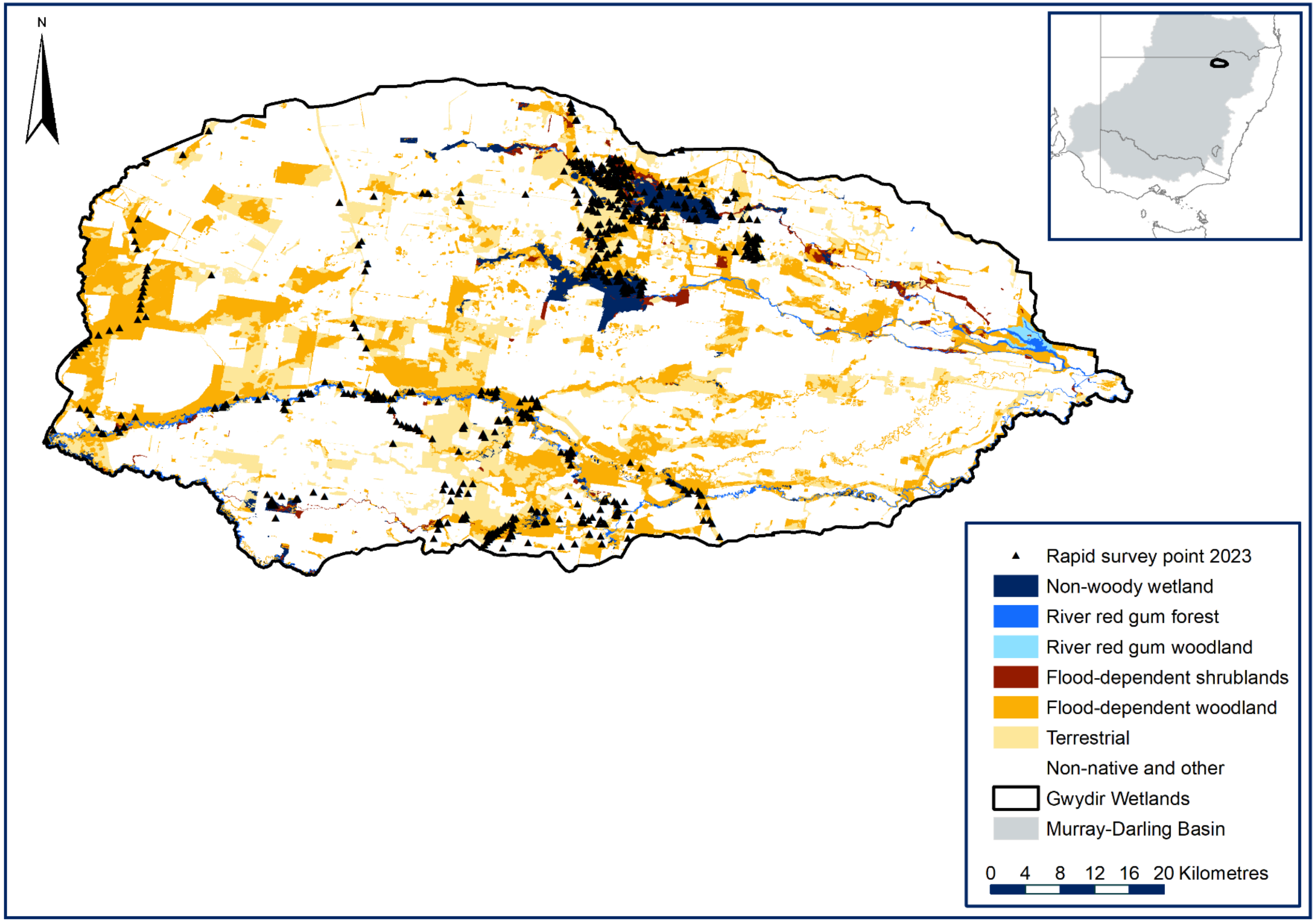

Figure 5 **Map of Gwydir Wetland flood-dependent vegetation 2022 and location of survey points included in the map accuracy assessment. This map was produced from aerial imagery collected in August 2022 and January 2023**

Accuracy assessment of 2022 map

A total of 780 rapid survey points were obtained from rapid field surveys and other available survey datasets. These points were used to test the accuracy of the 2022 map (Figure 5). The spatial spread of sites across the study area was clustered into accessible areas on public land and along roads. This may have affected the accuracy scores and is a limitation of this study. No rapid field data was collected or available for the relatively small area mapped as RRGW because this area was inaccessible for field survey. Therefore, an estimate of accuracy of RRGWs mapping could not be generated.

The results of the accuracy assessment are presented in Table 8, and figures 6 and 7. Table 8 shows a confusion matrix summarising the number of survey points correctly and incorrectly mapped for each map category (flood-dependent vegetation functional groups). Figure 6 shows the overall map accuracy and kappa statistic. Figure 7 shows the accuracy for individual map categories.

The confusion matrix in Table 8 below shows where there is disagreement between the field-assessed reference sites and the mapped category at the same location. These results show that larger amounts of confusion occurred where FDW reference sites (29 out of total of 255 FDW sites) were incorrectly mapped as terrestrial vegetation. Additional FDW sites were mapped as FDS or NWW. Also, some terrestrial sites were mapped as FDW, some NWW sites were mapped as terrestrial vegetation, and some FDS sites were mapped as FDW.

Table 8 **Confusion matrix showing field reference sites correctly or incorrectly mapped for flood-dependent vegetation types at the Gwydir Wetlands. Counts represent the number of field reference sites in each category. The number of correctly mapped field reference sites are shown in bold for each functional group**

Field functional group		Mapped functional group: Flood-dependent shrublands	Flood-dependent woodland	Non-native or other	Non-woody wetland	River red gum forest	Terrestrial
	Terrestrial	0	14	0	1	2	**135**
	River red gum forest	3	7	0	0	**59**	6
	Non-woody wetland	7	5	2	**113**	2	22
	Non-native or other	0	3	**42**	5	0	5
	Flood-dependent woodland	14	**187**	2	16	7	29
	Flood-dependent shrublands	**61**	15	1	7	7	1

Overall, the majority of field-assessed sites were classified into the correct map category. This resulted in an acceptable overall accuracy of 0.77 (77%) and a kappa statistic of 0.70 (Figure 6). The accuracy of mapping for individual vegetation classes ranged from 68% (for terrestrial vegetation) up to 80% for NWW and FDW (Figure 7).

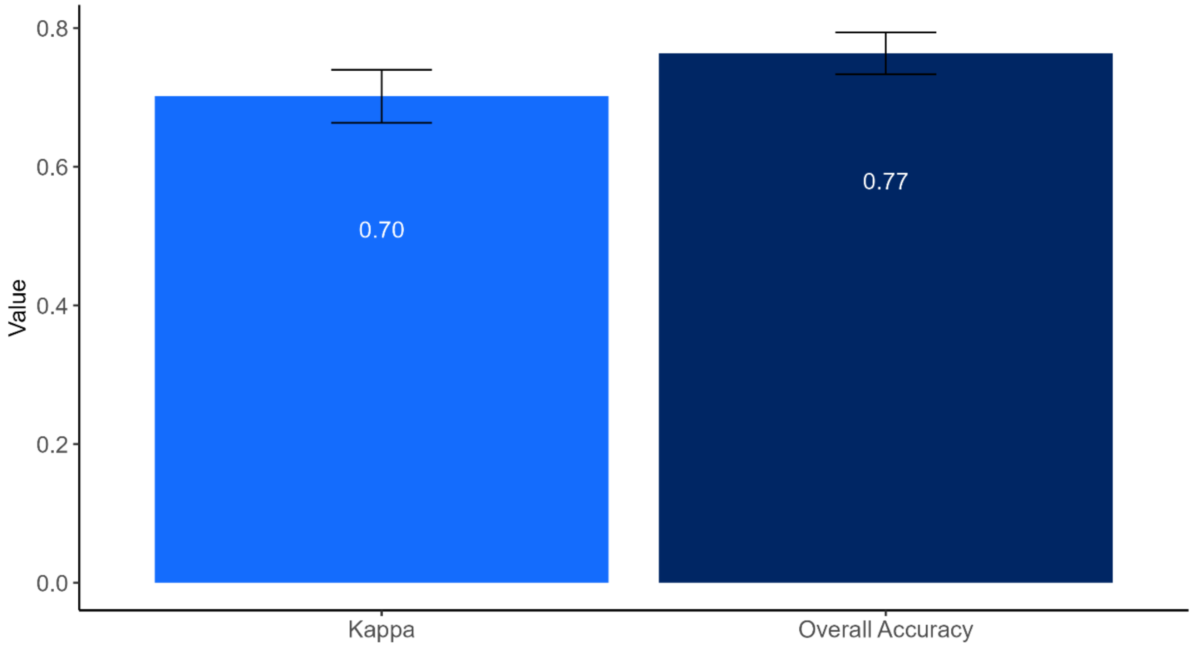

Figure 6 **Kappa statistic and overall accuracy for the Gwydir Wetlands 2022 map of flood-dependent vegetation. The overall accuracy is the percentage of field-assessed reference sites that were correctly mapped. The kappa statistic is an overall assessment of accuracy adjusted for chance agreement.**

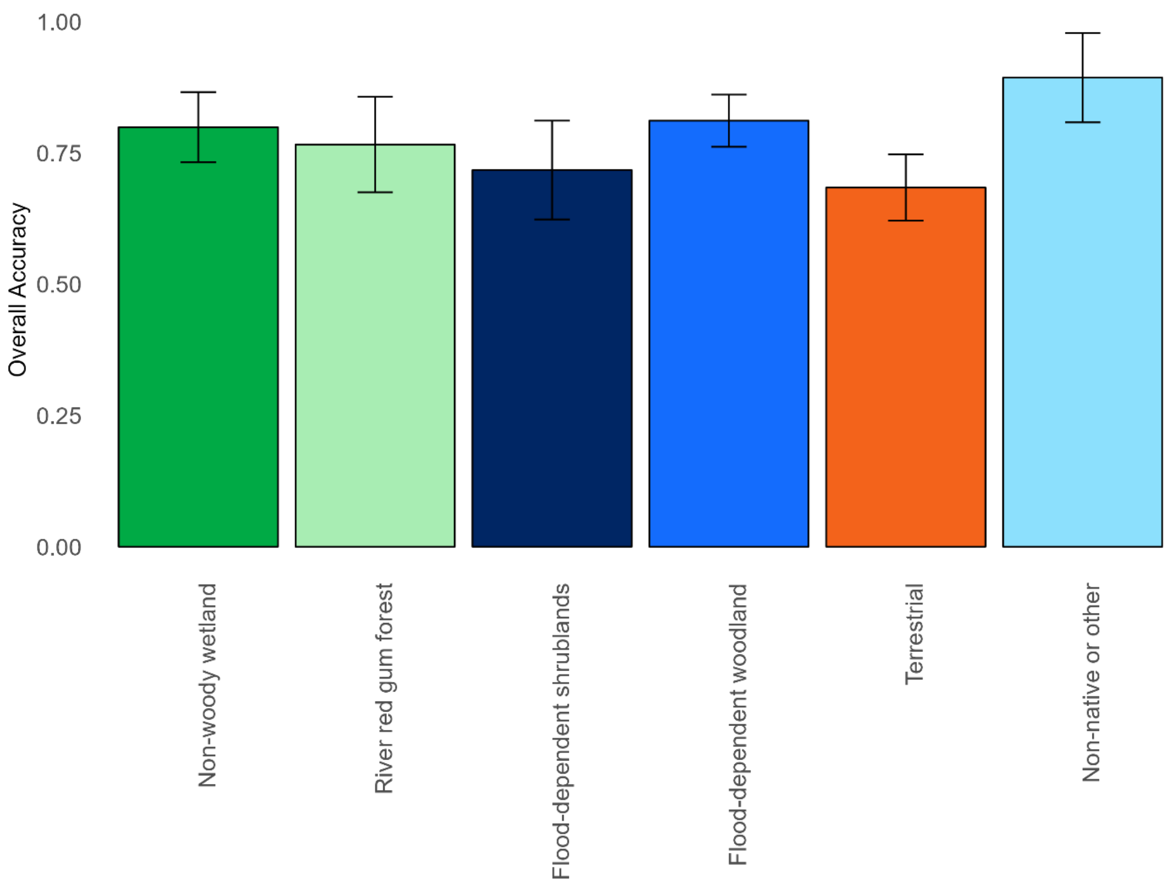

Figure 7 **Overall accuracy and 95% confidence interval for each flood-dependent vegetation functional- group class. The overall accuracy is the percentage of field-assessed reference sites that were mapped as the same category**

Map comparison and assessment of vegetation extent objectives

Results of vegetation class comparisons between the 2015 map and 2022 map for the Gwydir Wetlands are shown in Figure 8. All flood-dependent vegetation types remained represented from 2015 to 2022. No differences in vegetation extent were detected. Changes in terrestrial vegetation (small increase) and FDW (small decrease) were more likely related to map error arising from observer bias than a true change in woodland type. These types of errors can be due to difficulties in distinguishing terrestrial vegetation and FDW.

Overall, this assessment found that all LTWP targets, to maintain or increase the extent of flood-dependent vegetation communities, were met.

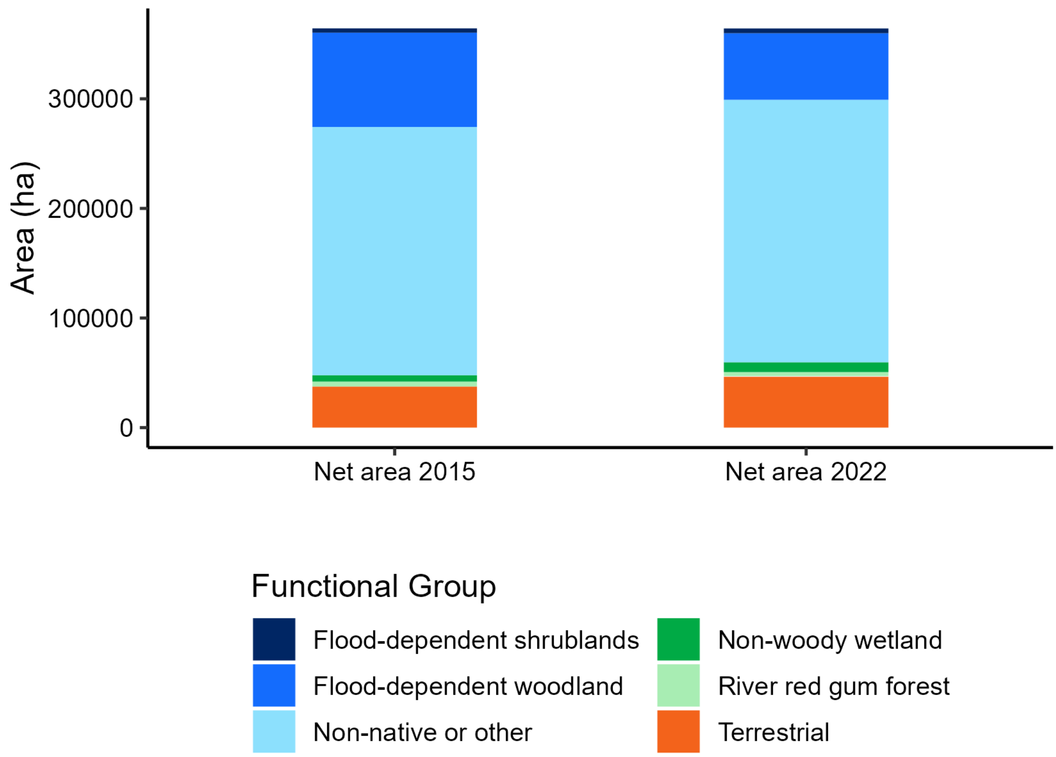

Figure 8 **Net extent of vegetation in the Gwydir Wetlands study area in 2015 and 2022**

Macquarie Marshes

Map of flood-dependent vegetation 2022

Figure 9 depicts the extent of flood-dependent vegetation communities at Macquarie Marshes, developed via the API method. Survey points included in the map accuracy assessment are also shown.

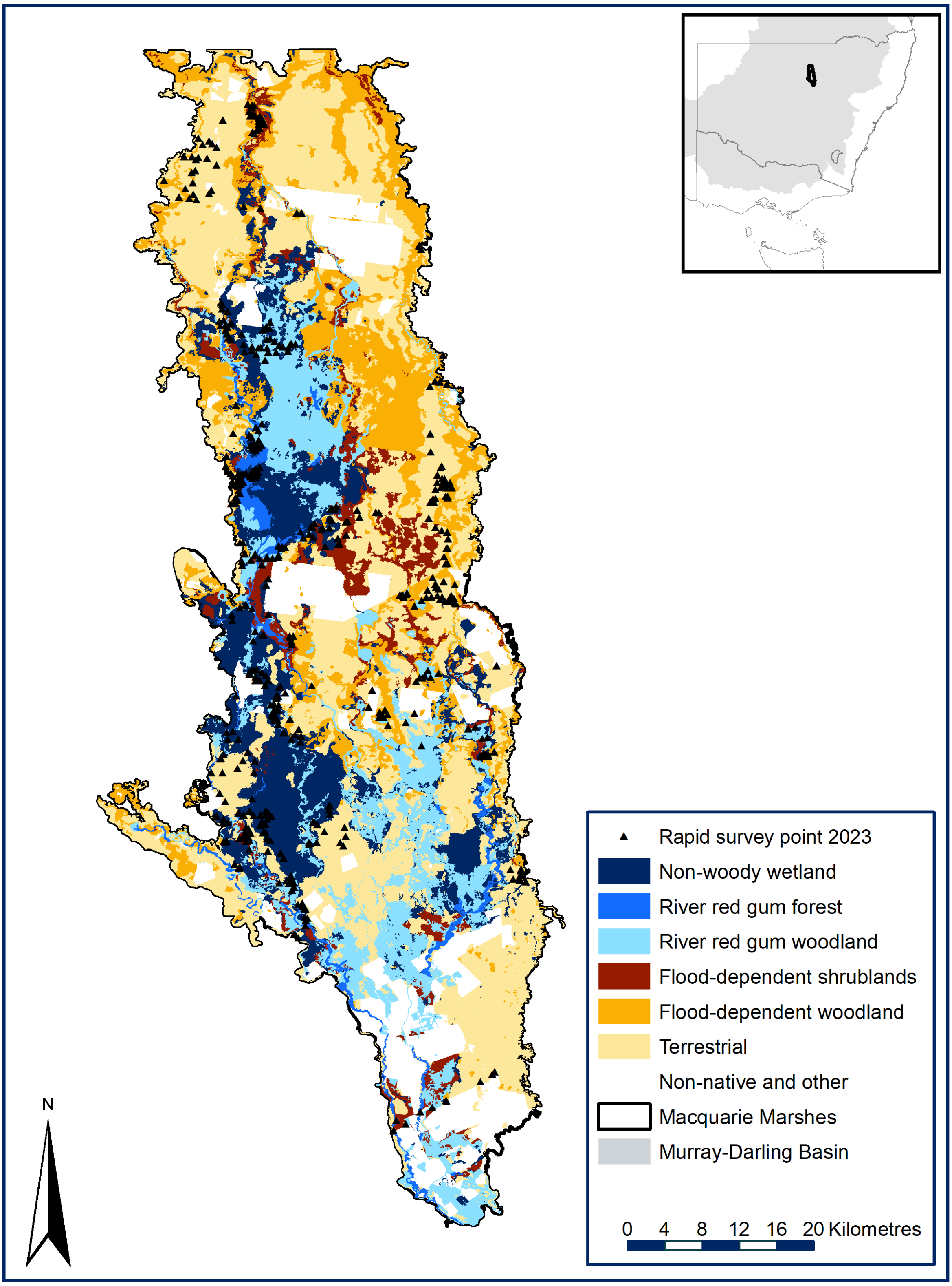

Figure 9 **Map of Macquarie Marshes flood-dependent vegetation 2022, and survey points included in the map accuracy assessment. This map was produced from aerial imagery collected in June 2022**

Accuracy assessment of 2022 map

A total of 505 rapid survey points were obtained from rapid field surveys. These points were used to test the accuracy of the map at Figure 9. The spatial spread of sites across the study area was clustered in areas of public land and along roads due to access restrictions, and within a few private properties that were accessible with landowner permission at the time of the field survey.

The results of the accuracy assessment are presented in Table 9, and figures 10 and 11. Table 9 shows a confusion matrix summarising the number of survey points correctly and incorrectly mapped for each map category (flood-dependent vegetation functional groups). Figure 10 shows the overall map accuracy and kappa statistic. Figure 11 shows the accuracy for individual map categories.

The confusion matrix at Table 9 shows where there is disagreement between the field-assessed reference sites and the mapped category at the same location. Of the identified disagreements, a larger number of terrestrial reference sites were mapped as FDW or NWW. Also, higher counts of RRGW sites were mapped as RRGF or FDW; RRGF sites were mapped as RRGW; NWW sites were mapped as terrestrial vegetation; FDW sites were mapped as terrestrial vegetation, and cleared areas were identified as terrestrial vegetation.

These errors are likely explained by observer bias in the API mapping method. Forests and woodlands dominated by eucalypts are difficult to visually distinguish from one another in aerial imagery. Similarly, NWW can be difficult to visually distinguish in aerial imagery from derived native grasslands that sit within the terrestrial vegetation class.

Overall, most sites were classified into the correct map category. The overall accuracy of the map is 0.74 (74%) with a kappa statistic of 0.67 (67%) (Figure 10). These accuracy metrics are considered acceptable for understanding broad vegetation extent patterns.

Table 9 **Confusion matrix showing field reference sites correctly or incorrectly mapped for flood-dependent vegetation types at Macquarie Marshes. Counts represent the number of field reference sites in each category. The number of correctly mapped field reference sites are shown in bold for each functional group**

Field functional group	Terrestrial	0	10	11	9	0	2	84
	River red gum woodland	6	4	0	4	13	69	1
	River red gum forest	2	1	0	0	4	11	0
	Non-woody wetland	2	4	0	140	0	4	11
	Non-native or other	0	0	0	0	0	0	0
	Flood-dependent woodland	3	47	0	2	0	8	19
	Flood-dependent shrublands	32	0	0	2	0	0	0
		Flood-dependent shrublands	Flood-dependent woodland	Non-native or other	Non-woody wetland	River red gum forest	River red gum woodland	Terrestrial
		Mapped functional group						

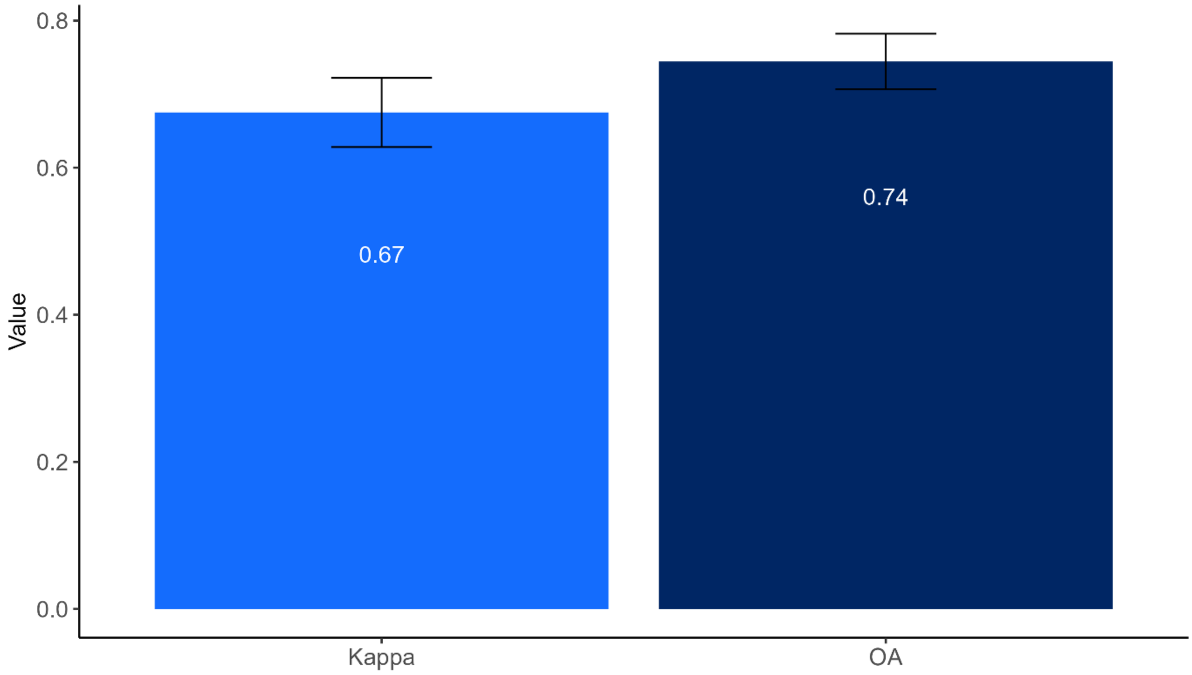

Figure 10 **Kappa statistic and overall accuracy for Macquarie Marshes 2022 map of flood-dependent vegetation. The overall accuracy is the total number of field-assessed reference sites that were correctly mapped. The kappa statistic is an overall assessment of accuracy adjusted for chance agreement**

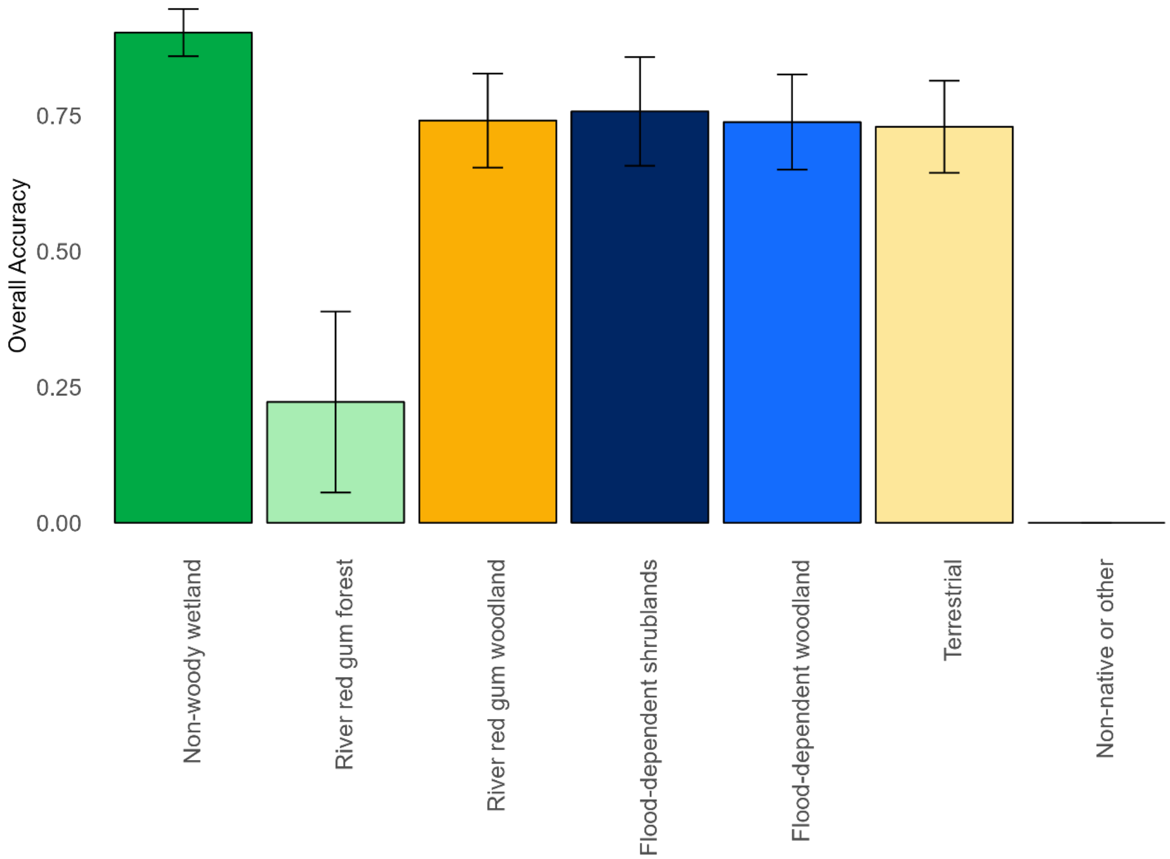

Figure 11 **Overall accuracy and 95% confidence interval for each flood-dependent vegetation functional-group class. The overall accuracy is the percentage of field-assessed reference sites that were mapped as the same category**

Most vegetation functional groups were mapped with high accuracy. Almost all individual vegetation class accuracies were estimated at greater than 70% (Figure 11). An exception was RRGF which was estimated to have a lower overall accuracy of 24%. This low accuracy is largely explained by the proportionally large number of RRGF reference sites mapped as RRGW. Table 9 shows that of the 17 RRGF sites identified in the field survey, 13 of these were incorrectly mapped as RRGW. The lower estimated accuracy of this vegetation class is likely a result of observer bias in the mapping method. It is difficult to visually distinguish boundaries of woodland from forest in aerial imagery. A clear explanation of the structural differences (such as canopy cover or tree density) in vegetation community profiles, provided either in the NSW plant community type classification or the LTWP objectives, would assist with API to separate RRGF from RRGW.

Map comparison and assessment of vegetation extent objectives

Results of vegetation class comparisons between the 2013 and 2022 maps for Macquarie Marshes are shown in Figure 12. All flood-dependent vegetation types remained represented from 2013 to 2022. There was an increase in NWW in 2022. This expansion occurred into areas previously mapped as terrestrial vegetation, with a small component of this expansion into areas of FDS. These results explain the small decrease in net area of FDS. All other changes are likely explained by map errors due to observer bias when applying the API method.

The expansion of NWW is interpreted as a healthy adjustment to the overall wetter conditions in 2022, relative to 2013. NWW are known to expand and contract quickly, relative to woodland and forested wetlands. This is because the herbaceous component of the plant species grow rapidly from available seed banks as terrestrial areas are wetted by increased inundation following dry periods. The expansion of NWW into mostly terrestrial areas is also indicative of a healthy soil seedbank available for regeneration of wetland species as wetter conditions are experienced.

Overall, as the only difference between maps from 2013 and 2022 was the healthy expansion of NWWs, all targets to maintain or increase wetland vegetation extent at Macquarie Marshes were considered to be met.

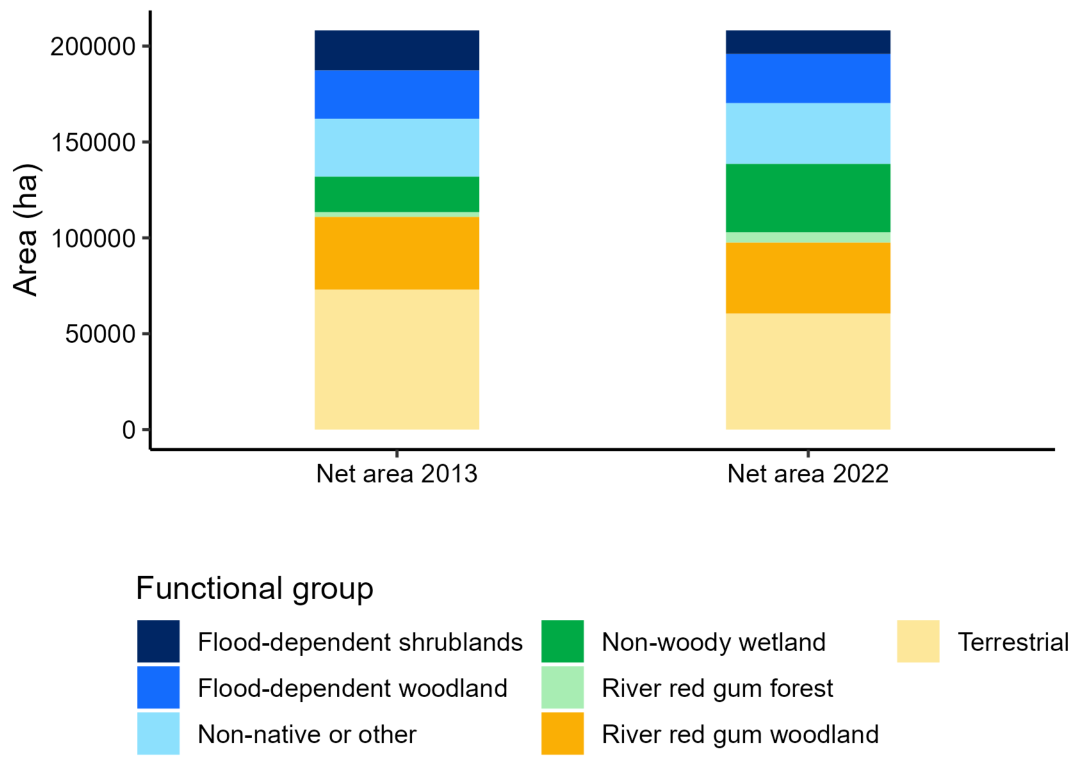

Figure 12 Net extent of vegetation in Macquarie Marshes study area in 2013 and 2022

3.2 Vegetation condition

Results over the 2011 to 2023 period demonstrate an overall maintenance of vegetation condition (percentage cover and species richness) at most sites in the Gwydir Wetlands and Macquarie Marshes.

Non-woody vegetation and the understorey of woody vegetation had dry and wet phases in response to patterns of water availability. Native species were dominant over non-native species, and native amphibious species were dominant over native terrestrial species in both the Gwydir Wetlands and Macquarie Marshes. Marsh club-rush and water couch flowered and set seed in the Gwydir Wetlands between spring 2019 and autumn 2023. Tree cover likely increased at 13% and 50% of woody sites in the Gwydir Wetlands and Macquarie Marshes respectively, and remained the same at almost all of the remaining sites.

Estimated duration of inundation (number of months) had positive relationships with cover of native and/or native amphibious species at most sites from 2016 to 2023, although this was not the case for RRGF sites in Macquarie Marshes.

Non-woody wetland vegetation

Gwydir Wetlands

Percentage cover trend

Non-woody wetland (NWW) vegetation and bare ground cover were maintained at most sites in the Gwydir Wetlands (>70% of sites, Figure 13). The average native amphibious species cover likely increased at 14% of sites and likely decreased at another 14% of the sites (Figure 13). The average bare ground cover and native terrestrial species cover likely increased at more than 10% of sites (Figure 13).

The average cover of native species was 38% more than that of non-native species (99% likelihood) with average cover differences ranging between 33% and 47% (96 to 99% likelihood) across the water years (Figure 13). The average percentage cover of native amphibious species was 40% more (99% likelihood) than that of native terrestrial species. Average cover differences between native amphibious and native terrestrial species ranged between 34% and 48% (97 to 99% likelihood) across the water years (Figure 13).

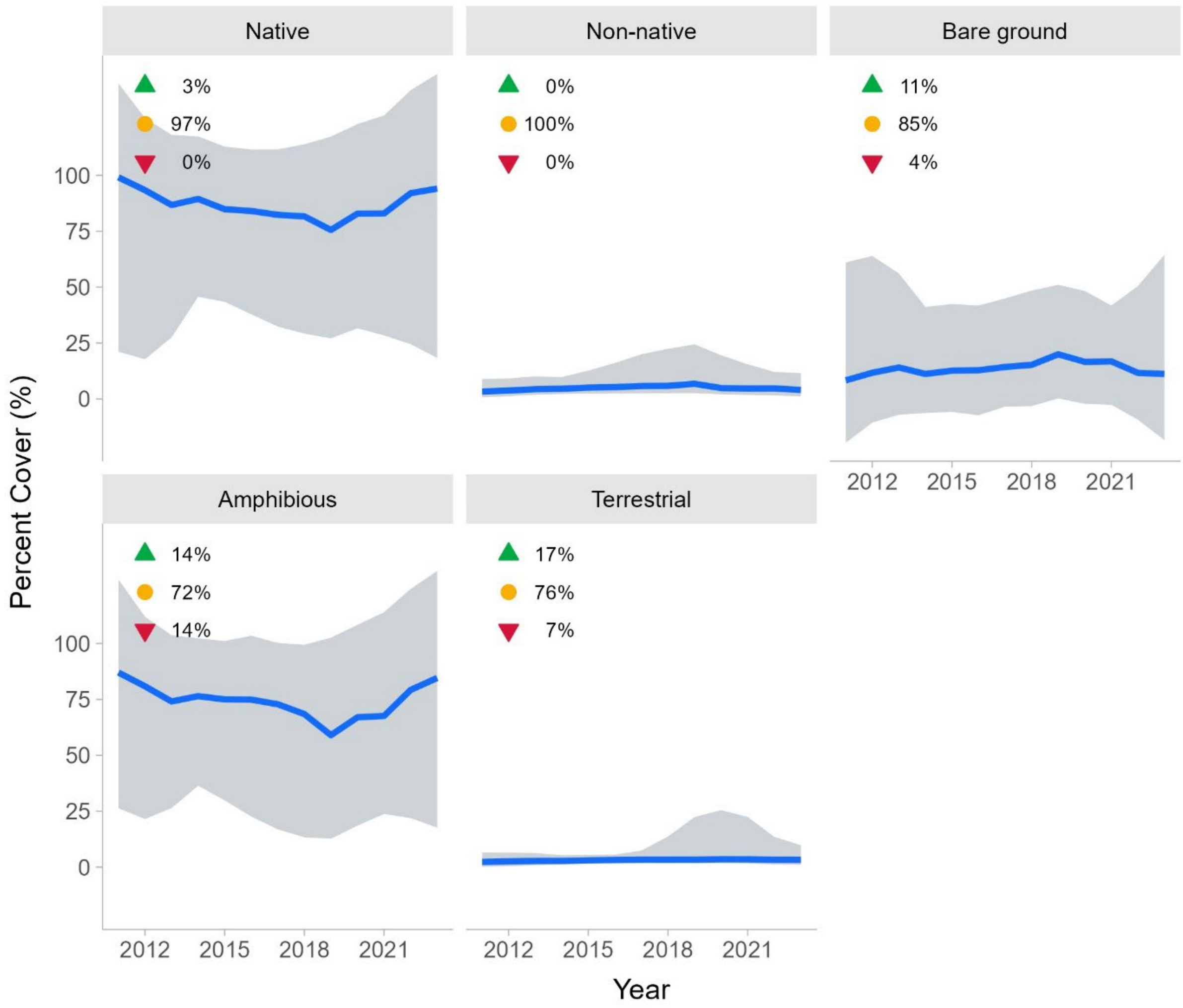

Figure 13 **Trends in average percentage cover of native, non-native, native amphibious and native terrestrial species of NWW vegetation, and bare ground for the Gwydir Wetlands (n=29) from 2011 to 2023. The bold blue lines represent the predicted average cover. Shaded areas represent 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites at which average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

There was evidence of a positive trend in native species cover with inundation duration driven by native amphibious species (Figure 14). An increase in the estimated number of months that sites were inundated in a water year was associated with a likely increase in average cover of native amphibious species (Figure 14). The increases in cover levelled out after 6 to 8 months of inundation.

A weaker negative trend was observed indicating a likely decrease in average cover of native terrestrial and non-native species with increasing inundation duration (Figure 14).

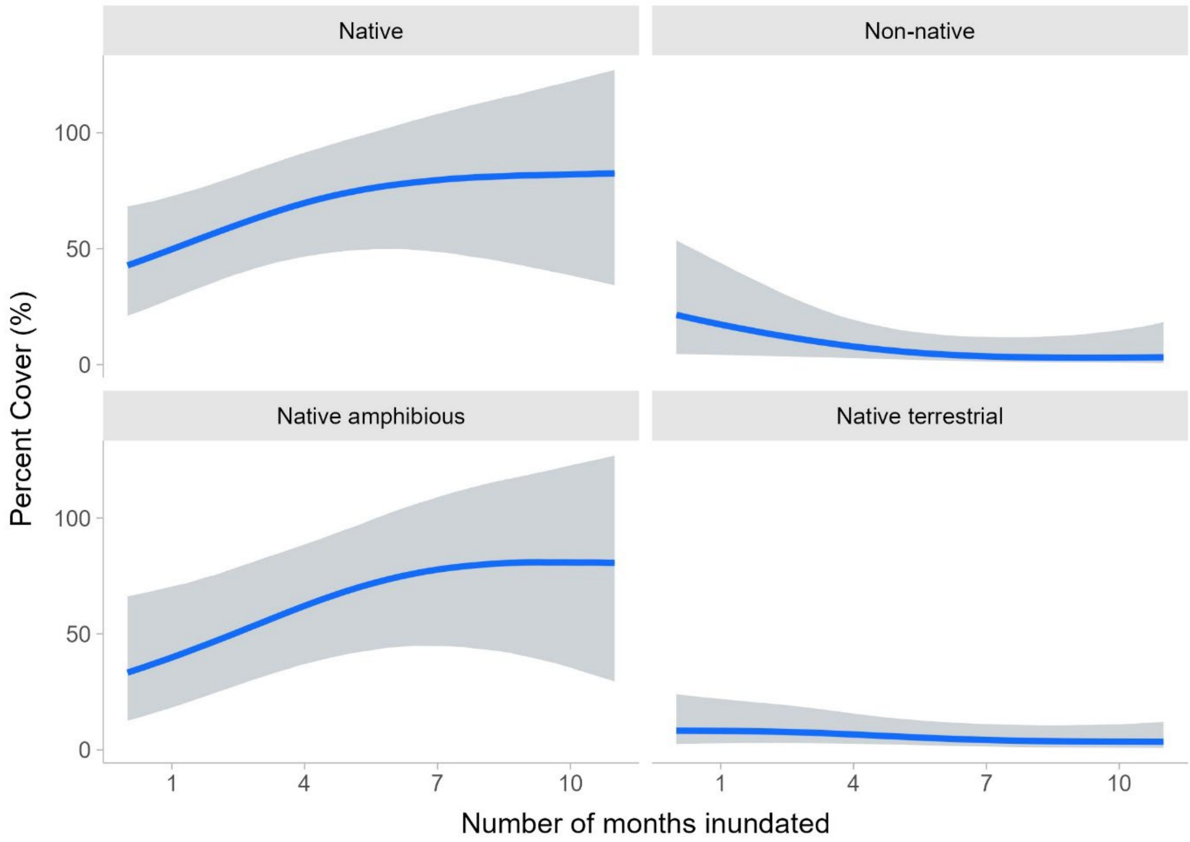

Figure 14 **The impact of the number of months of inundation during a water year on the average percentage cover of native, non-native, native amphibious, and native terrestrial species in NWW of the Gwydir Wetlands (n=29). The blue lines represent the predicted average cover. The shaded areas are 95% credible interval bounds around the predicted average**

Species richness trend

In this study, 149 distinct native and 64 non-native NWW plant species were recorded. The average number of species recorded was maintained at most sites (>60% of sites) (Figure 15). There was a likely increase in the average number of native species, specifically native amphibious species at over 30% of sites, and non-native species at 14% of the sites (Figure 15).

The average number of native species exceeded that of non-native species by 7 species (99% likelihood) with a variation across water years ranging from 6 to 8 (96 to 99% likelihood, Figure 15).

It is very likely (93% likelihood) that the average number of native amphibious species exceeded the average number of native terrestrial species by 4 (Figure 15). The difference between average number of native amphibious species and native terrestrial species ranged from 4 to 5 across the water years (89 to 99% likelihood).

Figure 15 **Trends in the average number of native, non-native, native amphibious and native terrestrial species at NWW sites for the Gwydir Wetlands (n=29) from 2011 to 2023. The blue lines represent the predicted average number of species. The shaded areas are 95% credible intervals around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Macquarie Marshes

Percentage cover trend

The average cover of NWW vegetation functional groups and bare ground was maintained at most sites in Macquarie Marshes (>80% of sites, Figure 16). Average native amphibious species cover likely increased at 12% of sites and likely decreased at 6% of the sites. Average cover of native terrestrial species and bare ground likely decreased at 9% and 6% of the sites respectively (Figure 16).

It is virtually certain (99% likelihood) that the average cover of native species was 50% more than average non-native species cover (Figure 16). The observed difference in native cover relative to non-native cover was non-linear and varied with water year but ranged between 47% and 54% (99% likelihood) (Figure 16). The average percentage cover of native amphibious species over time was extremely likely to have been 44% more (96% likelihood) than the average native terrestrial species cover (Figure 16). The difference in average cover between native amphibious and native terrestrial species across water years ranged between 43% and 45% (89 to 99% likelihood).

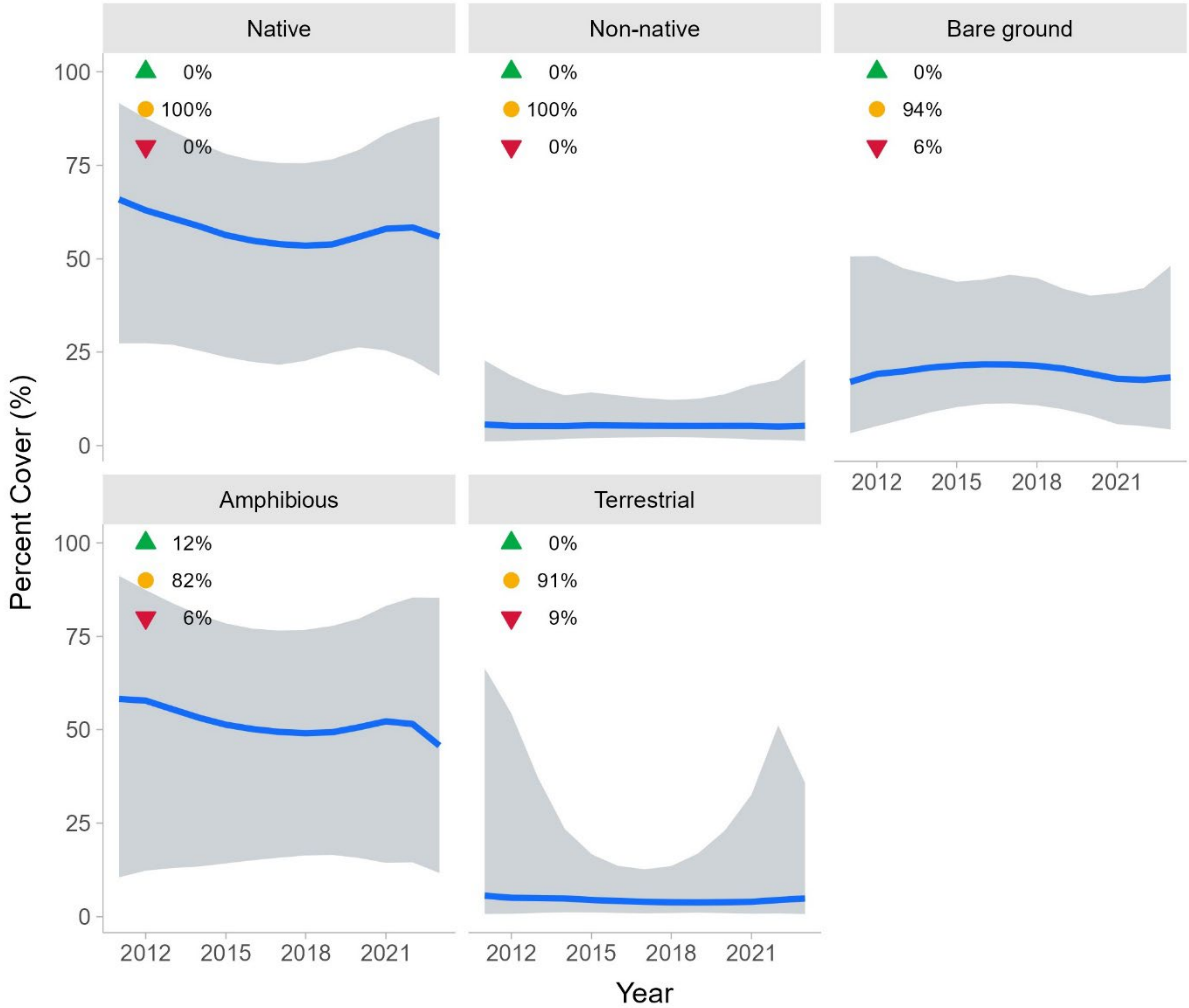

Figure 16 **Trends in average percentage cover (%) of native, non-native, native amphibious and native terrestrial species of NWW vegetation, and bare ground for Macquarie Marshes (n=33) from 2011 to 2023. The blue lines represent the predicted average cover. Shaded areas represent 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites at which average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

An increase in the estimated number of months that sites were inundated in a water year was associated with a likely increase in average cover of native species, largely due to an increase in native amphibious species cover (Figure 17). The increases in native terrestrial and native amphibious cover levelled out after 4 to 5 months, with a longer inundation associated with a likely decrease in native amphibious cover and therefore overall native species cover (Figure 17).

There was a weaker negative trend in non-native and native terrestrial species cover with increasing inundation duration (Figure 17). However, the predicted non-native and native terrestrial species cover remained minimal after the initial one to 2 months of inundation (Figure 17).

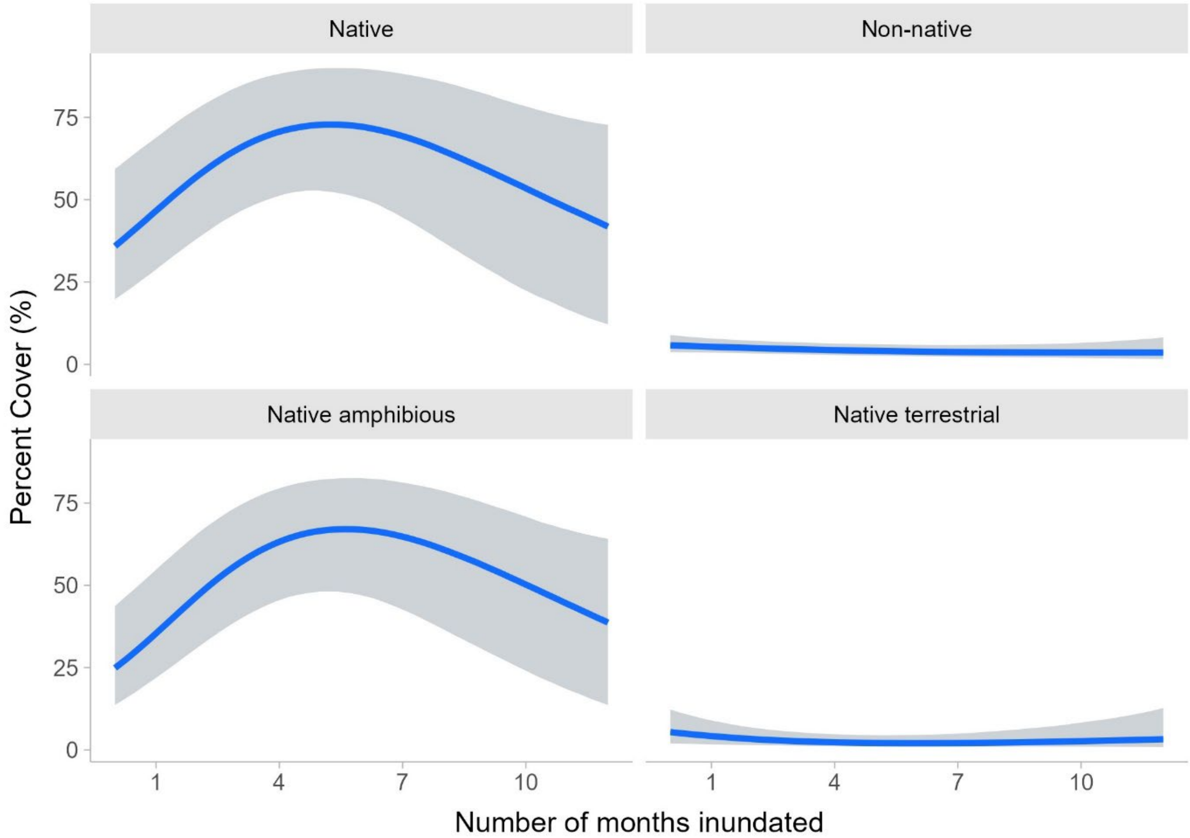

Figure 17 **The effect of the number of months of inundation during a water year on the average percentage cover of native, non-native, native amphibious, and native terrestrial species in NWW of Macquarie Marshes (n=31). The blue lines represent the predicted average cover. The shaded areas are 95% credible interval bounds around the predicted average**

Species richness trend

In Macquarie Marshes, 188 native and 69 non-native plant species were recorded over the study period. The average number of species recorded was maintained at most sites (>90% of sites, Figure 18). The average number of native species exceeded that of non-native species by 7 species (96% likelihood), with an average variation across water years ranging from 5 to 10 species (92 to 98% likelihood).

The average number of native amphibious species was likely to have exceeded the average number of native terrestrial species by 3 species (75% likelihood, Figure 18). The mean difference in the number of native amphibious and native terrestrial species in Macquarie Marshes across the water years ranged from zero to 4 species (70 to 80% likelihood).

Figure 18 **Trends in the average number of native, non-native, native amphibious and native terrestrial species at NWW sites for Macquarie Marshes (n=33) from 2011 to 2023. The blue lines represent the predicted average number of species. The shaded areas are 95% credible intervals around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Reproduction of marsh club-rush and water couch

Marsh club-rush (*Bolboschoenus fluviatilis*) and water couch (*Paspalum distichum*) wetland species flowered and set seed in most water years in the Gwydir Wetlands (Table 10). There was an increase over time in the number of sites where these species were recorded to have flowered or fruited, from 2019–20 to 2022–23.

Table 10 **Site counts where flowering and fruiting of marsh club-rush and water couch have been recorded since 2019. The total number of sites with the species are included in parentheses**

		Marsh club-rush		Water couch	
Water year	**Season sampled**	**No. of sites fruiting**	**No. of sites flowering**	**No. of sites fruiting**	**No. of sites flowering**
2019–20	Spring	(3)	2 (3)	0 (16)	0 (16)
2019–20	Autumn	0 (3)	0 (3)	0 (5)	0 (5)
2020–21	Spring	0 (0)	0 (0)	0 (14)	1 (14)
2020–21	Autumn	2 (3)	1 (3)	6 (18)	2 (18)
2021–22	Autumn	1 (3)	2 (3)	8 (14)	5 (14)
2022–23	Autumn	5 (5)	0 (5)	5 (14)	4 (14)

Data reliability assessment

The reliability of data used to assess vegetation condition was evaluated using the method outlined by Battisti et al. (2014). NWW vegetation cover and species richness data were scored as being ‘fair’. Further detail on the reliability score is provided in Appendix E (Table 13).

River red gum floodplain forest

Macquarie Marshes

Percentage cover trend

Understorey vegetation and bare ground cover in RRGF communities was maintained at most sites (>60%) over the 2011 to 2023 period (Figure 19). However, there were a few exceptions. Native amphibious understorey cover, native terrestrial understorey cover and bare ground cover increased at 10 to 21% of the sites. There was a decrease in native amphibious understorey cover, non-native understorey cover and bare ground cover at 14 to 17% of the sites (Figure 19). It is likely that tree cover increased at more than 50% of the sites, was maintained at 34% of sites and decreased at 14% of the sites (Figure 19).

It is extremely likely that the average percentage cover of native understorey was approximately 32% more than non-native understorey cover (98% likelihood, Figure 19). The difference in average percentage cover between native understorey and non-native understorey ranged between 30% and 35% (95 to 99% likelihood) across the water years. It is very likely that the mean cover of native amphibious understorey remained at approximately 25% more than that of native terrestrial understorey cover (92% likelihood, Figure 19). The difference in mean amphibious and terrestrial cover varied across water years and ranged between 21% and 30% (78 to 99% likelihood).

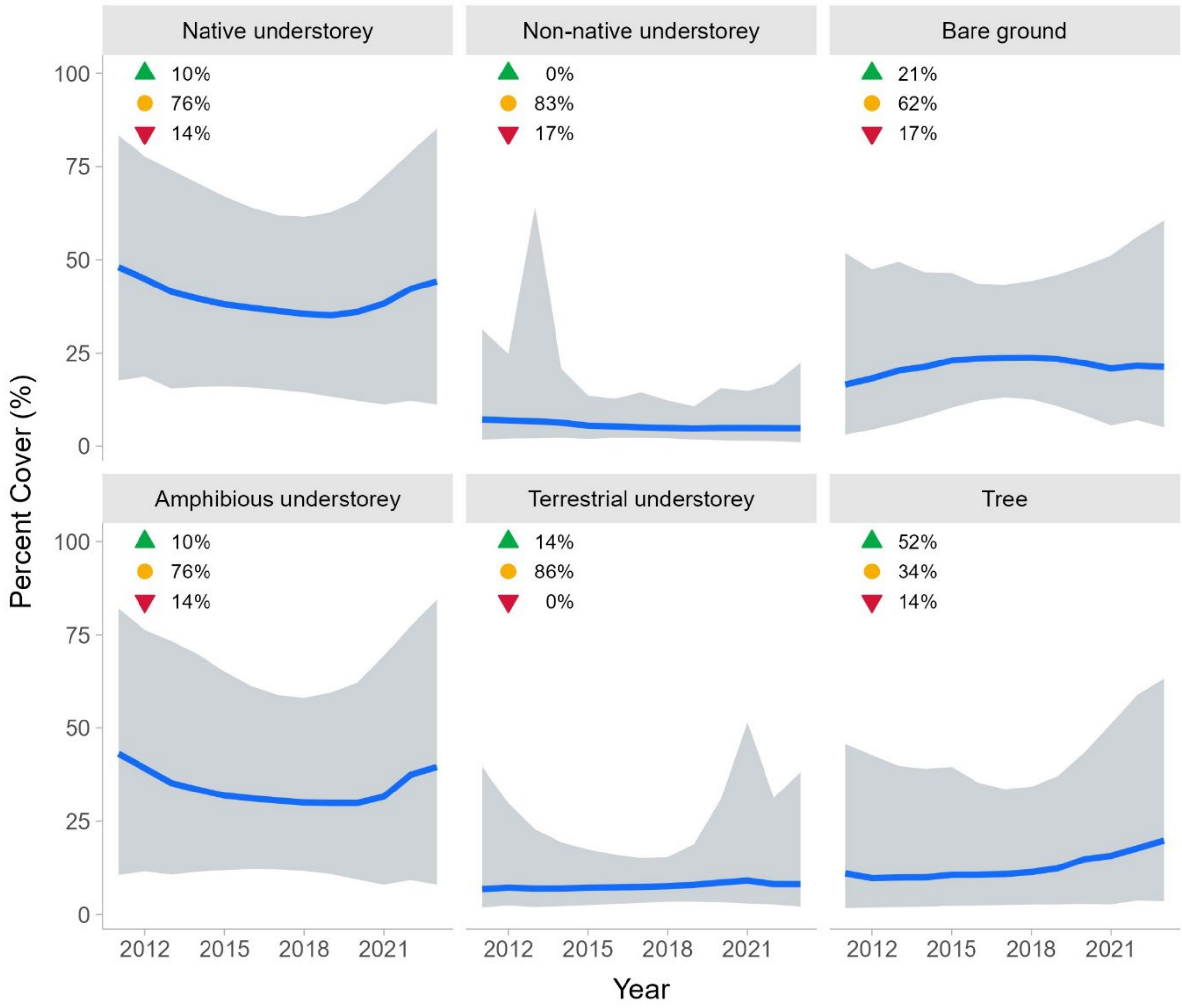

Figure 19 **Trends in average percentage cover of native, non-native, native amphibious and native terrestrial understorey species, trees and bare ground for RRGF sites at Macquarie Marshes (n=29) from 2011 to 2023. The blue lines represent the predicted average cover. The shaded areas represent 95% credible interval bounds around the predicted average. Annotations show the proportion of sites where average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011to 2023 period**

RRGF understorey cover did not show any strong trends with months flooded per water year. Instead, average cover for all understorey vegetation functional groups was maintained in relation to the predicted number of months of inundation, with a clear difference between native and non-native species (Figure 20).

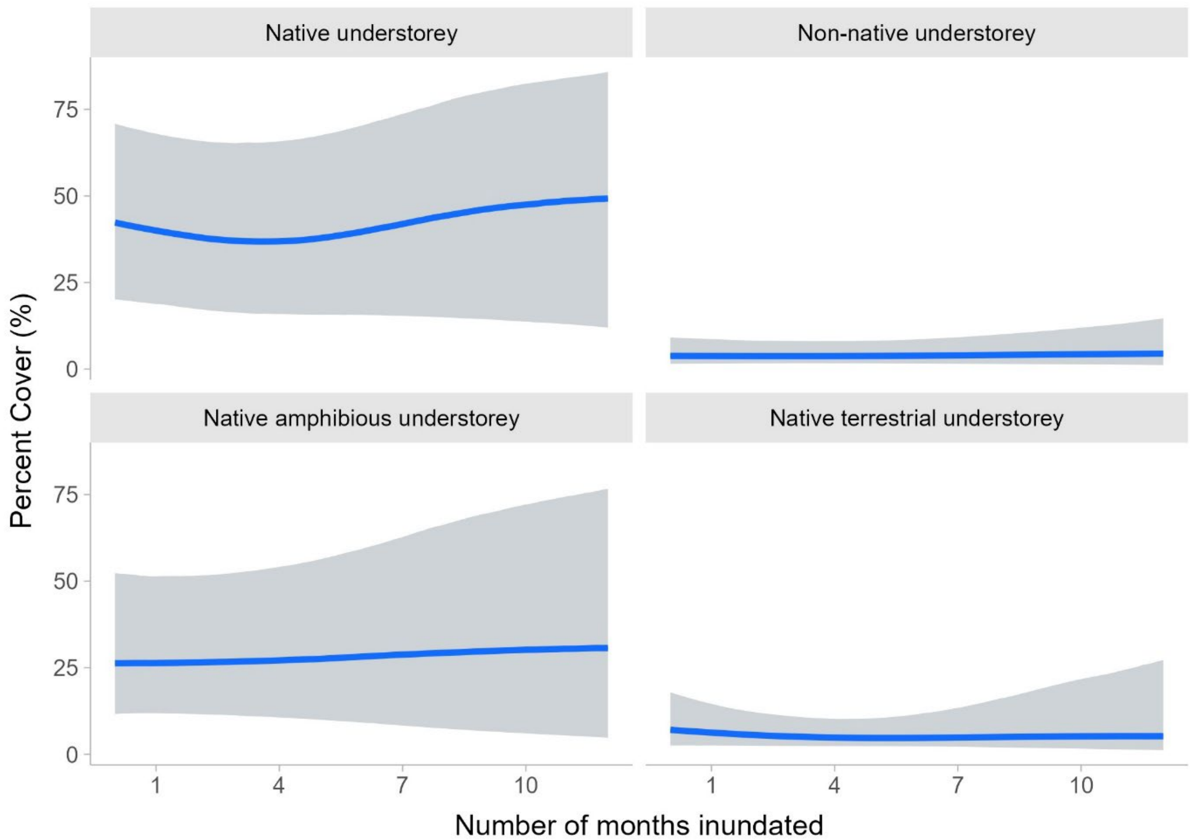

Figure 20 **The impact of the number of months of inundation during a water year on the average percentage cover of native, non-native, native amphibious and native terrestrial understorey species in RRGF sites of Macquarie Marshes (n=29). The blue lines represent the predicted average cover. The shaded areas are 95% credible intervals around the predicted average**

Species richness trend

In this study, 195 native and 75 non-native species were recorded in RRGF communities in Macquarie Marshes. The average number of species recorded was maintained at most RRGF sites (>93 to 100%, Figure 21). Likely increases in native terrestrial species richness were found at 7% of sites, and in non-native species richness at 3% of sites (Figure 21).

It is virtually certain that the average number of native species exceeded the number of non-native species by 10 species (99% likelihood) with a difference of between 1 and 11 species (95 to 99% likelihood) across the water years (Figure 21). It is likely that the average number of native amphibious species exceeded the number of native terrestrial species by about 2 species (70% likelihood, Figure 21). The difference in average native amphibious and native terrestrial species richness ranged between zero and 4 species across water years (59 to 79% likelihood).

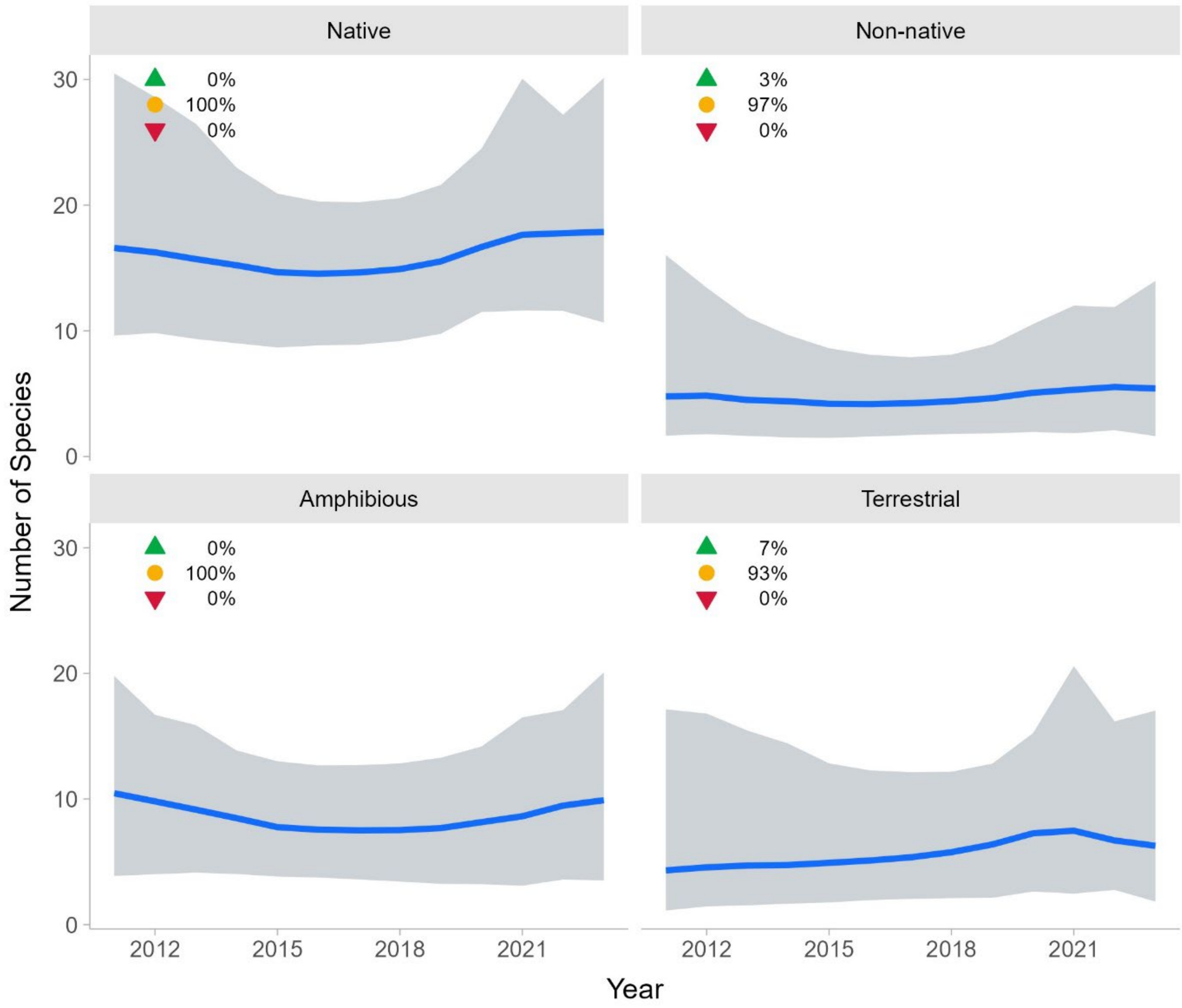

Figure 21 **Trends in the average number of native, non-native, native amphibious and native terrestrial species at RRGF sites in Macquarie Marshes (n=29) from 2011 to 2023. The blue lines represent the predicted average number of species. The shaded areas are 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Data reliability assessment

RRGF vegetation cover and species richness data were scored as being 'fair'. Further detail on the reliability score is provided in Appendix E (Table 14).

River red gum floodplain woodland

Macquarie Marshes

Percentage cover trend

The average cover of native understorey species, non-native understorey species and bare ground were maintained at most of the RRGW sites (>67% of sites, Figure 22). Average tree and native amphibious understorey cover were likely to have increased at

50% of the sites and were likely maintained at the remaining sites (Figure 22). Average non-native understorey cover likely decreased at 17% of sites and average native terrestrial understorey cover likely decreased at 33% of the sites resulting in a likely decrease in overall native understorey cover at 17% of the sites (Figure 22). A 'U-shaped' response was seen, with a decreasing trend in average native understorey cover in the years leading up to the 2018–19 water year, after which an increasing trend was observed (Figure 22). Native amphibious understorey species cover contributed to the U-shaped trend in native understorey cover response over time. An opposite trend was observed in bare ground cover over the study period (Figure 22).

The average native understorey cover was extremely likely to have exceeded the average cover of non-native understorey by approximately 33% (97% likelihood), however the difference varied over time, ranging from 20% to 52% (94 to 95% likelihood) (Figure 22). The average native amphibious species cover was unlikely to have differed from that of native terrestrial species cover over the study period (28% likelihood) (Figure 22).

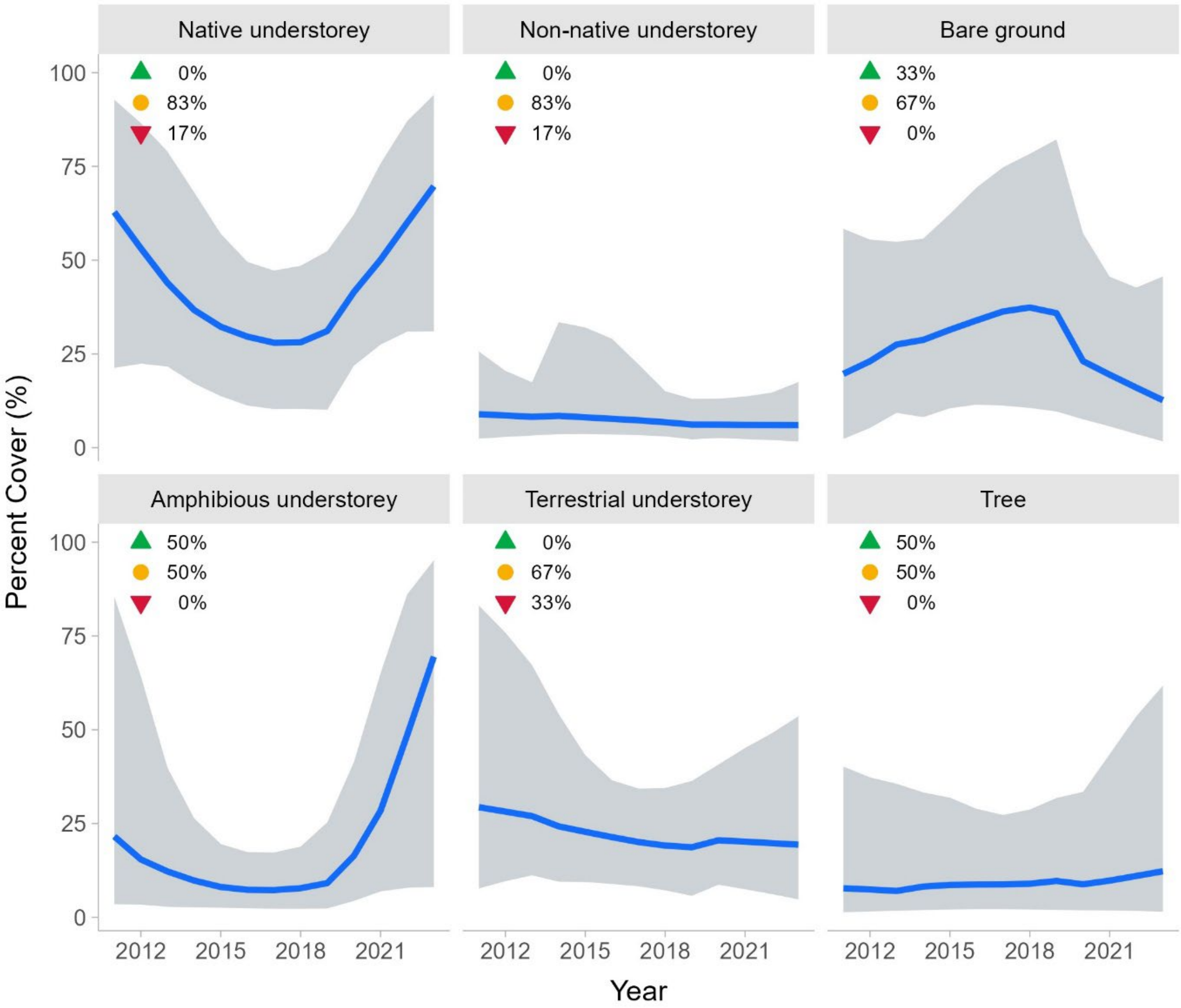

Figure 22 **Trends in average percentage cover of native, non-native, native amphibious and native terrestrial understorey species, trees and bare ground at RRGW sites in Macquarie Marshes (n=6) from 2011 to 2023. The blue lines represent the predicted average cover. The shaded areas are 95% credible interval bounds around the predicted average. Annotations show the proportion of sites at which average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

There was a likely positive relationship between native understorey cover and the estimated number of months sites were inundated per water year (Figure 23). This was largely due to an increase in native amphibious understorey cover (Figure 23). Native amphibious understorey cover showed the largest response to the number of months of inundation, especially between 4 and 8 months of being flooded. However, there was high variation among sites as reflected by wide bounds around the mean cover (Figure 23). For native terrestrial understorey cover, increasing the number of months flooded to more than 4 months in a year resulted in a likely (80%) chance of decreasing cover.

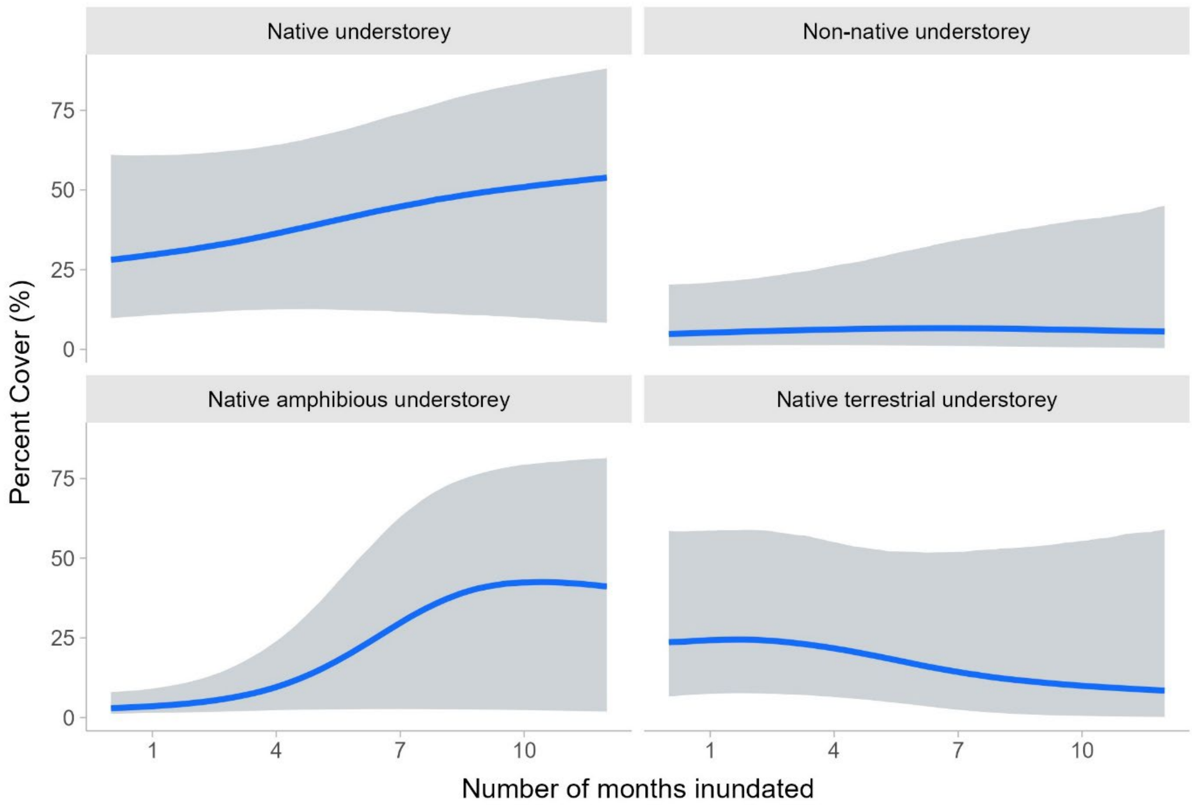

Figure 23 The effect of the number of months of inundation in a water year on the average percentage cover of native, non-native, native amphibious, and native terrestrial understorey species in RRGW sites in Macquarie Marshes (n=6). The blue lines represent the predicted average cover of the respective vegetation category. The shaded areas are 95% credible interval bounds around the predicted average

Species richness trend

In this study, 132 native and 53 non-native species were recorded in RRGW communities in Macquarie Marshes over the study period. The average number of species was maintained at all sites (Figure 24). An increasing trend in native amphibious richness was seen from the 2019–20 water year onwards (Figure 24).

The average number of native species exceeded the average number of non-native species by 11 species (99% likelihood, Figure 24), with the difference ranging between 9 and 14 species across the water years (95 to 99% likelihood). It is very likely that the average number of native terrestrial species exceeded the average number of native amphibious species by about 6 species (90% likelihood, Figure 24). The difference in average number of species across the years ranged from 3 to 7 species (67 to 99% likelihood).

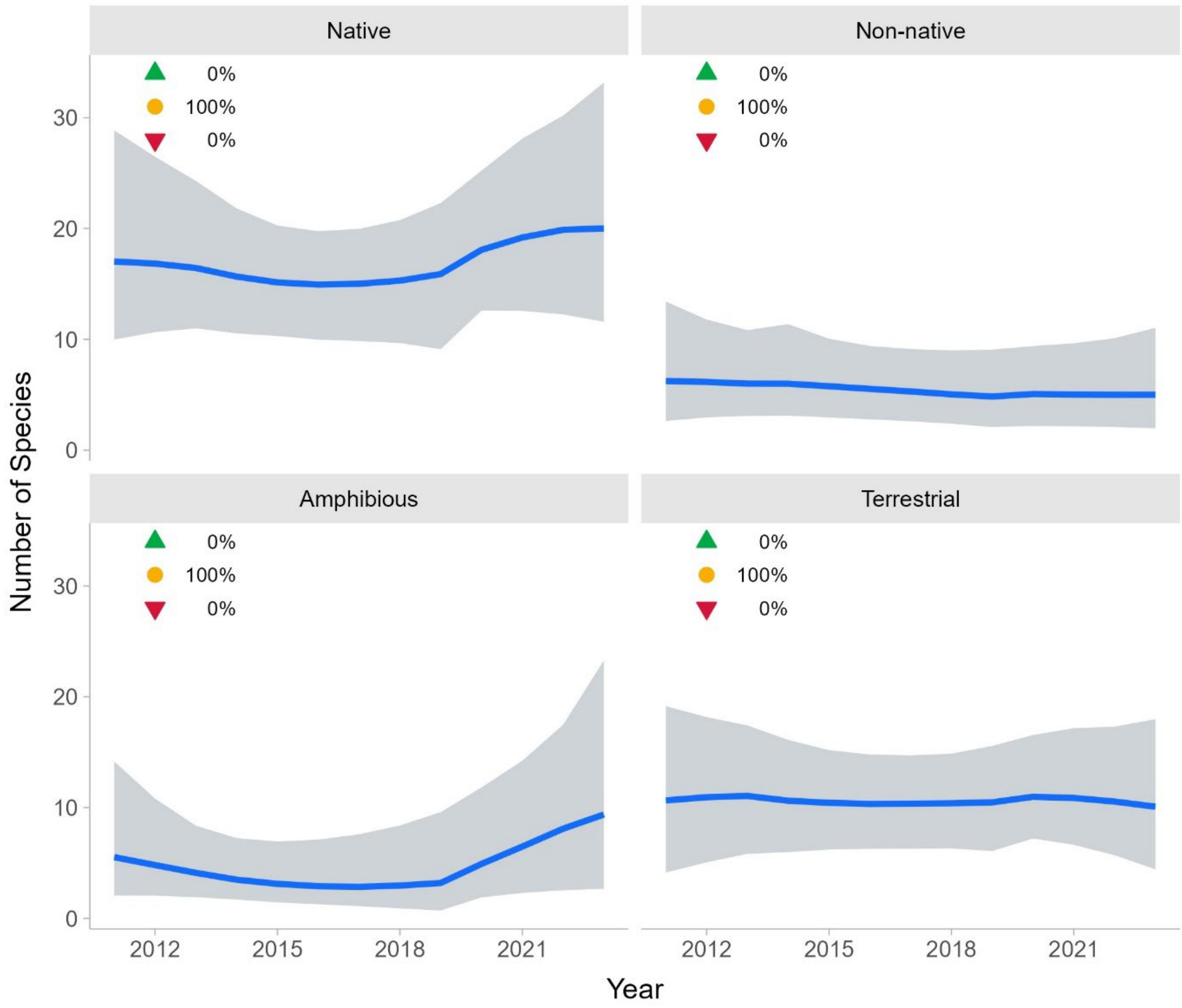

Figure 24 **Trends in the average number of native, non-native, native amphibious and native terrestrial species at RRGW sites at Macquarie Marshes (n=6) from 2011 to 2023. The blue lines represent the predicted average number of species of the respective vegetation category. The shaded areas are 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Data reliability assessment

RRGW vegetation cover and species richness data were scored as being 'fairly reliable'. Further detail on the reliability score is provided in Appendix E (Table 15).

Coolibah and black box flood-dependent woodlands

Gwydir Wetlands

Percentage cover trend

The average understorey vegetation cover and tree cover in coolibah and black box woodlands were maintained or likely increased at most sites (>90% of sites) while bare ground cover likely decreased at all sites in the Gwydir Wetlands (Figure 25).

The average native understorey cover likely exceeded the average non-native understorey cover by 19% (79% likelihood), ranging between 15% and 30% (71 to 89% likelihood) across the water years (Figure 25).

There was likely a higher average cover of native amphibious understorey species compared with native terrestrial understorey by 27% (86% likelihood), with the difference ranging between 20% and 37% (80 to 94% likelihood) across the water years (Figure 25).

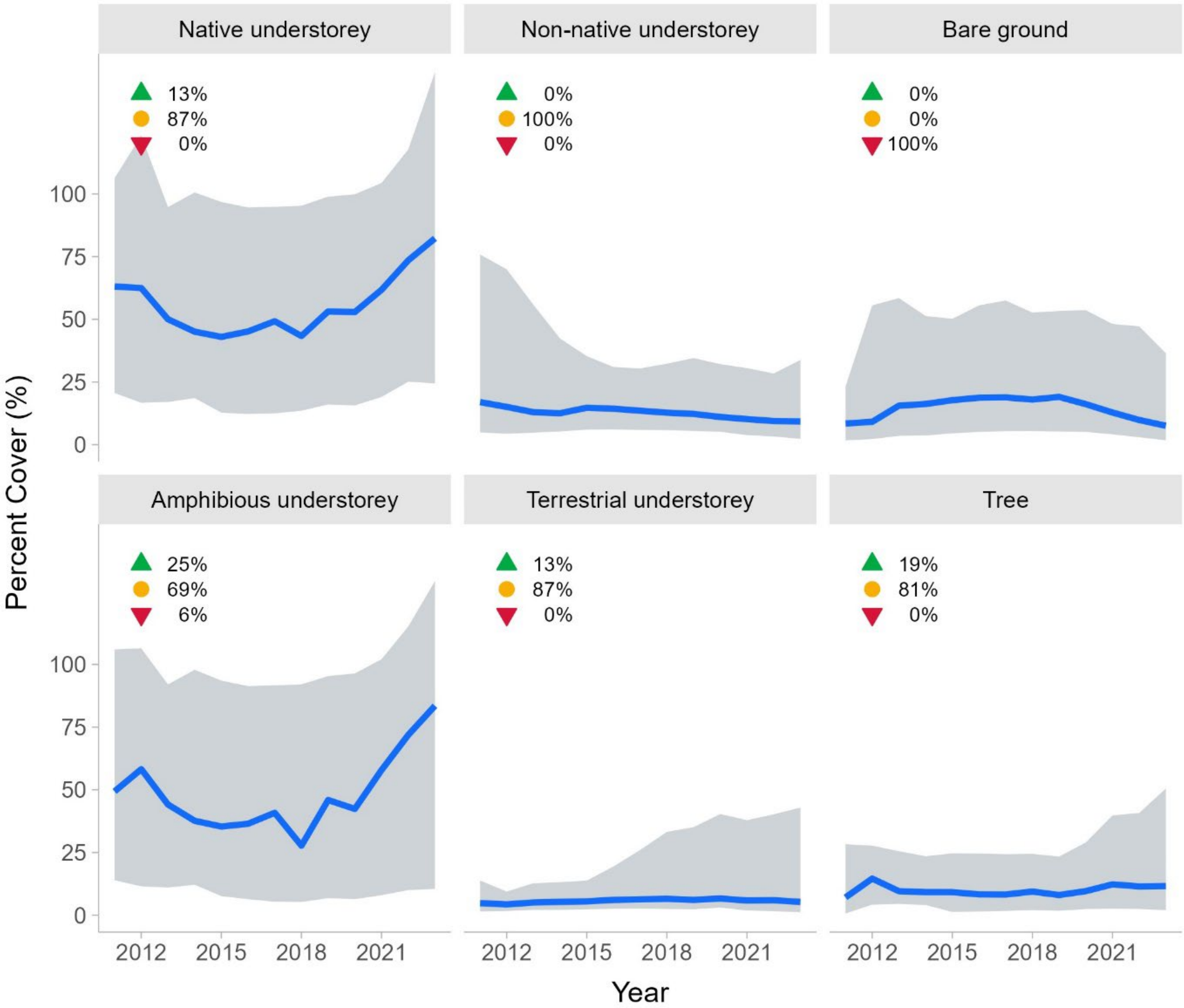

Figure 25 **Trends in average percentage cover of native, non-native, native amphibious and native terrestrial understorey, trees and bare ground in FDW sites for the Gwydir Wetlands (n=16) from 2011 to 2023. The blue lines represent the predicted average cover of the respective vegetation categories. The shaded areas are 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites where average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

An increase in the estimated number of months in a year that sites were inundated was associated with a likely increase in average understorey cover for native amphibious species resulting in an increase in native understorey species cover (68 to 86% likelihood, Figure 26).

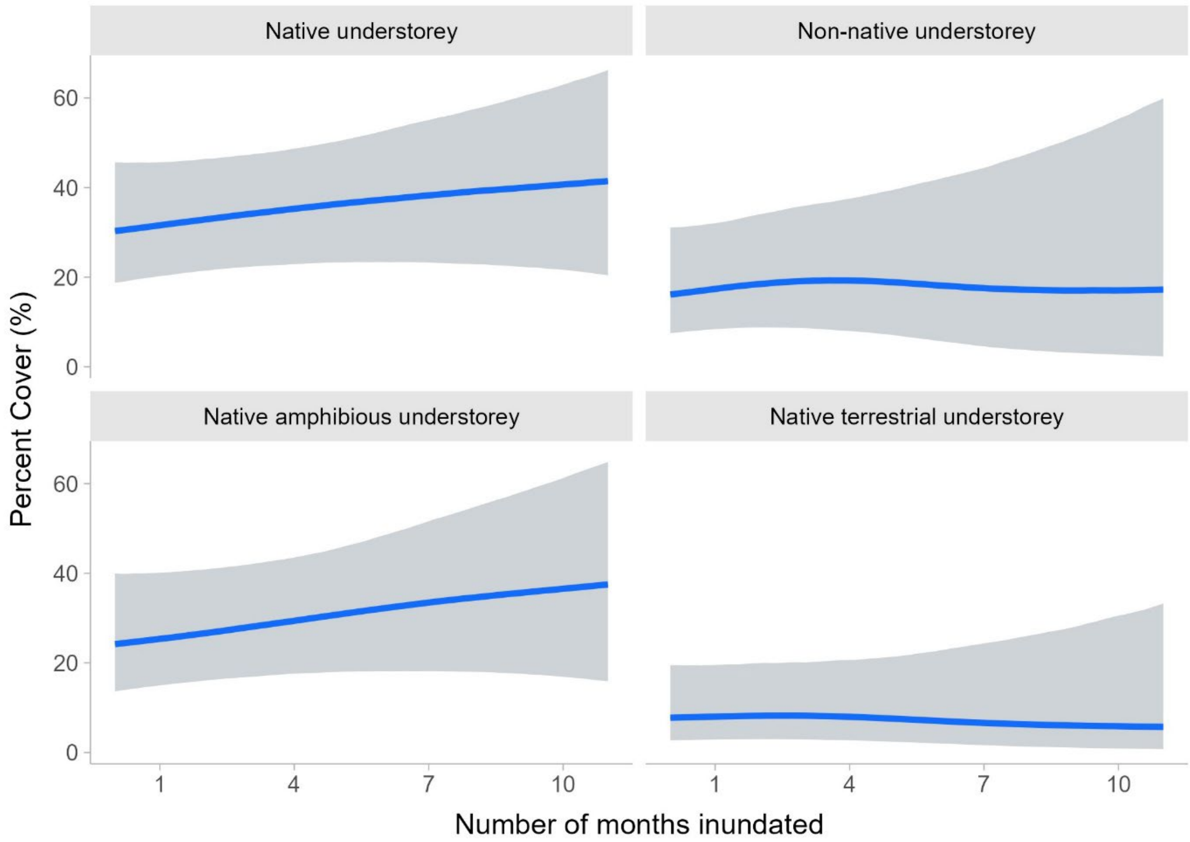

Figure 26 **The effect of the number of months of inundation during a water year on the average percentage cover of native, non-native, native amphibious and native terrestrial understorey species in FDW sites in the Gwydir Wetlands (n=16). The blue lines represent the predicted average cover of the respective vegetation category. The shaded areas are 95% credible interval bounds around the predicted average**

Species richness trend

In this study, 180 native and 56 non-native species were recorded in coolibah woodlands in the Gwydir Wetlands. Average species richness of the various vegetation functional groups was maintained or was likely to have increased at most sites (>88% of sites, Figure 27). Average native species richness was likely to have decreased at 12% of the sites.

The average number of native species exceeded the average number of non-native species by approximately 10 species (99% likelihood, Figure 27). The difference in average species numbers ranged between one and 12 species across the water years (94 to 99% likelihood).

Average native amphibious species richness likely exceeded average native terrestrial richness by approximately 2 species (69% likelihood, Figure 27). These numbers ranged between one and 3 species across the water years (63 to 75% likelihood).

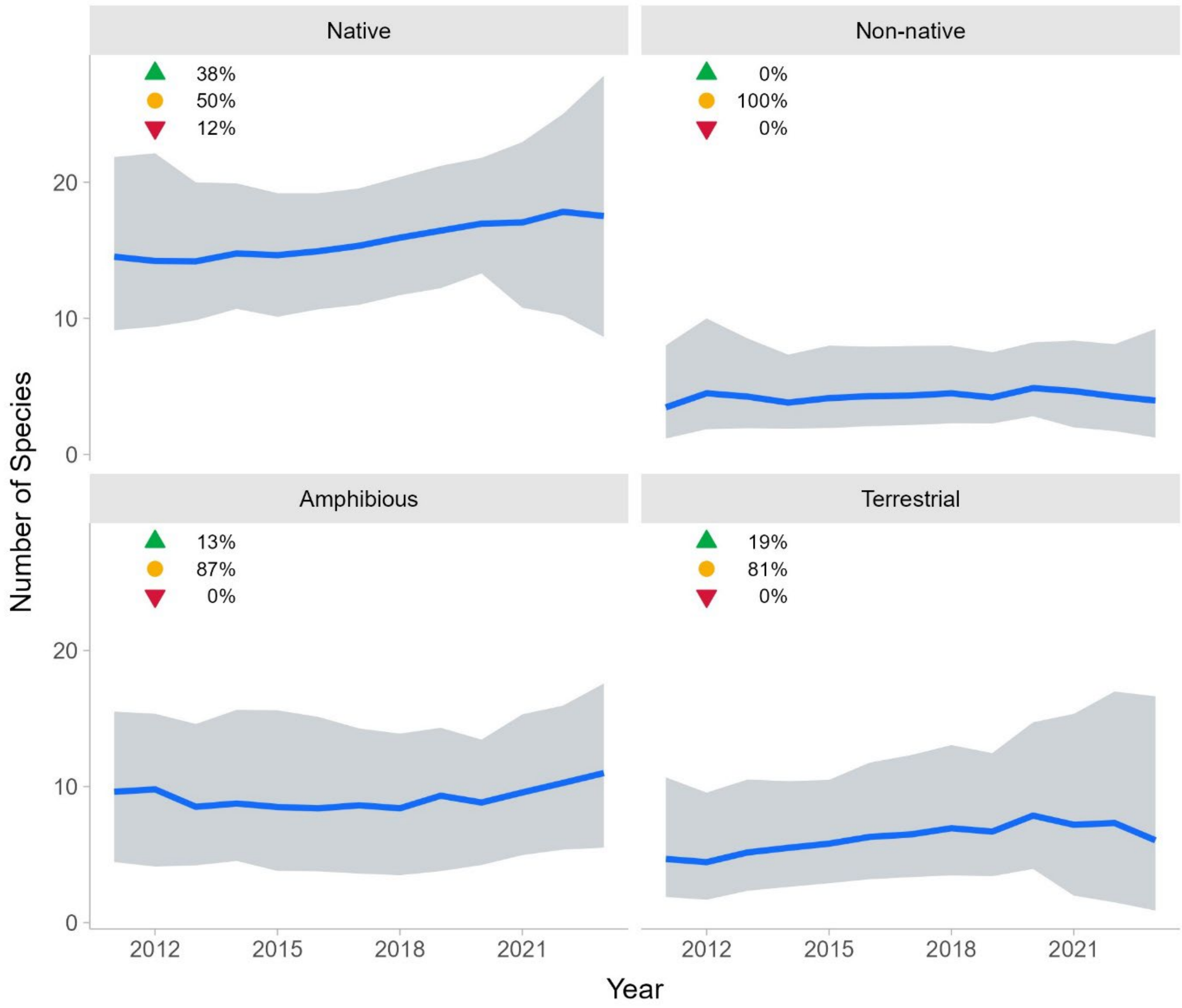

Figure 27 **Trends in the average number of native, non-native, native amphibious and native terrestrial species at FDW sites for the Gwydir Wetlands (n=16) from 2011 to 2023. The blue lines represent the predicted average number of species of the respective vegetation category. The shaded areas are 95% credible intervals around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Macquarie Marshes

Percentage cover trend

The average native and non-native understorey species cover in coolibah and black box woodlands was maintained at most sites (>80% of sites, Figure 28). Maintenance of native understorey cover was driven by native terrestrial species cover, which was maintained at 60% and increased at 20% of the sites. Conversely, native amphibious cover was likely to have decreased at 80% of the sites. Average bare ground cover likely increased or was maintained at 20% and 40% of the sites, respectively, and likely decreased at the remaining 40% of the sites (Figure 28). Tree cover likely increased at 20% of the sites, was maintained at 40% of them, and likely decreased at the remaining 20% of the sites (Figure 28).

The average native understorey cover exceeded that of non-native species by about 29% (99% likelihood) and ranged between 22% and 44% across the water years (98 to 100% likelihood, Figure 28). The average cover of native amphibious understorey species and native terrestrial understorey species were comparable, with the mean difference ranging between 5% and 10% across the water years in favour of terrestrial species (66 to 81%, Figure 28).

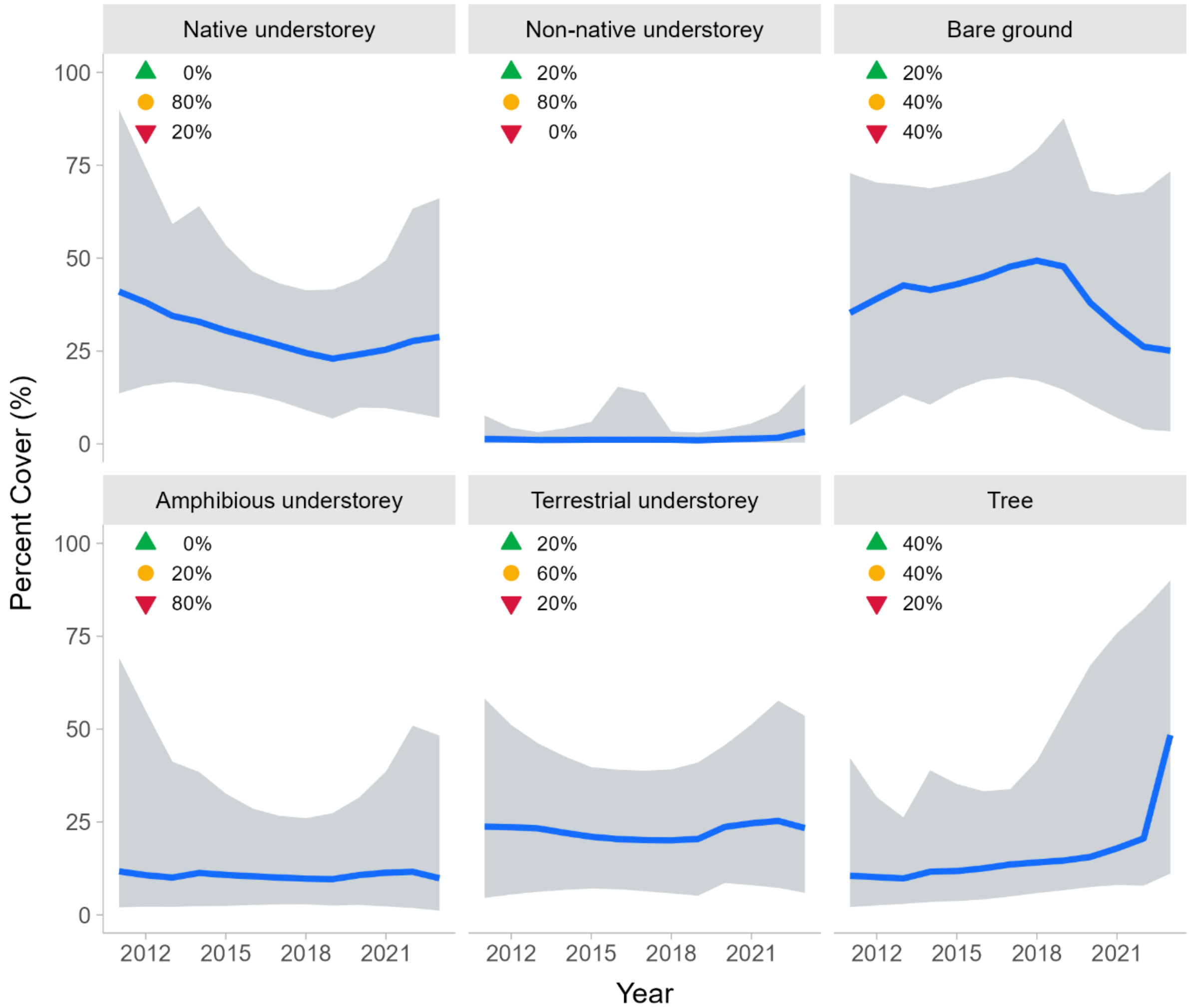

Figure 28 **Trends in average percentage cover of native, non-native, native amphibious and native terrestrial understorey, trees and bare ground in FDW sites for Macquarie Marshes (n=5) from 2011 to 2023. The blue lines represent the predicted average cover of the respective vegetation categories. The shaded areas are 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites where average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

There was a trend of increasing native understorey species cover with estimated flood durations of zero to 5 months. However, the average native amphibious understorey cover remained low (Figure 29). There was high variability in native (amphibious and terrestrial) understorey cover among sites as indicated by the wide 95% credible interval bounds around the average (Figure 29).

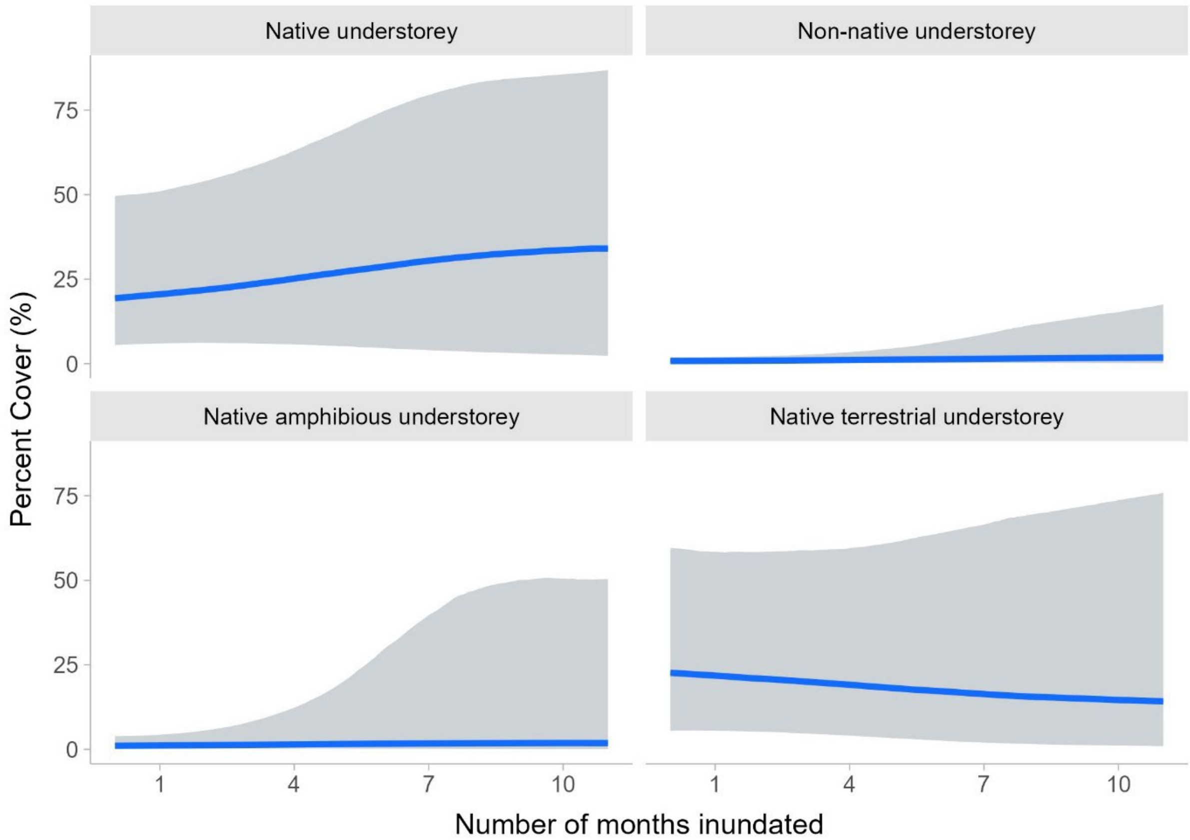

Figure 29 **The effect of the number of months of inundation during a water year on the average percentage cover of native, non-native, native amphibious and native terrestrial understorey species in FDW sites in Macquarie Marshes (n=5). The blue lines represent the predicted average cover of the respective vegetation category. The shaded areas are 95% credible interval bounds around the predicted average**

Species richness trend

In this study, 138 native and 32 non-native species were recorded in coolibah and black box woodlands. The average species richness of the various vegetation functional groups was maintained, or was likely to have increased, at most sites (>60% of sites, Figure 30). Average native species richness likely increased at 80% of the sites. This was driven by an increase in average native terrestrial species richness at 40% of the sites as native amphibious species richness was maintained at all sites (Figure 30). However, there was a likely decrease in average native species richness at the remaining 20% of the sites (Figure 30). Average non-native species richness increased at 20% of sites, was maintained at 40% of sites and decreased at the remaining 40% of the sites (Figure 30).

The average native species richness exceeded non-native species richness by 16 species (100% likelihood, Figure 30). The difference in the average species richness ranged between 12 and 20 species across the water years (>99% likelihood). Average native amphibious richness was very likely to have been lower than average native terrestrial species richness by about 12 species (93% likelihood) with the difference across the water years ranging from 9 to 17 species (77 to 99% likelihood, Figure 30).

Figure 30 **Trends in the average number of native, non-native, native amphibious and native terrestrial species at FDW sites for Macquarie Marshes (n=5) from 2011 to 2023. The blue lines represent the predicted average number of species of the respective vegetation category. The shaded areas are 95% credible intervals around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Data reliability assessment

FDW vegetation cover and species richness data were scored as being 'good' for the Gwydir Wetlands. Data reliability was scored as being 'fair' for Macquarie Marshes as only 5 sites were sampled, meaning that sampling was not representative of the spatial extent of the community. Further detail on the reliability score is provided in Appendix E (Table 16 and Table 17).

Flood-dependent shrubland

Gwydir Wetlands

Percentage cover trend

Average cover of all vegetation functional groups at river cooba and lignum shrubland sites in the Gwydir Wetlands were maintained at most sites (>70%, Figure 31). Average bare ground cover was likely to have decreased at 43% of the sites. The average cover of native amphibious species likely increased at 14% of sites and likely decreased at another 15% of sites (Figure 31). Average cover of native terrestrial species was likely to have increased at 29% of sites.

The average percentage cover of native understorey species exceeded the average non-native understorey cover by approximately 48% (100% likelihood, Figure 31). This varied across the water years, ranging between 46% and 51% (>99% likelihood).

In the native understorey, average amphibious species cover exceeded average terrestrial species cover by approximately 48% (100% likelihood, Figure 31). This varied across the water years, ranging between 47% and 50% (>99% likelihood).

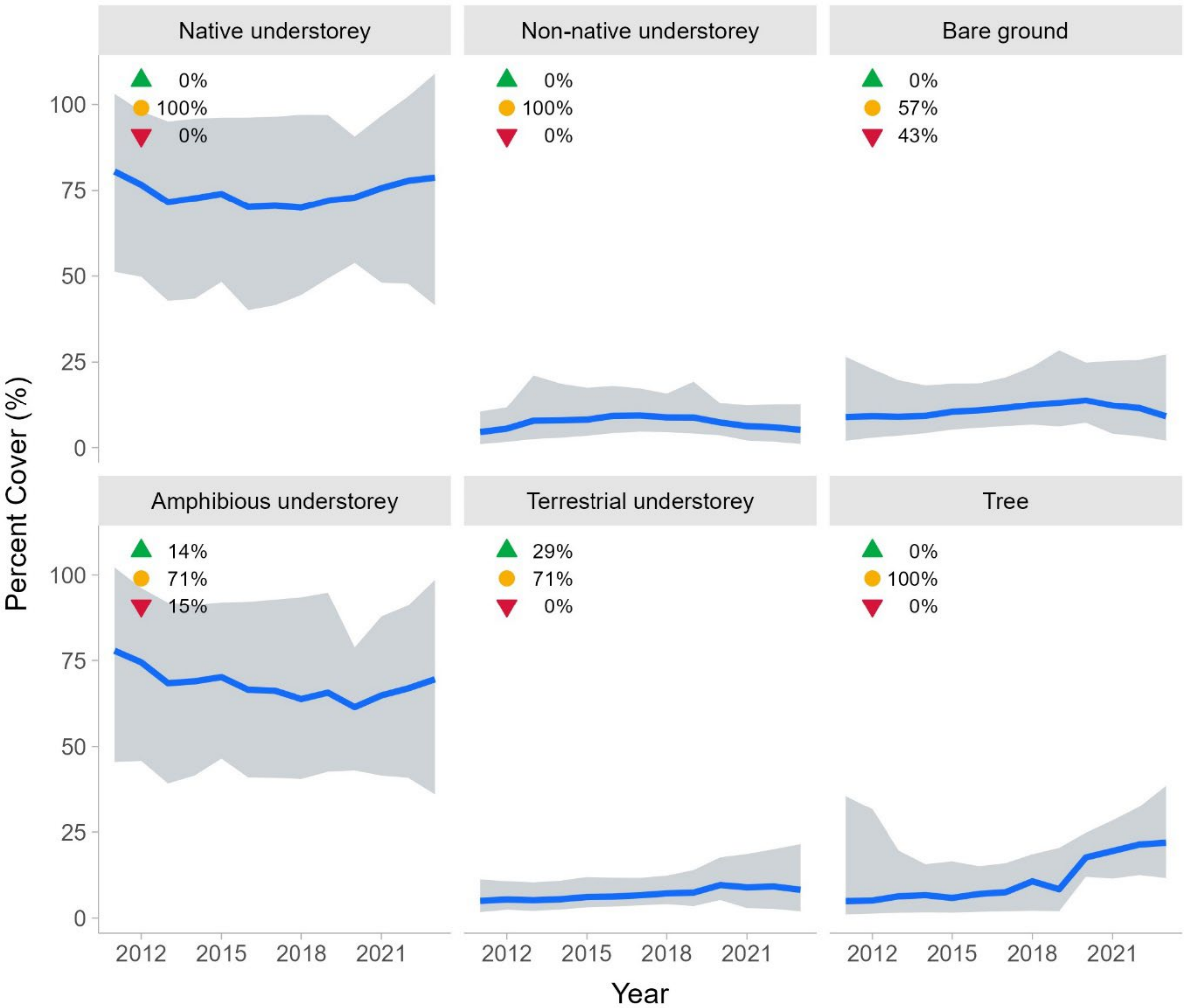

Figure 31 **Trends in average percentage cover of native, non-native, native amphibious and native terrestrial understorey, trees and bare ground at river cooba and lignum shrubland sites for the Gwydir Wetlands (n=7) from 2011 to 2023. The blue lines represent the predicted average cover of the respective vegetation categories. The shaded areas are 95% credible interval bounds around the predicted average. Annotations show the proportion of sites at which average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Average percentage cover of native understorey species, and their amphibious subset, in river cooba and lignum shrublands showed a slight increase as the number of months inundated increased (Figure 32). However, none of the surveyed shrubland sites in the Gwydir Wetlands experienced more than 5 months of inundation in a water year over the last 7 years. There was no clear trend in average cover of non-native and native terrestrial understorey species with increased inundation duration.

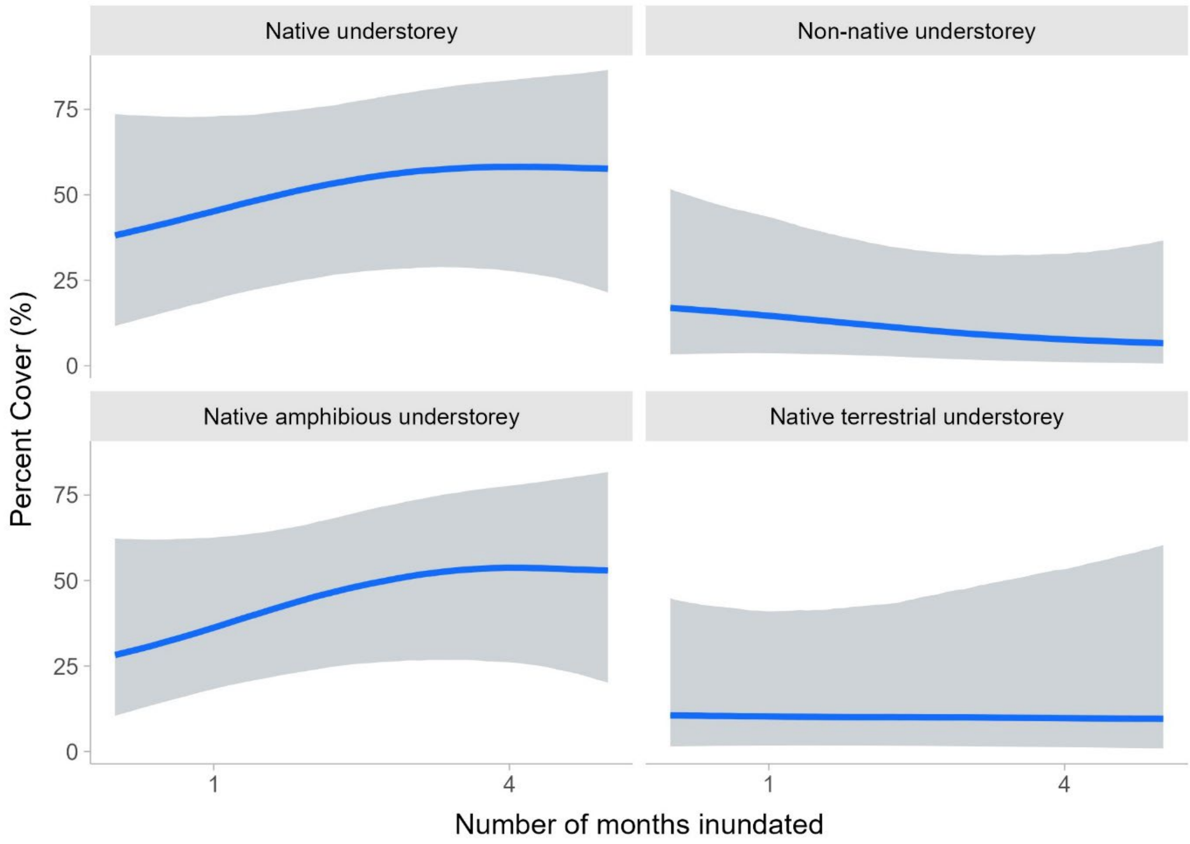

Figure 32 **The effect of the number of months of inundation in a water year on the average percentage cover of native, non-native, native amphibious and native terrestrial understorey species at river cooba and lignum shrubland sites in the Gwydir Wetlands (n=7). The blue lines represent the predicted average cover of the respective vegetation categories. The shaded areas are 95% credible interval bounds around the predicted average**

Species richness trend

In this study, 106 native and 32 non-native species were recorded in river cooba and lignum shrubland sites of the Gwydir Wetlands. Average species richness was maintained at most sites (>57%, Figure 33). Exceptions included a likely increase in average species richness of native species (14% of sites), and native amphibious and terrestrial species subsets at 29% and 43% of sites, respectively (Figure 33).

The average number of native species exceeded the average number of non-native species by approximately 12 species (99% likelihood, Figure 33). These numbers varied across water years, ranging from 11 to 14 species (>99% likelihood).

Average native amphibious species richness was greater than average native terrestrial species richness, by approximately 8 species (98% likelihood, Figure 33). These numbers varied across water years, ranging from 7 to 8 species (94 to 99% likelihood).

Figure 33 **Trends in number of native, non-native, native amphibious, and native terrestrial species at river cooba and lignum shrubland sites in the Gwydir Wetlands (n=7) from 2011 to 2023. The blue lines are the predicted average number of species of the respective vegetation category. The shaded areas are 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2023 period**

Macquarie Marshes

Percentage cover trend

The average cover of all vegetation functional groups and bare ground cover in river cooba and lignum shrubland sites were maintained at most sites (>70%) in Macquarie Marshes (Figure 34). Average cover of non-native understorey species was likely to have increased at 29% of the sites and bare ground cover likely increased at 14% of the sites (Figure 34).

It is extremely likely that average native understorey cover exceeded that of non-native understorey cover by approximately 58% (98% likelihood, Figure 34). This varied across the water years, ranging between 53% and 62% (91 to 100% likelihood). Further, it is extremely likely that the average cover of native amphibious understorey species exceeded average terrestrial understorey cover by 48% (96% likelihood, Figure 34). This varied across the water years, ranging from 46% to 50% (89 to 100% likelihood).

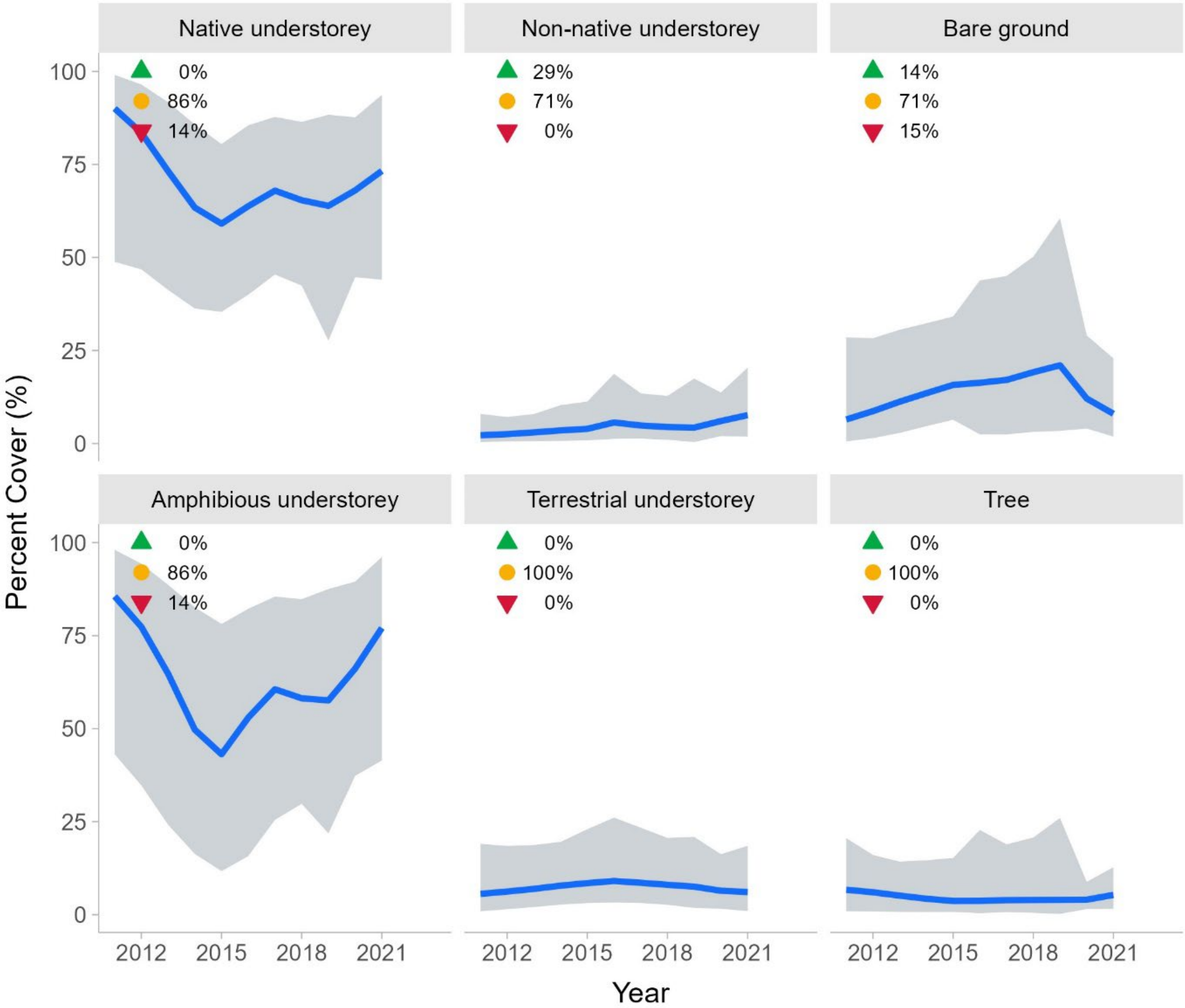

Figure 34 **Trends in average percentage cover of native, non-native, native amphibious and native terrestrial understorey, trees and bare ground at river cooba and lignum shrubland sites for Macquarie Marshes (n=7) from 2011 to 2021. The blue lines represent the predicted average cover of the respective vegetation categories. The shaded areas are 95% credible interval bounds around the predicted average. Annotations show the proportion of sites at which average percentage cover has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2021 period**

Percentage cover of native understorey species and their amphibious subset in river cooba and lignum shrublands showed a slight increase as the number of months inundated increased (Figure 35).

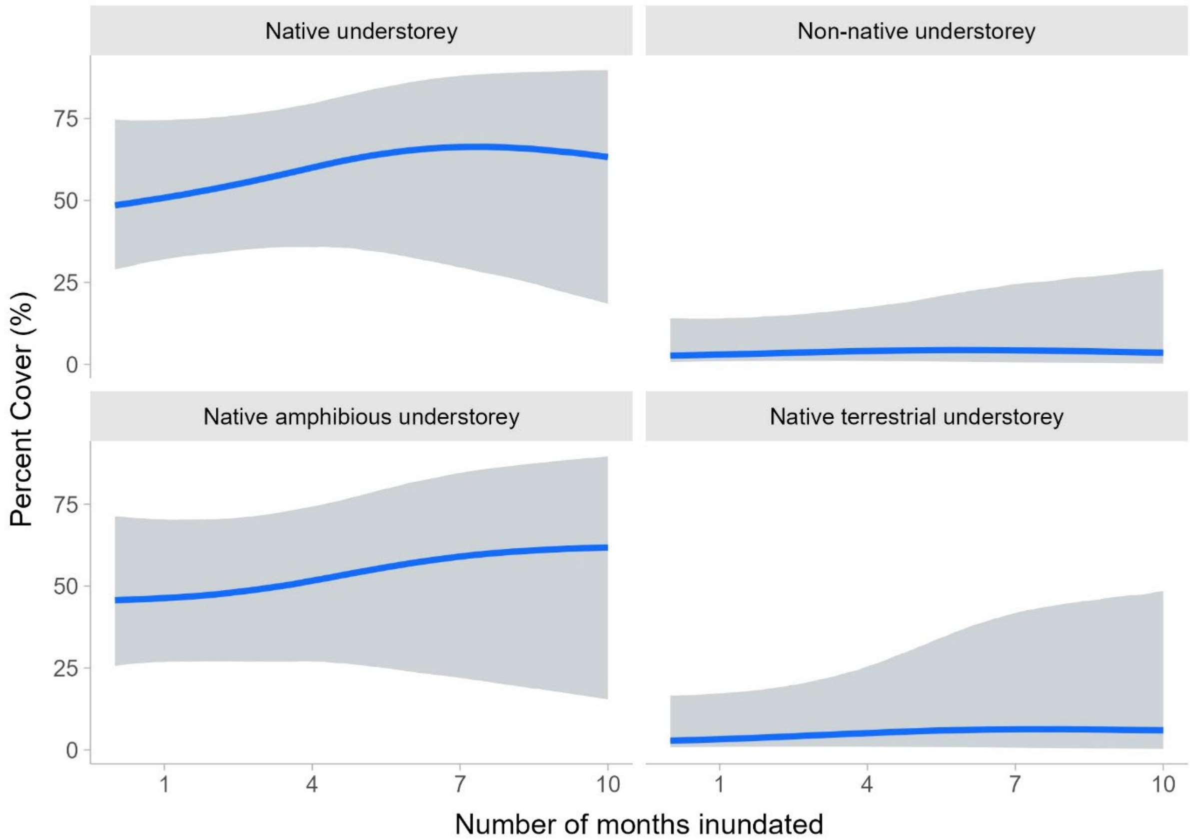

Figure 35 **The impact of the number of months of inundation in a water year on the average percentage cover of native, non-native, native amphibious and native terrestrial understorey species at river cooba and lignum shrubland sites in Macquarie Marshes (n=7). The blue lines represent the predicted average cover of the respective vegetation categories. The shaded areas are 95% credible interval bounds around the predicted average**

Species richness trend

In Macquarie Marshes, 67 native and 20 non-native species were recorded in river cooba and lignum shrubland sites. The average species richness was maintained at most sites (>71% of sites, Figure 36). Exceptions include a likely increase in average native species richness (both amphibious and terrestrial) at 14% of sites and a likely decrease in average species richness of all vegetation functional groups at another 14% of sites (Figure 36).

The average native species richness, which was maintained across the water years, was greater than average non-native species richness by approximately 6 species (99% likelihood, Figure 36).

The difference between average native amphibious and average native terrestrial species richness was approximately 3 species (91% likelihood, Figure 36). These numbers varied across water years, ranging from 3 to 4 species (88 to 93% likelihood).

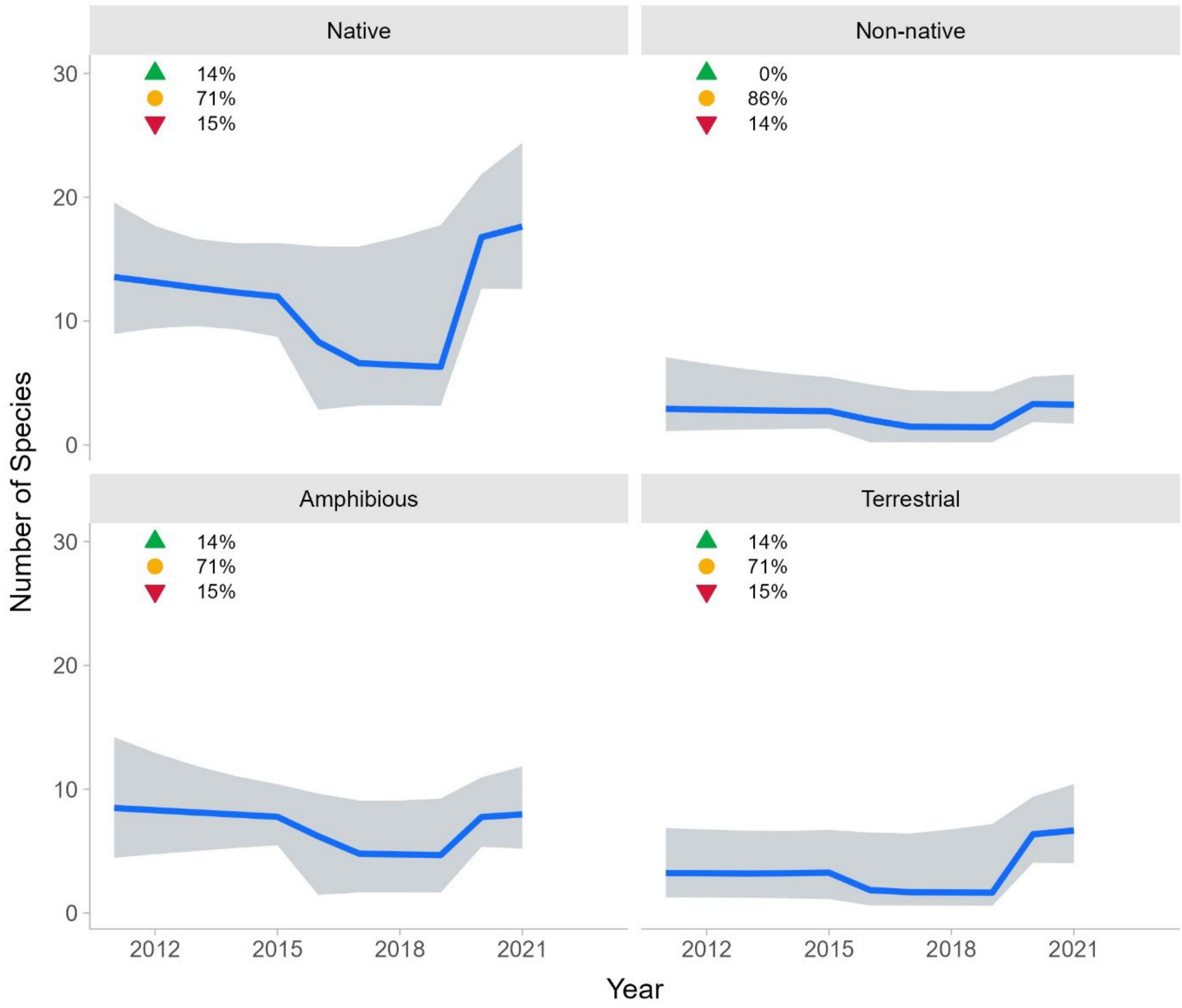

Figure 36 **Trends in mean number of native, non-native, native amphibious, and native terrestrial species at river cooba and lignum shrubland sites in (b) Macquarie Marshes (n=7) from 2011 to 2021. The blue lines are the predicted average number of species of the respective vegetation category. The shaded areas are 95% credible interval bounds around the predicted average. Annotations indicate the proportion of sites at which average number of species has (▲) increased, (●) been maintained, or (▼) decreased over the 2011 to 2021 period**

Data reliability assessment

Flood-dependent shrubland vegetation cover and species richness data were scored as being 'poor' for both the Gwydir Wetlands and Macquarie Marshes due to inconsistency in sampling methods, small number of site replicates, and poor representativeness of the spatial extent of the community. Further detail on the reliability score is provided in Appendix E (Table 18).

4. Discussion

4.1 What is the current status and trend for the monitored vegetation condition and extent?

Vegetation extent

This analysis found all wetland vegetation types remained represented at the Gwydir Wetlands and Macquarie Marshes, indicating that the range of wetland vegetation types occurring within wetlands has been maintained. Expansion of NWW at Macquarie Marshes was mostly into terrestrial areas, with a small proportion into FDS, which was interpreted as a healthy adjustment to the wetter conditions of 2020 to 2022. Thus, all targets to maintain or increase wetland vegetation extents were met.

Vegetation condition

Long-term trends from 2011 to 2023 indicated that vegetation condition had been maintained for most communities in both the Gwydir Wetlands and Macquarie Marshes. In all communities, native species had a greater average cover and species richness than non-native species. Average cover and richness of native amphibious species in NWW vegetation and the understorey of woody communities was greater than that of native terrestrial species. The exception to this was in the coolibah and black box woodlands of Macquarie Marshes where native terrestrial species dominated. This was likely due to the occurrence of this community higher on the floodplains where conditions are drier and less conducive for amphibious species. Key NWW species such as marsh club-rush and water couch flowered and set seed in most years (>3 consecutive years) in the Gwydir Wetlands.

Although there were variations among sites and across water years, long-term trends suggest that LTWP objectives for the various communities were met. However, results for RRGW, coolibah and black box woodlands (Macquarie Marshes), and lignum and river cooba shrublands, should be interpreted with caution as data reliability was relatively low.

The reliability of vegetation condition data was 'fair' for most communities in the Gwydir Wetlands and Macquarie Marshes. Exceptions include coolibah and black box woodland data reliability which was assessed as 'good' for the Gwydir Wetlands, whereas data reliability from FDS in both study areas was considered 'poor'. Low data reliability was a result of insufficient site replicates, poor representativeness of the whole extent of some communities, and inaccessibility to sites for some water years.

4.2 Are these results expected and why are we seeing these outcomes?

Vegetation extent

This study found that all vegetation communities remained represented, and extents were maintained at the Gwydir Wetlands from 2015 to 2022, and Macquarie Marshes from 2013 to 2022. NWWs increased in extent at Macquarie Marshes, mostly into terrestrial areas. These key findings indicate that wetlands have not declined in recent years. They also provide evidence that the ecological targets for wetland vegetation extent, as outlined in the respective LTWPs, were met. However, the limited data for this work precludes a deeper understanding of any potential longer-term trends including potential losses.

Without a longer period of data availability and greater frequency of mapping it was not possible to undertake a statistical trend analysis to separate seasonal responses to wetter years from longer-term trends. It therefore remains uncertain whether the seemingly good outcomes in this study (i.e. no loss of flood-dependent vegetation extent) are a temporary deviation from an ongoing declining trend as communities adjust to decades of river modification and water extraction.

Vegetation condition

In semi-arid regions, flow-dependent plants undergo 'boom and bust' cycles in response to variable flow regimes (Bunn et al. 2006). This pattern has been observed in the results of this project. Vegetation cover in both NWW communities and the understorey of woody communities increased following wet years (wet phase) and decreased during extended dry periods (dry phase). Increases in vegetation cover during a wet phase are triggered by the increased availability of water, nutrients, and sediments (Mason et al. 2022). A dry phase results in death or dormancy of many wetland plants due to desiccation or stranding (Nicol et al. 2003; Jenkins and Boulton 2007; Davis et al. 2015). The results also show that NWW vegetation cover can decrease during extended flooding as low-lying habitats turn into open water. Overall, monitoring indicated that NWW vegetation cover and understorey cover of woody vegetation was maintained.

Results suggest that tree and shrub cover were maintained or improved in both the Gwydir Wetlands and Macquarie Marshes, supporting the notion that long-lived species tend to persist over time (Roberts and Marston 2011). Woody communities monitored as part of this project generally have broad inundation frequency requirements that can range from one to 3 years, to once every 10 years (Roberts and Marston 2011). These inundation frequency requirements were met for most vegetation communities monitored as part of this study, in both study areas. Even though the number of survey sites was limited for some vegetation communities (RRGW, coolibah and black box woodland in Macquarie Marshes, and FDS in both study areas), the overall patterns of vegetation cover and species richness were typical of a wetland expression. This result suggests that wetland vegetation condition was maintained.

Water regimes influence community composition and species richness (Reid and Capon 2011). For example, native species cover and species richness may increase in a wet phase as habitats become more suitable for germination and growth of flow-dependent and amphibious species (Mason et al. 2022). Although there were variations among sites and across water years, the long-term results for the NWW vegetation and understoreys of most woody vegetation communities in both study areas support this notion. This is because native species dominated both vegetation cover and species richness. An exception was RRGW in Macquarie Marshes, a PCT that is typically dominated by native terrestrial ground cover species as a result of its location at a higher elevation on the floodplain. Studies have also shown that dry conditions are characterised by an increase in terrestrial species cover (Nicol et al. 2003) and non-native species richness (Catford et al. 2014; Webb et al. 2015; Webb et al. 2018).

The Gwydir Wetlands and Macquarie Marshes contain threatened ecological communities such as marsh club-rush and the regionally restricted water couch. Inundation duration, together with water depth, day length and temperature, influence patterns of growth and flowering of these wetland plants (Casanova and Brock 2000). The results of this work over the last 4 wet years in the Gwydir Wetlands indicate that marsh club-rush and water couch have successfully flowered and set seed at most sites in most water years since spring 2019. The spring surveys coincided with marsh club-rush flowering season (McCosker 2001). The autumn surveys coincided with water couch flowering season (Roberts and Marston 2011) so there was a higher chance of flowering being detected. However, as a summer-growing species, it is likely that water couch may have started senescing when the autumn surveys commenced, which may explain the detection of flowering at fewer sites.

Inundation duration is known to be an important factor influencing wetland vegetation condition (Mason et al. 2022). Results modelled using data from the last 7 years found positive correlations between estimated inundation duration and native and/or native amphibious vegetation cover for most vegetation communities of the Gwydir Wetlands and Macquarie Marshes, except for RRGF in Macquarie Marshes. For each water year, the average number of months of inundation for which an increase was predicted varied among the vegetation communities. For example, while cover of NWW vegetation communities increased with increasing inundation duration of up to 7 months, the cover of RRGW understorey only increased when it experienced an inundation duration of 4 to 8 months. This suggests there may be thresholds of annual average inundation duration below which vegetation condition may be improved. However, further research is needed to understand how duration interacts with other factors and to test and determine inundation-duration thresholds for various vegetation communities.

4.3 How has the Basin Plan (i.e. the availability of increased volumes of environmental water) contributed to outcomes?

Vegetation extent

It is highly likely that environmental water flows maintained the extent of wetland vegetation in core areas of the Gwydir Wetlands and Macquarie Marshes throughout the dry period of 2018 to 2020. However, this remains unconfirmed as the available maps provide snapshots of vegetation extent before and after but not during this dry period. No vegetation maps are available to show the extent of flood-dependent vegetation in the 2019–20 dry period. The unavailability of this data is partly explained by the resource-intensive nature of the manual API method. Development of remote-sensing methods would help to overcome this limitation.

Although this study found positive outcomes for flood-dependent vegetation, it remains uncertain whether the longer-term declines associated with flow regulation and water regulation have been slowed, halted or reversed by management interventions such as environmental water deliveries. Further research is required to better understand the ecological outcomes of environmental water flows on the extent of flow-dependent vegetation in the NSW MDB.

Vegetation condition

During dry periods, minimal natural flows were supplemented with managed environmental water flows. These flows may have influenced the maintenance of ground cover in both the Gwydir Wetlands and Macquarie Marshes over the study period. Environmental water flows have likely increased water levels in channels, therefore improving hydrological connectivity between habitats and maintaining NWW condition in adjacent wetlands. Environmental water flows do not usually directly affect vegetation communities occurring higher on the floodplains. However, these flows could contribute to ground water recharge, which is crucial in the upper floodplains. The positive, modelled relationship between estimated inundation duration and native amphibious cover suggests environmental water flows support ecological targets in the Gwydir Wetlands and Macquarie Marshes where they contribute to suitable inundation durations. Previous studies have outlined water regimes (including inundation duration) required to maintain or restore the condition of key long-lived plant species such as river red gum, black box, coolabah and lignum as surrogates for the various flood-dependent vegetation communities (Roberts and Marston 2011; Casanova 2015). However, there is a need to improve on this 'key species' approach by modelling responses of broader vegetation categories to inundation regimes (Casanova 2015). Vegetation condition responses to inundation spell (duration and frequency) have been modelled using 124-year time series datasets for broader flood-dependent plant community types in the southern MDB with promising results (McPhan et al. 2022a; 2022b). Similar work should be undertaken for flood-dependent vegetation communities of the Gwydir Wetlands and Macquarie Marshes to assist with the development of guidelines for managing inundation duration using environmental flows.

4.4 Recommendations for monitoring into the future

Vegetation extent

To further improve the current understanding and breadth of available data relating to vegetation extent across the NSW MDB, consideration should be given to developing repeatable and accurate satellite remote-sensing methods to monitor wetland vegetation extent. NSW Government has recently initiated research to address this need for improved mapping methods (Wen et al. 2024). These methods should be adopted to improve monitoring of wetland vegetation extents in the future. Drone survey techniques should also be developed for collection of vegetation data to train and validate remote sensing and spatial modelling methods.

These recommended actions and method developments will enable broader spatial coverage and better understanding of Basin-wide vegetation patterns. The recommended method improvements will also reduce map errors associated with observer bias and increase the frequency of map data collection to better understand trends. Implementation of these methods will support a more reliable assessment of vegetation extent LTWP objectives.

Vegetation condition

Monitoring programs require clear objectives and targets. The current LTWP targets for the various vegetation communities are not clearly articulated. A review of the LTWPs for the various wetlands of the MDB, including the Gwydir Wetlands and Macquarie Marshes, is ongoing. This is occurring alongside a review of the expected ecological outcomes for the various vegetation communities targeted in the Basin Plan. These reviews will assist in improving the monitoring program by setting clear objectives and targets.

Decisions for conservation management should be underpinned by reliable data gathered using appropriate standard methods. Reliability of data used in this report has been assessed as being 'fair' for most vegetation communities in the Gwydir Wetlands and Macquarie Marshes. This low data confidence is due to data gaps in the long-term data sets. These data gaps were due to several uncontrollable challenges: underrepresentation of some vegetation communities, including RRGW and FDW in Macquarie Marshes, and lignum in both study areas; sampling method changes; inaccessibility of sites due to high water levels during extremely wet years and subsequent thick impenetrable growth of stands. Under these conditions, health and safety risks were prioritised.

To address some of these challenges, plans are under way to increase the number of monitoring sites for under-represented communities. Additionally, new methods are being trialled to measure percentage cover and vigour (greenness) of those single-layered communities, such as lignum and common reeds that tend to form monocultures, using drone-captured imagery.

There are knowledge gaps for flow-dependent vegetation communities in other wetlands of the NSW MDB. There are also limited vegetation condition monitoring data for Narran Lakes, lower Lachlan, mid Murrumbidgee and the wetlands of the Murray. Additional monitoring resources are required for program expansion into these areas.

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Appendix A: Vegetation extent map development and look-up table

Several steps were taken to develop the 2022 maps of wetland vegetation extent at the Gwydir Wetlands and Macquarie Marshes. These are outlined in detail below.

1. Look-up table

A look-up table was developed to describe the vegetation community functional groups to be shown on the map, the alignment of these functional groups to the vegetation described in LTWP targets, and the alignment to plant community types included in previous mapping of Gwydir Wetlands and Macquarie Marshes (Bowen et al. 2019a; Bowen et al. 2019b). this look-up table is shown below (Table 12).

2. High resolution aerial imagery

High resolution orthorectified (i.e. straight down planimetric view) imagery was sourced as the primary basis for map generation. the imagery for the Macquarie Marshes included high resolution 40cm airborne Digital Sensor 40 (ADS-40) imagery and this was collected in June 2022. The imagery for the Gwydir Wetlands included high resolution 40 cm ADS-40 imagery collected in August 2022.

In addition, 15 cm high resolution orthorectified imagery collected between 12 January and 9 May 2023 was provided to assist interpretation of vegetation community extents for an eastern portion of the Gwydir Wetlands study area. This 15 cm imagery was collected by Woolpert and provided by the NSW Gwydir Reconnecting Watercourse Country Program.

3. Additional datasets to assist interpretation of aerial imagery

Additional datasets were collated to assist the interpretation of vegetation patterns from the aerial ADS-40 imagery. These included a set of environmental predictor layers including inundation frequency, soil mapping, landform and elevation data, and existing floristic data and BioNet species data.

Oblique aerial handheld photos captured from a helicopter were also adopted to inform the air photo interpretation. The set of oblique handheld photos adopted to inform the API included photos collected between January and December 2022 at the Gwydir Wetlands and from January 2022 to April 2023 at Macquarie Marshes.

4. Segmentation tool and polygon dataset

Following the method provided by Roff et al. (2022) a computer-based image analysis tool, known as segmentation, was applied to a set of raster datasets with a 5 m grid cell size using the Trimble eCognition Software v10.1 (Trimble 2021). This produced a spatial layer of ‘segments’ or very small polygons based on the combined spectral and textural features of the input rasters.

5. Import datasets to a GIS

All data was imported into ESRI ArcMap 10.8 for on-screen interpretation and GIS processing.

6. Air photo interpretation and map production

Within ArcMap the segmented layer was overlayed on the 40 cm aerial orthorectified imagery. Interpreters manually selected groups of segments and assigned classes (‘attributes’) to the polygons to delineate vegetation patterns. The use of the segmented spatial layer enabled more efficient mapping as interpreters did not need to manually draw polygon linework.

Table 11 **Look-up table prepared for the development of vegetation extent maps. The table shows the relationship between flood-dependent vegetation class, LTWP vegetation descriptions and PCTs**

PCT ID and name	Functional group and map unit	LTWP description
36: river red gum open forest of the Darling Riverine Plains (DRP) Bioregion	RRGF	RRGF on floodplains
36a: river red gum tall woodland wetland	RRGW	RRGW on floodplains
454: river red gum grassy chenopod open tall woodland (wetland)	RRGW	RRGW on floodplains
37: black box woodlands on floodplains of the NSW central and northern wheatbelt including the DRP	FDW	Black box woodland on floodplains
39: coolibah - River Cooba - lignum woodland wetland of frequently flooded floodplains mainly in the DRP	FDW	Coolibah woodland on floodplains
40: coolibah open woodland with chenopod grassy ground cover on grey and brown clay floodplains	FDW	Coolibah woodland on floodplains
53: Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains	NWW	Non-woody vegetation communities occurring in wetlands and on floodplains
181: common reed – bushy groundsel aquatic tall grassland of inland river systems	NWW	Non-woody vegetation communities occurring in wetlands and on floodplains
182: cumbungi rushland of shallow semi-permanent water bodies of the inland river systems	NWW	Non-woody vegetation communities occurring in wetlands and on floodplains
204: water couch marsh grassland of frequently flooded inland watercourses	NWW	Non-woody vegetation communities occurring in wetlands and on floodplains
205: marsh club rush very tall sedgeland/common reed–bushy groundsel aquatic tall grassland	NWW	Non-woody vegetation communities occurring in wetlands and on floodplains

PCT ID and name	Functional group and map unit	LTWP description
238: permanent and semi-permanent freshwater lakes; inland slopes and plains	NWW	Non-woody vegetation communities occurring in wetlands and on floodplains
241: River Cooba swamp/lignum shrubland on regularly flooded alluvial clay depressions in Brigalow Belt South (BBS) and DRP Bioregions	FDS	Lignum shrublands on floodplains
247: lignum shrubland on regularly flooded alluvial clay depressions in BBS and DRP	FDS	Lignum shrublands on floodplains

Appendix B: Location of vegetation condition monitoring sites

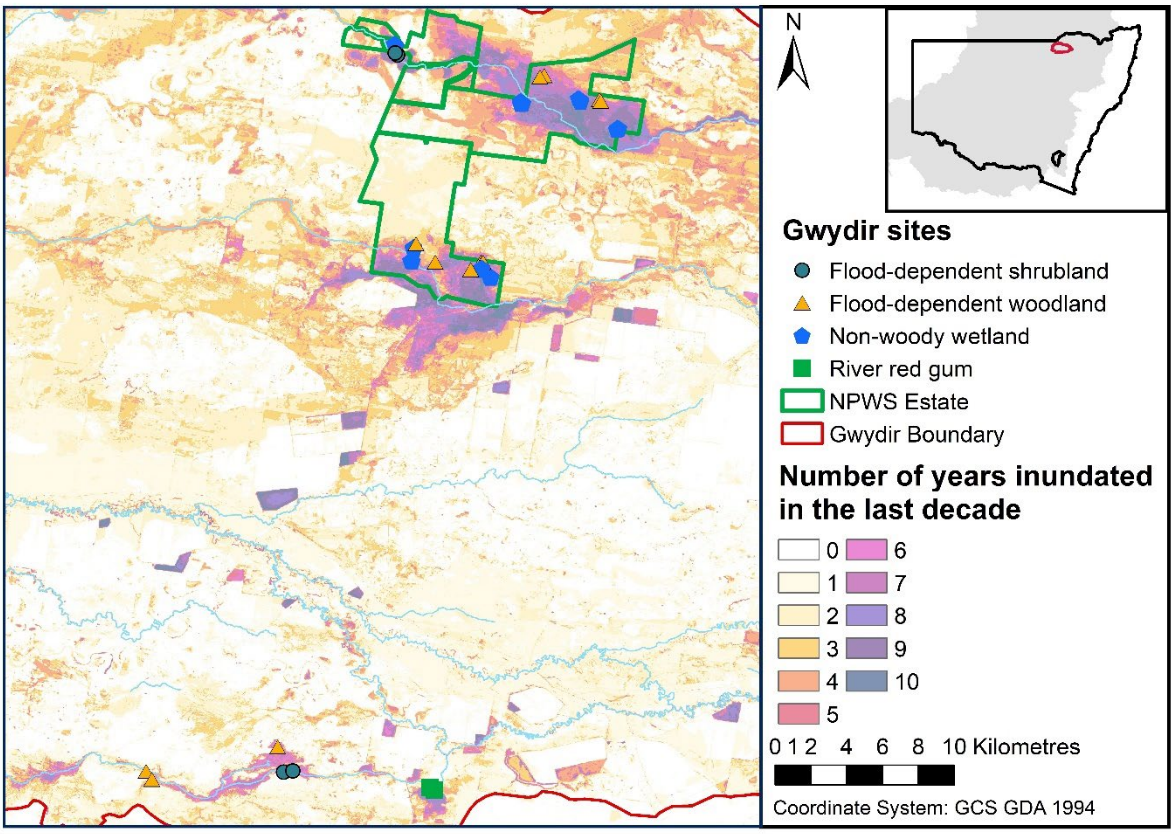

Figure 37 **Location of vegetation condition monitoring sites in the Gwydir Wetlands and the number of years the study area has been inundated over the last 10 years (July 2013 to June 2023). Top right inset shows the location of the Gwydir Wetlands with respect to the MDB (shaded grey) and NSW state boundaries (black lines)**

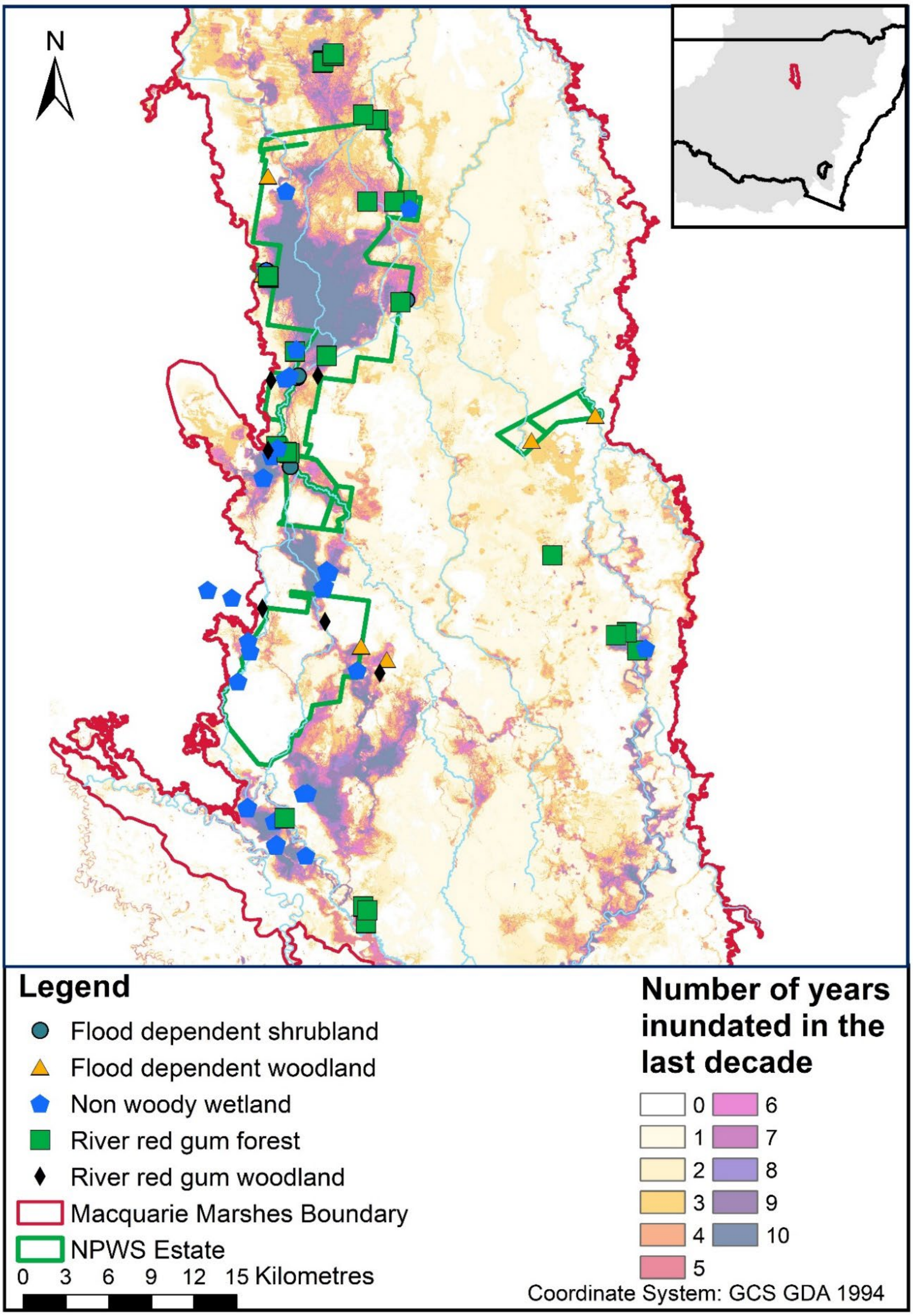

Figure 38 Location of vegetation condition monitoring sites in Macquarie Marshes and the number of years the study area has been inundated over the last 10 years (July 2013 to June 2023). Bottom left inset shows the location of Macquarie Marshes with respect to the MDB (shaded grey) and NSW state boundaries (black lines)

Appendix C: Data coverage for vegetation condition analyses

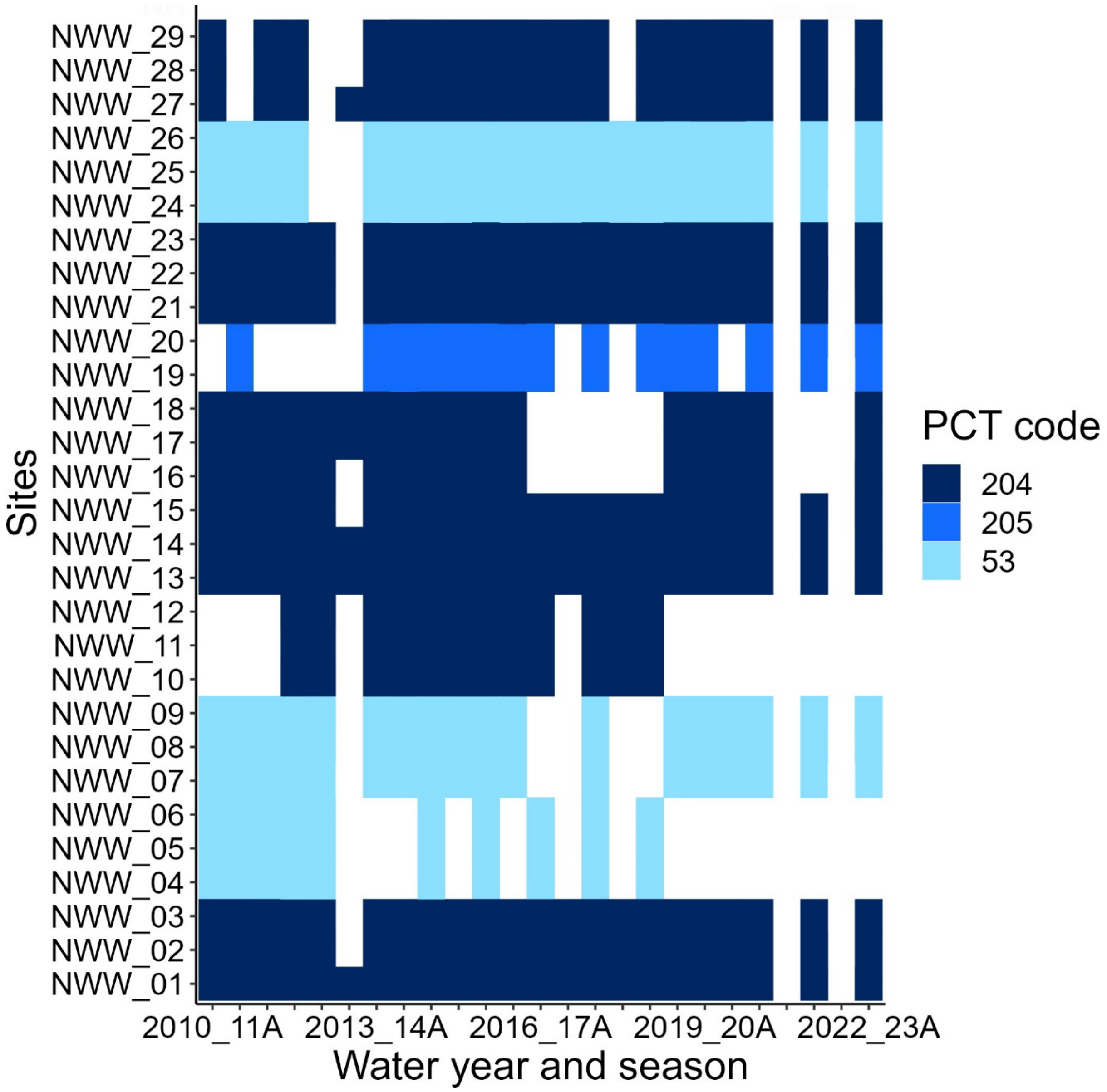

Figure 39 **Data coverage for NWW vegetation condition models in the Gwydir Wetlands**

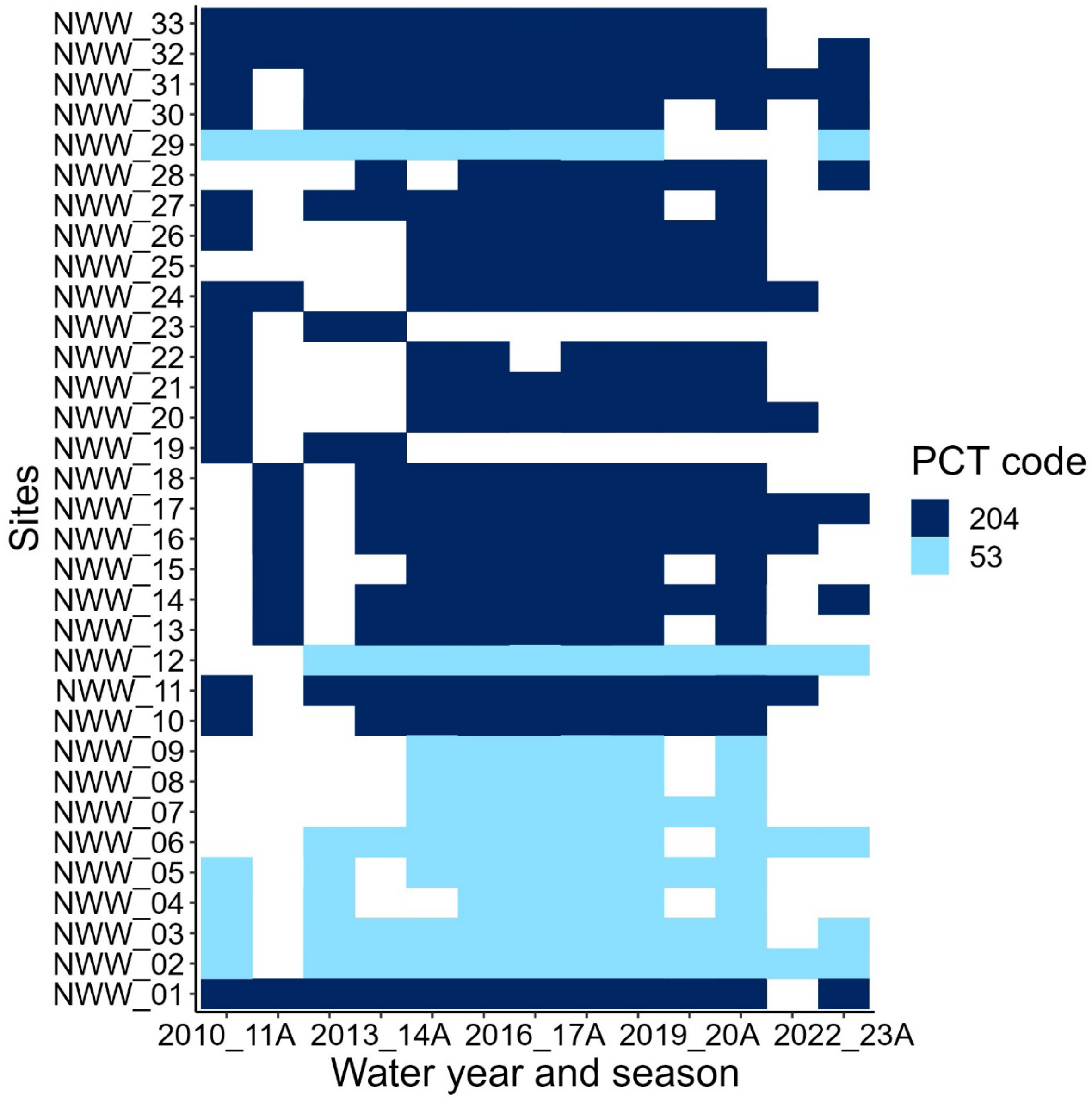

Figure 40 **Data coverage for NWW vegetation condition models in Macquarie Marshes**

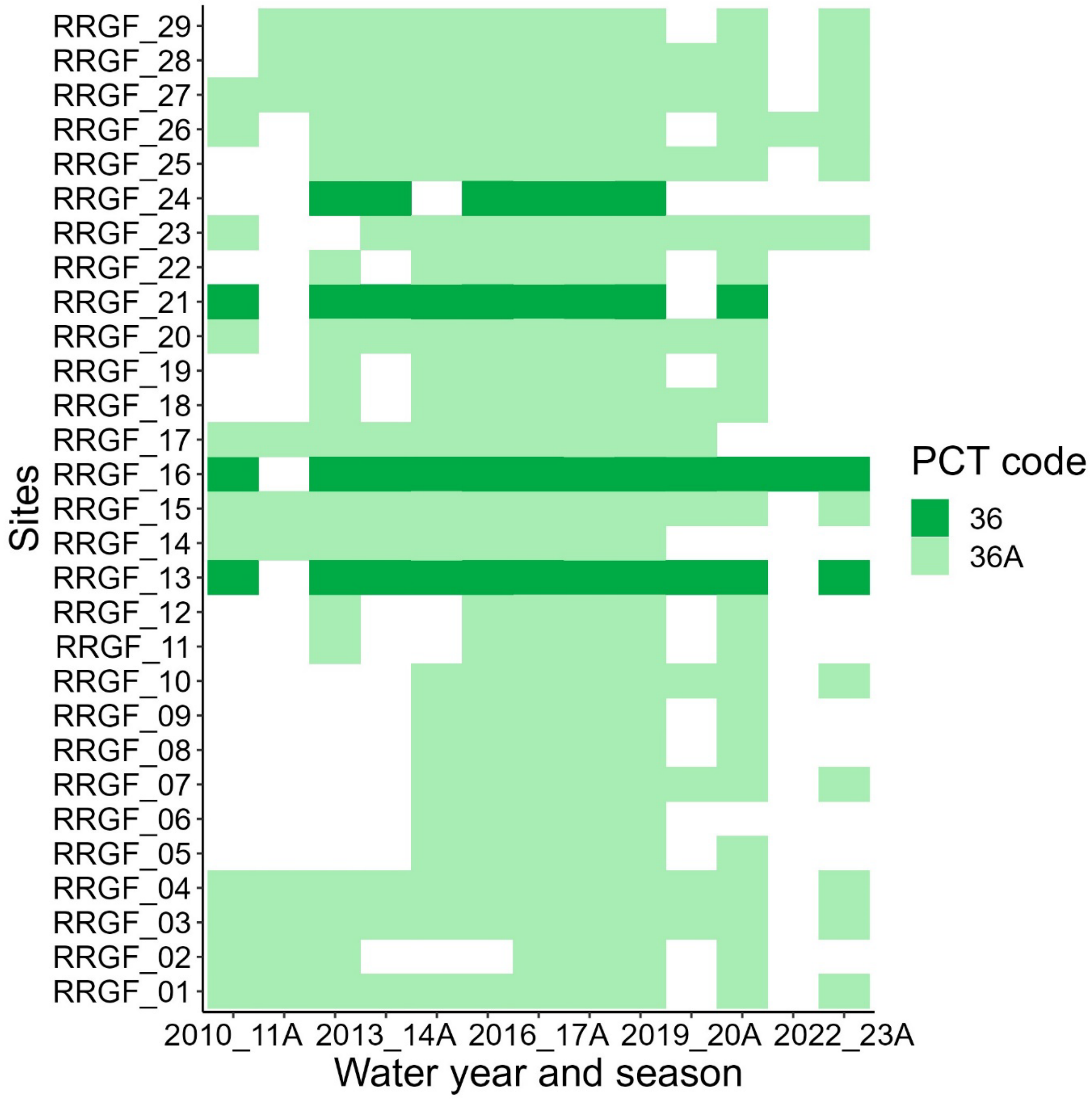

Figure 41 **Data coverage for RRGF vegetation condition models in Macquarie Marshes**

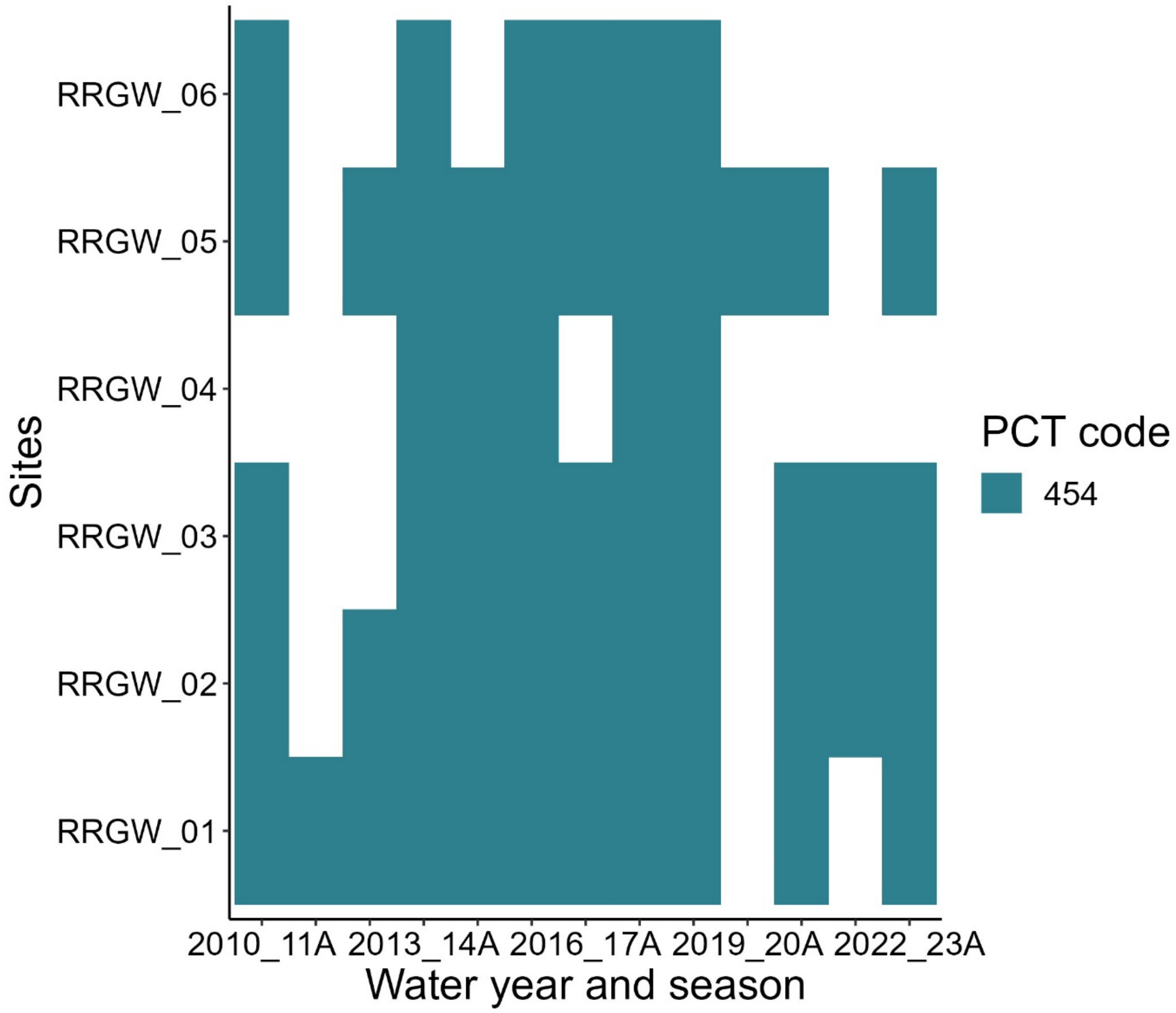

Figure 42 **Data coverage for RRGW vegetation condition models in Macquarie Marshes**

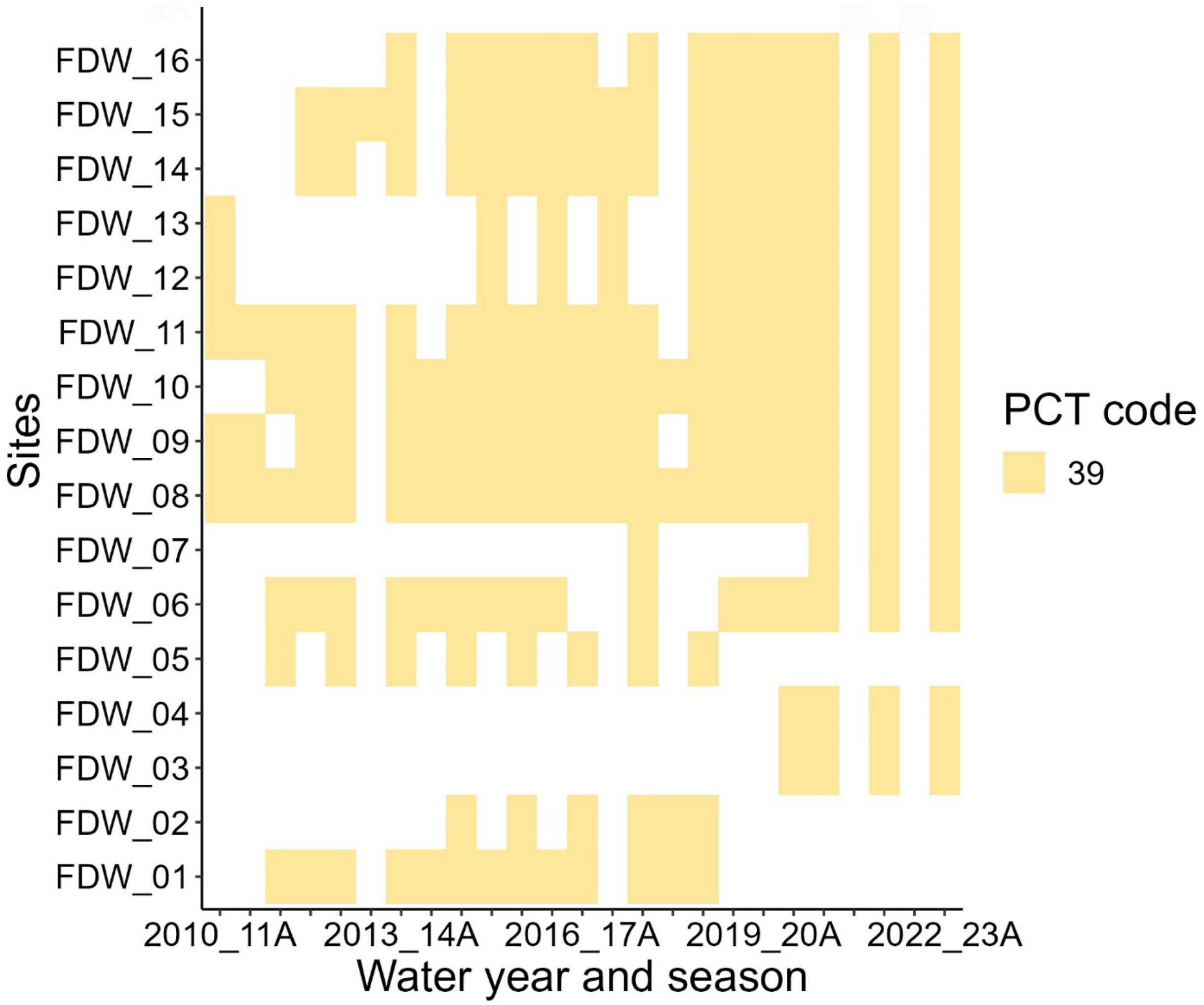

Figure 43 Data coverage for FDW vegetation condition models in the Gwydir Wetlands

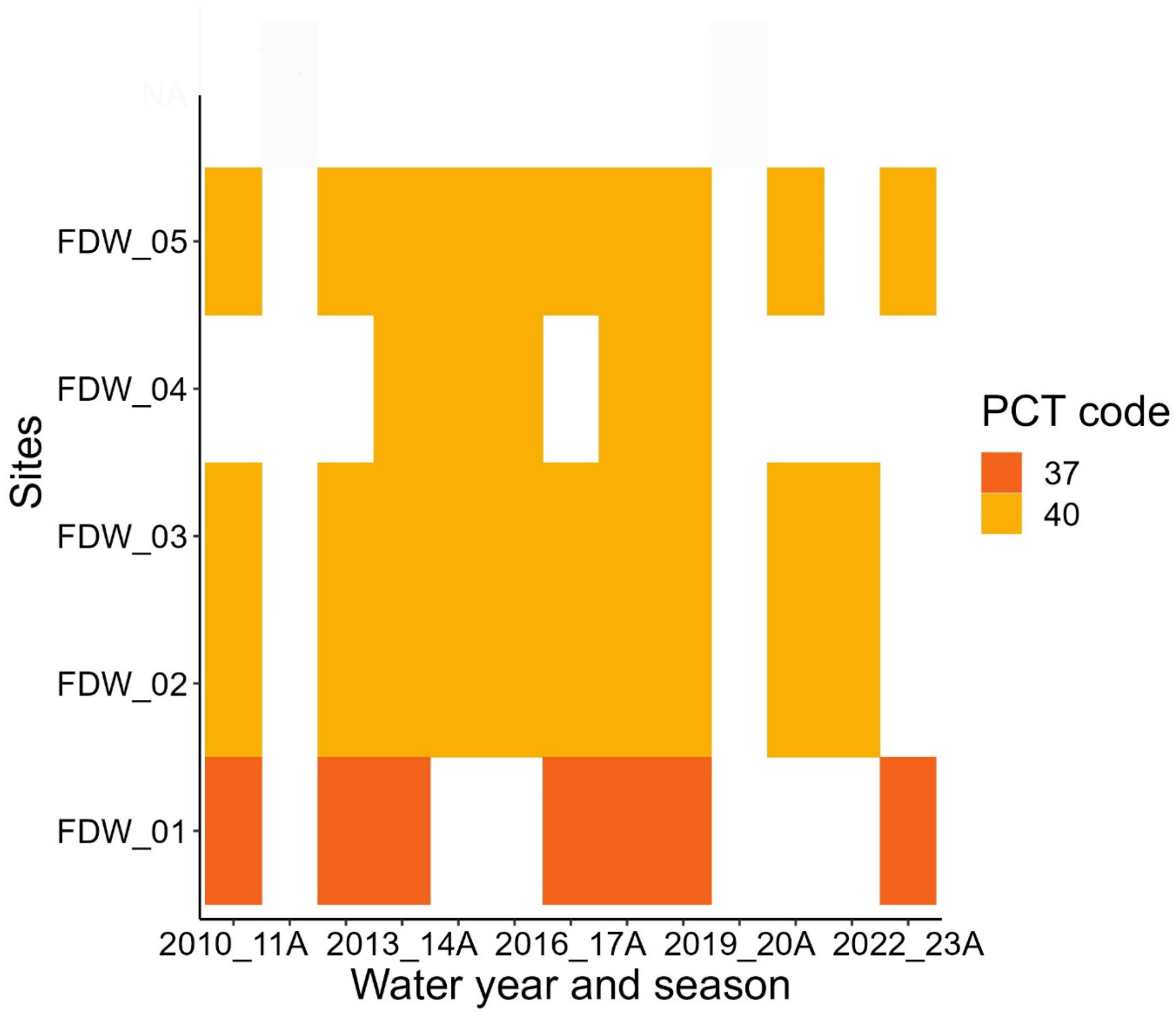

Figure 44 Data coverage for FDW vegetation condition models in Macquarie Marshes

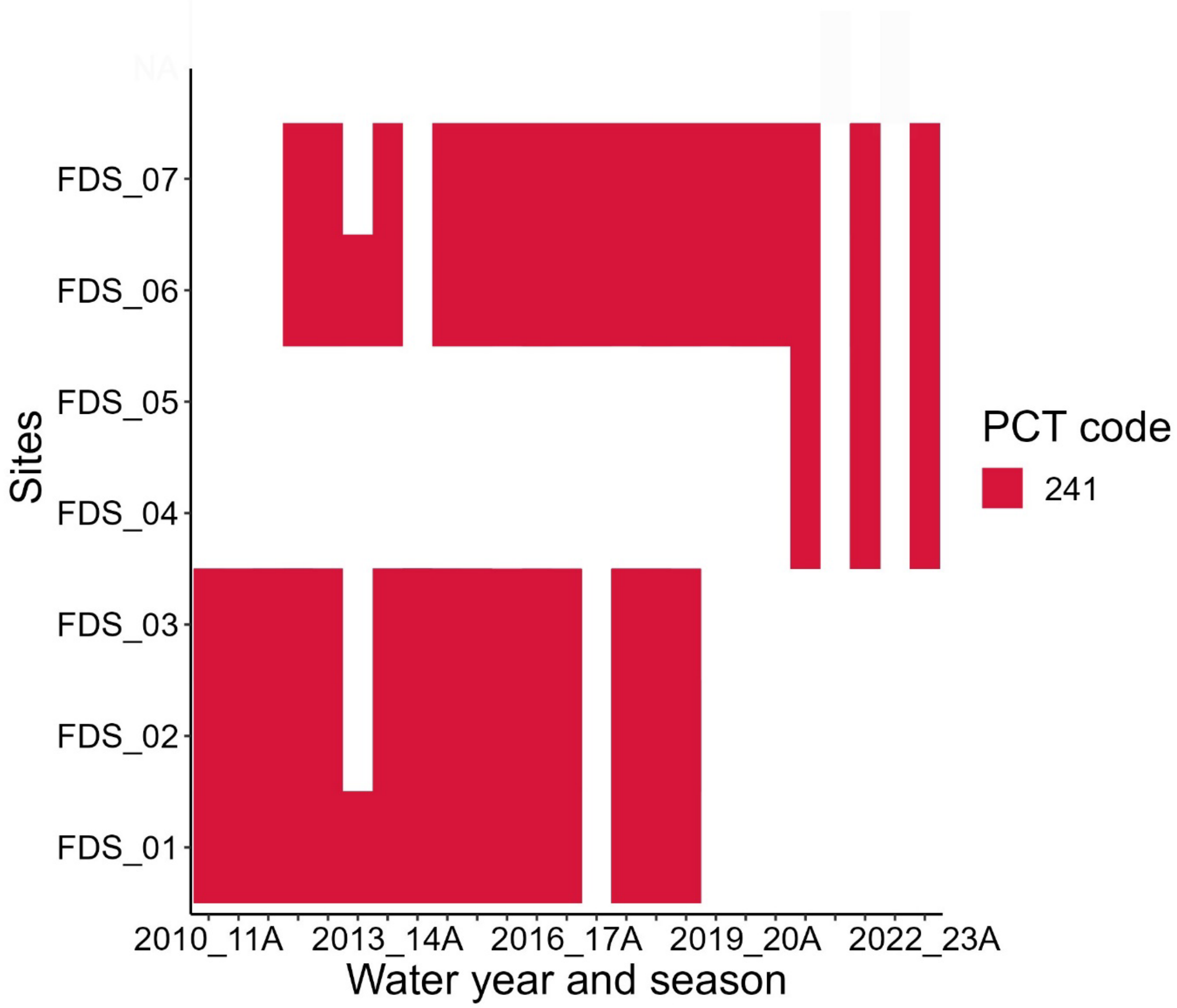

Figure 45 Data coverage for FDS vegetation condition models in the Gwydir Wetlands

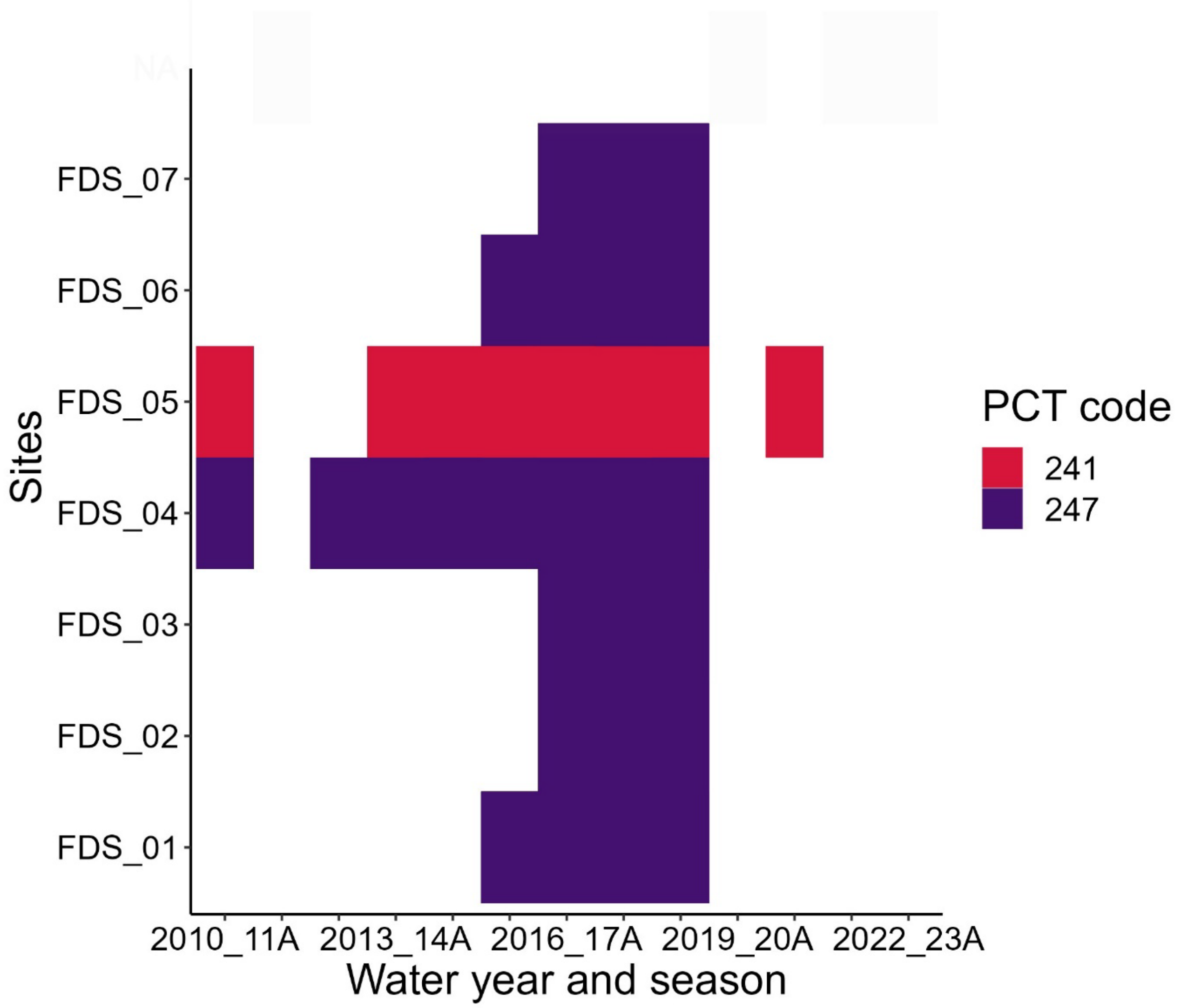

Figure 46 Data coverage for FDS vegetation condition models in Macquarie Marshes

Appendix D: Scoring system for data reliability assessment of vegetation condition

Table 12 **Scoring system for assessing the reliability of data used in this study to evaluate trend and progress towards LTWP targets and objectives (adapted from Battisti et al. 2014)**

Criteria	Question	Score
Methods used	Are the methods used appropriate to gather the information required for evaluation?	0–2
Standard methods	Has the same method been used over the sampling program?	0–2
Representativeness		
Space	Has sampling been conducted across the spatial extent of the community with equal effort?	0–2
Time	Has the duration of sampling been sufficient to represent change over the assessment period?	0–2
Repetition		
Space	Has sampling been conducted at the same sites over the assessment period?	0–2
Time	Has the frequency of sampling been sufficient to represent change over the assessment period?	0–2
Final score	–	0–12
Information reliability	Excellent/very good/good/fair/poor	

Scoring system: Yes = 2, Somewhat = 1, No = 0. Information reliability based on final score: Excellent = 12, Very good = 11, Good = 10, Fair = 9, Poor ≤ 8

Appendix E: Vegetation condition data reliability assessments

Table 13 Reliability assessment of NWW vegetation condition data for the Gwydir Wetlands and Macquarie Marshes

Question	Answer	Justification	Score out of 2
Are the methods used appropriate to gather the information required for evaluation?	Yes	Methods follow a published methodology (Bowen 2016) that is consistent with the NSW Biodiversity Assessment methodology (BAM).	2
Has the same method been used over the sampling program?	Somewhat	The survey included both transect and quadrat methods.	1
Has sampling been conducted across the spatial extent of the community with equal effort?	Yes	Plots were well stratified across the extent of the community with the component plant community types well represented.	2
Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	Thirteen years of annual sampling data has been used in this analysis which constitute sufficient duration to assess change.	2
Has sampling been conducted at the same sites over the assessment period?	Somewhat	Sampling was conducted at permanent plots, however not all plots were sampled all the time due to accessibility challenges.	1
Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	While plots are fixed, not all sites could be sampled in all water years due to accessibility challenges (in extremely wet years).	1
Total			**9/12**

Table 14 Reliability assessment of RRGF condition data for Macquarie Marshes

Question	Answer	Justification	Score out of 2
Are the methods used appropriate to gather the information required for evaluation?	Yes	Methods follow a published methodology (Bowen 2016) that is consistent with the NSW Biodiversity Assessment methodology (BAM).	2
Has the same method been used over the sampling program?	Somewhat	The survey included both transect and quadrat methods.	1
Has sampling been conducted across the spatial extent of the community with equal effort?	Yes	Plots were well stratified across the extent of the community with the component plant community types well represented.	2
Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	Thirteen years of annual sampling data was used in this analysis. This constitutes sufficient duration to assess change.	2
Has sampling been conducted at the same sites over the assessment period?	Somewhat	Sampling was conducted at permanent plots, however not all plots were sampled all the time due to accessibility challenges.	1
Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	While plots are fixed, not all sites could be sampled in all water years due to accessibility challenges during extremely wet years.	1
Total			**9/12**

Table 15 Reliability assessment of RRGW data for Macquarie Marshes

Question	Answer	Justification	Score out of 2
Are the methods used appropriate to gather the information required for evaluation?	Yes	Methods follow a published methodology (Bowen 2016) that is consistent with the NSW Biodiversity Assessment Methodology (BA.M)	2
Has the same method been used over the sampling program?	Yes	The survey method was consistently applied during each survey.	2
Has sampling been conducted across the spatial extent of the community with equal effort?	Somewhat	Sampling was only undertaken at 6 plots, and therefore does not represent the whole extent of the community.	1
Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	Thirteen years of annual sampling data was used in this analysis. This constitutes sufficient duration to assess change.	2
Has sampling been conducted at the same sites over the assessment period?	Somewhat	Sampling was conducted at permanent plots, however not all plots were sampled all the time due to accessibility challenges.	1
Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	While plots are fixed, not all sites could be sampled in all water years due to accessibility challenges during extremely wet years.	1
Total			**9/12**

Table 16 Reliability assessment of FDW vegetation data for the Gwydir Wetlands

Question	Answer	Justification	Score out of 2
Are the methods used appropriate to gather the information required for evaluation?	Yes	Methods follow a published methodology (Bowen 2016) that is consistent with the NSW Biodiversity Assessment methodology (BAM).	2
Has the same method been used over the sampling program?	Yes	The survey method was consistently applied during each survey	2
Has sampling been conducted across the spatial extent of the community with equal effort?	Yes	Plots were well stratified across the extent of the community with the component plant community types well represented.	2
Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	Thirteen years of annual sampling data has been used in this analysis. This constitutes sufficient duration to assess change.	2
Has sampling been conducted at the same sites over the assessment period?	Somewhat	Sampling was conducted at permanent plots, however not all plots were sampled all the time due to accessibility challenges.	1
Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	While plots are fixed, not all sites could be sampled in all the years due to accessibility challenges during extremely wet years.	1
Total			**10/12**

Table 17 Reliability assessment of FDW vegetation data for Macquarie Marshes

Question	Answer	Justification	Score out of 2
Are the methods used appropriate to gather the information required for evaluation?	Yes	Methods follow a published methodology (Bowen 2016) that is consistent with the NSW Biodiversity Assessment methodology (BAM).	2
Has the same method been used over the sampling program?	Yes	The survey method was consistently applied during each survey	2
Has sampling been conducted across the spatial extent of the community with equal effort?	Yes	Sampling was only undertaken at 6 plots, and therefore does not represent the whole extent of the community.	1
Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	Thirteen years of annual sampling data has been used in this analysis. This constitutes sufficient duration to assess change.	2
Has sampling been conducted at the same sites over the assessment period?	Somewhat	Sampling was conducted at permanent plots, however not all plots were sampled all the time due to accessibility challenges.	1
Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	While plots are fixed, not all sites could be sampled in all the years due to accessibility challenges during extremely wet years.	1
Total			**9/12**

Table 18 Reliability assessment of FDS vegetation condition data for the Gwydir Wetlands and Macquarie Marshes

Question	Answer	Justification	Score out of 2
Are the methods used appropriate to gather the information required for evaluation?	Yes	Methods follow a published methodology (Bowen 2016) that is consistent with the NSW Biodiversity Assessment methodology (BAM).	2
Has the same method been used over the sampling program?	Somewhat	The survey included both transect and quadrat methods.	1
Has sampling been conducted across the spatial extent of the community with equal effort?	Somewhat	Although 7 monitoring sites in each catchment is a fair number of replicates, there was a poor representation of lignum shrublands.	1
Has the duration of sampling been sufficient to represent change over the assessment period?	Yes	Thirteen years of annual sampling data have been used in this analysis. This constitutes sufficient duration to assess change.	2
Has sampling been conducted at the same sites over the assessment period?	Somewhat	Sampling was conducted at permanent plots, however not all plots were sampled all the time due to accessibility challenges.	1
Has the frequency of sampling been sufficient to represent change over the assessment period?	Somewhat	While plots are fixed, not all sites could be sampled in all water years due to accessibility challenges during extremely wet years.	1
Total			**8/12**