Biodiversity and Conservation Science

Vegetation and flora survey of the Nimalarragun wetlands, Dampier Peninsular

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GOVERNMENT OF WESTERN AUSTRALIA

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Cover: Mound Spring habitat, Nimalarragun. Photo: Valerie English

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Summary

The Nimalarragun wetlands occur on the Dampier Peninsula in the West Kimberley, on the eastern edge of the tidal-dominated Willie Creek system, about 20km north of Broome

The wetland complex is a Priority 4 ecological community (P4 PEC). The associated mound springs and freshwater wetland areas are also of major cultural significance (Department of Parks and Wildlife, 2016). A survey of the flora, vegetation and other biota was conducted on the wetland complex in May 2018.

The PEC is centred on *Melaleuca alsophila* woodlands in a waterlogged seepage zone with associated near-permanent waterbodies. The centre of the PEC includes mound-spring vegetation of *Melaeuca cajuputi* Open Forest over Fernland of *Acrostichum speciosum*. *Melaleuca alsophila* woodlands fringe the PEC, and are probably important for the functioning of the mound spring areas and hydrology especially immediately downslope of the spring. The PEC boundary encompasses this complex of communities, with the central mound spring vegetation the most significant with specialised plant assemblages and restricted habitats in a unique fire protected area.

Eight quadrats were established to sample the flora and vegetation and facilitate monitoring of long-term condition changes. A separate report provides a comparison of the flora of mound springs in the Nimalarragun wetlands with other selected Kimberley mound springs (Lyons *et al*. 2020).

A total of 93 plant species were recorded in eight quadrats established across the site. Two mapped vegetation units (unit 3 and 4) were associated with the springs and their margins.

The general condition of the springs and permanent water bodies of the Nimalarragun wetlands P4 community was excellent. Some minor damage was noted where cattle had encroached. A total of nine weed species, all in low numbers, were recorded in quadrats in the survey area. The key threats identified for the Nimalarragun wetlands and the component PEC are: grazing, hydrological changes (e.g. groundwater extraction), feral animals, weed invasion and altered fire regimes.

Management recommendations

- Groundwater should be carefully monitored and managed to ensure maintenance of the hydrological processes and the wetland assemblages they support.
- Proposals to remove existing levee banks should be reconsidered. Removal would produce both significant hydrological and physical disturbance. Modelling of the potential hydrological impacts of removal of the levees will provide information on the current and predicted water balance for the system with and without removal of the levee, and with projections for potential climatic and water extraction scenarios.
- Consider fencing along tracks that border Vegetation units 3 and 4 and 8 – the spring, open water bodies and associated wetland vegetation. These units are likely to be most sensitive to damage from vehicles, feral cattle, and horses.
- Map significant weed/s and control/eradicate including Parkinsonia (*Parkinsonia aculeata*), Neem trees (*Azadirachta indica*), stinking passionflower (*Passiflora foetida*) and tamarind (*Tamarindus indica*).

- Design and implement a monitoring program that utilises quadrats established during the current survey. Monitoring should also be designed to evaluate the effects of fire regimes and other management such including weed control and water extraction.

1 Background

The Nimalarragun wetlands complex (also known as Nimalaica claypan; hereafter called the Nimalarragun wetlands) occurs inland from Willie Creek about 20km north of Broome, about 1km west of the Broome-Cape Leveque Rd in the western Kimberley (Figure 1). The wetlands are a Priority 4 ecological community on the current list of priority ecological communities (PECs) maintained by Department of Biodiversity, Conservation and Attractions (DBCA). The area surveyed in the current study covers approximately 1187ha (Figure 1).

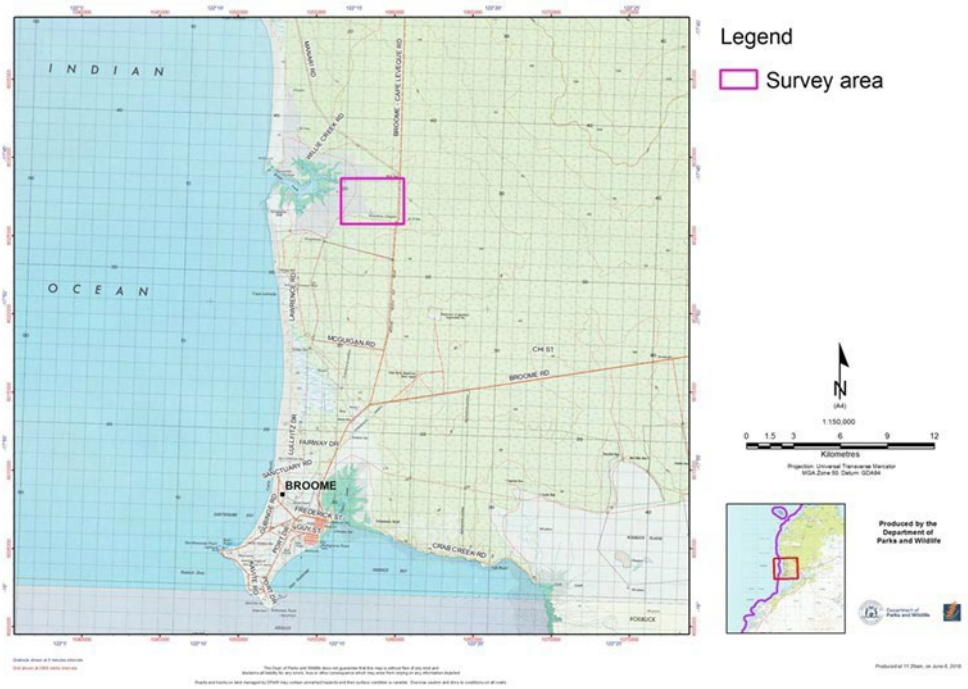

Figure 1: Location of Nimalarragun survey area

Nimalaica (now known as Nimalarragun) claypan was described by Kenneally *et al.* (1996) as a unique, almost permanent freshwater lake inland from Willie Creek. It was also identified as an important bird refuge, with dense fringing wetlands of *Eleocharis dulcis*, and a large submerged forest of tall *Melaleuca cajuputi*. Significant flora included the occurrence of *Philydrum lanuginosum*, and the particularly southerly occurrence of mangrove fern (*Achrostichum speciosum*) (Kenneally *et al.*,1996).

The Directory of Important Wetlands in Australia (Australian Nature Conservation Agency (ANCA),1996; Department of Environment and Energy (2019). states that mound springs occur at Nimalarragun (see Figure 2) and are described as wetlands inland from Willie Creek. The mound springs cover an area of about 20ha and are classified as B8 (Inland wetlands: Seasonal/intermittent

saline lakes) and B9 (inland wetlands: permanent freshwater ponds (<8ha) marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the year). Criteria of relevance to this report and that justified the wetland's inclusion in the Directory were (Australian Nature Conservation Agency,1996):

- It is a good example of a wetland type occurring in Australia.
- It supports species near the southern end of their range including *Philydrum lanuginosum* (frogsmouth) and *Acrostichum speciosum* (mangrove fern)
- It supports flora not known elsewhere on the Dampier Peninsula such as the aquatic *Ceratophyllum demersum* var. *demersum*, the herb *Heliotropium curassavicum* and the sedge *Schoenus falcatus*
- It is the most southerly coastal locality of *Pandanus spiralis* (screw pine).
- It supports an unusual partially submerged forest of *Melaleuca cajeputi*.
- It is a wetland which plays an integral ecological or hydrological role in the natural functioning of a major wetland system/complex.
- The wetland supports native plant or animal taxa or communities which are considered rare, vulnerable or endangered at the national level.

Figure 2: Nimalarragun mound spring plant community- Melaueca cajuputi and Timonium timon over Acrostichum speciosum.

In the Joint Management Plan for Yawuru Birragun Conservation Park, the Nimalarragun wetlands complex is termed *bilarra*. The plan covers areas from Willie Creek to Cape Villaret, including the Nimalarragun wetlands (DPAW, 2016). A series of recommendations in the plan are relevant to this report, as follows:

- Implement strategies described in Section 6.2 – Introduced species management to control any introduced plants and animals presenting a significant threat to *bilarra* values.

- Carry out (in collaboration with water resource management agencies and/or external researchers) wetland mapping, monitoring and research to increase understanding of bilarra

values and condition, and to facilitate assessments and reporting of management effectiveness.
- Investigate the feasibility of and management options for removal of artificial structures from Nimalarragun. Remove or modify those structures if this will help to meet objectives of this management plan.

The performance measures in the plan are:

1. Availability of baseline data and report on the values and condition of *bilarra*.
2. Ongoing condition of *bilarra.*

Relevant Targets in the plan are:

1. Wetland mapping, documenting baseline values and condition of *bilarra* in the *Yaruwu Birragun* Conservation Park and reporting to be completed by 2018.
2. Maintanance of current condition of *bilarra* in the Yaruwu Conservation Park (attributable to management activities or lack of appropriate management activities) over the life of the plan.

Little detailed information about the vegetation and other biota existed for the area prior to the May 2018 survey. The intention of the 2018 surveys was to characterise the flora and vegetation, and the vertebrate and aquatic invertebrate fauna that typify the springs, associated wetlands, and fringing communities. The flora of the fringing dampland *Melaleuca alsophila* forests and woodlands were also characterised and mapped. The results will be used to determine a logical boundary for the Nimalarragun wetlands PEC. The survey also documented major weeds present, assessed the level of threat posed by other factors, and delivered recommendations about priority management actions including possible removal of the levee bank that was installed over 20 years ago. This report therefore in part address the management strategies, performance measures and targets in the management plan through provision of:

- data about priority weeds for control noted during the survey.
- a baseline map of the wetlands of the Nimalarragun wetlands complex.data collected from a series of eight detailed floristic quadrats for baseline information about flora, vegetation composition and condition.
- background data to help guide decisions about appropriate management options for removal or modification of levee banks in Nimalarragun wetlands.

The single mapped occurrence of the Nimalarragun wetlands PEC, largely occurs on reserve 52354 managed by the Department of Biodiversity, Conservation and Attractions for the purpose of Conservation, Recreation and Traditional and Customary Aboriginal Use and Enjoyment (Figure 3). The land is managed under a Management Order by the Yawuru Native Title Holders Aboriginal Corporation and the Conservation Commission of Western Australia. A portion of the survey area including core spring areas also occurs on road reserves that cut through reserve 52354. The current mapped area of the PEC occurrence is 73ha.

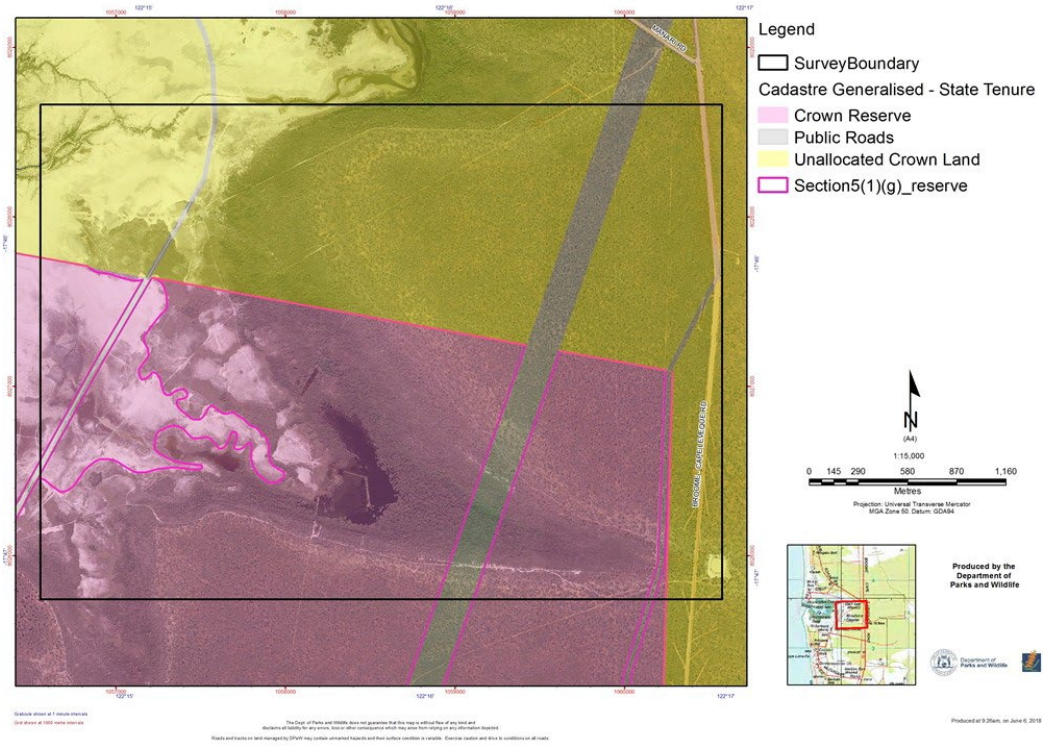

Figure 3: Tenure of survey area

1.1 Geology

The Dampier Peninsula mainly consists of sand plains and linear dunes (pindan) of weathered Broome Sandstone and Quaternary red sand. It varies from 170-230m above sea level along its axis, decreasing in elevation towards the coast. Willie Creek also includes narrow strings of Holocene limestone.

1.2 Climate

The Dampier Peninsula experiences a tropical semi-arid climate. Rainfall decreases from north to south, with Broome experiencing about 600mm/yr. Monthly rainfall averages vary from 1.4mm in September and October to 191.5mm in January. Broome experienced record rainfall in summer 2018, with 945mm recorded in January and 614mm in February 2018 (Bureau of Meteorology (BOM), 2018). This extraordinary rainfall will have affected the results of this flora survey.

The mean monthly minima vary from 13.7°C in July to 26.5°C in December, and average maxima vary from 28.9°C in July to 34.3°C in April (BOM, 2018).

1.3 Hydrology

The Broome Sandstone supports a regional freshwater aquifer that extends several kilometres inland and is underlain by salt water (Mathews *et al*. 2011). The coastal dunes can also contain fresh water and may be contiguous with the regional groundwater mound.

Low gradient streams dissect the dunes from east to west and emerge and discharge into the ocean west of the Nimalarragun wetlands complex. Some streams on the Peninsula occur as subsurface flows under a thin pisolitic to massive ironstone sheet beneath red sand (Mowanjum Sands - Mathews *et al*. 2011).

Spring discharge occurs along the edges of the interface of pindan dunes and high-tidal carbonate mud substrates where streamflow towards to coast is impeded by impermeable layers of these muds of the tidal flats. The freshwater grades into brackish to hypersaline in the high tidal flats (Mathews *et al*. 2011). Thickets and forests of *Melaleuca alsophila* and other melaleucas, and forests of the mangrove *Avicennia marina* occur in this zone in the survey area.

The Nimalarragun wetlands including permanent lakes and soaks formed by the discharge areas and small streams flowing east to west as they intercept the more impermeable carbonate muds (Mathews *et al*. 2011). Thickets and forests of *Melaleuca alsophila, M. cajuputi, Pandanus spiralis*, *Timonius timon* and *Achrostichum speciosum*, rushlands and sedgelands occur at these triangular shaped springs. Small fingers of sand, can transfer fresh water under the hypersaline flats. Where fresh discharge occurs, ameliorated soil salinity forms brackish areas supporting Melaleuca thickets as isolated stands (Mathews *et al*. 2011).

Three shallow piezometer bores are located within the Nimalarragun wetlands (Department of Water and Environmental Regulation (DWER), 2017) and are utilised to monitor groundwater levels. The DWER (2017) report refers to this area as ‘Crescent Lake, Nimalaica Swamp/Clay Pan’. The bores occur near the transition zone between the freshwater and saltwater plant species assemblages at Crescent Lake, one of the deeper wetlands in the survey area. Surface water was tested and groundwater dated at the bores for the DWER (2017) report.

DWER (2017) state that the depth to groundwater in a bore in freshwater vegetation in the Nimalarragun wetland system was 1.07m in April 2017 and increased away from the wetland. The groundwater was fresh at 380mg/L TDS. Groundwater dating implied a mixture of old and new water, possibly due to mixing of deeper older - 1262 year old water being forced up by impermeable substrates and mixing with more modern 37 and 70 year old water. Surface water was brackish at the end of the dry season also suggesting mixing of saline and fresh waters.

2 Objectives

A survey of selected biota of the Nimalarragun wetlands was completed in May 2018 by DBCA staff, Yaruwu traditional owners, and Environs Kimberley. This work forms part of a broader biodiversity survey program both on and off the conservation estate, funded under the Kimberley Science Conservation Strategy. The current survey included vertebrate and invertebrate fauna, flora and vegetation. This report descibes the surveys of the flora and vegetation of the Nimalarragun wetlands completed by Mike Lyons, Valerie English and Yawuru Rangers from 7-11 May 2018.

Prior to the current survey, only general descriptions of the vegetation and no vegetation mapping were available. This survey was undertaken to provide; a more detailed description of the PECs floristics, vegetation mapping and condition assessments, recommendations about urgent and longer term management actions, and serve as a basis for future monitoring. Vegetation mapping undertaken during

the current survey provides the basis to determine an amended boundary for the PEC as currently defined.

Other work that has significant linkages to this survey is the comparative work on the Kimberley mound spring flora (Lyons *et al*. 2020), and the invertebrate surveys (Pinder *et al.* 2019, 2020). The results of all these studies provide an ecological understanding of the current status of the wetlands and will have a significant influence on the management requirements of the Nimalarragun wetlands PEC.

3 Methods

Eight quadrats were marked with fence droppers in each corner (50 x 50m). The north east corner pegs were labelled with metal tags. Quadrats sampled the major habitats including saline flats, spring seepage area, damplands and mound springs. Within quadrats all plant species present were recorded and representative collections lodged with the WA Herbarium. Additional opportunistic collections were made outside formal quadrats.The marked quadrats are suitable for future rescoring to enable some analysis of change for monitoring purposes.

The quadrat information for each site include:

- GPS location
- soil and landform
- comprehensive flora list
- vegetation structure
- vegetation condition
- threatening processes
- management recommendations

These data will be added to the corporate TEC/PEC database.

Due to time limitations, only one quadrat was established in most of the broad vegetation units identified. No quadrats were established in the terrestrial grassland vegetation in the eastern portion of the survey area, the mangrove forest to the north, or in the open water. The vegetation of those areas is not described in detail in this report. The flora list is therefore not a comprehensive record of the floristics of the survey area.

4 Results

4.1 Flora

A total of 94 plant taxa were recorded during the survey including quadrat records and opportunistic collections. (Appendix 1). Nine of these were weeds. A Weed of National Significance, Parkinsonia (*Pakinsonia aculeata*) was recorded in an induated flat on the western edge of the main wetland area (near the track to Waterbank Station).

Two priority flora were recorded in quadrats. *Corymbia paractia* (Priority 1) was recorded on the margin of the mound spring in the vicinity of quadrat NCP07, and north of the wetland area within quadrat NCP08. These records are two new records north of the main species distribution in the vicinity of

Broome. *Stylidium pindanicum* (Priority 3) has a scattered distribution in the SW Kimberley centred on the Pindan habitats of the Dampier Peninsular (recorded here in quadrat NCP08).

4.2 Vegetation

Eight broad structural vegetation/habitat units were mapped in the survey area, of which five were sampled with quadrats (Tables 1 & 2, Figure 4). The vegetation units are described below, with sample quadrats and extent within the survey area in brackets.

Table 1. Vegetation units mapped during the current study (see Figure 4).

Vegetation Unit	**Quadrat**	**Mapped area (ha)**	**Comment**
Tecticornia low open shrubland / sparse low grassland	NCP01	213	
Grassland / open sparse sedgeland	NCP02, NCP06	122	
Melaleuca, Timonium open forest/*Acrostrichum* open fernland/Fimbristylis sparse rushland	NCP03, NCP07	51	Include extent of this map unit in PEC boundary.
Melaleuca open forest / Fimristylis open rushland / sparse grassland	NCP04	154	Include in modified PEC boundary
Melaleuca open forest/open grassland/Fimbristylis sparse sedgeland	NCP05		Include in modified PEC boundary
Mixed Eucalypt, *Melaleuca* woodland/*Acacia* sparse heathland/closed grassland	NCP08	50	
Grassland with emergent Eucalypts	not sampled	572	
Mangrove forest	not sampled	3	
Open water	not sampled	22	Include in modified PEC boundary

Table 2: Quadrat descriptions (adapted from Lyons et al. 2020).

Quadrat	Latitude (WGS 84)	Longitude (WGS 84)	Habitat	Vegetation description	Date
NCP01	-17.773439	122.256313	Supra-tidal Samphire	Low chenopod shrubland of *Tecticornia indica* subsp *julaceae* and *Tecticornia halocnemoides* subsp *tenuis* over very open low grassland of *Eragrostis falcata*.	8-Mar-18
NCP02	-17.773916	122.253968	Supra tidal flat	Sparse tussock grassland of *Panicum decompositum* over low closed heathland/low closed shrubland of *Tecticornia indica* subsp *julaceae, Vincetoxicum carnosum* and *Hibiscus panduriformis*, over low sparse sedgeland of *Fimbristylis cymosa* and *Fimbristylis rara*.	8-Mar-18
NCP03	-17.781576	122.263149	Spring riparian margin	Open forest of *Melaleuca cajuputi* over sparse forbland of *Acrostrichum speciosum*, over low sparse sedgeland of *Fimbristylis cymosa*, *Fimbristylis polytrichoides* and *Sporobolus mitchellii.*	8-Mar-18
NCP04	-17.768746	122.25675	Upland spring margin	Low woodland of *Melaleuca alsophila* over low isolated trees of *Timonius timon* over low sedgeland of *Fimbristylis cymosa* and a low grassland of *Sporobolus mitchellii*.	9-Mar-18
NCP05	-17.781169	122.259328	Spring upper margin	Low woodland of *Melaleuca alsophila* over tall sparse shrubland of *Acacia colei* var *colei* over low isolated shrubs of *Hibiscus panduriformis*, *Vincetoxicum carnosum* and *Gymnanthera oblonga* over isolated grasses and sedges of *Panicum mindanaense* and *Fimbristylis* sp.	9-Mar-18
NCP06	-17.780197	122.249588	Supra-tidal flat	Isolated clumps of grasses of *Panicum decompositum* with emergent *Melaleuca alsophila* over low sparse chenopod shrubland of *Tecticornia indica* subsp *julaceae.*	10-Mar-18
NCP07	-17.781518	122.268472	Mound spring	Open forest of *Melaleuca cajuputi* over woodland of *Timonius timon*, over fernland of *Arcrostrichum speciosum*	10-Mar-18
NCP08	-17.760147	122.262702	Pindan flat	Low open woodland of *Corymbia opaca*, *Melaleuca alsophila* and *Corymbia paractia* over low isolated clumps of *Bauhinia cunninghamii* and *Acacia colei* over closed grassland of *Chrysopogon pallidus* and *Sorghum sp*., over sparse forbland of *Buchnera* spp., *Calandrinia tepperiana* and mixed herbaceous Fabaceae.	11-Mar-18

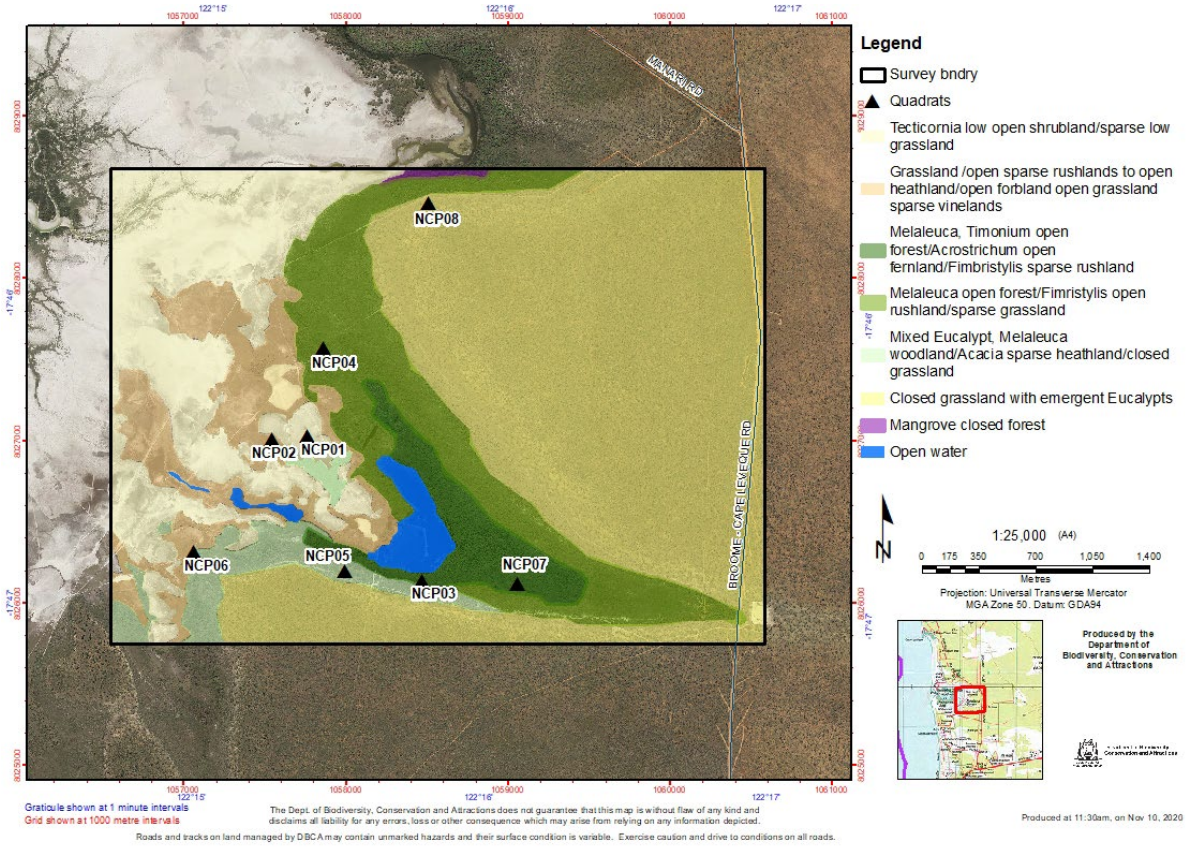

Figure 4: Vegetation map of the Nimalarragun wetland complex with vegetation quadrats shown. The mound spring vegetation is in dark green.

4.2.1 Vegetation unit descriptions

1. Tecticornia low open shrubland / sparse low grassland (213ha)

Quadrat NCP01 sampled the *Tecticornia* dominated vegetation of the supra-tidal saline flat (Figure 4). The unit dominates the saline clay flats in the western portion of the survey area. *Tecticornia* to 0.25m high, covered ~30%, and grasses to 0.25m covered <10%. The unit occurred on grey silty clay that was dry at the time of survey.

There was evidence of minor impacts from cattle, horses and vehicles but the vegetation unit was largely in Excellent condition (Vegetation condition scales as per Government of Western Australia, 2000).

Figure 5: Quadrat NCP01 in vegetation unit 1.

2. Grassland / open sparse sedgelands to open heathland / open forbland / open grassland / sparse vinelands (112ha)

Quadrat NCP02 and NCP06 represent the variable grasslands/heathlands/forblands that intergrade with Unit 1. It is a dominant unit in the survey area and appears to correlate with slightly higher microrelief in the clay flats and probably seepage of freshwater ameliorating soil salinity. It comprised 10-40% cover of forbs, 5% vines, up to 60% cover of grasses to 0.6m high, with <1% cover of Melaleucas and other shrubs to 0.7m high. The unit occurred on grey silty clay. There was evidence of moderate impacts from cattle, horses and vehicles but the vegetation unit was largely in Excellent condition (vegetation condition scales as per Government of Western Australia, 2000).

Figure 6: Quadrat NCP02 in vegetation unit 2.

3. *Melaleuca*, *Timonium* open forest/*Acrostrichum* open fernland/*Fimbristylis* sparse sedgeland (51ha)

Quadrats NCP03 and NCP07 pertain to this unit. It correlates with the waterlogged black/brown peaty soils that fringe the open water bodies and the seepage areas in the central southern portion of the survey area. The unit comprised up to 60% cover of *Melaeuca cajuputi* to 30m tall over, with cover to 25% of *Timonium timon* to 12m tall over up to 20% cover of *Acrostichum speciosum* to 1.5m tall, and 1% cover of Fimbristylis to 1.2m tall. *Pandanus spriralis* up to 1% cover was also recorded in the unit.

The waterlogged peaty soils were at least 0.2m deep, with pools of fresh water to 10cm deep common at the time of survey. The eastern portion of the unit corresponded with mound springs that oozed fresh ground water from a diffuse source.

Up to 1% cover of the invasive weed *Passiflora foetida* was recorded in the unit and very little cattle damage observed. The unit was in Excellent condition overall.

Figure 7: Quadrat NCP03 in vegetation unit 3

4. Melaleuca open forest / Fimbristylis open rushland / sparse grassland (154 ha)

Quadrat NCP04 represents the vegetation of this unit. It occurs on peaty damplands that fringe the core area of the mound springs (Unit 3, above). The soil comprised brown-black damp peaty loams.This unit consisted of 70% cover of *Melaleuca alsophila* to 8m high over 25% cover of *Sporobolus* sp. and other grasses to 0.4m high and 25% cover of *Fimbristylis* sp. to 0.4m. Cattle presence was noted, however the unit was in Excellent condition.

Figure 8: Quadrat NCP04 in vegetation unit 4

5. Mixed Eucalypt, *Melaleuca* woodland/*Acacia* sparse heathland/closed grassland (50ha)

This unit is represented by quadrat NCP05. It occurs between the terrestrial grasslands and the saline flats in the western portion of the survey area. This unit comprised 40% cover of *Melaleuca alsophila* to 6m tall over 5% cover of *Acacia colei* and other shrubs to 1.5m high, over 40% cover of grasses to 0.3m high, and 2% cover of *Fimbristylis* to 0.4m. Soils were grey silty loam.

Cattle impacts and low numbers of small (non reproductive) Neem trees (*Azadarachta indica*) were noted at the sample site, however it was largely in Excellent condition.

Figure 9: Quadrat NCP05 in vegetation unit 5.

6. Closed grassland with emergent Eucalypts (not sampled; 572ha)

A closed grassland dominated by *Sorghum ?plumosum*, with emergent Eucalypts dominated the eastern portion of the survey area. The vegetation unit was not considered part of the wetland complex or necessarily significant in terms of wetland function and was not sampled in detail through quadrat sampling.

Figure 10: Vegetation unit 6

7. Mangrove forest (not sampled; 3ha)

A mangrove forest was identified in the far northern section of the survey area along the margin of a tidal creek. The vegetation was not sampled due to limited time and and the fresh water wetland focus of the survey.

Figure 11: Landward edge of mangrove forest.

8. Open water (limited flora sampling -22ha)

The open water associations and the vegetation of the mound springs are considered to be the most uncommon and noteworthy vegetation included in the survey.along with the mound-springs. The risk of the presence of Saltwater Crocodiles prevented a thorough survey of the flora. *Ceratophyllum demersum, Schoenoplectus subulatus,* and *Nymphaea violacea* were recorded from the periphery of the waterbody.

Figure 12: Open water.

Levee banks/bunds were constructed over 20 years ago in the south-central section of the wetlands. They appear to have initially had significant influence on the wetland hydrology creating a near-permanent area of open water. . However, the hydrology appears to have restabilised since the levees were constructed, with vegetation composition and zonation adapted to the increased water levels and hydroperiods.

5 Threats

Grazing

The impacts of trampling, nutrient enriched droppings, and selective grazing by feral and stray cattle were noted in the survey of the Nimalarragun wetlands. Typically cattle will linger where they can access fresh water and may focus on the spring areas. Vegetation removal by grazing and trampling has the potential to cause an increase in drying of the springs, although the level of cattle impacts is currently very low. Drying is however associated with increasing acidity particularly in peat rich wetlands. Water temperatures may also subsequently rise, with potential concomitant effects on aquatic invertebrates. Cattle faeces may facilitate the introduction of weeds and increase nutrient levels in wetlands. This can adversely affect the aquatic invertebrates and flora. None of the Nimalarragun wetlands are currently

fully fenced and there is evidence of low level damage from stock on the margins of the wetland complex.

Hydrological changes

The freshwater wetlands are dependent on groundwater from the regional Broome Aquifer as they are considered permanent, are located on shallow groundwater, and respond to increased groundwater abstraction. The 'Water Opportunities' map prepared by the Department of Water and Department of Regional Development (DoW and DRD), 2017) indicates that the Nimalarragun wetlands are located in a zone of 'low water opportunities'. This indicates that they are in an area where groundwater development is highly constrained and vulnerable to over-abstraction. Areas mapped as 'low opportunity' occur where fresh groundwater and seawater are mixed, and where groundwater dependent ecosystems, TECs and existing users are present (DoW and DRD, 2017). Groundwater resources will require careful monitoring and management to ensure maintenance of the hydrological processes and the assemblages of the Nimalarragun wetlands that they support. The DoW and DRD (2017) report states that in most cases further hydrogeological and ecological investigations would be required for any groundwater extraction proposal.

Levee banks installed over 20 years ago to increase water levels when the wetlands were part of Waterbank pastoral station. The Joint Management Plan states that prior to installation of the levees, the claypan would have been dry over the winter months, however no evidence is provided for this. Water levels are apparently maintained at a higher level as a consequence of the levees (DPAW, 2016) however, recently due to increased water abstraction and very dry periods, the previously permanent wetlands have dried, resulting in fish deaths. Anecdotal evidence indicated this was likely to be as a consequence of low rainfall and increased groundwater abstraction from a borefield to the east that supplies water to Broome. Groundwater abstraction apparently declined leading to increased groundwater levels in autumn 2016 (DWER, 2017).

It appears likely that the levees may be ameliorating the impact of the dry seasons and water extraction to some extent, however this would need to be verified to determine if there are hydrological and/or other advantages or disadvantages to leaving the levees *in situ.*

Feral animals

Feral animals such as horses and donkeys also cause damage to the vegetation through digging, trampling and grazing, and nutrient enrichment of the water. Other feral animals, such as cats are likely to be present in the Nimalarragun wetlands. Carnivorous introduced fauna can also predate on native species and disrupt waterbird breeding.

Cane toads were recently found in the north east Kimberley and will likely arrive in the West Kimberley.

Weed invasion

Weed abundance was generally very low and localized within the Nimalarragun wetlands. The most common serious weed recorded was *Passiflora foetida* (Figure 13). This species should be carefully monitored and controlled as it is highly invasive.

Parkinsonia was recorded on the edges of one open water body in the SW of the study area (Figure 13). This weed poses a serious threat as it is extremely invasive and requires urgent control. Low

numbers of Neem trees were noted within and near quadrat NCM 05 and require urgent mapping and control (Figure 13). A single juvenile plant of Tamarind was recorded from the periphery of Nimalarragan wetland having likely spread from nearby mature plants at Waterbank Station (Figure 13).

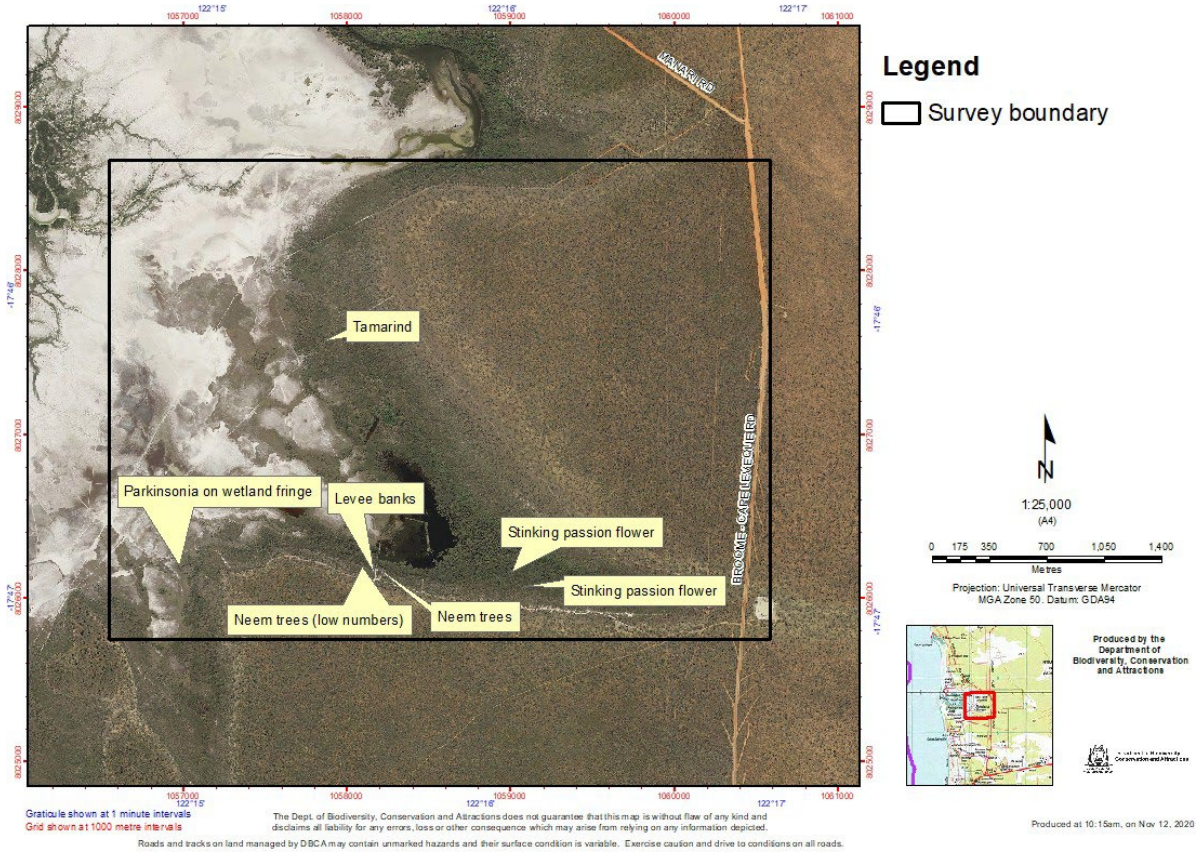

Figure 13: Location of significant weeds.

Altered fire regimes

Inappropriate fire regimes are a potential risk to the Nimalarragun wetlands. Historically, fire within the mound springs was probably only very occasional. It is likely that some of the ecosystems including parts of the wetlands may be adapted to occasional fire as they contain species that will easily carry fire when vegetation is dry, and some component shrubs would reproduce from seed following fire.

The impacts of fire, and fire regeneration response of the mound spring peat substrate and vegetation needs to be determined on an opportunistic basis following bush fire. The mound springs should not be included in routine burning as fires can cause total destruction of peat-based systems as they can smoulder for months, totally destroying the organic substrate that has accumulated over hundreds to thousands of years. However, it is not known if the peat layer will actually burn as it does in mound springs in the southwest of the state. This will probably depend on the moisture content at the time.

Climatic changes

The Nimalarragun wetlands are potentially at risk from changing climate. Potential effects may include altered surface water and groundwater recharge due to changes in rainfall, and more extreme fire behaviour.

Future climate projections are available for the Monsoonal North West region, that includes the Kimberley (CSIRO and Bureau of Meteorology, 2015). The following climate change predictions are quoted from the publications associated website (http://www.climatechangeinaustralia.gov.au/).

- Rainfall

"Changes to rainfall are possible but unclear. For the near future natural variability is projected to dominate any projected changes. The Monsoonal North experienced an overall slight increase in rainfall during the 20th century, which includes prolonged periods of drying as well as above average rainfall. The strongest increases have been across north-western regions during recent decades. Year to year variability is strongly influenced by the El Niño Southern Oscillation. Providing confident rainfall projections for the Monsoonal North cluster is difficult because global climate models offer diverse results, and models have shortcomings in resolving some tropical processes. Natural climate variability is projected to remain the major driver of rainfall changes in the next few decades. By late in the century, potential summer rainfall changes are approximately -15 to +10 per cent under an intermediate emission scenario (RCP4.5) and approximately -25 to +20 per cent under a high scenario (RCP8.5). Proportional changes are much larger in winter in some models, but these changes are less reliable because average winter rainfall is very low.

Assessment of the potential impact of climatic changes in this region should consider the risk of both a drier and wetter climate.

- **Temperature**
  - Average temperatures will continue to increase in all seasons (*very high confidence*). Temperatures have increased over the past century. One area of north-west Australia has seen a decrease in mean temperature since 1960 due in part to increases in rainfall and cloudiness.
  - There is *very high confidence* in continued substantial increases in projected mean, maximum and minimum temperatures in line with our understanding of the effect of further increases in greenhouse gas concentrations.
  - For the near future (2030), the annually averaged warming across all emission scenarios is projected to be around 0.5 to 1.4 °C above the climate of 1986 – 2005.
  - By late in the century (2090), for a high emission scenario (RCP8.5) the projected range of warming is 2.8 to 5.1 °C. Under an intermediate scenario (RCP4.5) the projected warming is 1.3 to 2.8 °C.

- **Extreme rainfall and drought**
  - Increased intensity of extreme rainfall events is projected, with *high confidence*.
  - Despite uncertainty in future projections of total rainfall for the Monsoonal North West sub-cluster, an understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with *high confidence* a future increase in the intensity of extreme rainfall events. However, the magnitude of the increases cannot be confidently projected.
  - Drought will continue to be a feature of the regional climate variability, but projected changes are uncertain.

- **Other**
  - With *medium confidence*, fewer but more intense tropical cyclones are projected.

- TROPICAL CYCLONES: Tropical cyclones are projected to become less frequent, but the proportion of the most intense storms is projected to increase (*medium confidence*).
- FIRE WEATHER: The primary determinant of bushfire in the Monsoonal North West is fuel availability, which varies mainly with rainfall. In regions where abundant rain falls (Top End and the Kimberley), climate change is not expected to change the frequency of fire (*high confidence*). In more southerly locations, changes to future rainfall will be the determining factor of change to fire frequency. When fire does occur, there is *high confidence* that fire behaviour will be more extreme.
- EVAPORATION: Potential evapotranspiration is projected to increase in all seasons as warming progresses (*high confidence*).
- HUMIDITY: There is little change projected in relative humidity until later in the century under a high emission scenario (RCP8.5), where a decrease in relative humidity is projected (*medium confidence*).

Addressing climate changes as a threatening process is outside the scope of this report however the recent droughts and extreme rainfall are expected to have impacts on the Nimalarragun wetlands resulting in increased incidence of flooding, increased droughts and concommittent increased incidence of extreme fire behaviours that may burn the peat-based wetlands.

Tourism usage

If ecotourism is developed near the mound spring zones, increased visitation has the potential to impact the springs through trampling, weed invasion and potentially increased fire frequency, and will need to be carefully managed.

6 Discussion

Habitats with permanent water including mound spring habitats are rare in the largely arid state of Western Australia. All mound spring habitats identified to date in WA have been listed as threatened or priority ecological communities (TECs or PECs) largely due to the unusual assemblages of flora and fauna they support. There are nine Western Australian TECs and three PECs that comprise mound spring habitats, with a total of 110 occurrences covering approximately 460ha (~0.002% of the total area of the state).

The Nimalarragun wetlands comprise a freshwater wetland complex in a regionally rare geological and stratigraphic setting in this semi-arid area and require special management (Mathews *et al.* 2011). The wetlands are also of major cultural significance (Mathews *et al.* 2011, DPAW 2016). Lyons *et al*. (2020) noted that the Nimalarragun mound spring and other south west and the north east Kimberley coastal springs, are floristically distinct from the mound springs of the central Kimberley.

Vegetation unit 3 as described in this report is the waterlogged black/brown peaty soils that fringe the open water bodies and the seepage areas in the southern portion of the survey area. The eastern portion of the unit corresponded with mound springs that ooze fresh ground water from a diffuse source. The mound springs and immediately adjacent wetlands that influence their hydrology are considered the most significant habitats and vegetation in the survey area as they are extremely restricted in distribution and support distinctive assemblages (Lyons *et al*. 2020, Pinder *et al*. 2019, 2020).

The most significant ongoing threat to the integrity of the wetlands is grazing and trampling by unmanaged cattle. Hydrological change is probably the next most significant threat to the future

ecological function of the wetlands. Current and future proposals for extracting water have potential to impact the aquifers that maintain the springs and associated groundwater dependent ecosystems.

Despite possible long-term historical grazing by cattle, few significant weeds were recorded during this survey, notably with few weedy grasses. Weeds have the potential to spread and have increased impacts on the springs in future however. Parkinsonia (*Parkinsonia aculeata*), neem trees (*Azadarachta indica*), stinking passion flower (*Passiflora foetida*), and tamarind (*Tamarindus indica*) in particular should be controlled as a matter of urgency, and carefully monitored in future.

Impacts of feral animals such as horses are currently relatively low but may increase.

There is little evidence that altered fire regimes or climate change are currently having a significant impact on the springs, but this may change in future.

7 Recommendations

- The potential impacts of removal of the levee bank were discussed with a DBCA hydrogeologist. The vegetation has been modified as a consequence of altered hydrology associated with levee construction however significant additional disturbance of vegetation that has since adapted to the new conditions would be associated with removal of the structure. In addition, water levels are apparently maintained at a higher level as a consequence of the levees (DPAW, 2016), or hydroperiod has been increased. Recently due to increased water abstraction and very dry periods, the previously permanent wetlands have dried, resulting in fish deaths. The potential hydrological impacts of removal of the levees should include modelling to indicate the current and predicted water balance for the system with and without removal of the levee, and with consideration of potential climatic and water extraction scenarios.
- Groundwater should be carefully monitored and managed to ensure maintenance of the hydrological processes and the wetland assemblages they support. As part of the environmental impact assessment process for water licencing, DBCA should advise that upgradient users (east) should be required to complete studies to examine if water can be extracted sustainably in terms of the future of the Nimalarragun wetlands.
- Consider fencing along tracks that edge vegetation units 3, 4 and 8 – the spring, open water bodies and associated wetland vegetation. These units are likely to be most sensitive to damage from vehicles, feral cattle, and horses.
- Map significant weed/s and control/eradicate them (a small patch of Parkinsonia in one of the western open water bodies, neem trees in fringing Melalueca communities,, *Passiflora foetida* in the spring unit, and tamarind (Figure 13).
- Design and implement a monitoring program that utilises quadrats established during the current survey (reasonably costly and time consuming but essential for management). Monitoring should be designed to provide information about the success of land management in the sensitive environment of the spring ecosystem, and the wetlands that fringe the open water bodies, in particular. Monitoring should also be designed to evaluate the effects of fire regimes and other management such including weed control and water extraction. This will likely require establishment of a more comprehensive network of quadrats, with some linked to the locations of groundwater bores if possible.

8 Appendix

Appendix 1. Taxa recorded in quadrats (NCP01-08) and opportunistic collections (adapted from Lyons et al. 2020).

Family		Taxon	Conservation code	NCP01	NCP02	NCP03	NCP04	NCP05	NCP06	NCP07	NCP08
Aizoaceae		*Sesuvium portulacastrum*			1				1		
Apocynaceae		*Gymnanthera oblonga*			1	1	1	1	1	1	1
		Vincetoxicum carnosum			1	1	1	1	1		
Araceae		*Landoltia punctata*				1					
Asteraceae		*Blumea integrifolia*									1
		Blumea saxatilis									1
	*	*Flaveria trinervia*			1						
		Pluchea rubelliflora			1				1		
		Pterocaulon intermedium									1
Byblidaceae		*Byblis filifolia*									1
Celastraceae		*Stackhousia intermedia*									1
Ceratophyllaceae		*Ceratophyllum demersum*				1					
Chenopodiaceae		*Tecticornia halocnemoides subsp tenuis*		1							
		Tecticornia indica subsp julacea		1	1				1		
Cucurbitaceae		*Cucumis melo*									1
Cyperaceae		*Bulbostylis barbarta*									1
		Cyperus conicus									1
		Fimbristylis cymosa			1	1	1		1		1
		Fimbristylis ferruginea				1				1	
		Fimbristylis polytrichoides				1	1	1	1		
		Fimbristylis rara		1	1				1		
		Schoenoplectus subulatus							1	1	

Family		Taxon	Conservation code	NCP01	NCP02	NCP03	NCP04	NCP05	NCP06	NCP07	NCP08
Droseraceae		*Drosera broomensis*									1
Elatinaceae		*Bergia ammannioides*					1				
Euphorbiaceae		*Euphorbia aff. hassallii*			1						
		Euphorbia hirta					1	1			
Fabaceae		*Acacia colei var. colei*						1		1	1
		Acacia holosericea									1
		Bauhinia cunninghamii									1
		Chamaecrista absus									1
		Desmodium filiforme									1
		Indigofera colutea									1
	*	*Parkinsonia aculeata*									
		Rhynchosia minima						1			1
		Sesbania cannabina			1		1	1	1		
	*	*Stylosanthes hamata*									1
	*	*Stylosanthes scabra*									1
	*	*Tamarindus indica*					1				
		Zornia muelleriana subsp. congesta									1
Lythraceae		*Ammannia baccifera*					1				
Malvaceae		*Brachychiton diversifolius*						1			
		Corchorus aestuans						1			1
		Grewia breviflora						1			
		Hibiscus panduriformis			1	1	1	1	1		1
		Malvastrum americanum									1
		Waltheria indica									1
Meliaceae		*Azadirachta indica*						1			
Menispermaceae		*Tinospora smilacina*						1			1
Montiaceae		*Calandrinia tepperiana*						1			1

Family		Taxon	Conservation code	NCP01	NCP02	NCP03	NCP04	NCP05	NCP06	NCP07	NCP08
Moraceae		*Ficus aculeata var. indecora*					1				
Myrtaceae		*Corymbia paractica*	P1								1
		Eucalyptus microtheca									1
		Melaleuca alsophila			1	1	1	1	1		1
		Melaleuca cajuputi				2				1	
Nymphaeaceae		*Nymphaea violacea*									
Orobanchaceae		*Buchnera asperata*									1
		Buchnera linearis									1
		Buchnera ramosissima									1
		Buchnera sp. indet									1
Pandanaceae		*Pandanus spiralis*								1	
Passifloraceae	*	*Passiflora foetida var. hispida*				1		1		1	1
Phyllanthaceae		*Flueggea virosa subsp melanthesoides*					1				1
		Phyllanthus maderaspatensis					1	1			1
Plantaginaceae		*Stemodia florentula*			1						
Poaceae		*Aristida hygrometrica*									1
	*	*Cenchrus setigera*									1
	*	*Chloris barbata*			1	1					1
		Chrysopogon pallidus									1
		Chrysopogon sp. indet.						1			1
		Dactyloctenium radulans			1						1
		Digitaria bicornis						1			1
		Diplachne fusca subsp. fusca							1		
		Ectrosia danseii			1						
		Eragrostis cumingii				1	1	1			1
		Eragrostis falcata		1							
		Eriachne obtusa									1

Family		Taxon	Conservation code	NCP01	NCP02	NCP03	NCP04	NCP05	NCP06	NCP07	NCP08
		Panicum decompositum			1				1		
		Panicum mindanaense					1	1			1
		Schizachyrium fragile									1
		Setaria surgens						1			1
		Sporobolus australasicus					1	1			
		Sporobolus mitchellii				1					
		Sporobolus virginicus		1					1		
		Thaumastochloa pubescens						1			1
		Xerochloa imberbis		1							
Portulacaceae	*	*Portulaca pilosa*			1						
Pteridaceae		*Acrostichum speciosum*				1				1	
Rubiaceae		*Oldenlandia mitrasacmoides*									1
		Spermacoce dolichosperma									1
		Timonius timon				1	1	1		1	
Sapindaceae		*Atalaya hemiglauca*						1			
Solanaceae		*Physalis angulata*									1
Stylidiaceae		*Stylidium pindandicum*	P3								1
Verbenaceae		*Phyla nodiflora*			1				1		
No. of taxa (in quadrats)				**6**	**19**	**17**	**18**	**26**	**16**	**9**	**54**

Glossary

Hydroperiod	The period of time during which a wetland is covered by water
PEC	Priority ecological community
TEC	Threatened ecological community

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