

Nyul Nyul freshwater management and monitoring plan

By Rebecca Dobbs, Christy Davies, Neil Pettit, Brad Pusey, Michelle Walker and Fiona Tingle

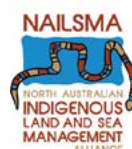


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The traditional knowledge presented here does not represent the full extent of the Nyul Nyul people's traditional knowledge of freshwater wetlands.

Cover photographs: Wobidong June 2013

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For further information contact Christy Davies christy.davies@nailsma.org.au

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Charles Darwin University, Darwin Northern Territory, 0909, Australia.

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The background story for this plan

Through funding from the Northern Australia Hub of the National Environmental Research Program (NERP) and the Hermon Slade foundation, researchers from the University of Western Australia (UWA), Griffith University, and I-Tracker staff from the North Australian Indigenous Land and Sea Management Alliance Ltd (NAILSMA) have been working with the Nyul Nyul Rangers to study the freshwater wetlands on Nyul Nyul country.

Freshwater springs and billabongs are central to the life of the Nyul Nyul people of the Dampier Peninsula in the Kimberley region of Western Australia. Through the Kimberley Land Council's (KLC) Ranger Network, the Nyul Nyul Rangers are employed to manage their country.

"We manage our land and sea. We work with our Traditional Owners. We protect our cultural sites and heritage. We maintain our springs and coastline"

Nyul Nyul Rangers

During training undertaken with the NAILSMA I-Tracker team and through the UWA Waterways Education Program (WEP), the Rangers expressed an interest in obtaining support for freshwater research. In the absence of a freshwater management plan, the rangers wanted to better understand, manage and monitor freshwater on Nyul Nyul country.

"If we look after our freshwater it will still be there for future generations to learn about the Nyul Nyul knowledge and scientific understanding of those freshwater places. Then they will also have the knowledge to tell other people."

Zynal Cox (Nyul Nyul Ranger)

This project provided the opportunity for Nyul Nyul Rangers to introduce the research team to these freshwater systems. The partnership approach combined scientific sampling with Nyul Nyul Indigenous Ecological Knowledge (IEK) gathered during the project to provide a broader understanding of the biodiversity and pressures/threats to these systems. Collaboration and sharing of knowledge resulted in a management plan that incorporates natural, cultural and social values, and recommends using both western science and traditional techniques and knowledge for managing freshwater ecosystems.

This management plan, developed by the project team, summarises the activities and the data/information collected with the Nyul Nyul Rangers, providing an overview of the different freshwater habitats on country, as well as recommendations for the local on-ground monitoring and management of these waterways. The plan will assist in guiding the Rangers' on-ground activities to manage existing and potential threats, with the aim of protecting and, where required, improving the ecological health of Nyul Nyul wetlands. The monitoring program provided will also help the Rangers to better assess changes to the health of freshwater habitats in response to their on-ground land management practices.

"Water is the lifeline of our country, Nyul Nyul country, and everybody knows that. It's not only good drinking water but also a part of our culture and heritage. This is one of the luckiest countries I know. If we look after the land and water it's going to look after us back."

Preston Cox (Nyul Nyul Ranger)

The study area

Freshwater ecosystems of the Dampier Peninsula (north of Broome) support communities of aquatic (within the water body) and riparian (on banks of a waterbody) plants and animals in an otherwise dry landscape and play an important role as refuges for terrestrial fauna. Many of these freshwater ecosystems are located on Nyul Nyul country. The Nyul Nyul Rangers are based in the township of Beagle Bay and manage over 200 000 hectares of traditional lands centred around Beagle Bay on the Dampier Peninsula north of Broome, Western Australia (Fig. 1). Nyul Nyul country is bordered by Bardi Jawi country to the north, Nimanburr country to the east and Jabirr Jabirr country to the south.

“We are freshwater people but also connected with the sea, which is special and unique”

(Nyul Nyul Rangers)

A variety of culturally significant freshwater habitats are located on Nyul Nyul country and this management plan uses the term ‘wetlands’ to refer collectively to all freshwater ecosystems present. Study sites have been classified based on their connectivity to other wetlands and water source and include Lakes (formed mainly by rainwater runoff and do not drain to the sea), Springs (formed mainly by groundwater) and Waterholes (formed by both rainwater and groundwater and located along creek lines that drain to the sea) (Fig. 1). Despite the significant IEK retained by local Aboriginal people, prior to this project, this IEK and the extent and ecological function of these freshwater systems had been poorly documented.

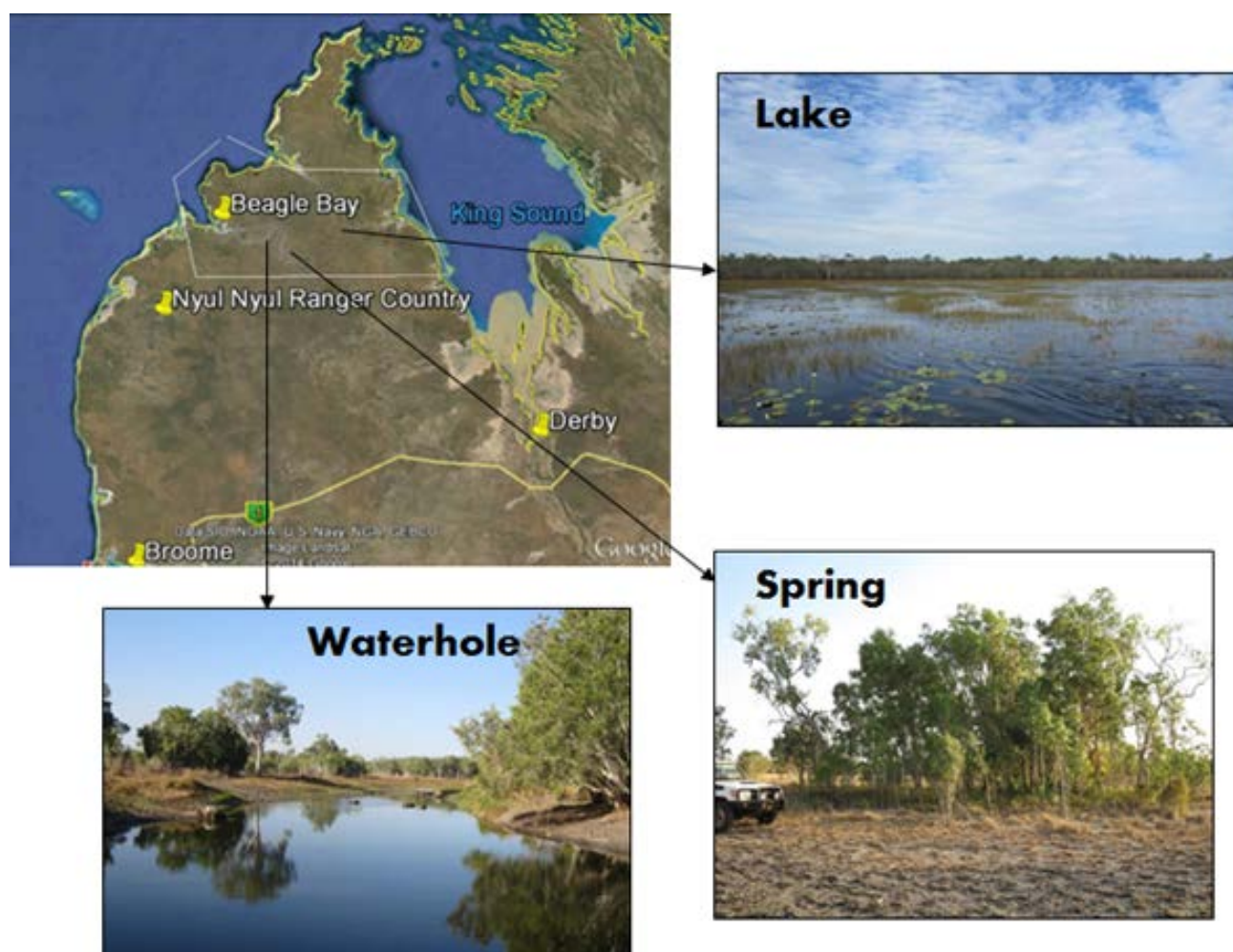


Figure 1: Location of the Nyul Nyul study area and the types of freshwater systems present.

Information to support the Plan

On country data collection

As there was a clear gap in the scientific knowledge of freshwater systems on the Dampier Peninsula, baseline data was collected to better understand these systems. The information collected during sampling trips is summarised below. The project team also developed a Supplementary Report (Dobbs *et al.* 2014) that contains detailed information on sampling techniques and results.

"We are not university students, what we're doing is ground-breaking. We have scientists coming here, helping us to understand what we need to know to look after our country".

Albert Wiggan (Nyul Nyul Ranger)

Sampling sites

The Nyul Nyul Rangers and researchers worked together to sample a range of freshwater habitats across the Rangers' operational area during five sampling trips throughout 2012, 2013 and 2014 (Table 1, Fig. 2). Sites were selected in consultation with Rangers and Traditional Owners, with sites of interest relevant to community concerns and potential threats identified by community members. Some culturally significant sites were not visited due to cultural reasons.

Field trips in 2012 (August and September), focussed on site selection, knowledge exchange, Ranger training (I-Tracker and scientific sampling techniques) and identification of issues/concerns including donkeys and introduced fish species. Field trips in June 2013 and July 2014 (early dry) and October 2013 (late dry) focused on ecological sampling of fish, macroinvertebrates (waterbugs), food web structure and IEK. All trips were designed to develop, test and modify monitoring tools for ongoing monitoring, using an I-Tracker application to record and manage the data.

Table 1. Summary table of sites visited.

	Sites	Sep/ Aug	June	Oct	July
Lakes	Weedong	✓	-	✓	✓
	Rubabunan (Lake Louisa)	✓	✓	✓	✓
	Yarp	✓	-	✓	✓
Waterholes	Wobidong	✓	✓	✓	✓
	Bungaduk	✓	-	✓	✓
	Boolamon	-	-	✓	✓
	Billard	-	✓	✓	✓
	Vincent Well	-	✓	dry	-
	Causeway	✓	✓	-	-
Springs	Nigilbuninj	✓	✓	✓	✓
	Donkey Springs	✓	-	-	✓
	Spring A "Bubble Springs"	✓	-	-	✓
	Spring B "Burnt Spring"	-	-	-	✓

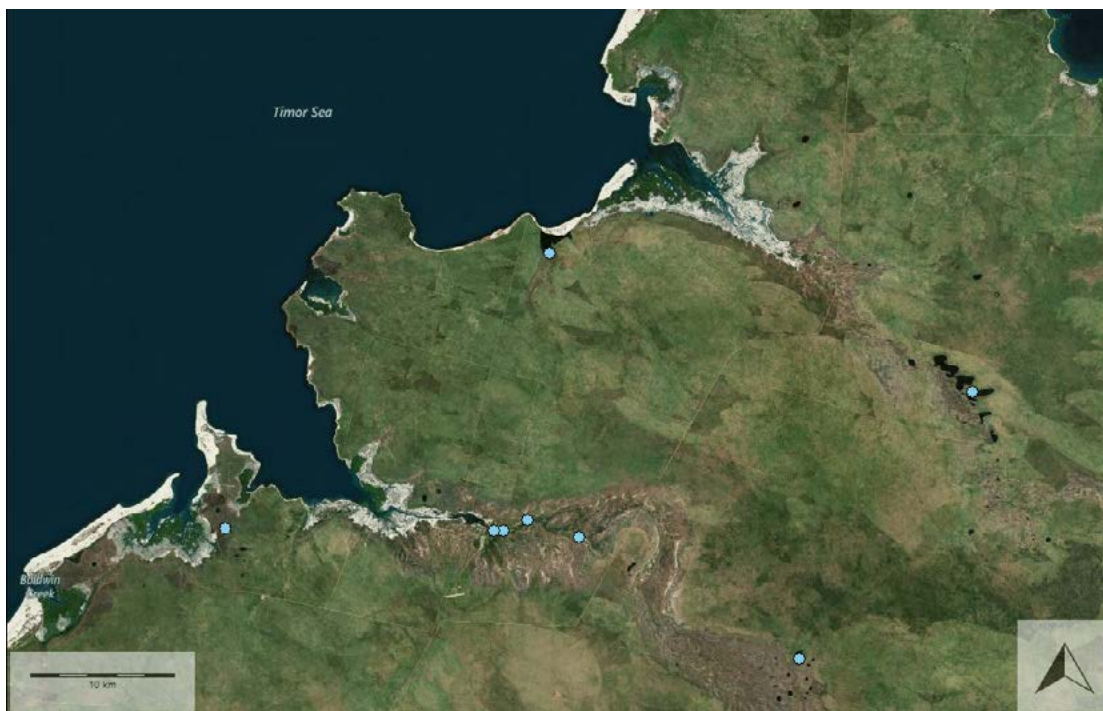


Figure 2: Relative location of the eight main wetlands sampled during the project. For more detail about the locations of sampling sites please contact the Nyul Nyul Ranger office on (08) 9192 4051.

Ecological information

Animal, plant and wetland names

Where possible the Nyul Nyul language names for plants, animals and wetlands have been included in this report; in the first instance plant and animals names appear in bold and are followed by a common and scientific name, thereafter they appear in plain text. Nyul Nyul language can be spelt in alternative ways. All spelling of language names adopted in this report were shared with the project team during field sampling, questionnaires and workshops and are based more specifically on the advice of the Rangers and senior Traditional Owner Stephen Victor.

Indigenous Ecological Knowledge (IEK)

The Nyul Nyul community possesses historical and locally specific IEK that was shared with the project team to build a greater understanding of local wetlands. This also enabled the management plan to incorporate both Western Science (WS) and Nyul Nyul specific knowledge, values, and objectives and strategies for managing wetlands. IEK was shared at each site with permission of the Traditional Owners. The Rangers identified appropriate Traditional Owners to speak for each area and questionnaires were used to assist in gathering IEK. Additional IEK was shared through a Wetland Remote Sensing and Community Mapping Workshop (19th and 20th March 2014) and Community Feedback Workshop (8th September 2014), both held in Beagle Bay. A participatory mapping exercise conducted during the first of these workshops facilitated discussion about individual freshwater ecosystems characteristics and cultural and natural values. This form of collaborative mapping provided a valuable opportunity for Elders to share their knowledge of country with Rangers and the research team, and for Rangers to share their monitoring observations with Traditional Owners. The collaborative workshop was invaluable in promoting sharing of perspectives, documenting a greater depth of Nyul Nyul knowledge and understanding of regional hydrology, and documenting in more detail Nyul Nyul values and aspirations for wetland management.



Scientific surveys

Water quality, groundwater input and morphology (size and shape)

“In the old days our water systems were really healthy. The threats affecting our water sources are different now, so it’s really important that we understand the water quality of the places we have on our land.”

(Nyul Nyul Rangers)

Standard water quality parameters commonly used in monitoring of freshwater ecosystems were measured using hand-held meters (Table 2). General site characteristics were also recorded including waterbody size (length, depth, width), available habitat and relative water levels. Water samples were collected to measure stable isotopes (hydrogen and oxygen) in the water. Comparing isotope signals from wetlands with rainwater samples and water from groundwater bores provides an indication of the influence of groundwater inputs to each Nyul Nyul wetland sampled. Water samples were tested for nutrients and Chlorophyll a.

In addition to those samples regularly taken for ecological studies, additional water testing was conducted to investigate concerns expressed by the Rangers that the sewage treatment plant (STP) may be impacting on the water quality of swimming holes.

Table 2. Water quality parameters measured at each site

Parameter	units	Explanation
pH	Scale 0-14	A measure of the acidity (pH 7) and alkalinity (pH >7) of a water body.
Conductivity	$\mu\text{S}/\text{cm}$	A measure of how salty the water is. Freshwater 0-800 $\mu\text{S}/\text{cm}$, and sea water 51,500 $\mu\text{S}/\text{cm}$ (Appendix 2).
Temperature	OC	How hot or cold the water is, can be affected by turbidity, water depth and level of shade.
Turbidity (nephelometric turbidity units)	NTU	A measure of how clear or cloudy the water is. Higher NTU's indicate greater turbidity
Secchi Depth	cm	Also a measure of how clear or cloudy the water is. Higher secchi depth indicates low turbidity



Fish

Fish were sampled from larger waterbodies using a 4.5m electrofishing boat. Smaller, shallower sites were sampled with a backpack electrofisher, seine net or hand net. Fish were collected using a standard method to enable comparison across sites, seasons and other studies across northern Australia. All fish collected were immediately placed in an aerated holding tank, identified and counted before being released. Alien (introduced) fish species were not returned. Samples of fish species were retained for deposition within the Museum and Art Gallery of the Northern Territory (matched body and tissue samples) or for inclusion in analyses of food web structure.



Macroinvertebrates “waterbugs”

Macroinvertebrates (waterbugs) can provide information about the health of freshwater sites and were collected using a standard method to enable comparison across sites, seasons and other studies across northern Australia. A 10m sweep sample, across a variety of habitats, was taken using a hand-held dip net. Waterbugs were live picked in the field, sorted into broad groups (Family) and the numbers of individuals in each group were counted. Sub samples were then provided for analyses of food web structure and the rest preserved and identified in the laboratory using a microscope.



Birds

Opportunistic sightings of waterbirds were recorded for a wide range of sites.

Plants - Riparian vegetation and waterplants

Riparian zones (streamside and bank vegetation) are considered to be vulnerable to many of the threats present on Nyul Nyul country including weed invasion, feral animals, fire, overgrazing and erosion. A modified version of The Tropical Rapid Appraisal of Riparian Condition (TRARC) method was undertaken at each site to measure this disturbance. The riparian monitoring (bank assessment) uses a 100 m transect running parallel to the edge of the waterbody. The entire assessment is a visual measurement of features (*indicators*) in and around the riparian zone that suggest good or poor condition. A range of indicators are recorded within three 5 X 5m quadrats located 50m apart, with additional indicators recorded looking back along the entire 100m transect. The TRARC method was designed to assess the condition of rivers, not wetlands and therefore a transect was added perpendicular to the riparian transect to assess both the littoral zone (edge of wetland) and the macrophytes (waterplants) growing in and around the wetlands. Along the transect the type of vegetation was recorded in addition to animal impacts. At each site the dominant riparian and aquatic plant species were also recorded.



Identifying food webs using isotope analysis

Samples of primary food sources (aquatic and terrestrial vegetation), aquatic macroinvertebrates (water bugs) and fish were collected to construct a food web for the wetlands. Food webs describe the feeding relationships and the flow of energy throughout the ecosystem combining information on ecosystem processes and biological community structure. Food webs generally start with primary producer organisms (e.g. plants and algae), which are then eaten by primary consumers animals that are in turn eaten by secondary and higher order consumers (predators). A sample of each type of plant and animal, as well as leaf litter and periphyton (algae attached to stable surfaces such as rocks, wood or plants) were collected. Laboratory analysis of the ratios of stable carbon ($^{13}\text{C}/^{12}\text{C}$) and nitrogen ($^{15}\text{N}/^{14}\text{N}$) isotopes ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$) is a standard method for determining the link between consumers and what they eat.

Pressures/threats

Pressures that could impact on each of the freshwater systems were recorded along the riparian and aquatic transects including; fire, feral and managed animal impacts. Feral animal pads and trampling were included in the transect measurement as they are likely to be the most consistent indicator of disturbance (pressure) within the riparian zone and can be consistently measured using a transect approach. IEK was also valuable in identifying community concerns, threats, impacts and longer-term ecological changes.



Additional data

Historical satellite images

While the on-country sampling tells us what the freshwater habitats are like now, remote sensing (like IEK) allows us a rare opportunity to see into the past. Information derived from satellite data were used to build an understanding of changes in freshwater areas on Nyul Nyul country over time (Ward and Tews, 2014). The ability to capture past environmental conditions relies on a number of satellite sensors which have significant and freely accessible historic archives. For example, the Landsat archive used in this project has an approximately 30 year archive, and the MODIS satellite has a 12 year archive. The MODIS satellite captures an image of the same location on the earth's surface every day and is



consequently useful for capturing flood events that may last from days to weeks. Wet season MODIS imagery between 2000 and 2010 was captured and applied to map wet season flood extents on the Dampier Peninsula over this period (except when cloud cover prevented image classification).

Landsat satellites capture an image of the same location on the earth's surface every 16 days but have a much finer resolution (30m pixels) than MODIS imagery (250m pixels) making Landsat imagery useful for tracking waterhole dynamics (Ward *et al.* 2012). Satellite images of the larger waterbodies (Yarp, Rubabunan, Weedong and Bobbis Creek Drainage line) were analysed to determine patterns of filling and drying, turbidity (water cloudiness) and aquatic vegetation cover.

Historic satellite imagery was therefore applied in this project to 1) capture the flood extent and connectivity between wetlands resulting from wet season floods; and 2) capture seasonal and inter-annual dynamics of waterholes. This data was used to add to our understanding of the ecology of these freshwater systems and assist in planning and management. In direct response to a request from the community a map of water content was also developed for the area around Beagle Bay community to assist in town planning.

Overview of Nyul Nyul wetland environmental and cultural values

The project was able to answer some key questions about freshwater wetlands to assist in their management. Indigenous Ecological Knowledge and Western Science have been drawn upon to identify values, build an understanding of how these systems function and what threats could be impacting on their ecological health. The main findings from the project have been summarised below and individual sites summaries provided in Appendix 1 (See Dobbs *et al.* 2014 and Ward and Tews, 2014 for more detailed analysis of the sampling and data).

Cultural values

“We grew up with wetlands – these areas are special to us, they are part of our identity”

(Nyul Nyul workshop participant)

The wetlands were identified as being important not only as a source of water for people and all life, but as strongly connected to Nyul Nyul people's identity. Nyul Nyul people's connection to freshwater has many elements. Important cultural meanings, sites and stories are associated with waterholes, lakes and springs. Wetlands have many practical uses, such as a source of drinking water, providing habitat for hunting and fishing species, and supporting many different plants that are valuable as food, medicine, or materials. Wetlands are places of learning, family time, play, and a source of memories from past times. Stories told by Nyul Nyul participants demonstrate how waterholes, lakes and springs have remained important through changing ways of life. Before Europeans arrived freshwater wetlands were hubs of daily life. After the Beagle Bay Mission was established, these places continued to be visited and used by Nyul Nyul people, with freshwater crucial in maintaining the cattle industry, vegetable growing and other local industries. Today, young Nyul Nyul people still grow up visiting and using freshwater ecosystems. Nyul Nyul Ranger, Ninjana Walsham describes his connection to freshwater;

“For me, growing up, the whole [freshwater system] is important. It provides food. Some lakes we go to for goanna, so we go to for birds. It's what we grow up with. We don't want the population of these things to go down”.

Ninjana Walsham (Nyul Nyul Ranger)

Nyul Nyul knowledge and practice for managing freshwater ecosystems

Some IEK documented for this project relates to Nyul Nyul worldviews and explanations for how wetlands are created and remain healthy. For example **Nigilbuninj** (Indian shortfinned eel *Anguilla bicolor*) play an important role in creating new springs through their actions in burrowing through the soil. Although Nigilbuninj are fished and eaten, especially in the past, protocols existed to ensure they were not over-fished, as this may jeopardise the creation of new springs.

Nyul Nyul people discussed various practices for maintaining healthy wetlands. Several comments indicate that flow of water through wetlands is important for healthy country. Some elders recalled how their ancestors would physically scoop out water to stimulate fresh water for drinking. Traditional owners consider that maintaining or bringing back flow to wetlands is an important management strategy:

“We’ve got to clear it up [some springs] and make sure that the water is running through and the spirit is running through [the country]”

Mary O’Reeri (Traditional Owner).

Also, Nyul Nyul protocols guide correct behaviour towards country that can help to ensure it stays healthy and productive.

“With any Aboriginal place you go you’ve got to follow the rules, respect the country, talk to the country. Some places you get a rock, rub it under your arms and throw it in the river... Here you’ve just got to talk to the old people [spirits] this side of the country, tell them what you’re here for.”

Brendan Smith (Nyul Nyul Ranger)

Like any community, Nyul Nyul people’s ideas about how to keep wetlands healthy vary. Take donkey management as an example. For the generation who grew up on the Beagle Bay mission, donkeys were associated with religion and considered hard-working animals with a rightful place in society. In comparison, the Rangers, who are a younger generation and have worked with scientists and ecologists, perceive that donkeys damage wetlands and believe controlling these animals should be a major priority for management. It is important to recognise these different perspectives when deciding on strategies for managing wetlands. If management strategies are chosen that have whole community support, this will increase chances of those strategies succeeding.

Water

How do the wetlands connect during the wet season?

Some of the wetlands on the Dampier Peninsula are part of “internal drainage systems” because the creeks and streams that supply them do not flow into the sea (i.e. Yarp and Rubabunan); while others are part of “external drainage systems” because they are connected to creeks and streams that do flow into the sea (Bobbis Creek waterholes).

The connectivity of water flow can influence wetland characteristics, particularly the fish species present and the structure of food webs. Satellite images (between 2000 and 2010) showed limited and only very brief periods of flood connectivity between Rubabunan, Yarp and the wetlands along Bobbis Creek (Fig. 3). In 2005 there was no flooding and all of the waterbodies dried up.



Figure 3: Wet season connectivity across the study area for a dry year (2005) and a wet year (2000) (Figure taken from Ward and Tews, 2014)

It is important to note that this may not be a typical pattern, as this was a very dry period across all of Australia so it is likely that there have been periods of higher flood connectivity in the past decades (e.g. 1970-80). Periods of higher flood connectivity could also be expected in the future based on climate change projections for rainfall for Northern Australia.

Are the wetlands permanent or do they dry up in the dry season?

Satellite imagery shows that in recent times all of the larger lakes and waterholes have completely dried up at least once (even Weedong). Nyul Nyul participants also remember wetlands drying up or holding less water over the past decades. Rubabunan usually dries up by the end of the dry season, except for really wet years (e.g. 2000). The largest of the Yarp Lakes and Weedong only dried up in the driest years (2005 and 2002). The spring fed areas around Beagle Bay remain wet all year around (Ward and Tews, 2014).

In particular 2005 was a very dry year and a lot of the wetlands dried up and became disconnected and fragmented. Nyul Nyul participants attributed the cause to disconnection within the community occurring at the time:

The country was feeling it [the community dysfunction] and not filling up. It's a spiritual thing; the country was responding to the liyan [feeling] and not giving back to the people.

Mary O'Reeri (Traditional Owner)

The community itself was disconnected on a spiritual level. The country responded to community dysfunction by also becoming disconnected, emphasising the importance of the connection between people and country. Some of this connection can also be two-way (e.g. people responding to country).

What is the water quality like?

The water quality of wetlands is important for Nyul Nyul people for recreational use including fishing and swimming and therefore the health of the community. Investigations into water quality were conducted in the context of threats identified by the Nyul Nyul Rangers and community. The wetlands were generally clear with low turbidity (cloudiness of water) however some of the smaller springs recorded very high levels of turbidity. Riparian transects at these springs showed a high level of trampling by donkeys and therefore it is likely that the high turbidity is caused by donkeys walking into the water and disturbing the soil when coming to the springs to drink. Larger waterholes and lakes are generally clear early in the dry season, and naturally become more turbid towards the end of the dry as they dry out. Weedong remained relatively clear all year round. At sites having little or no input of groundwater, conductivity levels (saltiness of the water) increased slightly towards the end of the dry season as these wetlands evaporated. Levels of dissolved nutrients were generally low at all sites particularly for phosphorus. Only Wobidong in October had nutrients levels that were high enough to possibly cause excessive algal growth.



Some sites including Bungaduk, Wobidong and Nigilbuninj, recorded high levels of *E. coli* (one of the types of bacteria found in poo). The location of these sites indicates that the *E. coli* levels were not related to the sewage treatment plant. It is likely that the bacteria have come from dung from donkeys or other warm blooded animals such as waterbirds.

What is the main source of the water for these wetlands?

An analysis of water samples showed that evaporating water is rapidly replaced by groundwater at spring sites, including Nigilbuninj and Bobieding. These springs therefore rely on input from groundwater and are more likely to be affected by groundwater extraction than other wetlands that rely on rainfall (surface water). In comparison, Rubabunan had a high evaporation rate due to its saucer shape and there was little or no groundwater input to replace evaporated water over the dry season. It may be presumed that the other large lake-like wetlands such as Weedong and Yarp would be similar, with these wetlands relying on rainfall and surface water flows.

Wobidong waterhole showed some groundwater input but not enough to compensate for evaporative loss over the dry season. Or it may be that the size and shape of the smaller waterholes like Wobidong means they are less exposed to evaporative loss compared to the large, shallow lake-like wetlands.

Although further investigation is required to better understand the dynamics of surface/groundwater interactions of these wetlands, these findings can be used to inform management and monitoring for impacts from any future water resource development.

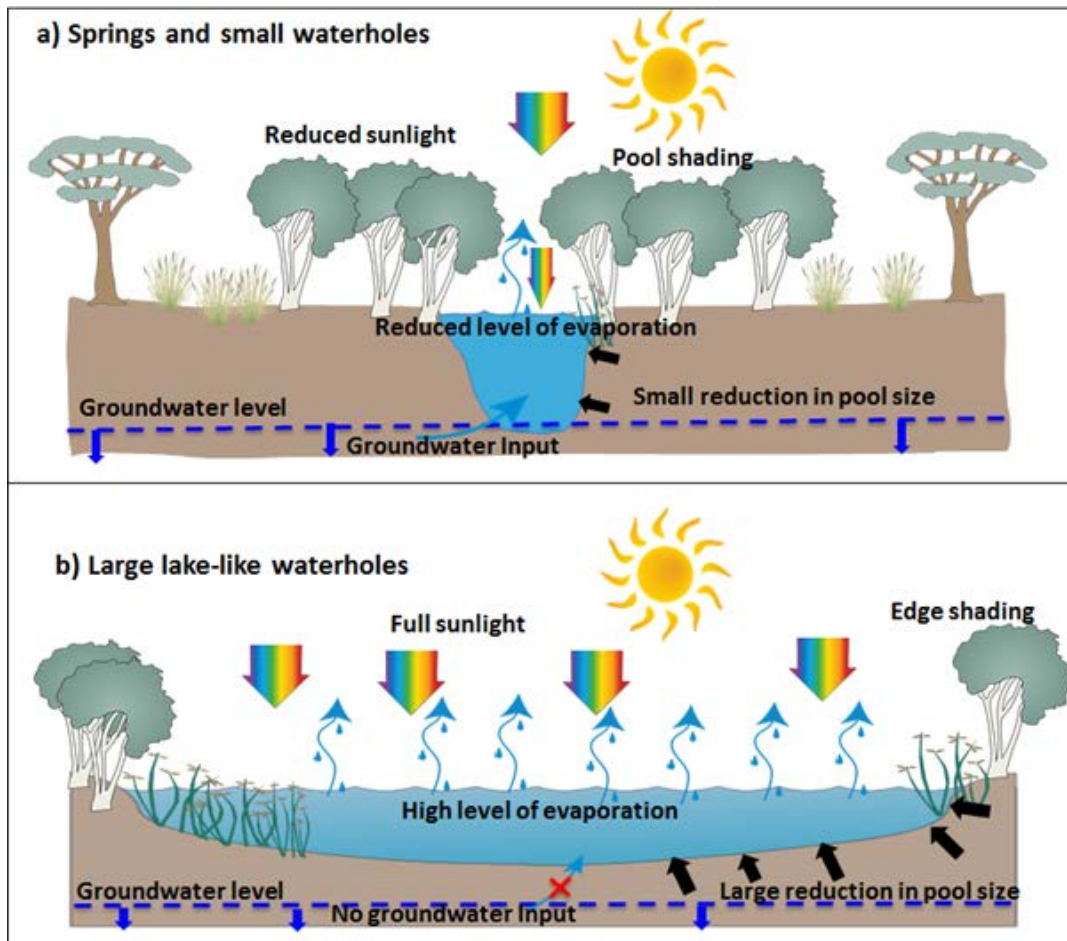


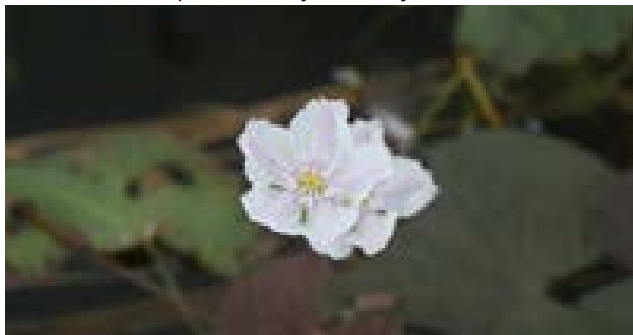
Figure 4: Comparison of the effects of evaporation and groundwater inputs on different types of wetlands with a) springs and groundwater-fed waterholes usually have high shading and input of groundwater which slows the reduction of the size of the pool over the dry season. In contrast lake-like waterholes (b) have large surface, little shading and no groundwater input so the reduction in pool size is greater.

Plants and animals

What are the main plants present?

Plant and tree species are valuable to Nyul Nyul people for a host of reasons. For example trees and aquatic plants have multiple uses including providing bushfruits, terrestrial habitat/food chains, materials and shade. A survey of the dominant native riparian and aquatic plants recorded a total of 90 species including 16 aquatic species. Billard had the highest species richness (number of species) and diversity (different types) while the small springs had the lowest species richness. Nyul Nyul wetlands are likely to be a stronghold for the Beagle Bay Marshwort (*Nymphoides beaglensis*) shown on the following page. This species was identified at a number of wetlands and has a Priority 2 conservation status in Western Australia, meaning it is a species that is known from only one or a few collections or sight records, some of which are on lands not under imminent threat of habitat destruction or degradation (ALA, 2014). None of the waterholes surveyed appeared to be affected by exotic plants (weeds) except Billard which used to be a nursery site and contains a number of introduced plants including palms.

Riparian and aquatic vegetation communities were linked to wetland size with similar plant species present at large lake-like wetlands including **Lardik** the Freshwater Mangrove *Lophostemon grandiflorus* and **Nimalgoon** a Paperbark *Melaleuca nervosa*; compared to smaller in-stream waterholes (**Walamanggar** a Paperbark *Melaleuca viridiflora*, shown below on right, and the emergent sedge *Schoenoplectus mucronatus*) and small springs. According to Kenneally *et al.* (1996), **Nimalgoon** is attributed to *Melaleuca viridiflora* in Bardi (a neighbouring language). Wetland size was more important than groundwater influence on the types of plants present at each site. All of the smaller springs dominated by groundwater seepage were very similar, most likely related to their small size and permanent water availability. These small springs are also highly susceptible to external disturbances, particularly donkey use and fire.



What animals live in the wetlands?

Fish

Nyul Nyul people harvest higher-order fish for bait or eating and this project provided the first comprehensive assessment of the biodiversity of freshwater fishes in spring systems within the Nyul Nyul traditional lands. The wetlands support a small number of native fishes, almost all of which are marine or estuarine dependent species. Twelve native and one introduced fish species were recorded across the wetlands sampled (Table 3). Three species of elasmobranch (cartilaginous fish like sharks and rays) have been known to occur in the estuarine section of Bobbis Creek, **Garnamerr** (Bull shark *Carcharhinus leucas*), **Jinup** (Freshwater whipray *Himantura dalyensis*) and **Jubinyank** (Freshwater sawfish *Pristis pristis*). The highly invasive introduced Mosquitofish (*Gambusia holbrooki*) was widespread in Bobbis Creek drainage system (recorded from every site examined in this drainage). It was absent from Weedong and Yarp, neither of which contained any other fish species and also absent from Boolamon.

Table 3. Scientific and common names of the fish species captured across Nyul Nyul wetlands

Species	Common name	Language name
<i>Gambusia holbrooki</i> #	Mosquitofish	
<i>Anguilla bicolor</i>	Indian shortfinned eel	Nigilbuninj/Nigilbardiny
<i>Megalops cyprinoides</i>	Ox-eye herring	Jalabunan
<i>Chanos chanos</i>	Milkfish	Madjalk
<i>Elops hawaiiensis</i>	Giant herring	
<i>Hypseleotris compressa</i>	Empire gudgeon	
<i>Lates calcarifer</i>	Barramundi	Gajarr
<i>Lutjanus argentimaculatus</i>	Mangrove jack	Marran*
<i>Neoarius graeffei</i>	Lesser salmon catfish	Barool
<i>Amniataba caudivittata</i>	Yellowtail trumpeter	Rararr
<i>Selenotoca multifasciata</i>	Scat	Banjarr
<i>Mugil sp.</i>	Mullet	Noongul

#introduced species, *Bardi word

Locally the wetlands play an important role as juvenile habitat for migratory species that are more commonly found in estuarine habitats including valuable food and bait species, **Gajarr** (Barramundi *Lates calcarifer*) and **Marran** (Mangrove Jack *Lutjanus argentimaculatus*). Nearly all of the species recorded need to move to the estuary or the ocean to breed. Wetland sites along the Bobbis Creek drainage line that connect to the estuary had the highest number of fish species. A number of sites had low numbers of fish (including Rubabunan) suggesting that freshwater habitats of the area have substantially dried out in the recent or historical past. Satellite imagery (2000 to 2010) and Nyul Nyul knowledge have confirmed that Rubabunan dries out most years and also rarely connects to other areas in the wet season, so there is limited opportunity for fish to move into the lake.

Although Weedong appeared to be a large permanent body of water capable of supporting fish, our study recorded no resident fish. Nyul Nyul participants helped to explain this unexpected result by recounting that permanent water at this site is a relatively recent phenomenon.

“Weedong wasn’t there in the ‘60s and ‘70s. I used to muster cattle across this area when I was young”.

Stephen Victor (Traditional Owner)

Nowadays the wetland is still not considered a fishing site. Nyul Nyul people attribute the change to a build-up of sand dunes that encouraged water accumulation. Coupled with an understanding of the wetland’s isolation from other aquatic systems derived from remote sensing, Nyul Nyul knowledge provided an explanation for the lack of fish that could not be gleaned using standard WS field methods in isolation.

The presence of the Nigilbuninj in a few locations within the Bobbis Creek drainage is of conservation significance. Whilst it is common in the Fitzroy River drainage basin (and potentially elsewhere in the Kimberley region), it is not widespread across northern Australia. For Traditional Owners Nigilbuninj (also spelled Nigilbardiny) are an indicator of healthy wetlands. They are an important totemic species, and this significance is highlighted by their inclusion in the Nyul Nyul Ranger logo. Elders describe specific eel fishing protocols that maintain the eel population, which is considered to be vital to generation of new springs in the region.



Macroinvertebrates (waterbugs)

Macroinvertebrates (waterbugs) are an important part of the food web and can provide information about the health of freshwater sites. The wetlands contained a total of 92 types of macroinvertebrates from 34 groups (families) across the three sampling trips. Most of these species are widespread across the Kimberley. The highest number of species was recorded at Yarp Lakes (29 species) and the fewest species recorded at the small springs (9 species). The larger lakes (Rubabunan and Weedong), the waterholes (along Bobbis Creek) and the springs (Nigilbuninj) each contain different communities of waterbugs showing a link between the macroinvertebrate communities and the hydrology and source of water (ie groundwater/surface water). Lake sites were dominated by microcrustacea, springs dominated by snails and beetles. At sites with no fish such as Weedong, the waterbugs present were consistent with no top-down predation, that is, in the absence of fish predators, many large predatory insects such as water boatmen are able to flourish.



What is the most important food source for these animals?

Samples from the lakes, waterholes and springs showed that periphyton/biofilm is the most important food source for waterbugs and some fish. Periphyton is the slimy green algae that grows on submerged rocks, wood and plants, and it provides a good food source that is easy to digest “delicious and nutritious!”. Periphyton is eaten by a variety of waterbugs, which are then eaten by predators including other waterbugs and fish within the wetlands. Other food sources such as aquatic macrophytes and terrestrially derived plant material (litter) are generally of much lesser importance, but can be locally important at some sites at certain times of year. An understanding of these complex food web linkages (Figure 5) and food sources can be used to guide management that is aimed at minimising disturbance of these important food sources and hence the animals that it supports.

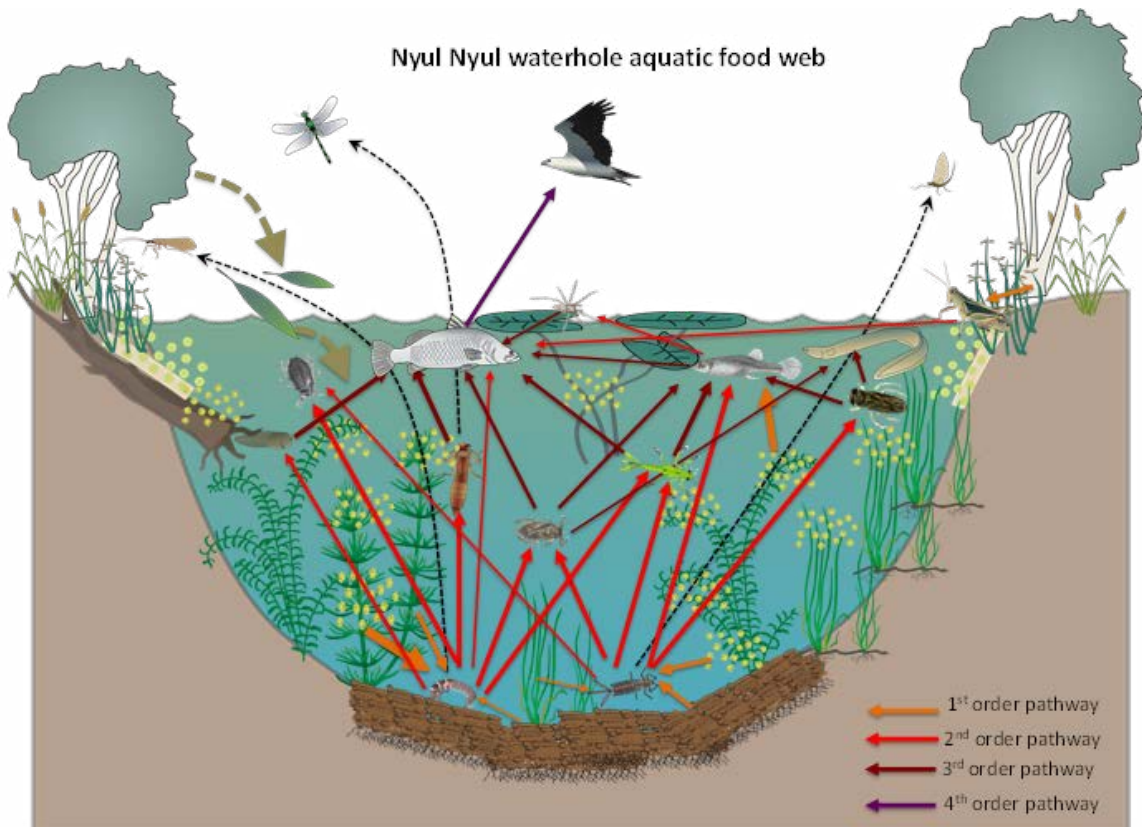


Figure 5: Aquatic food webs in waterholes indicating the complex interactions between primary food sources, including algae on surfaces (periphyton), water plants and decaying leaf litter, with consumers (animals) which feed directly on plants (1st order), or other animals (higher order) or more than one. Arrows indicate the feeding link between the plants and animals and the colour and thickness of arrows indicates order and strength of the connection.

Threats, impacts and disturbance to wetlands

The ecological health of these freshwater ecosystems is threatened by hot wildfires that damage sensitive riparian vegetation, Mosquitofish, and increased water turbidity and bank erosion from donkeys (*Equus africanus asinus*). The Rangers and the community also expressed concern about the impact of the sewage treatment plant, septic systems and the causeway and its influence on flow and connectivity. Freshwater will be a valuable resource for any future development in region and therefore potential threats include water extraction associated with development.



Donkeys

"And now we've got donkeys...we've got heaps of donkeys and the donkeys are just running wild, and they are in such large numbers, and they have impacted on the bank systems."

Albert Wiggan (Nyul Nyul Ranger)

Most of the freshwater sites showed signs of significant visitation by feral donkeys. The extent of the impact of donkeys on the Nyul Nyul wetlands was difficult to assess given that no site examined during the study could be classified as a control (i.e. no donkeys) against which a comparison might be validly made. None-the-less sites with high levels of visitation showed signs of bank degradation, damage to the riparian zone and elevated turbidity. Sites with the highest impacts included Bungaduk which had signs of bank erosion and infilling and the smaller springs along Bobbis Creek drainage line (Fig. 4).

“A healthy waterway is one with clear water, green around; not healthy if water fills up with soil.”

(Traditional Owner)

Donkeys can cause elevated turbidity and bank degradation from trampling and grazing, increased nutrient levels from faecal deposition within the water body and damage to riparian vegetation. All of these impacts are known to negatively affect fish and waterbugs, can reduce aquatic plant cover, and have the potential to disrupt the growth of periphyton (the main food source in Nyul Nyul wetlands) (Fig. 6). In addition to threats to the ecological health of the wetlands, feral donkeys can impact on cultural uses. For example infilling of waterholes or increased turbidity may affect the availability of fish used for bait or food, and reduce the appeal of these places for swimming. Damage to riparian and aquatic vegetation may also affect plants valuable as food, medicine or other materials.

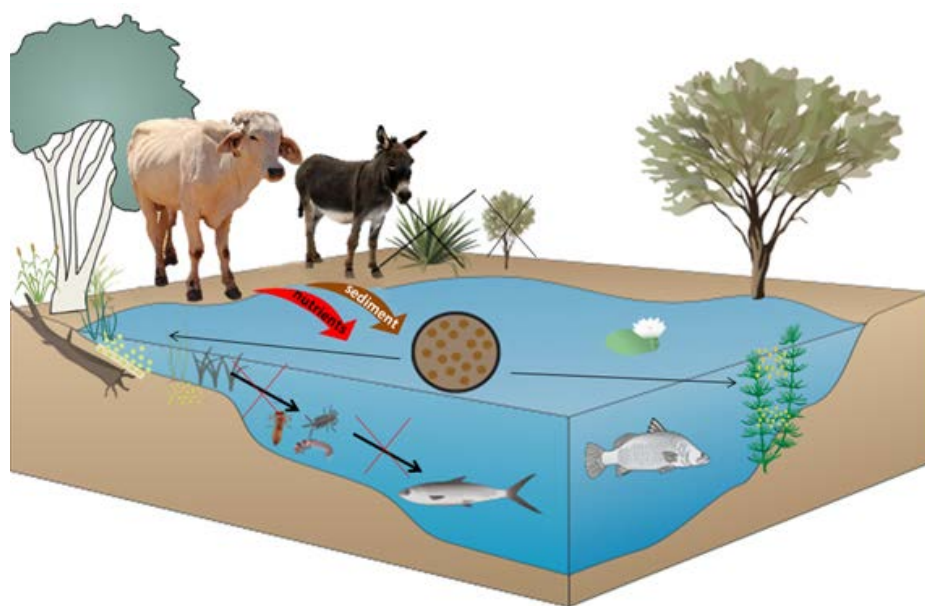


Figure 6: Feral animal impacts (a) Bank erosion evident at Bungaduk (b) trampling of vegetation and increased turbidity at smaller springs (Spring A) (c) Diagram showing the link between feral animals (donkeys and cattle) and food webs. Removal of riparian (bank) vegetation from trampling can result in increased sedimentation which can disrupt the growth of periphyton and hence the main food source for Nyul Nyul bugs and fish.

Fire

The group of plants that grow around and provide shade for wetlands such as Billard (often called riparian vegetation) is very different to the surrounding woodlands. Like the monsoon vine thickets that also occur on Nyul Nyul country, riparian vegetation is very sensitive to hot fires. If a late season wildfire burns riparian vegetation it may take a long time to grow back (resulting in similar impacts to removal of vegetation by donkeys). Extra sunlight can change a waterbody by encouraging more evaporation and growth of macrophytes (waterplants). This combined with increased erosion could also eventually lead to wetlands filling up/drying out. By altering vegetation, hot fires within the riparian zone can also affect the number and type of animals present, by removing habitats and food sources. Overall, fire can therefore impact on the recreational and cultural use of waterholes. For example populations of species targeted for hunting may be reduced and the physical characteristics that cause Nyul Nyul people to visit, picnic or use freshwater resources may change, for example through destruction of shade trees and bush fruit trees.

Disruptions to wetland and estuary connectivity

Maintaining connection of water flow between the freshwater habitats of Bobbis Creek and the estuary allows for the upstream movement of fishes (including eels) and is therefore a key management issue. Such movement occurs mostly during the wet season when water levels are high. During the dry season however when water levels are low, the causeway across Bobbis Creek would present a barrier to movement of fish and eels but the ecological significance of this is unknown. Regardless of the magnitude of the wet season, maintaining flow between the wetlands and the estuary of Bobbis Creek is essential to allow fish migration. Without it, the fish fauna of the individual wetlands in the region will degrade over time. When creeklines become overgrown with vegetation and weeds, some fish may not be able move upstream. Poorly constructed road crossings and causeways can also inhibit fish movement especially during the dry season. Water abstraction may reduce flow disconnecting different waterholes more quickly than would occur naturally and thus limit the upstream passage of some fish.

A key concern of the community is the causeway at Bobbis Creek. The causeway was built in the 1980s to enable vehicles to cross Bobbis Creek to increase access to country including nearby outstations. While the causeway was built to meet these community needs, the community and Rangers are concerned that the way it was constructed has had a negative impact on the wetland environment and use of wetlands by community members. The causeway was constructed (and is periodically added to) using waste building materials, and inadequate culverts restrict water flow along Bobbis Creek. There is also concern that the waste materials such as scrap metal and concrete structures including old septic tanks may pose a health risk. Restriction of the normal water flow has resulted in the silting up of what had previously been a deep pool (used by the community for swimming and fishing) and the emergence of dense vegetation, including extensive and impenetrable stands of bulrushes, and some areas of mangroves (see photos below). This in turn has also impacted the use of adjacent spring areas as the community can no longer walk across this area of the country to access nearby springs and waterholes. An elder used to walk on the other side of the causeway from town to Billard, Wobidong and Bungaduk; but now there's lots of water and the vegetation has become more dense.



Sewage contamination

Early in the project the Rangers expressed concern that the sewage treatment plant was affecting water quality at a number of locations including a popular swimming hole near the causeway. The project team conducted preliminary testing which showed that *E. coli* levels were elevated in some wetland sites above guideline levels for recreation (swimming) and fishing (see Dobbs *et al.* 2014). However the location of these sites (both upstream and downstream from the sewage treatment plant) indicates that the high levels could not be caused by the STP alone. The source of *E. coli* at some sites may be donkeys or other warm blooded animal such as waterbirds; and changes to the natural flow regime could also be a contributing factor to elevated levels.

Potential threats

Future water use/extraction

There is general concern amongst the Rangers and community about the future water abstraction in the area and how this may affect springs and other wetlands. Results from this preliminary study indicate that there is groundwater input to some wetlands including Billard, Nigilbuninj and possibly Wobidong. These wetlands therefore are mostly likely to be affected by water resource development. The small springs that are expressions of the groundwater are also likely to be impacted by groundwater abstraction. The large lake-like wetlands (Rubabunan, Weedong, Yarp and Boolamon) are not likely to have groundwater inputs and therefore less likely to be affected by groundwater abstraction.

Weeds

Although no invasive weeds were recorded at sites surveyed, weed species are prevalent across the Kimberley and there is potential for weeds to spread to these freshwater sites.

Strategies to protect values and reduce threats

The Nyul Nyul people consider it a cultural obligation to ensure that wetlands on their country remain healthy into the future. By recognising a knowledge gap and initiating this collaborative research project the Nyul Nyul Rangers and community have positioned themselves strongly to take full ownership of freshwater management on their country. The scientific baseline data and Ecological Knowledge gathered during the project, as well as the capacity building that has occurred will assist the Rangers to plan and implement on-ground activities to effectively manage existing and emerging threats to wetlands.

Recommended management actions

Recommendations for ongoing management include actions to address feral animals (donkeys and introduced fish), fire and connectivity of wetlands.

1. *Managing donkey impacts*

The Rangers are interested in minimising disturbance from donkey activity around the waterholes, lakes and springs. Donkey access to priority sites can be restricted through fencing of particularly vulnerable or culturally significant waterholes or springs. Smaller spring sites would be suitable for trial fencing (i.e. Donkey Spring, "Bubble Spring" and "Burnt Spring") although the high number of small springs means that it is not practical to fence them all. Fencing would also not be appropriate/practical at many of the larger wetlands, and may affect access and the aesthetics of the landscape. Therefore a reduction in donkey numbers would be more effective for managing multiple sites and reducing impacts across the broader landscape.

If it is agreed by the community that donkey culling is an option a partnership approach might be a way to move forward, with information about the current donkey population used to inform the best course of management (e.g. trapping or shooting). In the meantime the Rangers can use either the I-Tracker Wetland Application or Land Patrol Application to record all opportunistic sightings of donkeys (and other feral animals) to help to build a picture of the populations' distribution across the landscape. This will assist in planning any future control actions.

2. *Managing fire in riparian zones*

Riparian vegetation is particularly sensitive to fire. The Rangers are currently involved in broad scale fire management to reduce the intensity and extent of late season fires and asset protection burning. If additional resources were available they should extend this work to implement targeted early dry season protective burns around priority wetlands. This would assist in reducing the frequency and intensity of fires burning riparian vegetation in and around springs. Rangers could also investigate any historical Nyul Nyul techniques for using fire to protect water places by interviewing Elders to identify any specific burning techniques used to protect riparian vegetation.

3. *Managing weeds*

Although it is fortunate that the wetlands surveyed as part of this project are not currently impacted by weeds it is important that Rangers are aware of the weed species found in the surrounding region that could invade the riparian zone in the future. Rangers should maintain distribution records of invasive weed species through monitoring of wetlands and undertake control to address any weed occurrences as they appear. Non-native species recorded at Billard should be monitored or removed to limit their potential to spread.

4. *Managing and maintaining connectivity (water flows)*

To ensure adequate water flow and hence fish passage, any new infrastructure (roads, causeways etc.) should be designed to maintain connectivity. Rangers can assist with any decision making by educating the community on the benefits provided to those fish species (including eels) that require connection between freshwater habitats and the estuary or near-shore coastal environment in order to reproduce. As water abstraction can also reduce flow and limit the upstream passage of some fish, if there is any increase in water abstraction, water levels will need to be compared to historical levels to determine whether there are significant changes in wetland depth. To assist with this gauge boards should be installed (see Section 7 for more information). Fish populations can also be monitored in partnership with researchers to track connectivity.

Measures required to address the changes that have already resulted from the causeway include the design and construction of a new causeway to best practice engineering standards, taking into account normal freshwater and tidal flow, freshwater flooding and extreme tidal events, community amenity (including fishing and swimming) and community health and safety. One option for progressing this issue is to seek advice from *Engineers Without Borders*, a non-government organisation that works in partnership with Indigenous and other local communities to develop engineering solutions to meeting basic human needs, including infrastructure and sanitation. Further information on *Engineers Without Borders* is available at <http://www.ewb.org.au/>, or contact info@ewb.org.au or phone (03) 9329 1166.

5. *Managing introduced fish*

There are currently no appropriate control methods to eradicate Mosquitofish from the Nyul Nyul wetlands. The spread of this species within Bobbis Creek has already reached its maximum, being spread throughout the watershed. Although this species is an extremely able disperser because of its small size and its well-developed physiological tolerance, any further spread in the region would most likely occur by people deliberately introducing them to new locations, for example as a source of bait, or by releasing them from fish tanks or ponds. It is important that the Rangers monitor any spread of this species, using the feral animal sighting section of the I-Tracker Wetland Application (or the Land Patrol Application) to record opportunistic sightings. Rangers should focus on those sites outside of the Bobbis Creek drainage system, as it is already known that Mosquitofish are present at all of the sites sampled within Bobbis Creek. The species was absent from Weedong and Yarp, neither of which contained any other fish species and also absent from Boolamon. The Rangers should visit these sites at least once a year to record the presence or absence of Mosquitofish. Educating the community about this invasive species will help to prevent introduction to other wetlands on the Dampier Peninsular. The *Fishes of Nyul Nyul country* poster produced as part of this project will be a useful education tool.

6. *Cleaning out wetlands*

Nyul Nyul TO's have previously engaged the Rangers in cleaning out of wetlands or springs. Cleaning of wetlands is not usually undertaken in western ecological management. Consequently, this management technique represents a potential difference between Nyul Nyul and Western Science approaches. The research team encourages the Rangers to investigate further into their own knowledge and practices for managing wetlands. For example, the Rangers could investigate the concept of cleaning wetlands through interviews with elders. Key questions may include: Why this cleaning was undertaken? Was it undertaken for ecological purposes such as encouraging water flow and to reduce infilling of waterholes, or was it undertaken to enhance the amenity of wetlands for obtaining clean drinking water or to make it easier for fishing etc? If appropriate, the Rangers may wish to investigate wetland cleaning using scientific monitoring techniques, under the guidance of elders. That is, the Rangers could conduct routine monitoring before and after (several weeks at least) cleaning a spring or waterhole to investigate any changes resulting from this practice and how it affects the cultural and ecological values of these wetlands.

7. *Managing and addressing future threats*

Water levels over seasonal and yearly cycles should be monitored to measure possible groundwater drawdown effects. This can be done by the installation of gauge boards to monitor water levels. Gauge boards have been purchased through this project and will be installed by Rangers at various sites (with the assistance of the Department of Water). Gauge boards will assist the Rangers in recording data on depth at a range of wetlands and enable them to better monitor and react to potential impacts including water resource development (i.e. increased groundwater abstraction). Sites recommended for gauge board installation include Wobidong, because isotope analysis suggests it is influenced by both groundwater and surface water inputs, Yarp, Rubabunan, and two spring sites (Nigilbuninj, Donkey Springs, Spring A or B).

8. *Continue and expanding research to other Nyul Nyul freshwater ecosystems*

This project has assisted the Nyul Nyul Rangers to investigate their own knowledge of freshwater on Nyul Nyul country. The researchers recommend that the Rangers continue documenting IEK and consider further scientific surveys to build knowledge of springs, lakes, waterholes and other freshwater ecosystems. In particular, this could occur through involving Elders in documenting current knowledge and stories related to these ecosystems, and investigating what was important for these places and how they were managed in the past. This would include sites that have had limited IEK documented (e.g. Boolamon, general springs area). Rangers could also expand this study to other Nyul Nyul identified freshwater ecosystems not covered in this plan such as coastal freshwater resources that are accessed through digging. Although these resources aren't necessarily in the form of surface waterbodies, they may also be susceptible to pressures such as groundwater extraction and therefore may require monitoring and management.

Monitoring to assist management

This project has generated a significant amount of baseline information, increasing our understanding of Nyul Nyul freshwater systems. Ongoing monitoring is important as it can be used to build on this baseline data, address both local management concerns such as donkeys and fire, and also broader management issues (future water resource development and an increase in the accessibility of these sites).

Tools developed for ongoing monitoring

A key aim of the project was to provide a sampling method that would allow the Nyul Nyul Rangers to undertake repeatable ongoing monitoring of freshwater habitats and allow for the detection of any change in condition over time, without the need for support from a scientist or any additional staff.

Monitoring methods were developed largely from adapting the existing Tropical Rapid Appraisal of Riparian Condition (TRARC) to provide sampling techniques which are practical for use by the rangers. In place of traditional paper based datasheets an application was then created using CyberTracker™ software and tested by the Nyul Nyul Rangers to allow them to collect, manage, and map the wetland monitoring data. The I-Tracker Kimberley Wetland Assessment Application (referred hereafter as the I-Tracker Wetland App) includes some special features, for example the dominant riparian plant list can be displayed in local language names, which facilitates the continued application of this traditional knowledge (for detailed information about the program and its development see the “I-Tracker Kimberley Wetland Monitoring Field Book” and Dobbs *et al.* 2014).

Dominant riparian tree/s	
<input type="checkbox"/>	Lardik
<input type="checkbox"/>	Goonoorr
<input type="checkbox"/>	Nguloorngoord
<input type="checkbox"/>	Nimalgoon
<input type="checkbox"/>	Garnboorr
<input type="checkbox"/>	Manbang
<input type="checkbox"/>	Galarrajen
<input type="checkbox"/>	Other riparian plant
<div>    </div>	



Figure 7: Plant lists appear in local language names when collecting assessment data, however the database also links these records to their common and scientific names

Data collected using the application is exported from the database and then pasted in a pre-formatted excel spreadsheet that automatically generates summaries and figures to assist the Rangers to interpret the monitoring data. Over time this will create baseline data and allow the Rangers to assess the success of management actions.

Recommendations for ongoing monitoring

When undertaking monitoring it is important to consider the five steps outlined in Fig. 9. Recommendations for monitoring have been summarised using these key steps and provided in Table 4. Rangers can use this information to decide on what monitoring they would like to adopt to inform management. The type of monitoring will depend on the threats that the Nyul Nyul Rangers would like to address (i.e. feral animals, weeds or effects of water extraction) and also any future management actions that the Rangers may undertake (e.g. reducing feral animal access to waterholes).



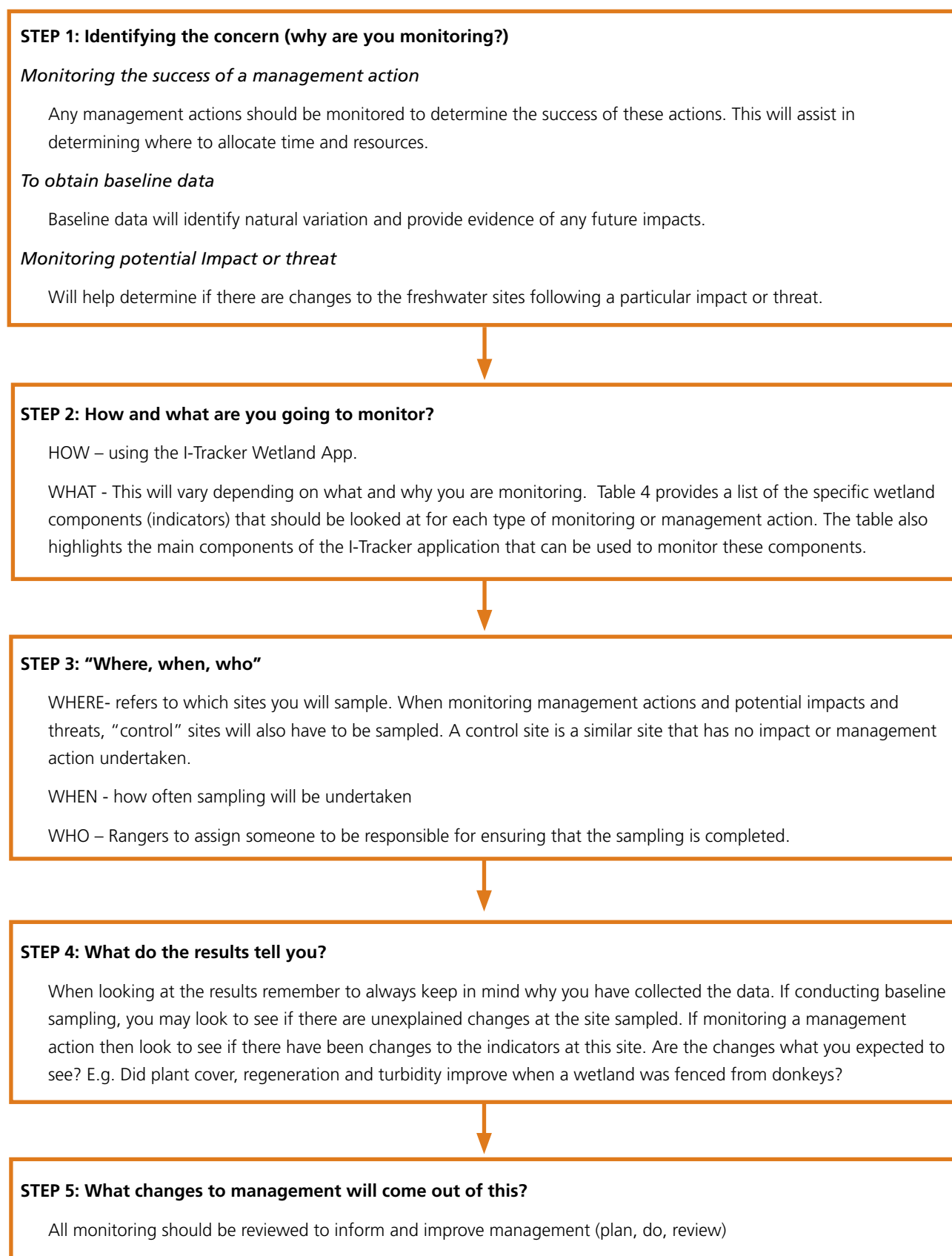


Figure 8: Steps to take into account for undertaking a good monitoring program

Table 4. Monitoring that can be undertaken by Nyul Nyul Rangers to address management actions

STEP 1 Why are you monitoring?		STEP 2 and 3 What are you going to monitor? *	STEP 3 Where and when are you going to monitor?#	STEP 4 and 5 What do the results show and what changes to management will be made?
Reason	Management Action (To protect wetland values)			
Monitoring Management Actions	Feral Donkeys	<p>Trial fencing of a small wetland (Spring) e.g. Nigilbuninj</p> <p>Changes in vegetation structure (plant cover, regeneration), feral impacts, turbidity:</p> <p>In Routine Mon. section of I-Tracker Wetland App do:</p> <p>Bank Assessment</p> <p>Water Quality</p> <p>Waterplant Assessment</p> <p>Continue recording donkey sightings using the feral animal section of the I-Tracker Wetland App</p>	<p>Monitor fenced site and similar sites not fenced (to provide a control),</p> <p>Sample before installing the fence and after</p> <p>Sample at least once early dry and once late dry</p>	<p>If the water quality and vegetation condition of fenced sites improves compared to non-fenced sites, (this may take several seasons), then continue to maintain fencing and look at opportunities to fence additional sites or investigate broad-scale management of donkeys (see below).</p>
	Investigate options for broad-scale management of donkey population i.e. a reduction of the number of Donkeys through culling	As above	Monitor a selection of wetlands to include at least one spring, waterhole and lake. Monitor sites at least once early and late dry	If feral animal impacts (recorded in bank assessment) are reduced and coincide with improvements in vegetation condition and water quality (may take several seasons), continue to maintain reduced donkey numbers
	Fire managed to reduce intensity and occurrence in the riparian zone of wetlands	<p>Changes in vegetation structure (plant cover, regeneration) and time since fire:</p> <p>In Routine Mon. section of I-Tracker Wetland App do:</p> <p>Bank Assessment</p> <p>Fire scar data is available via NAFI www.firenorth.org.au to monitor success</p>	Monitor a selection of wetlands to include at least one spring, waterhole and lake (including those known to have high fire frequency or intensity). Monitor sites at least once early and late dry	If improvements are observed continue fire management
	Weeds	<p>Changes to the distribution and density of weeds at wetlands:</p> <p>In Routine Mon. section of I-Tracker Wetland App do:</p> <p>Bank Assessment (weed scores)</p> <p>Record opportunistic weed sightings on Nyul Nyul country using 'Other Events' section of I-Tracker Wetland App or 'Weeds' section of I-Tracker Land Patrol App, especially important to record any new weeds</p>	Monitor a selection of wetlands (making sure that sites are spread across Nyul Nyul country) Monitor sites at least once early and late dry	<p>If weeds present investigate options for weed management</p> <p>Continue monitoring to ensure that any new weed species is identified early</p>

STEP 1 Why are you monitoring?		STEP 2 and 3 What are you going to monitor? *	STEP 3 Where and when are you going to monitor?#	STEP 4 and 5 What do the results show and what changes to management will be made?
Reason	Management Action (To protect wetland values)			
Maintain Connectivity	Ensure wetland connectivity considered in future infrastructure construction (e.g. road or causeway)	Undertake long-term monitoring of water levels using gauge boards Monitoring of fish populations to ensure fish movement is maintained between wetlands (this would require a partnership with a university/ researcher)	Upstream and downstream from infrastructure Before and after the infrastructure is put in place (for several years)	Compare to baseline data (recorded before infrastructure in place) if changes to depth of wetlands or fish populations then infrastructure changes required
Monitoring Management Actions		Consult TOs for assistance in identifying wetlands that require improved flow and to identify correct management techniques for cleaning out wetlands	Monitor cleaned wetlands and similar sites not cleaned (to provide a control), Sample before and after cleaning Sample at least once early dry and once late dry	Assess whether cleaning of wetlands is effective to achieve desired outcomes
	Invasive fish species	Ongoing education and monitoring to minimise transfer of Mosquitofish to additional sites	Visit and record annually the presence or absence of Mosquitofish at Boolamon, Yarp, Weedong (which are currently the only sites without Mosquitofish). Also include any additional sites not sampled during this project outside of Bobbis Creek	The distribution of Mosquitofish on Nyul Nyul country and highlight any future spread of Mosquitofish outside of the Bobbis Creek Drainage, Ongoing education to reduce further spread should be maintained

* this section highlights the main monitoring sections to focus on using the I-Tracker application.

Why are you monitoring?	What are you going to monitor?	STWhere and when are you going to monitor	What changes to management will be made?
Baseline Data	Collecting long term data to record the natural variation within wetlands to provide baseline data to assess future threats and management	<p>Monitor a selection of wetlands to include at least one spring, waterhole and lake at least once early and late dry</p>	Unexpected changes in results should be investigated taking into account current and additional threats
	Collecting baseline data for comparison when or if water abstraction occurs	<p>Include sites where gauge boards have/will be installed (i.e. Yarp, Rubabunan, Wobidong and two spring sites)</p> <p>Sites should be monitored regularly (beginning and the end of the dry season), especially at the end of the dry season when wetlands are the driest to obtain a baseline level for each wetland.</p> <p>Identify/map wetlands vulnerable to water extraction.</p>	Data should be graphed at the end of each year to determine the natural variation and any unexpected changes in data investigated
Other	Investigate elevated E. coli levels in wetlands (Initial sampling showed several wetlands had elevated levels of E. coli including a number of sites where the levels would not be attributed to the STP but potentially caused by donkeys or waterbirds.)	<p>Repeat sampling at previous sites</p> <p>Note any sampling will require samples to be sent to the laboratory within 24hrs</p>	If sites continue to show high levels of E. coli, Rangers should educate the community on which waterholes are above swimming guidelines
	Investigate funding opportunities to improve causeway to enhance wetland connectivity	Upstream and downstream of the causeway	Highlight the importance of maintaining flow and connectivity for future infrastructure

where specific sites are not listed or referred to, then site selection should be driven by community and ranger priorities and values

Future opportunities

A monitoring program been developed to allow the Nyul Nyul Rangers to undertake ongoing monitoring of freshwater habitats and allow for the detection of any change in condition over time, without the need for support from a scientist or any additional staff. This collaborative project has highlighted how partnerships between research organisations and ranger groups can increase our understanding of how freshwater systems function. Future opportunities for research that could be adopted by Rangers and achieved through partnerships are provided below in Table 5.

Table 5. Additional Ranger Monitoring activities/ management activities that could be undertaken in partnership

Future partnership/project Opportunities	What issues/potential threats these projects can help to address
Bore level monitoring	<p>Impacts from water abstraction</p> <p>A bore monitoring section in the I-Tracker Wetland App was developed in consultation with the Department of Water (DoW). This will allow the rangers to collect and provide data to DoW and provide opportunities for fee for service work.</p>
Trialing off channel watering points	<p>Impacts from unmanaged/pest animals</p> <p>Given the difficulties and cost of fencing Rangers could investigate the possibility of putting in a bore to provide an alternative water supply for cattle/ferals. Old windmill bores with cattle troughs are located on the east side of the Cape Leveque Road, they could possibly be an option for an off channel watering point.</p> <p>UWA are currently looking at funding opportunities to assist ranger groups with off channel watering points and associated monitoring.</p>
Monitoring frogs and terrestrial animals supported by wetlands	<p>Impacts of cane toads, impacts from water abstraction</p> <p>Conduct terrestrial fauna surveys at a selection of wetlands e.g. springs, waterholes and lakes. This is particularly important given that cane toads will arrive within a few years. Rangers could target important conservation species through surveys, but also animals which with a high cultural value including various Goannas, which may be significantly affected by cane toads.</p> <p>Undertake frog surveys with support from University/researchers</p>
Further investigations into Nyul Nyul techniques for managing freshwater ecosystems.	<p>Maintain Nyul Nyul Values for wetlands</p> <p>Community members expressed an interest in mapping Nyul Nyul country [in order to identify and create cultural corridors [for protecting]. By doing this, Nyul Nyul could identify and prioritise areas for conservation.</p>
Further investigations into unknown impacts including climate change, tourism and future mining pressures	<p>Monitoring and education on the effects of tourists, climate change and mining</p> <p>For example tourist impacts could include water Quality impacts including nutrients, loss of woody debris and an increase in weeds and rubbish at waterholes frequented by tourists. This research could be undertaken as part of a research partnership with the University/researchers</p>

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Appendix 1 - Site summaries

Indigenous Ecological Knowledge (IEK) and Western Scientific knowledge have been drawn upon to provide a summary of each of the sites sampled with site-specific recommendations for monitoring and management. These site summaries contain baseline data and information from the I-Tracker monitoring method which can be compared with future monitoring results to show how the site has changed over time. Information has been provided below to assist in interpreting these results.

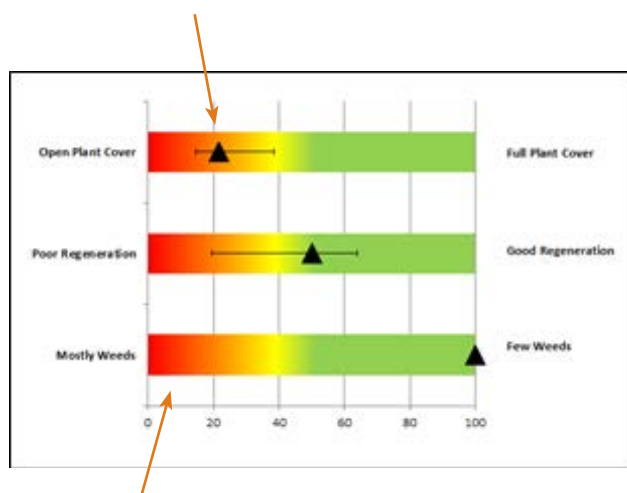
Riparian vegetation is responsible for:

- Bank stabilisation
- Water Flow Reduction
- Organic input into streams
- Filtering of sediments, nutrients and pollutants
- Creation and maintenance of plant and animal habitats.

Riparian vegetation can be impacted by:

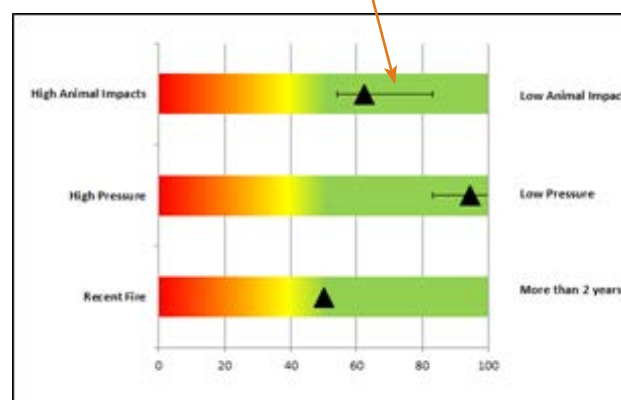
- Feral Animals
- Fire
- Clearing
- Weeds.

The triangle depicts the most recent sampling event (July 2014).



Scores that fall into the red or yellow zone highlight when scores for vegetation are low (structure is open with low regenerations). The colour zones provide an indication only so Rangers can keep an eye on these low or high values and do not necessarily mean there is a problem at the site, i.e. low levels of regeneration and plant cover may be a natural occurrence at some sites. What is more important is looking at the change over time (especially following management actions).

The bars represent the range in scores that were recorded at this site over the various sampling trips (June 2013, Oct 2013).



Scores that fall into the red or yellow zone highlight when 'pressures' are high.

Lake sites

Rubabunan

Values

Rubabunan is the largest of a complex of waterbodies located North East of Beagle Bay. The lake is an example of an internal drainage system, where the rain that falls on the surrounding area drains into the lake instead of into a creek or river then into the ocean. This site is important as a hunting place where Nyul Nyul people hunt for cattle, bush turkey, duck and duck eggs, goanna, and other birds like Brolga. Also important are the trees growing around the lake, including **Lardik** (Freshwater Mangrove *Lophostemon grandiflorus*) and **Nimalgoon** (Paperbark *Melaleuca nervosa*).



Environmental

The main water body usually dries up by the end of the dry season, except for really wet years (e.g. 2000). It is more affected by evaporation than other sites, due to its wide and shallow 'saucer shape' and there is little or no groundwater input to replace the evaporated water.

Fauna (fish and waterbugs)

As Rubabunan dries out and rarely connects to other areas in the wet season there is limited opportunity for fish to move into the wetland. It is likely that fish type and abundance varies greatly from year to year. The only native fish species recorded were the **Jalabunan** (Ox-eye herring *Megalops cyprinoides*) and **Madjalk** (Milkfish *Chanos chanos*). Only four specimens of Jalabunan were collected (all juveniles) and were the result of colonization during the preceding wet season. The most abundant fish species (1000s) was the introduced Mosquitofish. The number of waterbug groups stayed consistent across the late dry and early wet season (ranging from 19 to 24). The main groups at Rubabunan included highly mobile waterbugs (beetles, mayflies and true-waterbugs) and snails and crustacea.

Food web

As the site is rarely connected to the downstream estuary the few fish sampled and macroinvertebrates (waterbugs) are strongly reliant on local periphyton all year round, with little difference between the early and late dry season. The food web at this site is also relatively simple with fish occupying the highest trophic level.

Concerns/impacts/changes

Fire and unmanaged animals (cattle and donkeys) are the main threats to this site. The Rangers recalled an event when a plane flew overhead and noticed the surface was shining like silver. On closer inspection the shininess was revealed to be dead fish. Fish kills could occur at this wetland late in the dry season, driven by increasing water temperature and decreasing water levels, removing oxygen from the water.

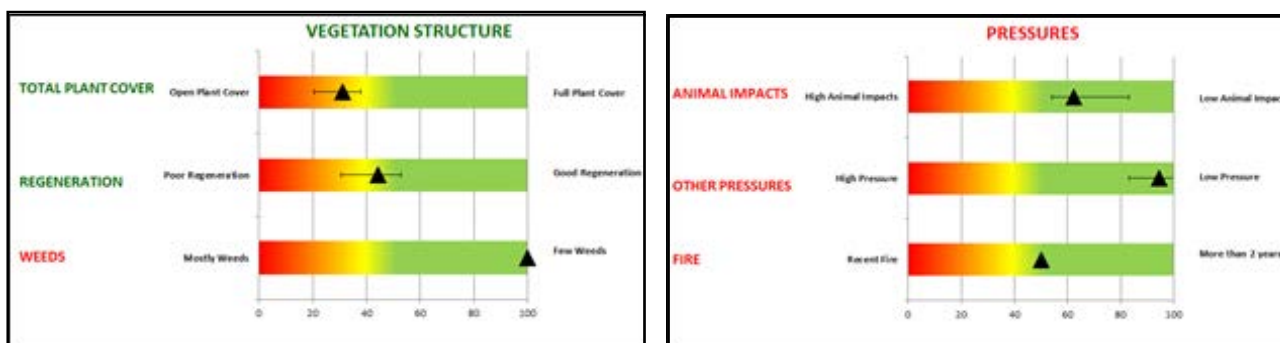
I-Tracker monitoring results

Water quality

Rubabunan had fresh, acidic to neutral (5.8 to 7.76) waters with low turbidity.

Riparian vegetation transect

Dominant tree species included Lardik and Nimalgoon.

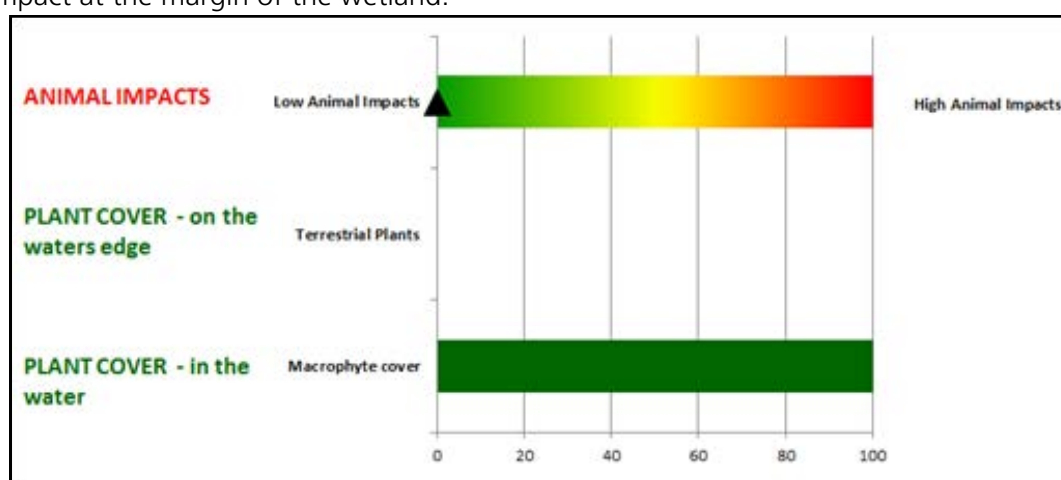


a) Rubabunan Bank Vegetation (Riparian) Transect

Plant cover changed across seasons (lowest levels recorded late dry) which also coincided with higher animal impacts. This pattern would be expected with less water around in the late dry season and hence higher feral animal visitation to these freshwater refuges. Other pressures recorded at this site included rubbish (tyres, old bottles and beer cans). There were no weeds recorded at Rubabunan.

Aquatic vegetation transect

100% aquatic macrophyte cover (mixture of emergent, floating and submerged) with low levels of animal impact at the margin of the wetland.



b) Rubabunan Bank Aquatic Transect (June 2014)

Recommended management actions and monitoring at Rubabunan

- Continue baseline monitoring
- Install and monitor depth gauge (site with high evaporation and little groundwater)
- Feral animal reduction and rubbish management to reduce impacts.

Weedong

“One of the main important things here is our wildlife, what lives in this area.”

Ninjana

Values

Weedong is a large coastal lake located immediately behind sand dunes. Monsoon vine thickets line the edge of the lake at the foot of the sand dunes. The area is valuable for hunting animals around the lake including cattle, ducks and goanna. Within the waterbody **Wirdamunga** (Waterlily *Nymphaea violaceae*) are valuable as food. Trees surrounding Weedong attract animal species hunted as food such as **Nimunburr** (Black flying fox *Pteropus alecto*) and **Jibalgurr** (Little friarbird *Philemon citreogularis*), and provide indicators of important seasonal events. The dominant trees are **Garnboorr** (a Paperbark *Melaleuca dealbata*) and **Lardik**. There are certain areas at Weedong that are restricted to women. Middens and burial grounds are located nearby.



Concerns/impacts/changes

The large body of water at Weedong has only recently formed from a small wetland area (without a clearly defined channel) that Nyul Nyul people could walk across. At times there was only a small lake created close to the dunes (western side of the lake) which would dry up during the dry season. This changed around 20 years ago, (possibly from a cyclone) with a build-up of sand dunes. This meant that more water collected within the lake's boundary and it became almost permanent; it no longer dried up every year.

Environmental

Weedong wasn't there in the '60s and '70s. I used to muster cattle across this area (when he was young).

Stephen Victor

Although some of the larger lakes increase in turbidity as they dry, Weedong remains relatively clear all year round. In recent times Weedong has only dried up in the driest year (2005).

Fauna (fish and waterbugs)

No fish were collected from Weedong and the wetland is not regarded as a fishing site by the community. The absence of fish is probably due to the fact that it has recently dried out completely (and used to do so often prior to the damming effect of the migrating dunes). Any fish would have died during the drying event and the lake's isolation would have prevented recolonisation. Despite the lack of fish, the Rangers have sighted a saltwater crocodile at this site.

Weedong recorded 18 to 25 waterbug groups with the highest number of "true waterbugs" (Hemiptera) at any site on any of the sampling occasions. The main groups were similar to those at the other lake sites and included microcrustacea (common in still water lakes) and also snails and dragonfly larvae. The macroinvertebrate fauna, particularly the high abundance of water boatman and backswimmers at this site, reflects the absence of fish predation.

Food web

As no fish were recorded the food web is dominated by macroinvertebrates with a strong reliance on local sources of periphyton (attached algae) as a food source. The food source for Ostracods (microcrustaceans) could not be determined; these animals live in the sediments and have perhaps been feeding on material derived from terrestrial animals.

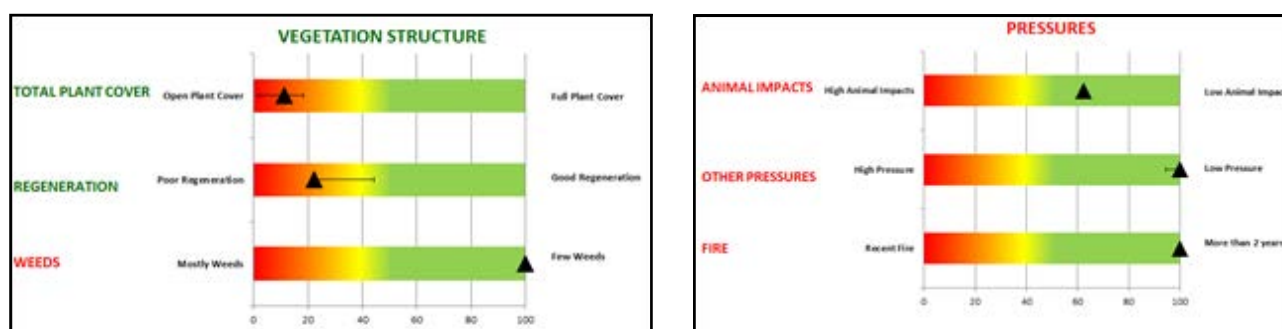
I-Tracker monitoring results

Water quality

Weedong had fresh, slightly alkaline (7.77 – 8.15) waters with low turbidity.

Riparian vegetation transect

The dominant trees at Weedong are Garnboorr and Lardik.

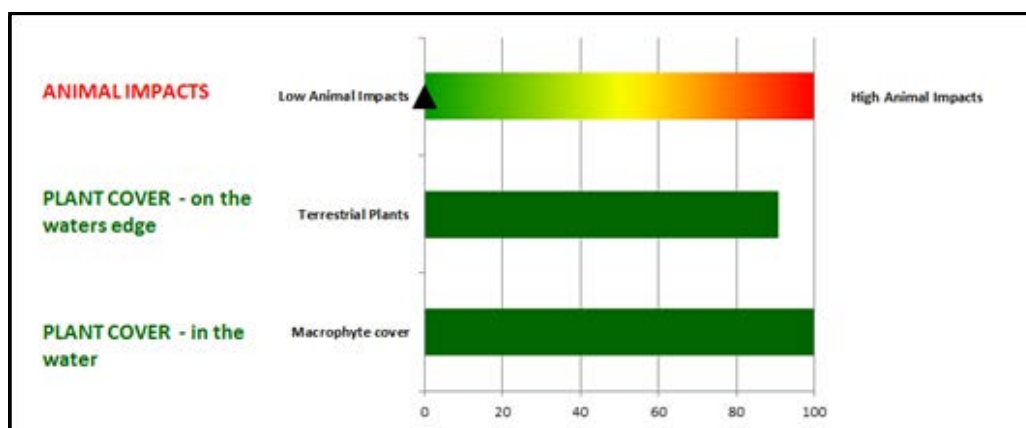


a) Weedong Bank Vegetation (Riparian) Transect

Weedong recorded low levels of plant cover and low to medium levels of plant regeneration. There was evidence of cattle at Weedong. There were no weeds present. Other pressures at this site included low levels of impact from 4WD tracks.

Aquatic vegetation transect

Similar to the other lakes, Weedong showed high levels of edge plant cover and 100% aquatic macrophyte cover (all emergent grasses/sedges) with low levels of animal impact at the margin of the wetland.



b) Weedong Aquatic Vegetation Transect

Main recommendations for management actions and monitoring at Weedong

- Continue baseline monitoring (early and late dry)
- Rangers expressed an interest in erecting signs on the beach to protect middens and burial grounds. This is important for managing country.

Yarp

Value

The Yarp lakes are another example of an internal drainage system made up of a series of waterbodies in the north-east of the Nyul Nyul Rangers operational area. People will sometimes come to Yarp for hunting but not too regularly as it is quite a distance from Beagle Bay. Good hunting species found here include ducks, bush turkey and Nigilbuninj. Important plants include **Goonoor** (Weeping Ghost Gum *Corymbia bella*) and Wirdamunga.



“When it’s very dry, low, people would come [and] turkey would be everywhere. Turkey, broilga, Ibis...you’d probably bump into a couple of goanna, big goannas, kangaroos... the sugar gliders. I remember them telling us they found a couple here too. When I was small I heard stories, you know, they saw some. [Also] finches, you might get black cockatoos rock up now and then for water.”

Zynal Cox

Concerns/impacts/changes

Fires and feral animals damage this place and like all sites there is a pending threat of Cane toads. There used to be bigger numbers of large birds that were hunted, like swans, magpie geese, Ibis and spoonbill. Younger Nyul Nyul Rangers observe that Yarp hasn’t changed since they were very young.

“It’s always been like this”.

Zynal Cox and Ninjana Walsham

Environmental

Over the last 20 years or so, the largest of the Yarp Lakes only dried up in the driest years (2005 and 2002).

Fauna (fish and waterbugs)

Despite **Nigilbuninj** (Indian shortfinned eel *Anguilla bicolor*) being recorded from this lake in the past, none were recorded during the study. In fact, no fish, not even the Mosquitofish were present. The Painted Snipe (*Rostratula australis*) has been recorded by the Rangers at this site during terrestrial biodiversity sampling.

The highest number of waterbug species were recorded at Yarp (29 species) which coincided with the absence of fish and hence predation. The main groups included snails (Gastropoda), Microcrustacea, damselflies (Zygoptera), true-waterbugs (Hemiptera), fly larvae (Diptera) and beetles (Coleoptera).

Food web

As there were no fish recorded at Yarp, the food web is dominated by macroinvertebrates with a strong reliance on local sources of periphyton (attached algae) as a food source. As with Rubabunan, the food source for Ostracods (microcrustaceans) could not be determined.

I-Tracker monitoring results

Water quality

Yarp had fresh, slightly acidic (6.16 to 6.40) waters with low turbidity.

Riparian vegetation transect

Dominant tree species included Lardik and Goonoor.

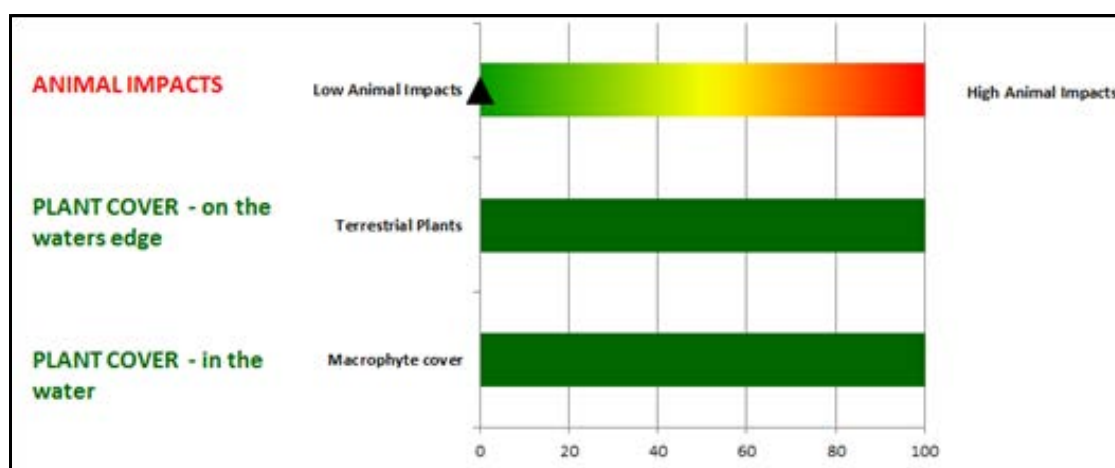


a) Yarp Bank Vegetation (Riparian) Transect

Similar to the other Lake sites, Yarp recorded low levels of plant cover and low to medium levels of plant regeneration in the riparian zone. There was evidence of feral donkeys and cattle, and no weeds were recorded. Other pressures at this site included low levels of impact from 4WD tracks.

Aquatic vegetation transect

Yarp recorded 100% edge plant cover and aquatic macrophyte cover (emergent grasses/sedges and submerged plants) with low levels of animal impacts at the margin of the wetland.



b) Yarp Aquatic Vegetation Transect

Recommended management actions and monitoring at Yarp

- Continue baseline monitoring
- Install and monitor depth gauge at this site (wetland with high evaporation)
- Feral animal reduction (to reduce donkey impacts).

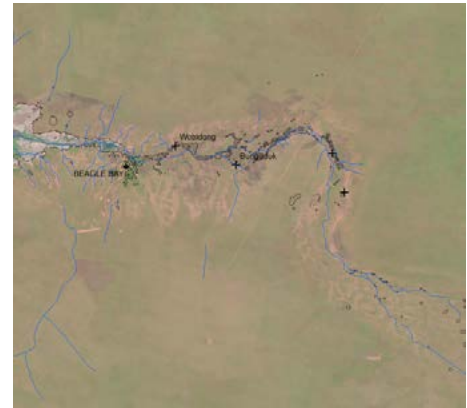
Waterholes

Numerous waterholes are located along Bobbis Creek, the main drainage system located next to the Beagle Bay community.

Wobidong

Value

Wobidong is a narrow river pool (waterhole) on the Bobbis Creek drainage line. It is an important place for the community where people hunt, fish, catch bait for ocean fishing, camp at and have picnics, both now and in the past. This billabong is a popular swimming hole for the community. Important trees include paperbark trees like **Gooloongoorr** (Saltwater Paperbark *Melaleuca alsophila*) and **Walamanggar** (a Paperbark *Melaleuca viridiflora*).



Concerns/ impacts/changes

Traditional Owner, Stephen Victor recalls that when he was young there were no Gajarr in this water hole and now they appear more often. The water in Wobidong may have become shallower in the past decade. Stephen Victor also observed that vegetation in the area surrounding Wobidong has thickened and populations of Emus, kangaroos and wallabies seem to have declined, possibly related to big fires in the past 60 years.

Environmental

Wobidong showed low evaporative loss early in the dry but an increased loss later in the dry season. This may indicate that there is some groundwater input but not enough to compensate for evaporative loss over the dry season. Or alternatively, that the shape of these smaller waterholes are not as exposed to evaporative loss as the large, shallow wetlands (ie Yarp and Rubabunan). This waterhole can dry up late in the dry (i.e Sept 2012).

Fauna (fish and waterbugs)

Wobidong contained the greatest number of fish species (7 in total). Mosquitofish was very abundant. Native species included the Giant herring (*Elops hawaiiensis*), **Jalabunan** (Ox-eye herring *Megalops cyprinoides*), **Marran** (Mangrove jack *Lutjanus argentimaculatus*), **Gajarr** (Barramundi *Lates calcarifer*), the Empire gudgeon (*Hypseleotris compressa*) and **Banjarr** (Banded scat *Selenotoca multifasciata*). The types of fish present changes from year to year, probably depending on how easily fish can migrate upstream from the estuary during the wet season and also as people fish there. For example, Empire gudgeon, Gajarr and Banjarr were only collected in 2014 and were very abundant. **Barool** (Lesser Salmon catfish *Neoarius graeffei*) are reported to occasionally occur in this waterhole. Dominant waterbugs included snails (Gastropoda) true bugs (Hemiptera) beetles (Coleoptera) and mayflies which generally need good quality fresh water to breed.

Food web

At Wobidong there is a strong reliance on local sources of periphyton (attached algae) as a food source for consumers. In the late dry season mayflies appear to be strongly reliant on leaf litter as a food source, while all other macroinvertebrates closely connected to periphyton.

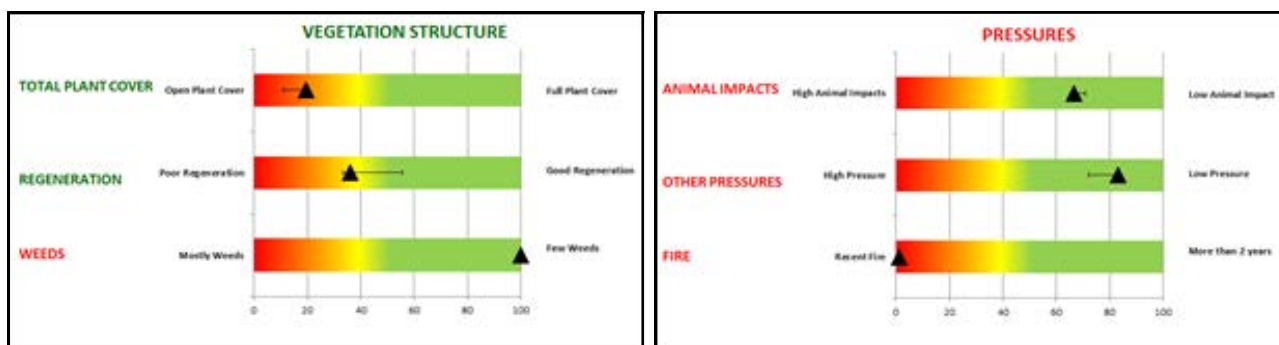
I-Tracker monitoring results

Water quality

Wobidong had fresh water ranging from acidic to alkaline. Turbidity increased from low (early dry) to medium levels in late dry (October 2013).

Riparian vegetation transect

Paperbarks including Gooloongoorr and Walamanggar are the dominant tree species.

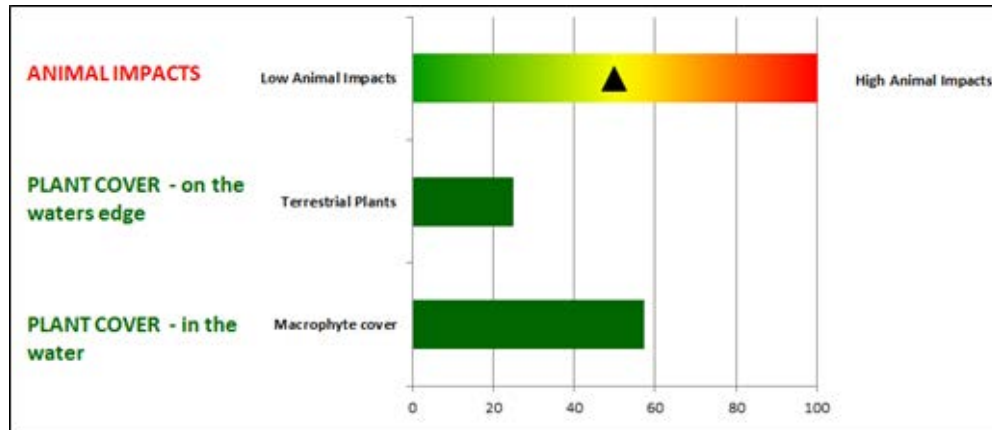


a) Wobidong Bank Vegetation (Riparian) Transect

Plant cover at this site was generally low with medium levels of regeneration (vegetation around floodplain waterholes on Bobbis Creek is quite open). Recent fire was recorded at this site on all sampling occasions, with other pressures including 4WD tracks, fishing and rubbish.

Aquatic vegetation transect

Wobidong recorded low levels of edge plant cover coinciding with reasonably high donkey impact. Medium levels of aquatic macrophyte cover were recorded.



b) Wobidong Aquatic Vegetation Transect

Recommended management actions and monitoring at Wobidong

- Limit 4WD tracks around site to reduce vegetation removal and erosion
- Feral animal eradication
- Install and monitor depth gauge at this site (waterhole that may be reliant on groundwater).

Bungaduk

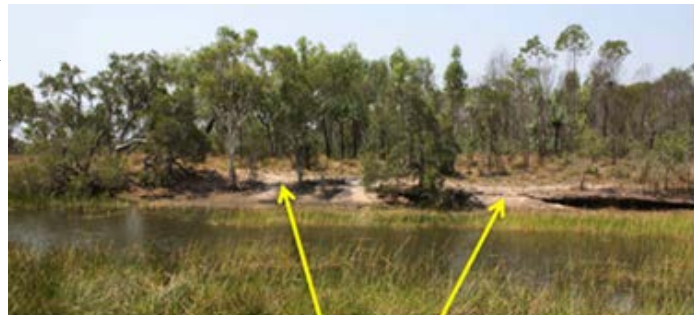
Value

Bungaduk is an important local picnic and camping place both now and in the past. It is part of a significant song cycle and was part of an old migration route going north. Bungaduk is also a half way mark for visitors traveling from Beagle Bay to One Arm Point. Years ago travellers would stop and rest here. Important animals that live at this wetland include goanna, blue tongue, and hunted birds such as ducks, ibis, and brolga. Children used to eat pigeons and Jibalgurr. Children would also hunt Nimunburr, especially the Doolburr (male).



Concerns/ impacts/changes

In the past cattle were run on this land to stock several stations. Now there are uncontrolled donkeys. The waterhole used to have areas of deep water but is a lot shallower and reeds have taken over since the Rangers were young.



Impact from donkeys; donkey trail (pad) and bank collapse where they access the water

Environmental

Fauna (fish and waterbugs)

Bungaduk was a hunting dinner camp – when the water was low you could see the fish and they caught Marran with a net.

“The fish we catch [here] are mainly from the sea”.

Five species of fish were collected from this location. The most common was the Mosquitofish. The Empire gudgeon, Jalabunan, Gajarr and Barool were the only native fishes collected and all were collected in small numbers only. The fish fauna of Bungaduk, like that of Wobidong, probably changes from year to year depending on how easily fish can migrate upstream from the estuary during the wet season. The number of waterbug groups present was lower in the late dry season compared to the wet season sampling (reduced from 27 to 18) and dominated by snails, microcrustacea and Trichoptera in the late dry and snails, dragonflies and beetles in the early dry season.

Food web

There is a strong reliance on local sources of periphyton (attached algae) as a food source for consumers (macroinvertebrates) although this may be a mixture of algae as well as animals such as microinvertebrates or bacteria. Leaf litter does not appear to be an important food although macrophytes may be used as a food source by consumers.

I remember coming here as a child and just jumping straight into the water and really not remembering any sort of vegetation around the banks. But when you consider the impact of cattle, because this was a fully functional commercial/pastoral station....so I guess the introduction of cattle [must have impacted the wetland].

Albert Wiggan

I-Tracker monitoring results

Water quality

Bungaduk contains brackish (slightly salty), slightly acidic water with low turbidity.

Riparian vegetation transect

Dominant tree species include Walamanggar and Gooloongoorr.

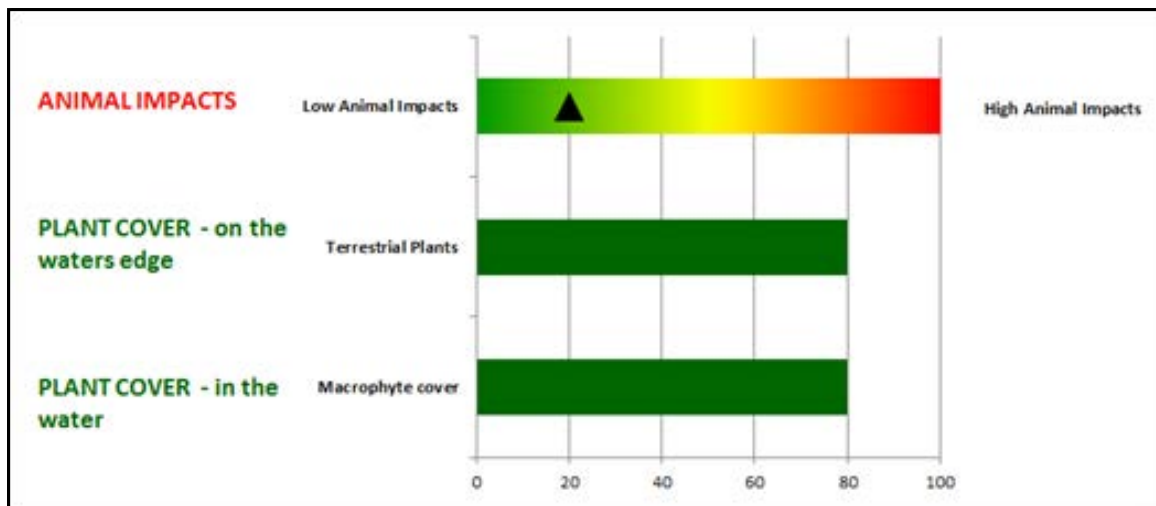


a) Bungaduk Bank Vegetation (Riparian) Transect

The plant cover was low, with medium levels of regeneration and there was recent fire evident during all sampling seasons. Although this site showed signs of bank collapse and infilling, levels of donkey trampling along the monitoring transect were similar to other sites sampled (donkey access was predominantly from the opposite bank and future sampling should include a transect on this bank).

Aquatic vegetation transect

Aquatic plant and edge plant cover were high (80%) with donkey impacts evident.



Recommended management actions and monitoring at Bangaduk

- Feral animal eradication (this site showed bank erosion from donkey visitation)
- Continue baseline monitoring
- Fire management to reduce fire frequency.

Boolamon

Value

Boolamon is a coastal lake-like waterhole, shallow and broad, located south-west of Bobbis Creek drainage. The cultural values of Boolamon were not recorded.

Environmental

Fauna (fish and waterbugs)

The four species of fish were collected from Boolamon were Jalabunan, Madjalk, Gajarr and Banjarr. Only the last species was abundant and it was abundant in the 2014 only. Boolamon is significant because it is the only location sampled that contained fish but did not also contain Mosquitofish. The waterbug community at Boolamon was similar to the lake sites with dominant groups including microcrustacea, true-bugs and snails.



Food web

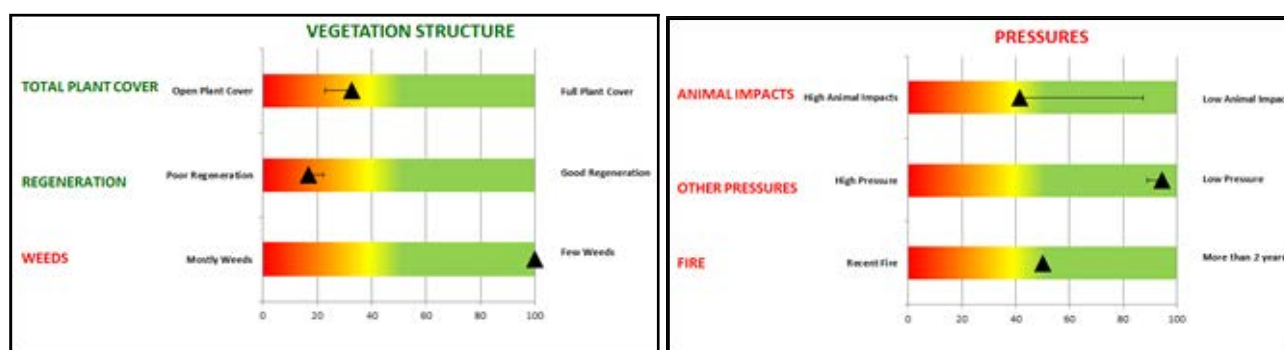
Consumers are reliant on a mixture of sources including periphyton, macrophytes and litter, although periphyton is still the most important food source for macroinvertebrate consumers.

I-Tracker monitoring results

Water quality

Boolamon contained brackish, neutral water with low turbidity.

Riparian vegetation transect

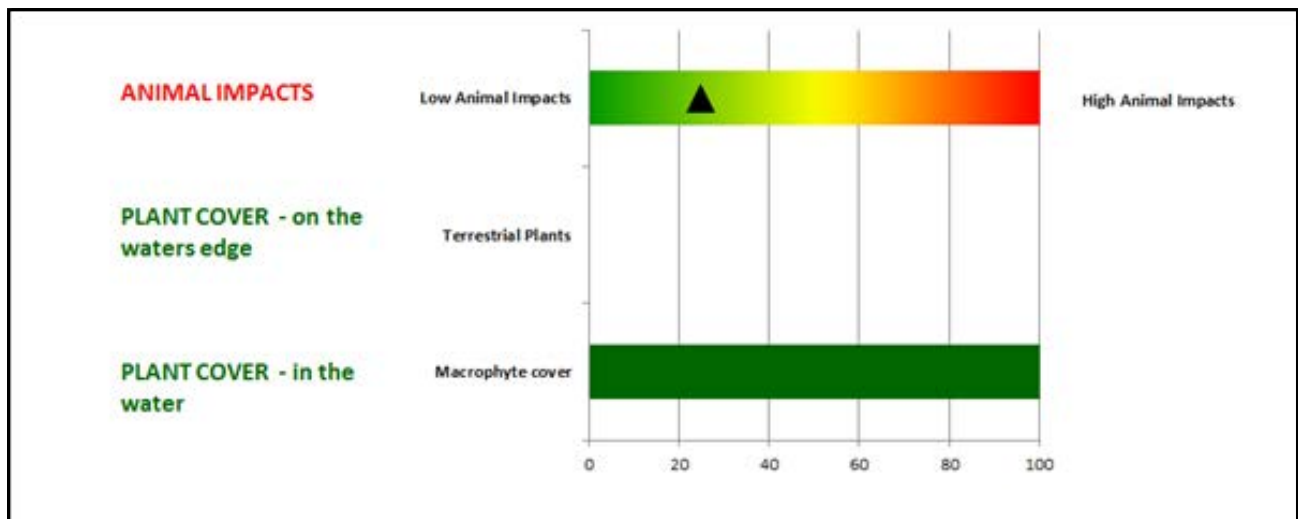


a) Boolamon Bank Vegetation (Riparian) Transect

Boolamon showed similar vegetation structure to other larger wetlands, with low plant cover and low levels of regeneration. Despite canopy cover being high at this site, low plant cover was influenced by little ground and shrub cover. Animal impacts varied significantly across sampling periods with high cattle and donkey impacts recorded in July 2014 as the site had been heavily grazed.

Aquatic vegetation transect

There was no plant cover only bare ground along the waters edge, with 100% macrophyte cover (all submerged plants).



b) Boolamon Aquatic Vegetation Transect

Recommended management actions and monitoring at Boolamon

- Feral animal reduction/eradication
- Continue baseline monitoring, particularly as a control site for Mosquitofish
- Carefully monitor for Mosquitofish
- Document IEK and values for this site.

Billard

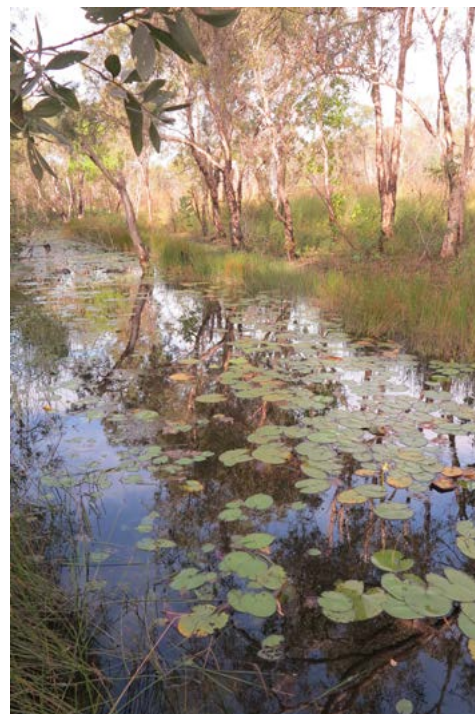
Value

Billard is located on the Bobbis Creek Drainage line upstream of the causeway. Around 1998, a bore was sunk to provide water for a nursery that was built at Billard. The bore provided a constant flow of water and this fed a large depression that was excavated along a natural drainage to create a swimming hole.

This was the main spot for swimming, especially for kids. They would also catch fish, including Gajarr and Nigilbuninj. The traditional owner for Billard is actively managing the area to protect sacred ground that is located nearby. This has led to some changes, generally that access is now limited to this waterhole.

Concerns/impacts/changes

The bottom of the water hole used to be white sand and now it's covered with silt. The area around the water hole also used to be less vegetated, was easy to walk around and the water flowed freely. Now there are a lot more shrubs, ferns are abundant and the trees have grown into large trees. This change began after the bore was put in.



"I reckon 1998, that's when everything started to change. [The bore was put in], might even have been 1992. The bore wasn't here when I was growing up. Then when they started that nursery up here, they needed the water see [and] they started putting that down there, [the] bore. [The nursery was]... coconut trees, all sorts of flowers, trees, plants. Not the natives, they wouldn't grow that...They would have got plants from Broome."

Environmental

Fauna (fish and waterbugs)

Four species of fish were collected from Billard. The most common was the alien Mosquitofish (518 total) but the Empire gudgeon was also common (325 total). The other species collected included Nigilbuninj (3) and Gajarr (1). Waterbug species were dominated by groups similar to other waterhole sites including trichoptera, beetles, and dragonflies.

Food web

As with other sites there is a strong reliance on local sources of periphyton (attached algae) as a food source for consumers. The fish in this groundwater fed waterhole appear to switch from outside food sources in the early dry to local periphyton in the late dry season. This most likely reflects the estuarine origin of these fish as they move into the connected waterholes in the wet season and when the waterholes become disconnected as the dry season progresses the fish become reliant on local sources of food.

I-Tracker monitoring results

Water quality

Billard recorded fresh, acidic (5.41-5.98) water with low turbidity

Riparian vegetation transect

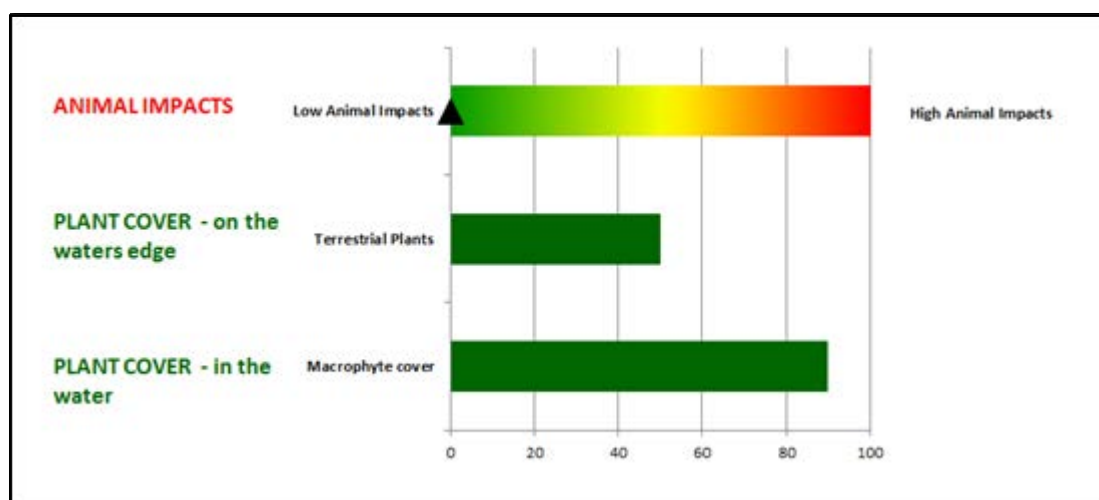
Billard had the highest species richness and diversity of plants of all wetlands sampled. Walamanggar is the dominant tree species.



Despite recent fire, medium to low plant cover and regeneration remained at this site with a canopy cover maintained and high levels of leaf litter. Although there were no weeds recorded by the project team at the site during field sampling, the rangers report seeing a number of weeds in the vicinity of the waterhole during other visits. Animal impacts were not evident at Billard.

Aquatic vegetation transect

Plant cover in and out of the water was high with no animal impacts recorded along the water's edge.



Recommended management actions and monitoring at Billard

- Remove or control the spread of any introduced species (introduced palms and lantana).

Springs

Nigilbuninj

Value

A large permanent spring which is heavily shaded, being surrounded by a dense stand of mature paperbarks and significant grass growth. The banks are significantly undercut in places and a thick cover of Duckweed (*Lemna* sp.) was present across the entire water surface with a thick layer of leaf litter, woody debris and fallen trees on the bottom. This spring is a culturally significant site and is one of a number of springs where the community fishes for Nigilbuninj.



Concerns/ impacts/changes

The spring is infilling with vegetation and sediment and getting shallower, this may be due to a natural cycle of springs with new springs forming as older springs slowly disappear. Nigilbuninj also has significant donkey impacts and a high frequency of fire which are likely to be contributing to this process.

Environmental

Fauna (fish and waterbugs)

The Nigilbuninj was collected from this spring. Other species present included Jalabunan and the Empire gudgeon and the very abundant alien Mosquitofish. These species were present on all sampling occasions. The waterbug groups from Nigilbuninj were dominated by snails and species with a highly mobile adult life stage including dragonflies, beetles and true-bugs.

Food web

As with other sites there is a strong reliance on local sources of periphyton (attached algae) as a food source for consumers. The fish in this groundwater fed waterhole appear to switch from outside food sources in the early dry to local periphyton in the late dry season.

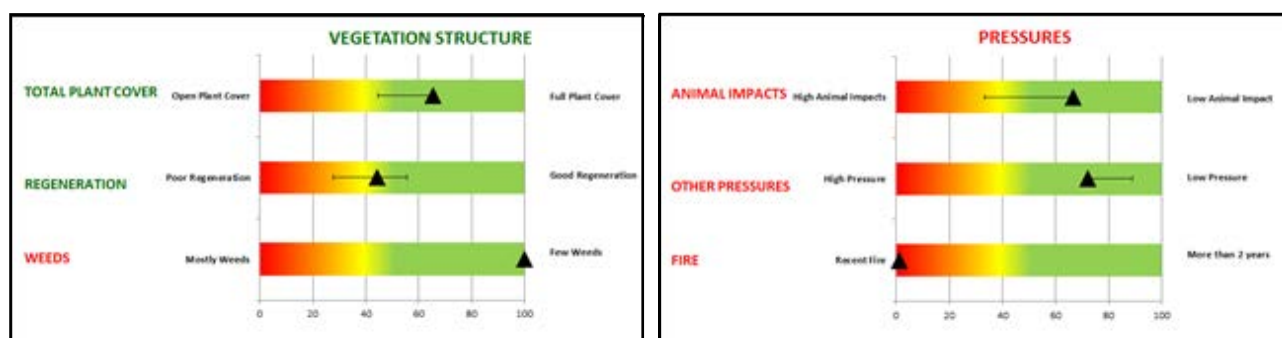
I-Tracker monitoring results

Water quality

Nigilbuninj contained acidic, fresh water with low turbidity.

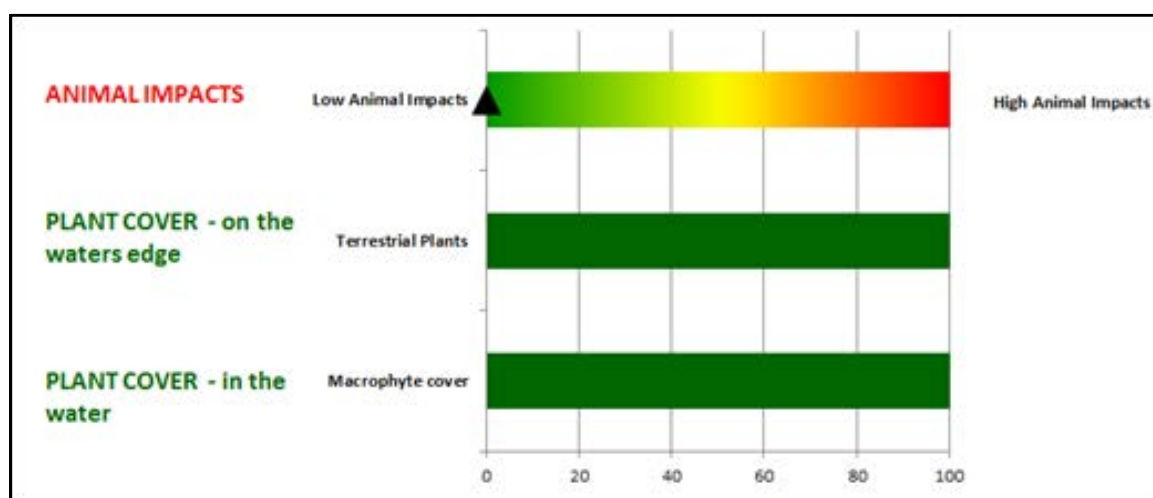
Riparian vegetation transect

Walamanggar is the dominant tree species. Higher levels of plant cover and regeneration were recorded with a decline in donkey impacts in 2014. A fire had recently been through the area although the impact on the riparian zone was quite patchy, burning everything right to the edge in some spots and stopping well outside the riparian zone elsewhere which resulted in high plant cover scores.



Aquatic vegetation transect

Nigilbuninj had 100% aquatic plant cover (emergent and floating vegetation) and no animal impacts were recorded at the waters edge.



Recommended management actions and monitoring at Nigilbuninj

- Continue baseline monitoring
- Feral animal exclusion through either culling or fencing
- Install and monitor depth gauge at this site (spring reliant on groundwater)
- Record Nyul Nyul values.

Smaller springs

Value

There are numerous springs dotted along the Bobbis Creek drainage line that have a particular importance to Nyul Nyul people. Springs are associated with Nigilbuninj, which is a culturally important animal to Nyul Nyul people. Historically Nyul Nyul people would visit the spring country to fish for Nigilbuninj. The freshness of water in the spring area can be smelt and this area is particularly good for hunting. The springs vary in size and also in age, some surrounded with mature stands of various Paperbarks, others with only a thicket of saplings. The spring fed areas around Beagle Bay remain wet all year around. The spring fed areas seem to be driest at the end of the wet and become wettest in mid dry. The only fish present in these springs were the Mosquitofish and the Empire gudgeon. The key threats for these small springs include fire and feral animal disturbance. While many of the bigger wetlands dry out toward the end of the dry season, in the absence of disturbance it would be expected that these springs would contain water all year, providing fresh water for native animals across a wide area. The community structure of waterbugs at these springs were different to the waterholes and lakes but also different from one another. The small springs are also likely to be highly susceptible to external disturbances, particularly donkey use and fire.



Donkey Spring

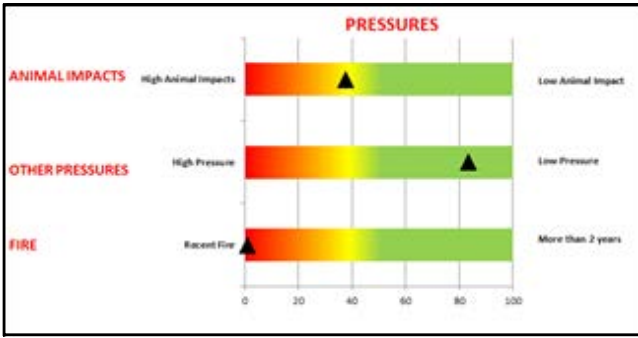
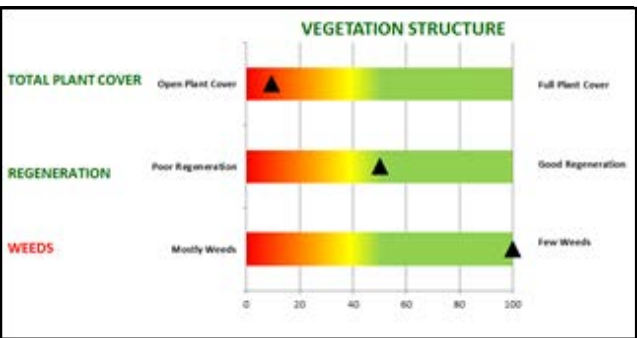
Donkey springs is a medium sized spring filled with a thick cover of sedges and a small amount of open water. Donkeys are prevalent at this site.



I-Tracker monitoring results

Water quality

Donkey Springs contained fresh, slightly alkaline water with low turbidity.



Riparian vegetation transect

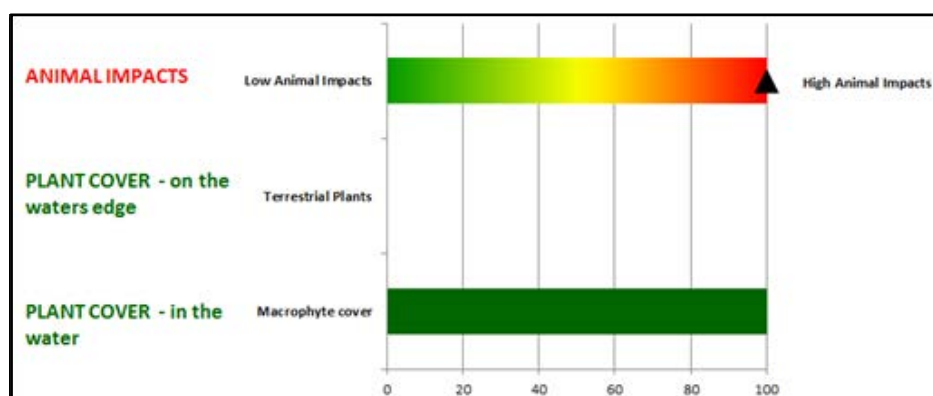
The dominant tree species is Goonoor.

Donkey Spring recorded one of the highest animal impacts of all sites both in the riparian zone and along the water's edge (see aquatic transect below). The vegetation around Donkey Spring is very open with medium levels of regeneration. The main pressure recorded was the recent and frequent fire at this site.

Aquatic vegetation transect

Donkey Spring contains a thick cover of emergent sedge *Schoenoplectus mucronatus* as well as other *Cyperaceae* species. There was no riparian plant cover, outside of the spring itself. Only bare ground was recorded at the waters edge, coinciding with high levels of donkey impacts and also a recent fire which had burnt to the edge of the spring.

"Bubble Springs" (Spring A) and "Burnt Springs" (Spring B)



Many of the springs had high levels of feral animal visitation (particularly donkeys), there were well worn tracks leading to the springs, more palatable vegetation was cropped and often the substrate was highly disturbed.



Water quality

Bubble Spring had high turbidity as a result of being heavily trampled by donkeys and water quality at Burnt springs was also high as a result of being recently burnt.

Recommended management actions and monitoring for smaller springs

- Fire management to reduce fire frequency
- Feral animal eradication/exclusion through either culling or fencing
- Record Nyul Nyul IEK values for smaller springs.





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NORTHERN AUSTRALIA HUB

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Email: nerp.northern@cdu.edu.au
Phone: 08 8946 6761



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