

# Pacific Highway Upgrade – Sapphire to Woolgoolga

Operational Phase Fauna Monitoring  
Year 2 – Giant Barred Frog  
(*Mixophyes iteratus*) Population  
Monitoring



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**Cover Photo:** Giant barred frog (*Mixophyes iteratus*) observed at Arrawarra Creek, NSW (Photo: D. Owner).

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# Table of contents

1.	Introduction.....	1
1.1	Background.....	1
1.2	Species Ecology.....	1
1.3	Monitoring Aims and Objectives.....	2
2.	Study Area.....	2
3.	Methods.....	4
3.1	Monitoring Sites.....	4
3.2	Timing of Sampling Events.....	4
3.2.1	Construction Phase.....	4
3.2.2	Operational Phase.....	4
3.3	Sampling Hygiene Protocol.....	5
3.4	Frog Surveys.....	5
3.5	Tadpole Surveys.....	5
3.6	Water Quality Sampling.....	6
3.7	Revegetation Monitoring.....	6
4.	Results.....	7
4.2	Water Quality.....	9
4.3	Frogs.....	10
4.3.1	Presence/Absence.....	10
4.3.2	Abundance.....	11
4.4	Tadpoles.....	11
4.5	Riparian Habitat.....	13
4.5.1	Floristic Composition.....	13
4.5.2	Vegetation Structure.....	15
5.	Discussion.....	18
5.2	Effectiveness of Mitigation Measures.....	19
5.2.1	Sediment Controls.....	19
5.2.2	Site Rehabilitation.....	19
6.	Recommendations.....	19
7.	References.....	20
	Appendix A – Field Survey Results.....	23

## List of tables

1. Grey's Dam frog pipes monitoring effort.....	9
2. Number of species and taxa group detections and crossing likelihoods.....	11
3. Number and direction of movements and pipe crossing likelihood of frogs detected at Grey's Dam pipes. ...	15

## List of figures

1. Location of frog pipes at Grey's Dam. ....	6
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## List of plates

1. Habitat surrounding south-west frog pipe. ....	6
2. Habitat surrounding north-west frog pipe. ....	7
3. Habitat surrounding south-east frog pipe. ....	7
4. Habitat surrounding north-east frog pipe. ....	7
5. Pipe everts/floors were covered in 50-100mm thick mulch. ....	8
6. The Reconyx HC500. ....	13
7. A carpet python moving west in the north pipe.....	13
8. Common brushtailed possum moving west in the north pipe. ....	14
9. Eastern horseshoe bat flying into the south pipe.....	14
10. Giant barred frog moving west in the north pipe.....	15
11. Barred frog sp. moves east during a confirmed crossing of the south pipe.....	16

# 1. Introduction

## 1.1 Background

Roads and Maritime Services (RMS) NSW contracted Sandpiper Ecological Surveys (SES) to monitor a giant barred frog (*Mixophyes iteratus*) population identified along the Sapphire to Woolgoolga (S2W) Pacific Highway Upgrade project (hereafter referred to as the Upgrade). Giant barred frog is listed as endangered on the NSW *Threatened Species Conservation (TSC) Act 1995* and Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*.

The Environmental Assessment (EA) prepared for the S2W Upgrade identified potential habitat for giant barred frog at four sites within the Upgrade corridor. These sites included Woolgoolga Creek, Poundyard Creek, Arrawarra Creek and Little Arrawarra Gully. The species was subsequently detected at two of the predicted sites – Woolgoolga Creek and Arrawarra Creek. However, during the construction phase giant barred frog was recorded at three additional sites, a dam on Halls Creek (referred to as Freeman’s Dam) (Chainage 27400), a dam north of Grey’s Road (referred to as Grey’s Dam) (Ch. 24600) and a dam north of Barkhut Road (referred to as Barkhut Dam) (Ch. 27730).

In response to the above records the Office of Environment and Heritage (EOH) requested amendments be made to the approved Ecological Monitoring Program (in accordance with MCoA 3.1) and Biodiversity Offset and Management Strategy (in accordance with MCoA 2.12e and 2.12h) to reflect potential impacts of the upgrade on the giant barred frog population.

A Construction Phase Management Strategy (CPMS) for the giant barred frog population was prepared (BEM 2011) and included a requirement to conduct population monitoring at all sites where the species was detected. Population monitoring was subsequently undertaken during giant barred frog breeding seasons (i.e. October – March) in 2011/12 and 2012/13.

The surveys described in the current report have been undertaken as part of the operational phase monitoring requirement specified in MCoA 3.1(c). Year 1 population monitoring occurred during 2014/15 after the Upgrade became operational in July 2014. This report presents results of year 2 (i.e. 2015/16) operational phase population monitoring.

Additional surveys to determine presence/absence of giant barred frog were recommended for Freeman’s Dam and Barkhut Dam in the 2012-13 construction phase monitoring report. These surveys were not undertaken during year 1 or 2 operational phase monitoring periods. At the Freeman’s Dam site, the S2W upgrade design included installation of a noise wall, which prevents giant barred frog individuals accessing trafficable areas, hence there was no need to confirm presence of the species at the site. Site access permission could not be obtained for the Barkhut Dam site.

## 1.2 Species Ecology

The giant barred frog is a large (up to 120 mm) ground dwelling Myobatrachid frog found within areas of wet sclerophyll forest and rainforest at elevations below 1000 m (Lemckert & Brassil 2000; Anstis 2013; NPWS 2002). The species is associated with permanent flowing drainages, from shallow rocky rainforest streams to slow-moving rivers in lowland open forest (NSW Scientific Committee 1999).

The species forages and lives amongst deep, damp leaf litter where it feeds primarily on large insects and spiders (NPWS 2002). Individuals generally remain within 20 to 30 m of the edge of a stream (Lemckert & Brassil 2000). Breeding usually occurs from late spring to summer around permanent shallow flowing streams (Lemckert & Brassil 2000; NPWS 2002; Tyler & Knight 2009). Males call from leaf litter along the banks of creeks and streams (Robinson 1993). Females deposit eggs onto moist banks or rocks above water level, where the eggs adhere in a layer to a surface above water (Knowles *et al.* 2015; Anstis 2013; NPWS 2002). Hatchlings fall or wriggle down into the water (Anstis 2013; NPWS 2002). The tadpoles grow up to 100 mm total length and take from 10 to 14 months to reach metamorphosis (Lemckert & Brassil 2000; Hines 2002; NPWS 2002; Tyler & Knight 2009).

### 1.3 Monitoring Aims and Objectives

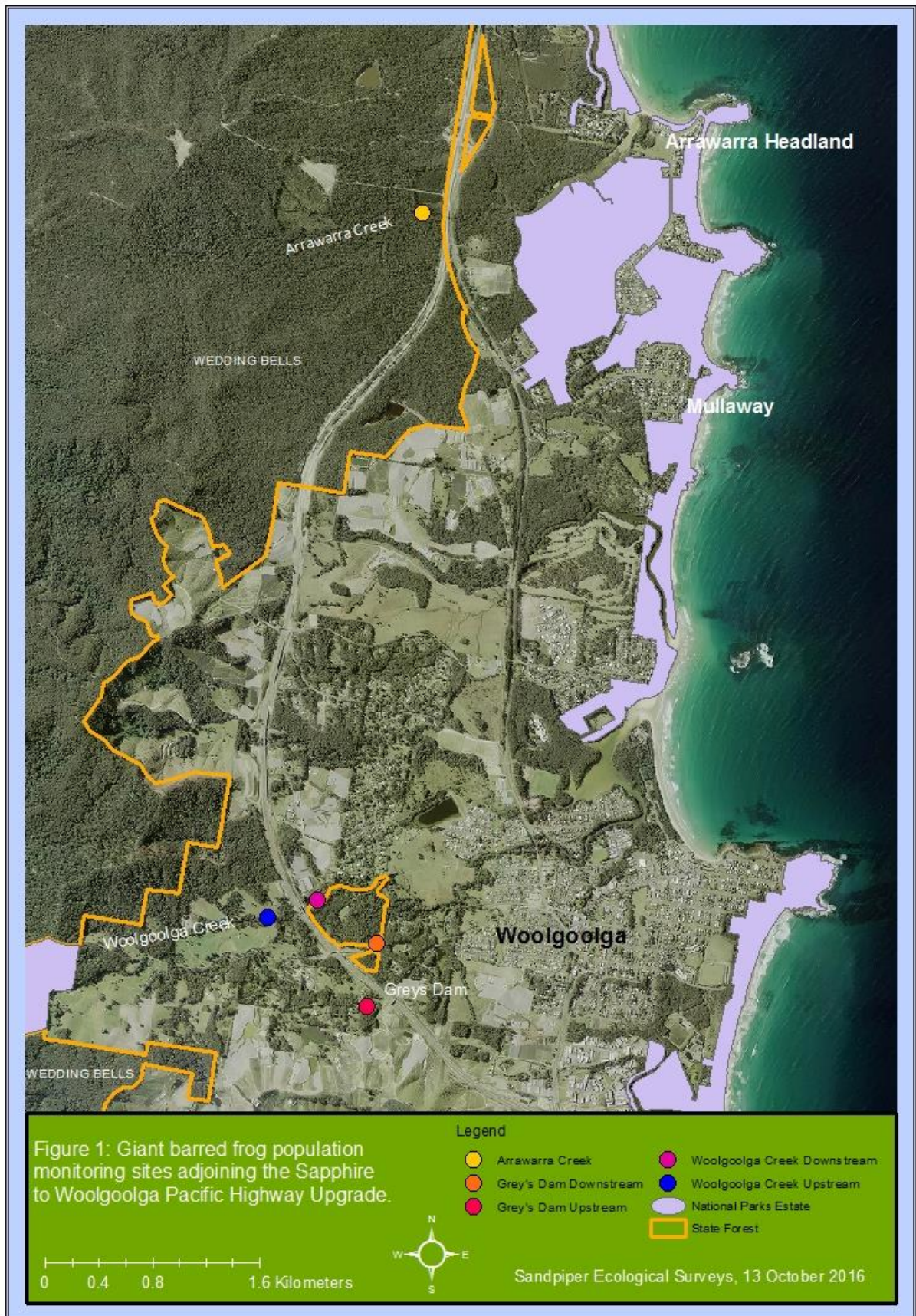
The aim of the giant barred frog population monitoring is to assess presence/absence and long-term viability of giant barred frog sub-populations in areas directly affected by the Upgrade.

The objectives of the monitoring program are to:

- identify changes to giant barred frog presence and relative abundance at all known sites affected by the Upgrade;
- identify any changes to key habitat components caused by the Upgrade that have the potential to impact on the long-term viability of giant barred frog sub-populations in the locality; and
- assess the presence, developmental stages and relative abundance of giant barred frog larvae, juveniles (sub-adults) and adults.

## 2. Study Area

The study area includes three watercourses traversed by the Upgrade project corridor between chainage 24600 and chainage 31000. The watercourses include an unnamed stream north of Grey's Road (Ch. 24600) referred to as Grey's Dam, Woolgoolga Creek (Ch. 25400) and Arrawarra Creek (Ch. 31000). All sample sites are located within 600 m of the Upgrade corridor (Figure 1). An additional site at Darkhum Creek was sampled during construction phase monitoring. However, this site was subsequently excluded due to lack of suitable habitat for giant barred frog.



## 3. Methods

### 3.1 Monitoring Sites

Five monitoring sites have been established within the study area (Figure 1). Sampling sites upstream and downstream of the project corridor have been established at Grey's Dam and Woolgoolga Creek. A monitoring site upstream of the project corridor has also been established at Arrawarra Creek. There was insufficient suitable habitat for giant barred frog at Freeman's Dam, Barkhut Dam or downstream of the project alignment at Arrawarra Creek to enable monitoring of the species.

Each monitoring site consisted of a 200m section of riparian habitat, after Lewis and Rohweder (2005). Sampling transect widths corresponded with the extent of suitable giant barred frog habitat (e.g. dense leaf litter and intact riparian vegetation) within 30m of the stream edge (Lemckert and Brassil 2000). The downstream sites at Grey's Dam and Woolgoolga Creek incorporate the release points used to relocate giant barred frog adults and tadpoles displaced during the Upgrade construction phase (see BEM 2013).

### 3.2 Timing of Sampling Events

#### 3.2.1 Construction Phase

The CPMS states that, "the timing of sampling events will be spaced throughout the breeding season in order to detect the relative abundance of tadpoles in different development stages (i.e. between early October and late March)". Construction phase sampling was completed during 2011-12 and 2012-13 breeding seasons. Spring/early season sampling was not undertaken in the 2011-12 breeding season due to delays in approval of the CPMS and associated monitoring methodology and funding.

The timing of sampling events was delayed several times because of heavy rain and flooding in the study area yet were consistent with the recommended survey guidelines for the species prepared by the Department of Environment, Water, Heritage and the Arts (DEWHA 2010).

#### 3.2.2 Operational Phase

Three sampling events were completed during the 2015-16 operational phase population monitoring (Table 1). Surveys spanned late-spring to mid-autumn. Year 2 operational phase surveys build on the three sampling events completed during year 1.

**Table 1:** Timing of giant barred frog monitoring events undertaken in the 2015-16 breeding season.

Monitoring Event	Visual Search/Call Playback	Tadpole Sampling
Event 1	25/11/2015 – 17/12/2016	25/11/2015 – 17/12/2016
Event 2	28/1/2016 – 16/3/2016	16/2/2016 – 22/2/2016
Event 3	4/4/2016 – 7/4/2016	28/4/2016 – 29/4/2016



### 3.3 Sampling Hygiene Protocol

All field sampling was conducted in accordance with the hygiene protocol for the control of disease in frogs (NPWS 2001). Relevant control measures included:

- vehicles not traversing potential frog habitat;
- cleaning and disinfection of boots and waders prior to entering frog habitat;
- disinfection of dip-nets and bait traps prior to entering frog habitat;
- a fresh pair of surgical gloves worn for the handling of each individual frog;
- captured frogs and tadpoles placed separately into plastic bags and aquariums. All plastic bags were disposed of after a single use. Aquariums were disinfected after each use.

Captured frogs and tadpoles were kept isolated from other captured individuals throughout the entire capture/release process.

### 3.4 Frog Surveys

Each sampling event for frogs consisted of a combined nocturnal visual search and a call playback survey. Field sampling was generally undertaken between 1900 and 0100 hours. Visual searches consisted of a walk traverse of each 200m transect for a minimum duration of 1.5 hours (3 person hours/event). Two experienced field personnel using spotlights undertook each traverse. Captured individuals were measured (snout-vent length), weighed, and photographed (dorsal surface pattern) to determine approximate age and sex. Individuals with a snout to vent length less than 68mm were considered to be juveniles (Tyler & Knight 2009). Males were determined either by call or by presence of nuptial pads. Photographs of the dorsal surface were taken to enable possible identification of recaptured individuals between sampling events. The location of each captured individual was recorded using a handheld Garmin GPS62.

Weather conditions were recorded immediately prior to and after sampling each site with a Kestrel 3000 handheld weather meter. The weather variables recorded included relative humidity, air temperature, dew point, cloud cover, wind speed and direction. Rainfall during the previous 24 hours and moon phase were also recorded.

### 3.5 Tadpole Surveys

Tadpole sampling using dip-nets and bait traps was conducted to assess giant barred frog breeding activity. Dip-netting was performed for a minimum of one hour per 200m transect by two experienced field personnel (i.e. two person hours per monitoring event) (Plate 1). Bait traps (three per transect) were set prior to dip-net sampling and checked upon completion of other sampling tasks. Tadpole length and development stage (as per Anstis 2013) was recorded for each capture.



**Plate 1:** Dip-netting being conducted at Arrawarra Creek.

### 3.6 Water Quality Sampling

Water quality was assessed during each tadpole sampling event. Variables recorded were pH, water temperature, and turbidity. Water pH and temperature were measured using a Eutech pH 5+ pH meter, whilst turbidity was measured using a turbidity tube.

### 3.7 Revegetation Monitoring

The aim of revegetation monitoring was to compare structural and floristic characteristics of vegetation within the riparian areas at Grey's Dam and Woolgoolga Creek impacted by the project with adjacent riparian areas unaffected by the project.

At each site four 25m-long transects were established perpendicular to the stream, two transects positioned within the impacted riparian area and two transects within the adjacent unaffected riparian area.

Floristic composition was assessed by establishing 25m<sup>2</sup> sampling plots (quadrat dimensions 5m x 5m) at three locations along each transect: top of streambank (0-5m); mid riparian (10-15m); and outer riparian (20-25m). Each sampling plot was randomly located either side of the transect. All plant species within each sampling plot were recorded, along with a visual estimate of vegetative cover for each species using a modified Braun-Blanquet cover value ranging from 1 to 6: 1 (<5% sparse); 2 (<5% many individuals); 3 (6-25%); 4 (26-50%); 5 (51-75%) or 6 (>75%). Nomenclature followed Harden (1990-93, 2000, 2002), with subsequent updates as provided by 'PlantNet', the online version of the Flora of NSW.

The Foliage Projective Cover (FPC) of overstorey and groundcover vegetation was recorded using FPC tubes at 1m intervals along each 25m transect to enable a quantitative measure of foliage cover of both native and introduced species. The proportion of leaf litter cover was recorded using the same technique.

Leaf litter depth was recorded at 5m intervals along each transect. The method of measuring leaf litter depth involved:

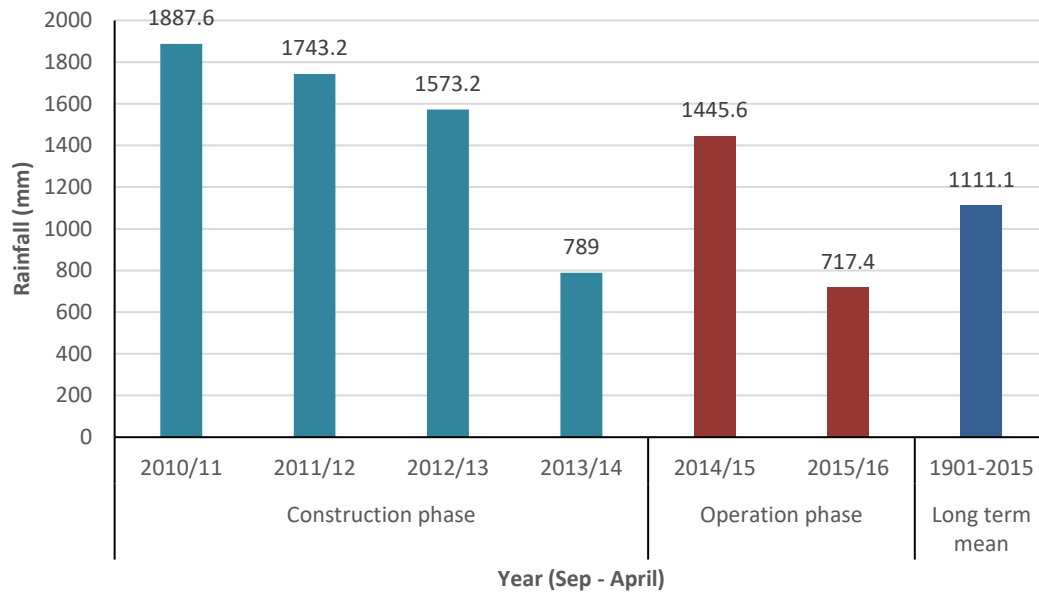
1. scraping a small hole in the leaf litter to the soil surface;
2. placing one end of a ruler into the hole on the soil surface;
3. obtaining a plate with a slot in the centre in which to insert the ruler;
4. slide the plate down the ruler until it rests (unweighted) on the leaf litter surface; and
5. read the depth measurement on the ruler as indicated by the top surface of the resting plate.

## 4. Results

### 4.1 Weather Conditions

Suitable weather conditions for sampling giant barred frog include warm air temperature ( $>18^{\circ}\text{C}$ ), high relative humidity and rainfall either during or recently preceding sampling (i.e. up to one week prior to sampling) (DEWHA 2010). Sampling should not be undertaken during periods of heavy rainfall or high stream flow (DEWHA 2010).

The construction phase population monitoring was undertaken during the 2011-12 and 2012-13 breeding seasons, both of which were years of above-average rainfall (Figure 2). The first year of the operational phase population monitoring (2014/15) was also above average yet followed a year (2013/14) of below average rainfall. In 2014/15 56% of rainfall in the Sept-Apr period fell in January and February. The 2015/16 (year 2) sample occurred during a period of rainfall which was 35% below the long-term average for the Sept-Apr period (Figure 2).



**Figure 2:** A comparison of long-term mean rainfall (1901 to 2015) and annual rainfall (Sep – April) for the S2W area 2010/11 through 2015/16. Construction phase monitoring was conducted during 2011/12 and 2012/13 and operation phase monitoring during 2014/15 and 2015/16. Source: Bureau of Meteorology Lower Bucca Station No. 059006.

Weather conditions during 2015/16 nocturnal frog sampling were largely consistent with those suitable for giant barred frog surveys. Humidity exceeded 68% and temperature 21°C during all surveys (Table 3). Nocturnal surveys were suspended if ambient air temperature fell below 18°C, the threshold temperature at which giant barred frogs are thought to burrow beneath the leaf litter (Koch and Hero 2007). The first and second sampling event occurred during or after periods of moderate rainfall. Unseasonably dry conditions during late summer/early autumn delayed the third sampling event. It was eventually conducted during dry conditions towards the end of the sampling period, in early April 2016 (Table 2).

**Table 2:** Weather conditions recorded during 2015/16 nocturnal field sampling.

Site	Sampling Date	Air Temp <sup>1</sup> (C°)	Humidity <sup>1</sup> (%)	Rainfall 7 days prior <sup>2</sup> (mm)
Arwarra Creek	10/12/15	21.9 – 21.3	85.9 - 82	52.0
	04/02/16	27.0 – 25.1		23.0
	04/04/16	23.4 - 23.4	67 – 68.1	3.0
Grey's Dam upstream	17/12/15	21.8 – 20.0	80 – 85.8	15.6
	16/03/16	23.9 - 21.7	90.5 - 94	23.0
	07/04/16	24.0 – 23.3	75.4 – 79.2	0
Grey's Dam downstream	02/12/15	21.0 – 20.9	98 - 100	39.8
	22/02/16	24.4	86.2	3.6
	07/04/16	23.3 – 24.1	79.2 – 80.6	0
Woolgoolga Creek upstream	30/11/15	27.8 – 25.9	76.1 – 80	41.8
	05/02/16	24.5 – 24.4	73 - 71	22.8
	06/04/16	23.5 – 23.8	79 – 74.1	0
Woolgoolga Creek downstream	25/11/15	23.9 – 24.3	78.8 – 84.3	3.0
	28/01/16	25.9 – 25.6	84.8 – 83	57.6
	06/04/16	23.8 – 21.3	74.1 – 83.8	0

1 – temperature and humidity range measured at start and finish of sampling;

2 – daily rainfall data source Bureau of Meteorology Lower Bucca Station No. 059006.

## 4.2 Water Quality

The below-average rainfall across the 2015-16 monitoring season resulted in reduced stream flow and relatively low pH and low turbidity levels at most sites compared to construction phase sampling (BEM 2013). Overall, the water quality sampling indicated little difference in water quality parameters between upstream and downstream sites and between monitoring events (Table 3).

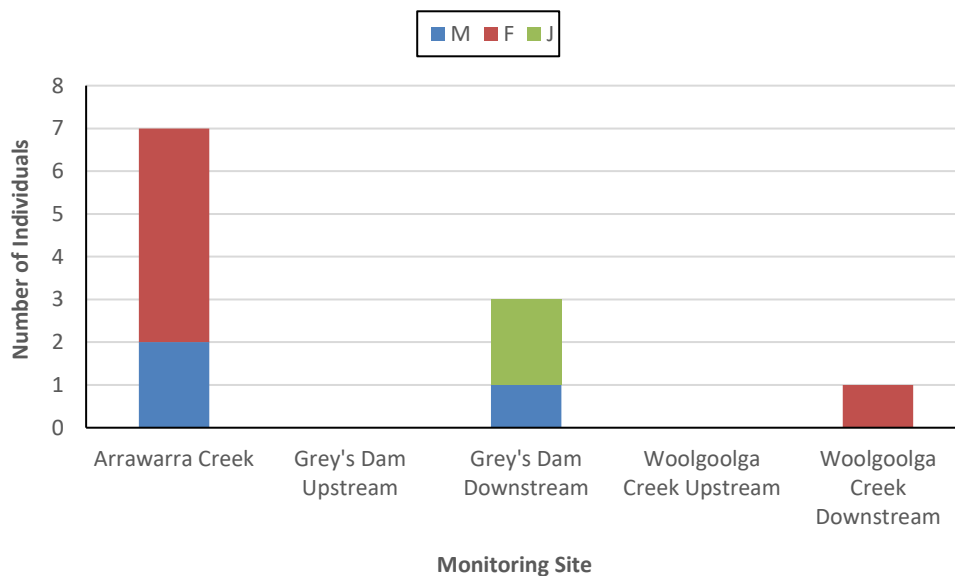
**Table 3:** Water quality variables recorded at each site during 2015/16 monitoring.

Site	Date	pH	Temp (°C)	Turbidity (ntu)
Arwarra Creek	10/12/15	5.75	23.2	<10
	17/02/16	6.35	23.3	11
	28/4/16	6.75	19.8	<10
Grey's Dam upstream	17/12/15	6.05	25.4	<10
	17/02/16	6.39	26	40
	29/4/16	6.62	20.6	<10
Grey's Dam downstream	02/12/15	5.9	21.4	<10
	17/02/16	6.03	21.7	<10
	29/4/16	6.53	19.7	<10
Woolgoolga Creek upstream	30/11/15	5.75	21.3	<10
	22/02/16	5.85	24.1	<10
	20/4/16	6.4	20.7	<10
Woolgoolga Creek downstream	25/11/15	5.96	22	<10
	16/2/16	5.87	25.2	<10
	28/4/16	6.3	21	<10

## 4.3 Frogs

### 4.3.1 Presence/Absence

Giant barred frogs were recorded during 2015/16 monitoring period at Arrawarra Creek and downstream sites at Grey's Dam and Woolgoolga Creek (Figure 3). Male and female giant barred frogs were captured at Arrawarra Creek. Only male and juvenile frogs were recorded at Grey's Dam downstream and a single female frog was captured at Woolgoolga Creek downstream. The highest number of individuals was recorded at Arrawarra Creek ( $n = 7$ ). No giant barred frogs were recorded at Grey's Dam or Woolgoolga Creek upstream sites. Full details of frog surveys are provided in Table A1, Appendix A.



**Figure 3:** Number of adult and juvenile giant barred frogs recorded during 2015/16 surveys.

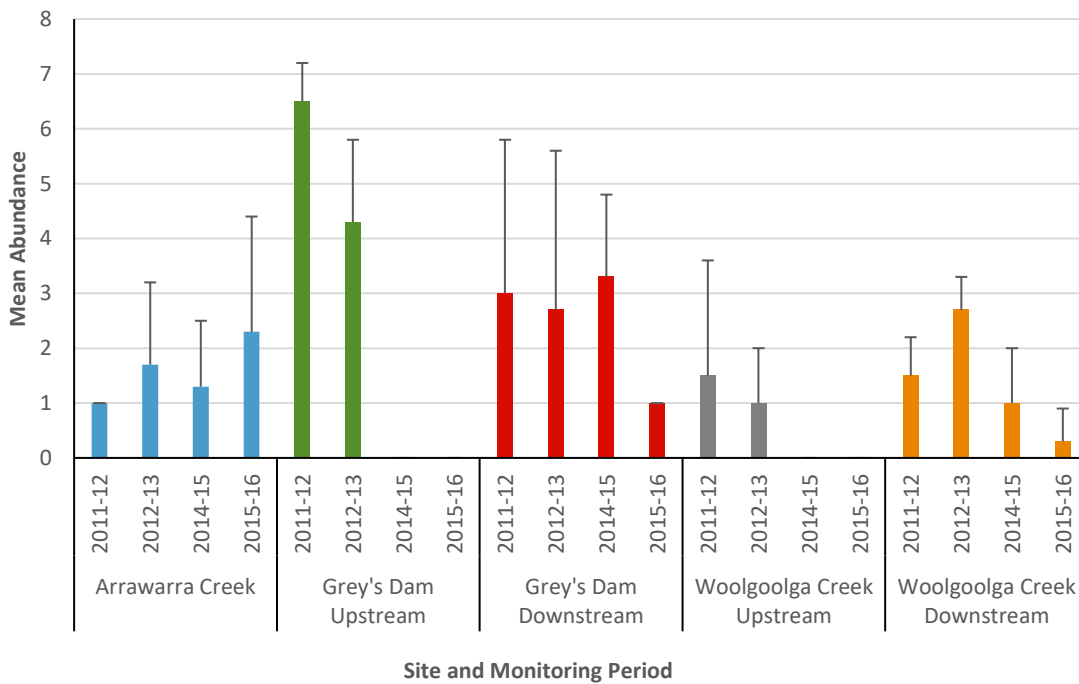
Based on the dorsal pattern photographs, two recaptures were recorded during the 2015/16 monitoring surveys. At Woolgoolga Creek downstream, a female captured in 5 March 2015 was recaptured at the same site on 28 January 2016 (Plate 2). A female was also recaptured at Arrawarra Creek on 10 December 2015 after first being captured at the same site on 1 April 2015. No individuals captured during construction phase monitoring were recaptured during the current monitoring period.



**Plate 2:** Adult female captured at Woolgoolga Creek downstream site on 5/3/2015 (L) during year one operational phase monitoring and recaptured at the same site on 28/1/2016 (R) during year two surveys.

### 4.3.2 Abundance

Mean abundance of giant barred frogs (i.e. mean of monitoring period sampling events) across the four monitoring periods showed a general downward trend during the 2014-15 and 2015-16 periods at all sites except Arrawarra Creek (Figure 4). In particular, giant barred frogs have not been recorded at Grey’s Dam or Woolgoolga Creek upstream sites since 2012/13.



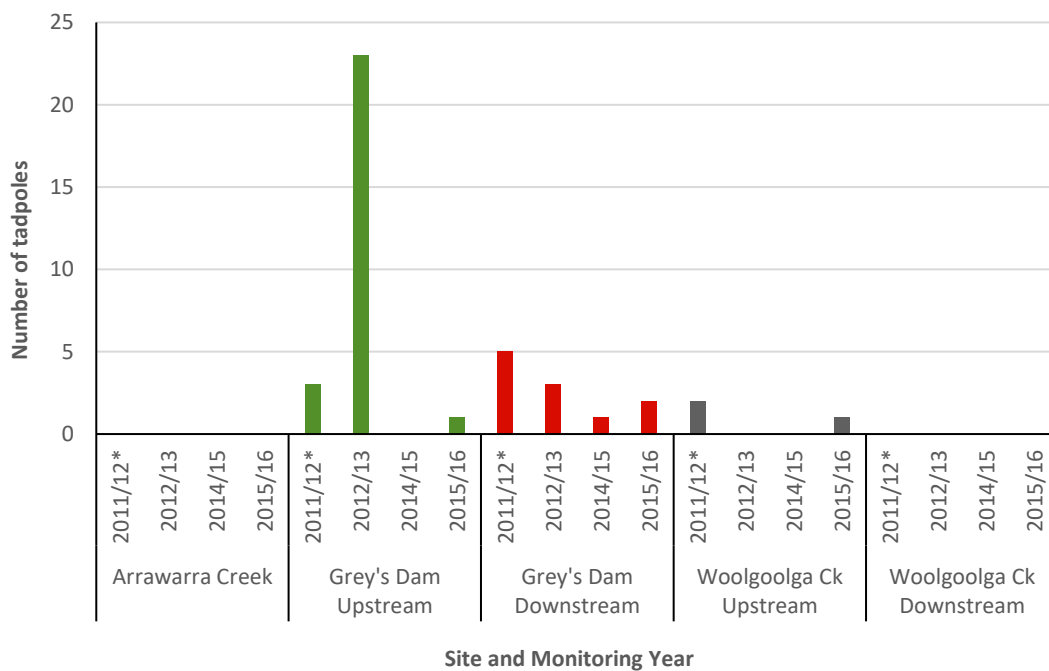
**Figure 4:** Comparison of giant barred frog mean abundance (+ standard deviation) at the five monitoring sites during four monitoring periods (construction phase = 2011/12 and 2012/13; operation phase = 2014/15 and 2015/16).

### 4.4 Tadpoles

Giant barred frog tadpoles were recorded at Grey’s Dam upstream and downstream sites and Woolgoolga Creek upstream (Figure 5). The greatest number of captures (n = 2) occurred at Grey’s

Dam downstream. The developmental stage of captures ranged between stages 27-40 (Plate 3). Tadpoles were captured during November and December 2015 and February 2016. Importantly, the tadpole recorded upstream at Greys Dam was captured adjacent the partially submerged pipe culverts, so may have been conceived on the eastern side of the project and swum upstream through pipes rather than being a product of breeding activity upstream. Tadpole captures during 2011/12 and 2012/13 occurred in the small, isolated dam further upstream, which suggests that tadpoles captured during these years were an artefact of upstream breeding rather than the result of upstream migration from the downstream section of dam.

More tadpole captures occurred during the 2015/16 monitoring period compared to the 2014/15 period however fewer captures have been recorded during the operational phase compared to the construction phase monitoring (Figure 5). Full details of tadpole surveys are provided in Table A2, Appendix A.



**Figure 5:** Number of giant barred frog tadpoles captured during four monitoring periods (construction phase = 2011/12 and 2012/13; operational phase = 2014/15 and 2015/16). \*2011/12 = only two sampling events during period.



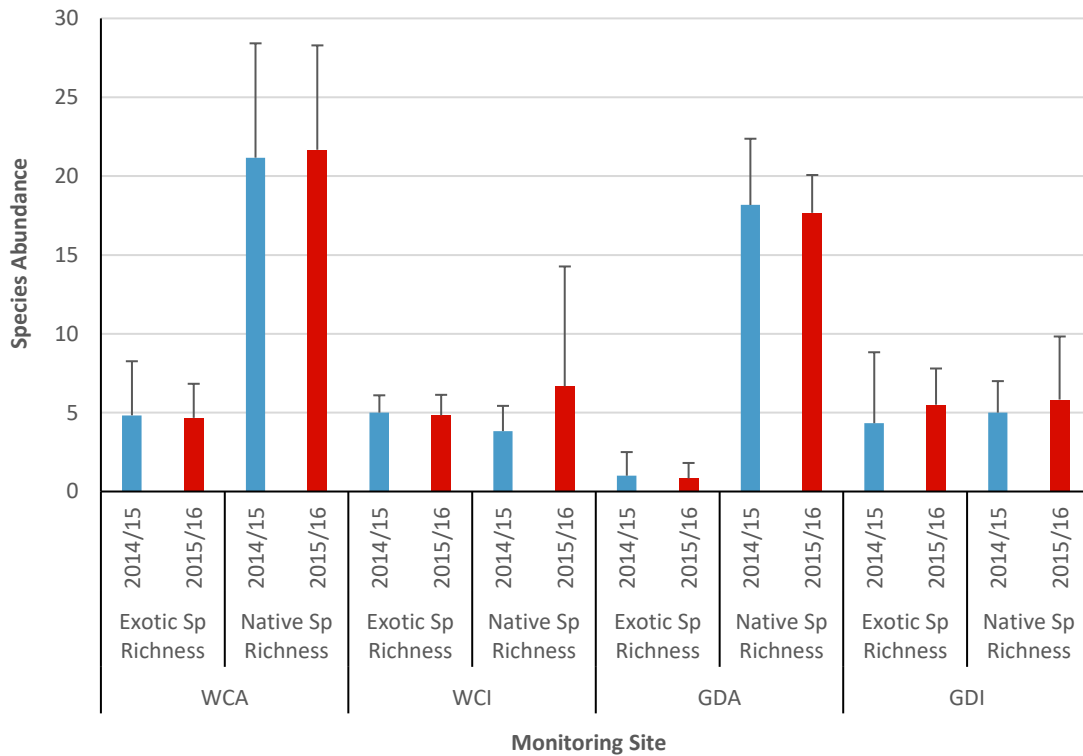


**Plate 3:** Giant barred frog tadpole captured at Woolgoolga Creek downstream during November 2015. Total length was 40mm. The approximate development stage was 40. Note the high arch and angular spots on the tail fin, which are diagnostic of this species.

## 4.5 Riparian Habitat

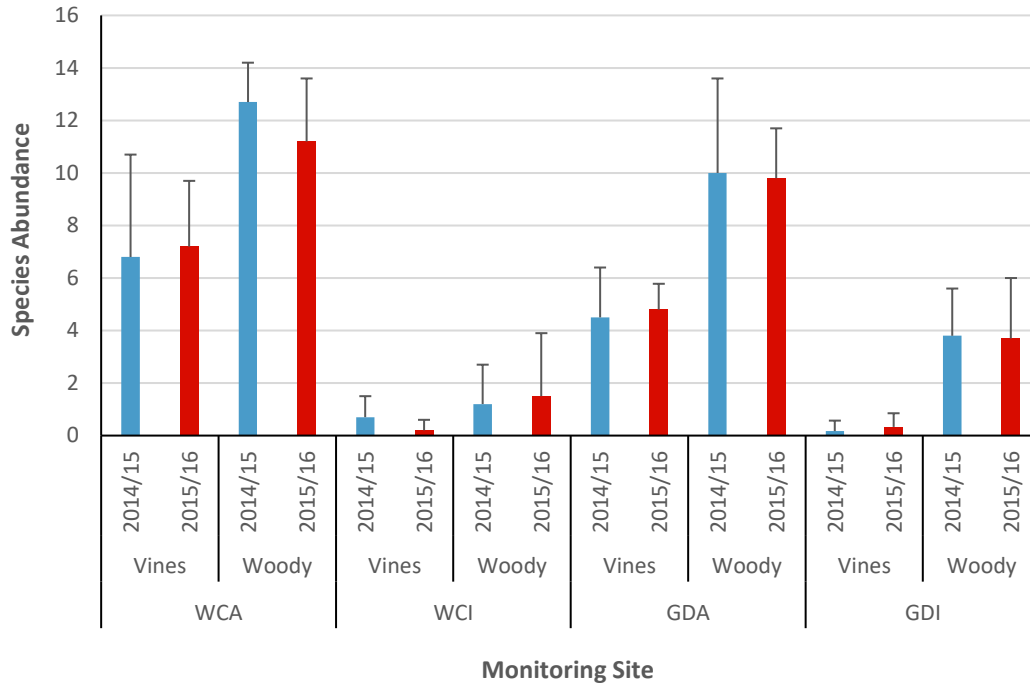
### 4.5.1 Floristic Composition

The abundance of native and exotic plant species showed different trends at disturbed sites (i.e. WCI and GDI) and undisturbed sites (i.e. WCA and GDA). Total species abundance and native species abundance was higher at undisturbed sites whereas exotic species abundance was highest at disturbed sites (Figure 5). At disturbed sites, native species richness trended upward between monitoring years whereas exotic species richness showed both slight upward (GDI) and downward (WCI) trends. Undisturbed sites showed mixed trends between monitoring years although the relative differences were small.



**Figure 5:** Native and exotic flora species richness or abundance at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15 and 2015/16 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

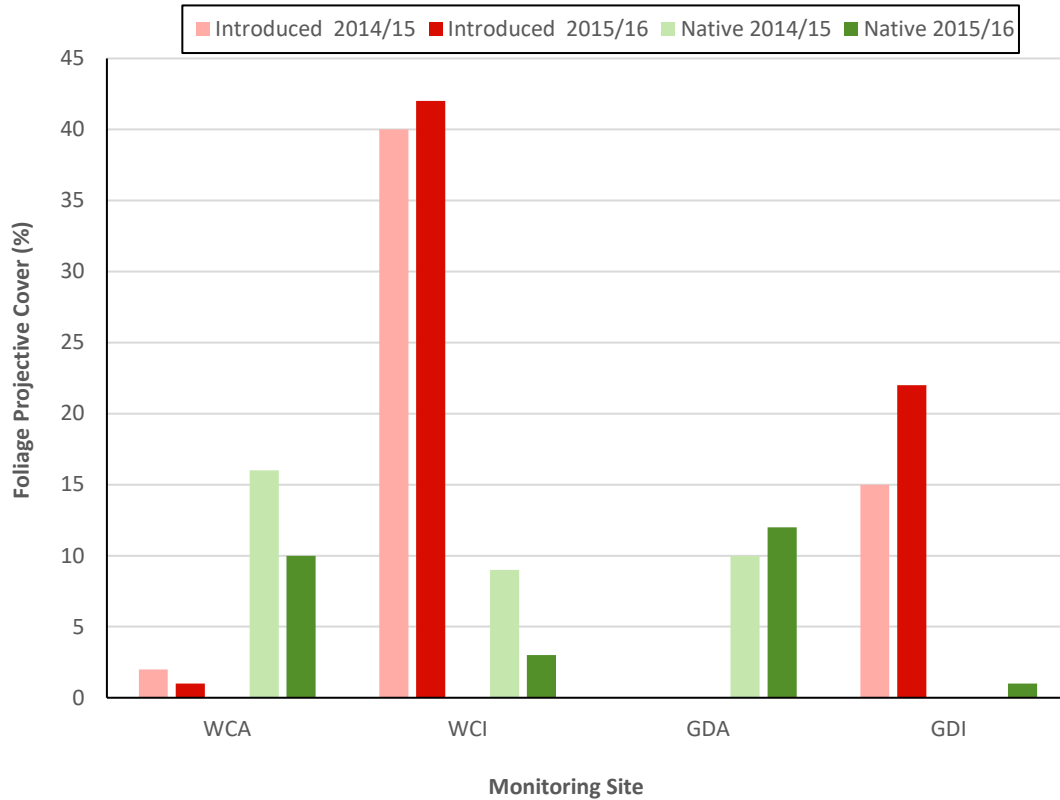
The abundance of native vine and woody species was greater at undisturbed sites compared to disturbed sites (Figure 6). Little change in abundance between monitoring years was evident at disturbed sites although woody species at WCI and vine species at GDI rose slightly between monitoring years.



**Figure 6:** Native vine and woody species abundance at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15 and 2015/16 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

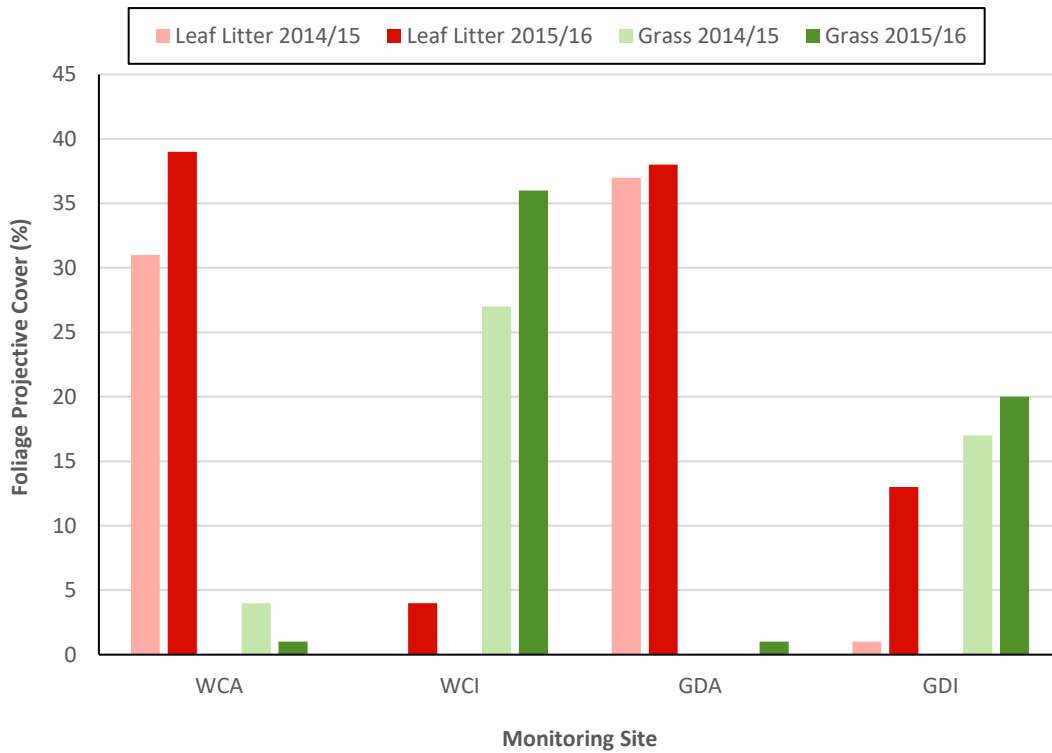
#### 4.5.2 Vegetation Structure

The projective cover of native vegetation was markedly higher within adjacent undisturbed forest areas compared to disturbed riparian areas within the project alignment whereas the converse was evident for introduced species (Figure 7). Disturbed sites showed mixed trends between monitoring years in foliage projective cover of native species and slight increases in cover of introduced species. Foliage cover trends at undisturbed sites were mixed although cover of introduced species declined between monitoring periods (Figure 7).

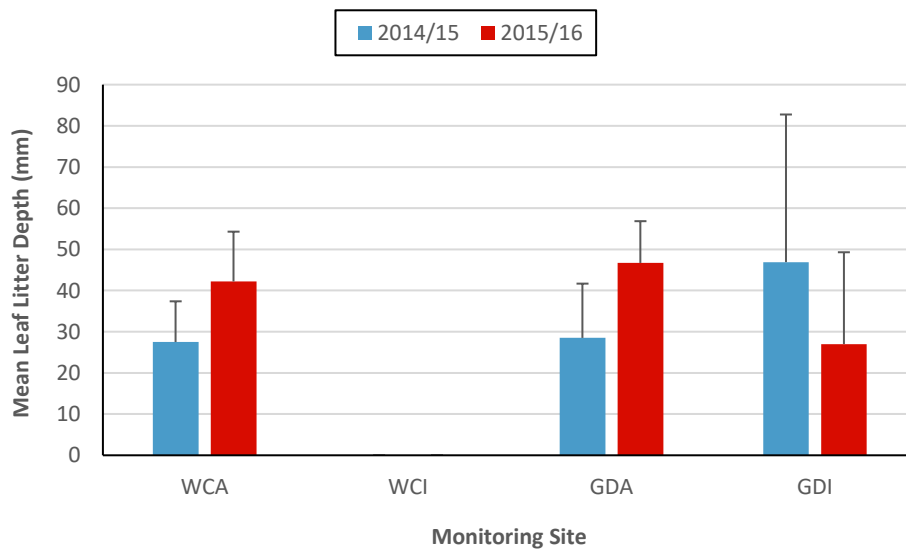


**Figure 7:** Comparison of Foliage Projective Cover (%) of native and introduced species at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15 and 2015/16 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

Leaf litter cover and depth was markedly greater in undisturbed forest areas compared to disturbed riparian areas in the project corridor (Figure 8 and 9). However, the Grey's Dam disturbed site featured relatively deep and broad leaf litter cover and wood chip that continued between monitoring years albeit patchy and prone to wash out during rain events. Grass cover was higher at disturbed sites and the trend continued over monitoring years (Figure 8).



**Figure 8:** Comparison of Foliage Projective Cover (%) of grasses and leaf litter at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15 and 2015/16 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.



**Figure 9:** Mean leaf litter depth (mm) at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15 and 2015/16 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

## 5. Discussion

### 5.1 Giant Barred Frog Presence/Absence and Abundance

The 2015/16 giant barred frog surveys across the five monitoring sites were typified by mixed results. The Arrawarra Creek site produced relatively high capture rates, including seven captures across the three surveys, resulting in a slight increase in abundance across the four monitoring periods (2011/12 to 2015/16). At Grey's Dam and Woolgoolga Creek, however, low capture rates largely continued the downward trend in population abundance at those sites. Indeed, giant barred frogs have not been captured at Grey's Dam and Woolgoolga Creek upstream sites since 2012/13 and downstream captures/observations at both sites were the lowest since monitoring began in 2011-12. This observed decline is further compounded by continued low levels of recruitment as evident from the low number of tadpole captures across all sites. It should be noted, however, that the high number of giant barred frogs recorded at Grey's Dam upstream during 2011/12 (Figure 4) may have been an artefact of displacement of individuals during vegetation clearing and dewatering of Grey's Dam and vegetation clearing. Indeed, 20 giant barred frogs were captured during pre-clearing surveys at Grey's dam compared to three at Woolgoolga Creek and one at Arrawarra Creek (Benchmark 2011).

Interpreting the apparent decline in giant barred frog abundance at Grey's Dam and Woolgoolga Creek sites should be informed by broader understanding of amphibian population dynamics. That is, frogs mostly exist in meta-populations that feature highly variable sub-populations which can fluctuate greatly over time (Alford & Richards 1999). Typically, populations may experience years of decline punctuated by years of high recruitment when environmental conditions are favourable (Green 2003). Indeed, two populations of Fleay's barred frog (*M. fleayi* - a congener of the giant barred frog) reportedly recovered over a seven-year period after suffering dramatic declines (Newell *et al.* 2013). At Grey's Dam and Woolgoolga Creek, the most plausible explanation for the apparent sub-population decline is the below average rainfall leading up to and during the 2015/16 period. Below average rainfall was a feature of 2013/14, the year prior to year one operational phase monitoring. Combined, the monitoring area has experienced below average rainfall during two of the last three years (Figure 2). Moreover, giant barred frog was not recorded at any site during field sampling for the EA in 2006 during a period of low rainfall. This further suggests that giant barred frog monitoring sites at S2W, particularly Grey's Dam and Woolgoolga Creek, feature marginal and highly variable sub-populations.

The relatively dry conditions experienced at the monitoring area in recent years have probably resulted in a contraction of the giant barred frog sub-populations within the wider Woolgoolga Creek catchment to areas of optimal or higher quality habitat. Support for this proposition is provided by the continued presence of giant barred frog adults and tadpoles at the Grey's Dam downstream site, which contains higher quality habitat (e.g. continuous riparian vegetation, greater pool/riffle sequences and more reliable streamflow). Similarly, the Arrawarra Creek and Woolgoolga Creek downstream sites feature relatively good quality habitat and continued presence of giant barred frogs. Conversely, Grey's Dam upstream is considered to represent atypical or marginal habitat for the species due to the lack of permanent stream flow (i.e. sporadically spring fed), no sequences of pools and riffles (i.e.

site contains two dams connected by ephemeral flow) and limited width and continuity of riparian vegetation. Individuals probably colonise the upstream area during periods of high rainfall, then contract back to areas of higher quality habitat downstream during drought. The same pattern is probably the case for Woolgoolga Creek. Subsequent population monitoring during years of high rainfall is required to clarify whether recolonization of upstream sites occurs. As such, it is too early to determine the long-term viability of giant barred frog sub-populations.

## 5.2 Effectiveness of Mitigation Measures

### 5.2.1 Sediment Controls

Water quality sampling recorded similar pH and turbidity levels upstream and downstream of the upgrade corridor indicating that site disturbance associated with the upgrade did not cause any noticeable impact on water quality parameters likely to affect giant barred frog habitat quality.

### 5.2.2 Site Rehabilitation

Site rehabilitation works were conducted during November 2015 at the Grey's Dam disturbed/impact sites. Work included removal of herbaceous weeds, thinning of woody regrowth blocking frog pipe entrances and spreading a layer of wood chip mulch to suppress weed growth/recruitment. The aim of such work was to encourage giant barred frog use of frog pipes to cross the project corridor. The rehabilitation works were evident in the increased cover of leaf litter/mulch at this site (i.e. GDI in Figure 8).

Rehabilitation work at Woolgoolga Creek largely consisted of re-shaping the stream channel after bridge construction, planting of mat rush (*Lomandra hystrix*) and placement of some woody debris in the channel. No rehabilitation work appears to have been undertaken since bridge construction.

Disturbed sites also demonstrated slight improvements in cover of woody shrubs and native species richness. However, the cover of exotic species increased slightly between monitoring years at disturbed sites but not at undisturbed sites suggesting rehabilitation has been inadequate. More concerted rehabilitation, particularly at Grey's Dam, should endeavor to gradually improve floristic and structural variables to more closely resemble undisturbed forest sites.

## 6. Recommendations

After completion of two operational phase population monitoring events, a number of recommendations are proposed for future monitoring and ongoing management of giant barred frog sub-populations within the project corridor:

- Continue monitoring of site rehabilitation measures at Woolgoolga Creek and Greys Dam, as per current scope;

- Continue sub-population monitoring at the Grey's Dam, Woolgoolga Creek and Arrawarra Creek sites for a minimum of three years into the operational phase of the Upgrade project in accordance with MCoA 3.1(c), as per current scope;
- Continue weed control and infill plantings within disturbed riparian areas of the project corridor adjacent Grey's Dam frog pipes to promote continuous giant barred frog habitat, as per current scope;
- Conduct weed control and infill plantings in the disturbed riparian areas of the project corridor adjacent Woolgoolga Creek monitoring site to promote continuous giant barred frog habitat, as per current scope. This should include planting out with native groundcovers and shrubs, as per the Giant Barred Frog Construction Phase Management Strategy (BEM 2011).
- Include Grey's Dam immediately to the east of the frog pipes as a population monitoring site. (This has recently been actioned by RMS and will form part of the scope for the 2016/17 monitoring period).

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## Appendix A – Field Survey Results

**Table A1:** Frog survey data for 2015/16 monitoring period; Observers: DO = Don Owner; TS = Tom St Vincent Welsh; Sex/Age: M = Male, F = Female, J = Juvenile; Observation Type: V = visual, C = Call.

Sample Site	Date	Start Time	Finish Time	Observers	Sex/Age	Obs Type	Captured	Total Length (mm)	Weight	Photo No.	Other Frogs
Woolgoolga Creek Downstream	25/11/15	20.10	21.40	DO; TW							Lit. latopalmata; Lit. fallax; Lit. peronii; Ps. coriacea; Ad. brevis
	28/01/16	20.10	21.40	DO; TW	F	V	Yes; Recap from 5/3/15	99.6	167	107-116	
	06/04/16	20.05	21.35	DO; TW							Lit. wilcoxii; Paracrinia haswelli; Lit. fallax
Woolgoolga Creek Upstream	30/11/15	20.00	21.30	DO; TW							Lit. fallax; Mix. fasciolatus; Lit. tyleri; Ad. brevis; Lim. peroni; Lit. wilcoxii; Lit. latopalmata; Lit. dentata
	05/02/16	20.10	21.40	DO; TW							Lit fallax; Ad. brevis
	06/04/16	18.30	20.00	DO; TW							
Grey's Dam Downstream	02/12/15			DO; TW	M	V	Yes	77.4	66	102-106	
	22/02/16	20.10	21.40	DO; TW	J	V	Yes	50.5		177-185	
	07/04/16	20.45	22.15	DO; TW	J	V	Yes	37.1	5	252-255	Lit. fallax; Lit. wilcoxii
Grey's Dam Upstream	17/12/15	21.30	23.00	DO; TW							Lit. tyleri; Lit peroni; Mix. fasciolatus; Lit wilcoxii; Lit. fallax; Ad. brevis; Up. fusca
	16/03/16	19.55	21.25	DO; TW							Mix. fasciolatus; Ad. brevis; Lit. peroni; Lit. fallax; Lit. wilcoxii
	07/04/16	19.15	20.45	DO; TW							Lit. wilcoxii; Lit. tyleri; no frogs calling
Arrawarra Creek	10/12/15	20.20	21.50	DO; TW	F	V	Yes	89.5	110	4287-4293	

					F	V	Yes, Recap from 1/4/15	103.7	190	4294-4302	
					M	V	Yes	71.1	62	4303-4310	
					M	V	Yes	76.5	56	4311-4316	
04/02/16	20.10	21.40	DO; TW								Lim peronii; Mix. fasciolatus; Lit. gracilentia
04/04/16	18.40	20.10	DO; TW	F?	V	Yes	90.1			219-230	
				F	V	Yes	94.5			231-238	
				F	V	Yes	99.1			239-251	

**Table A2:** Tadpole survey data for 2015/16 monitoring period (Observers: DO – Don Owner; TS – Tom St Vincent Welsh)

Site	Date	Observers	Start	End	Tadpole length (mm)	Development Stage
Woolgoolga Creek Downstream	25/11/15	DO; TW	19.00	20.00		
	16/02/16	DO; TW	18.30	19.30		
	28/04/16	DO; TW	11.10	12.10		
Woolgoolga Creek Upstream	30/11/15	DO; TW	18.25	19.25	103	40
	22/02/16	DO; TW				
	28/04/16	DO; TW	10.00	11.00		
Grey's Dam Downstream	02/12/15	DO; TW	17.45	18.45	100	36-38
	17/02/16	DO; TW	11.00	12.00	89	39
	29/04/16	DO; TW	13.00	14.00		
Grey's Dam Upstream	17/12/15	DO; TW	18.30	19.30		
	17/02/16	DO; TW			49	27-36
	29/04/16	DO; TW	15.00	16.00		
Arrawarra Creek	10/12/15	DO; TW	18.50	19.50		
	17/02/16	DO; TW				
	28/04/16	DO; TW	08.30	09.30		