Pacific Highway Upgrade

Sapphire to Woolgoolga – Giant Barred Frog (*Mixophyes iteratus*) Operational Phase Monitoring Program

Sandpiper Ecological

PO Box 401 Alstonville, 2477

0401 195 480

sandpipereco@optusnet.com.au

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Project Team: Don Owner – field survey and reporting

Dr. David Rohweder – field survey and report review

Dr. Sally Townley – field survey

Tim Thorncraft – field survey

Tom St Vincent Welch – field survey

Report prepared for: NSW Roads and Maritime Services

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
M 0401 195 480 | E **sandpipereco@optusnet.com.au**

Cover Photo: Giant Barred Frog observed at Arrawarra Creek, NSW.

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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 on the Sapphire to Woolgoolga Pacific Highway Upgrade project. *M. iteratus* is currently listed as endangered on the NSW *Threatened Species Conservation Act 1995* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Potential threats to the species include:

- reduction in water quality, from sedimentation or pollution;
- changes in water flow patterns, either increased or decreased flows;
- reduction of leaf-litter and fallen log cover through burning;
- timber harvesting and other forestry practices;
- vegetation clearance;
- predation on eggs and tadpoles by introduced fish;
- weed spraying close to streams; and
- chytrid fungal disease (Hines 2002; NPWS 2002).

The Environmental Assessment (EA) prepared for the Sapphire to Woolgoolga Pacific Highway Upgrade project (referred to hereafter as the Upgrade project) identified potential habitat for *M. iteratus* 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 *M. iteratus* was recorded at three additional sites, a dam on Halls Creek (referred to as Freeman's Dam) (Chainage 27400), a dam north of Greys's Road (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 any potential changes in impacts on *M. iteratus* resulting from the Upgrade project.

A Construction Phase Management Strategy (CPMS) for the subject *M. iteratus* population was prepared (BEM 2011), which specified a requirement to conduct population monitoring at all sites where the species was detected. Population monitoring was subsequently undertaken over the 2011-12 and 2012-13 *M. iterates* breeding seasons.

The surveys described in this report have been undertaken to fulfil the operational phase monitoring requirement specified in MCoA 3.1(c). This report presents the results of the first year of the operational phase population monitoring program.

It should be noted that additional surveys to determine presence/absence of *M. iteratus* were recommended for Freeman's Dam and Barkhut Dam in the 2012-13 construction phase monitoring report. These surveys were not undertaken during the first operational phase monitoring period. At the Freeman's Dam site the Upgrade project design has included installation of a noise wall, which prevents *M. iteratus* 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. Therefore, permission will need to be sought prior to commencement of sampling in the 2015-16 breeding season.

1.2 Species Ecology

M. iteratus is a large (up to 120 mm) ground dwelling Myobatrachid frog found within areas of wet sclerophyll forest and rainforest at elevations below 1000 metres (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 metres 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 to a large size (up to 100mm 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 *M. iteratus* population monitoring was to assess presence/absence and long-term viability of *M. iteratus* sub-populations in areas directly affected by the Upgrade project.

The objectives of the monitoring program were to:

- identify changes to *M. iteratus* 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 *M. iteratus* sub-populations in the locality; and
- assess the presence, developmental stages and relative abundance of *M. iteratus* larvae, juveniles (sub-adults) and adults.

1.4 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 sampling sites are located within 600 metres of the Upgrade corridor (Figure 1). An additional site had been sampled at Darkhum Creek during construction phase monitoring. However that site was excluded due to lack of suitable habitat for *M. iteratus*.

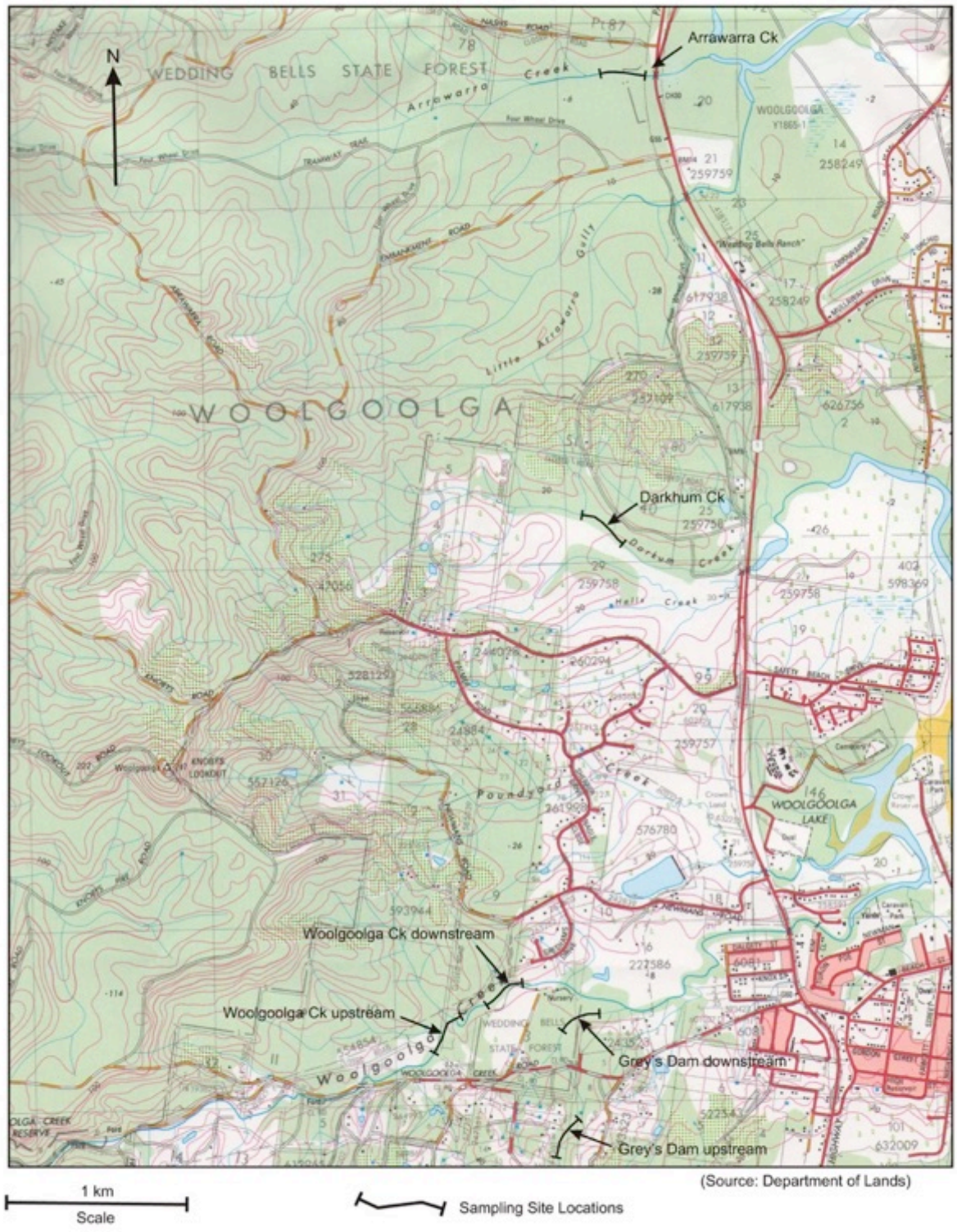

Figure 1: Location of former and current sampling sites within the study area.

2.0 Methods

2.1 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 *M. iteratus* 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 200 metre section of riparian habitat, after Lewis and Rohweder (2005). Sampling transect widths corresponded with the extent of suitable *M. iteratus* habitat (e.g. dense leaf litter and intact riparian vegetation) within 30 metres from the stream edge (Lemckert and Brassil 2000). The downstream sites at Grey's Dam and Woolgoolga Creek incorporate the release points used for relocating *M. iteratus* frogs and tadpoles displaced during the Upgrade project construction phase (see BEM 2013).

2.2 Timing of Sampling Events

2.2.1 Construction Phase

A total of five sampling events were completed during the construction phase, two during the 2011-12 breeding season and three during the 2012-13 breeding season (Table 1). Spring sampling was not undertaken in the 2011-12 breeding season due to delays in finalising the CPMS and associated monitoring methodology as well as obtaining funding approval.

Table 1: Timing of monitoring events undertaken in the 2011-12 and 2012-13 breeding seasons.

Monitoring Event	Visual Search/Call Playback	Tadpole Sampling
Summer 2012	30/01/12 - 15/02/12	23/02/12 - 27/02/12
Autumn 2012	27/03/12 - 02/04/12	26/04/12 - 2/05/12
Spring 2012	21/11/12 - 20/12/12	21/11/12 - 23/11/12
Summer 2013	22/01/13 - 31/01/13	22/01/13 - 04/02/13
Autumn 2013	02/04/13 - 11/04/13	09/04/13 - 12/04/13

It is stated in the CPMS 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)". The timing of sampling events was delayed several times due mainly to heavy rain and flooding in the study area. Nevertheless, the timing of sampling was consistent with the recommended survey guidelines for the species prepared by the Department of Environment, Water, Heritage and the Arts (DEWHA 2010).

2.2.2 Operational Phase

A total of three sampling events were completed during the first year (2014-15) of operational phase population monitoring (Table 2). Spring sampling was not undertaken due to contractual delays and dry weather conditions.

Table 2: Timing of monitoring events undertaken in the 2014-15 breeding season.

Monitoring Event	Visual Search/Call Playback	Tadpole Sampling
Event 1	20/01/15 – 29/01/15	29/01/15 – 30/01/15
Event 2	04/03/15 – 10/03/15	09/03/15 – 10/03/15
Event 3	31/03/15 – 02/04/15	01/04/15 – 02/04/15

2.3 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.

2.4 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 200 metre 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) and photographed (dorsal surface pattern) to determine approximate age and sex. Individuals with a snout to vent length less than 68 millimetres were considered to be juveniles unless nuptial pads were present in which case they were classified as males (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 Kestral 3000 handheld weather meter. The weather variables recorded include relative humidity, air temperature, dew point, cloud cover, wind speed and direction. Also noted prior to sampling was the incidence of rainfall and moon phase.

2.5 Tadpole Surveys

Tadpole sampling was conducted to assess breeding activity by *M. iteratus*. Dip-netting and bait trapping were used to sample tadpoles. Dip-netting was conducted for a minimum duration of one hour per 200 metre 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 (in accordance with Anstis 2013) were recorded for each capture.

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

2.6 Water Quality Sampling

Water quality variables recorded during each tadpole sampling event included 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.

2.7 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.

Impacted and retained riparian areas were sampled at Grey's Dam and Woolgoolga Creek. At each site 4 x 25m long transects were established perpendicular to the stream, two transects in the impacted riparian area and two transects in the adjacent unaffected riparian area.

Floristic composition was assessed by establishing $25m^2$ 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 tape. 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 one metre intervals along each 25m transect to enable a quantitative measure of foliage cover of both native and introduced species. The proportion of leaf litter groundcover was also recorded using the same technique.

Leaf litter depth was recorded at five metre 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.

2.8 Data summary

The data have been collected and structured to enable both univariate and multi-variate statistical analysis. However, only univariate data analysis has been undertaken up to this point due mainly to the limitations associated with small sample sizes.

The revegetation monitoring data has only been subject to univariate analysis during the current monitoring event given that the initial trends between disturbed and undisturbed sites are very clear. However, the data structure and content will enable multivariate analysis and generation of dendograms, box-plots and cluster analysis at later stages in the monitoring program if required.

3.0 Results

3.1 Weather Conditions

Suitable weather conditions for sampling *M. iteratus* include warm air temperature (>18^{0}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). Conversely, the first year of the operational phase population monitoring (2015) was undertaken following a year of below-average rainfall (Figure 2).

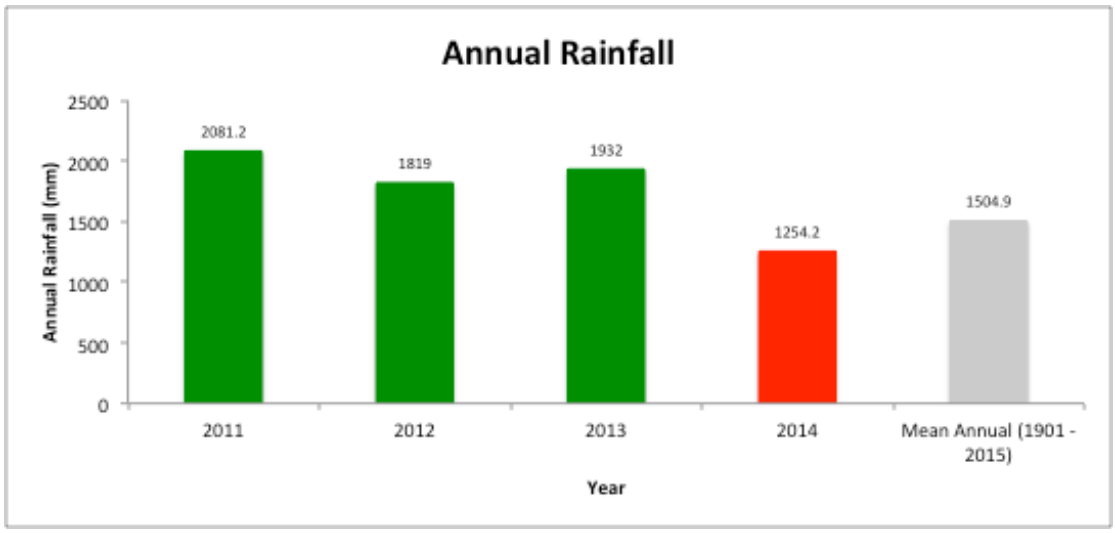

Figure 2: A comparison of the mean annual rainfall (1901 to 2015) and annual rainfall recorded during years in which population monitoring has been undertaken. Source: Bureau of Meteorology Lower Bucca Station No. 059006.

The weather conditions experienced during nocturnal field sampling for frogs were consistent with the suitable sampling conditions described above (Table 3). Field sampling was suspended during spring (2014) due to very dry weather conditions experienced throughout winter and spring. Field sampling was also suspended briefly during summer due to heavy rains and flooding in the locality. Furthermore, nocturnal field sampling was suspended if ambient air temperature fell below 18°C, which is thought to be the threshold temperature at which *M. iteratus* individuals burrow beneath the leaf litter (Koch and Hero 2007).

Table 3: Weather conditions recorded during nocturnal field sampling.

Site	Sampling Date	Air Temp[1] (C°)	Humidity[1] (%)	Rainfall 7 days prior[2] (mm)
Construction Phase Monitoring				
Arrawarra Ck	30/01/2012	24 – 25.3	79.4 - 86.4	383.6
	29/03/2012	19 - 20.5	83.1 – 89.2	19.2
	22/11/2012	19.9 – 20.4	100.0 – 100.0	72.4
	22/01/2013	23.9 – 24.9	80.0 – 83.0	6.4
	02/4/2013	19.3 – 19.3	89.0 – 90.0	18.6
Grey's Dam upstream	15/02/2012	23.1 - 23.3	70.2 – 83.4	91.2
	02/04/2012	18.8 - 20.1	75.5 – 82.9	16.4
	14/12/2012	18.5 – 21.9	73.3 – 94.0	37.6
	24/01/2013	23 – 23.7	85.6 – 85.9	9.8
	11/04/2013	19.0 – 20.9	82.2 – 89.5	84.4
Grey's Dam downstream	14/02/2012	22.4 – 25.0	69.2 – 80.0	91.0
	02/04/2012	21.7 - 23.8	72.1 - 73.5	16.4
	20/12/2012	26.4 – 27.2	72.6 – 74.9	1.4
	24/01/2013	22.8 – 23.6	92.2 – 93.7	9.8
	11/04/2013	20.9 – 23.5	73.4 – 81.3	84.4
Woolgoolga Ck upstream	06/02/2012	25.8 - 26.9	76.2 – 76.8	52.4
	28/03/2012	18.7 - 21.1	84.8 – 87.1	30.2
	21/11/2012	20.5 – 20.6	83.8 – 84.7	75.4
	31/01/2013	24.3 – 25.0	81.2 – 82.0	395.6
	03/04/2013	19.0 – 22.4	92.3 – 98.0	18.6
Woolgoolga Ck downstream	02/02/2012	20.5 - 21.4	93.8 – 98.3	65.6
	28/03/2012	18.7 – 18.9	84.2 - 87.1	30.2
	21/11/2012	19.9 – 20.5	82.0 – 84.7	75.4
	31/01/2013	24.3 – 24.8	81.4 – 82.9	395.6
	04/04/2013	18.0 – 22.0	92.0 – 100.0	17.0
Operational Phase Monitoring				
Arrawarra Ck	21/01/2015	21.9 – 20.8	91.4 – 95.2	35.0
	04/03/2015	27.0 – 25.1	70.0 – 75.5	47.0
	01/04/2015	21.6 – 19.7	80.1 – 91.9	12.2
Grey's Dam upstream	29/01/2015	25.3 – 23.2	58.7 – 60.9	122.6
	10/03/2015	24.6 – n/a	80.9 – n/a	67.0
	02/04/2015	22.0 – 20.2	87.1 – 90.3	37.2
Grey's Dam downstream	29/01/2015	23.8 – 22.9	64.7 – 61.9	122.6
	04/03/2015	24.0 – 23.9	79.0 – 86.3	47.0
	01/04/2015	19.9 – 20.6	90.8 – 85.8	12.2
Woolgoolga Ck upstream	20/01/2015	25.1 – n/a	74.1 – n/a	1.0
	05/03/2015	25.5 – n/a	63.9 – n/a	31.2
	31/03/2015	22.1 – n/a	85.3 – n/a	0
Woolgoolga Ck downstream	20/01/2015	n/a - 25.5	n/a – 74.3	1.0
	05/03/2015	n/a – 23.6	n/a – 70.5	31.2
	31/03/2015	n/a – 19.1	n/a – 91.9	0

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

2 – daily rainfall data source Bureau of Meteorology Woolgoolga Station.

3.2 Water Quality

The extended dry period and below-average rainfall leading into the 2014-15 breeding season affected water depth at all sample sites at commencement of monitoring in January 2015. The reduced stream flows resulted in relatively low pH levels and low turbidity levels at most sites in comparison to construction phase sampling.

Overall, the water quality sampling indicated little difference in water quality parameters between upstream and downstream sites and between monitoring events (Table 4). There was a slight increase in pH over the sampling period due to increased rainfall and higher stream flows.

Table 4: Water quality variables recorded at each site during each monitoring period.

Site	Date	Depth (mm)	pH	Temp (˚C)	Turbidity (ntu)
Construction Phase Monitoring					
Arrawarra Ck	23/02/2012	660	6.33	21.8	34.9
	27/04/2012	680	7.12	18.2	3.7
	22/11/2012	0	6.05	21.2	<10
	21/01/2013	0	6.19	24.8	46
	11/04/2013	552	5.9	19.3	14
Grey's Dam upstream	27/02/2012	600	6.68	22.9	588
	02/05/2012	650	6.58	19.1	360
	22/11/2012	0	6.12	20.8	12.5
	23/01/2013	0	6.68	27.3	<10
	11/04/2013	730	6.11	20.5	90
Grey's Dam downstream	24/02/2012	250	6	20.4	95.5
	02/05/2012	280	6.5	18.7	41.5
	23/11/2012	0	6.31	20.1	17.5
	23/01/2013	195	6.12	21.4	40
	08/04/2013	312.3	6.09	19.5	60
Woolgoolga Ck upstream	07/02/2012	760	6.15	23.4	n/a
	26/04/2012	920	6.5	18.3	n/a
	21/11/2012	620	6.03	21.1	<10
	03/02/2013	405	5.99	22.5	<10
	09/04/2013	662	6.04	21.3	<10
Woolgoolga Ck downstream	24/02/2012	510	6.38	22.9	15.3
	26/04/2012	660	6.27	17.9	26.5
	21/11/2012	490	6.3	20.1	<10
	03/02/2013	580	6.09	23.5	<10
	09/04/2013	n/a	6.21	22.5	<10
Operational Phase Monitoring					
Arrawarra Ck	29/01/2015	n/a	5.65	21.7	<10
	10/03/2015	n/a	6.0	22.0	12.0
	02/04/2015	n/a	6.09	20.4	32.0
Grey's Dam upstream	29/01/2015	n/a	6.1	22.6	35.0
	09/03/2015	n/a	6.05	25.3	80.0
	02/04/2015	n/a	6.22	21.9	20.0
Grey's Dam downstream	29/01/2015	n/a	6.2	22.4	18.0
	09/03/2015	n/a	5.94	22.6	35.0
	01/04/2015	n/a	6.11	20.7	<10
Woolgoolga Ck upstream	29/01/2015	n/a	6.0	22.7	14.0
	10/03/2015	n/a	6.03	22.5	<10
	01/04/2015	n/a	6.12	21.5	54.0
Woolgoolga Ck downstream	29/01/2015	n/a	6.01	22.7	14.0
	10/03/2015	n/a	6.0	22.9	<10
	01/04/2015	n/a	6.32	21.8	27.0

3.3 Frogs

3.3.1 Presence/Absence

The results of the operational phase nocturnal field surveys are provided in Appendix A and summarised in Figure 3. No male, female or juvenile individuals were recorded at upstream sites at Grey's Dam and Woolgoolga Creek in summer/autumn 2015. Adult males were recorded at downstream sites at Grey's Dam and Woolgoolga Creek. Adult females were recorded at Arrawarra Creek and downstream sites at Grey's Dam and Woolgoolga Creek. Only one juvenile was recorded at the downstream site at Grey's Dam.

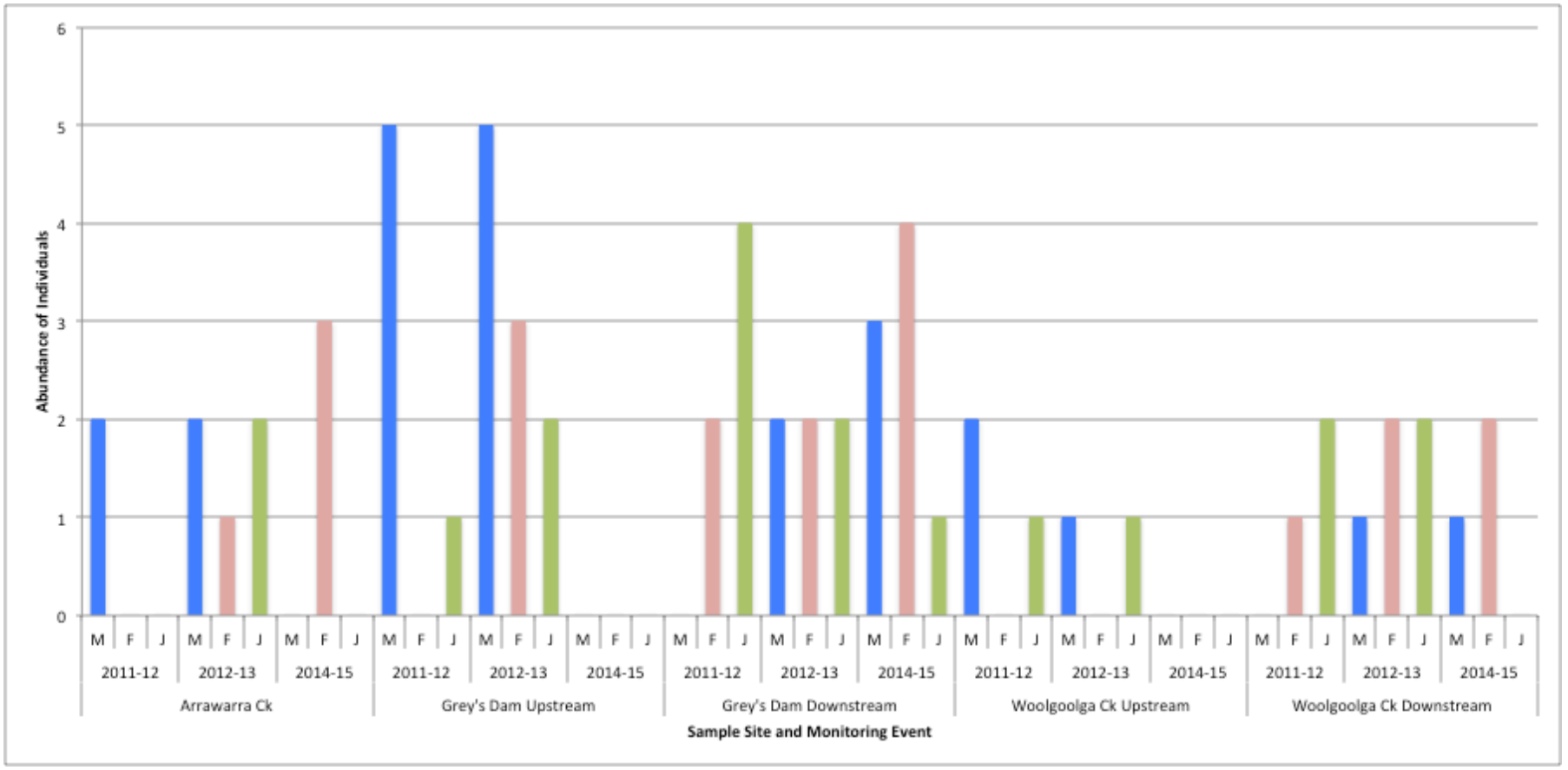

Figure 3: Adult and juvenile *M. iteratus* frogs recorded during the construction and operational phase monitoring periods.

Based on the dorsal pattern photographs one re-capture was recorded at the Greys Dam downstream site and one re-capture at the Arrawarra Creek site. At Grey's Dam downstream an adult male and female were observed in amplexus during the early March sampling and captured during the early April sampling (Plate 2). At the Arrawarra Creek site an adult female was captured during the early March sampling and recaptured during the early April sampling (Plate 3). No individuals recorded during the construction phase monitoring were re-captured during the operational phase monitoring. Furthermore, no movement of individuals between sampling sites was recorded.

Plate 2: Adult male observed in amplexus at Grey's Dam downstream in early March 2015 (L) and re-captured in early April 2015 (R).

Plate 3: Adult female captured at Arrawarra Creek in early March and early April 2015.

3.3.2 Relative Abundance

The pre-clearance surveys conducted prior to and during the vegetation removal phase of the highway upgrade applied similar survey methods and sampling effort to the monitoring program. Therefore, the pre-clearing data have been used to provide an indicative pre-impact baseline dataset (Figure 4).

The relative abundance of *M. iteratus* at each sampling site during the construction phase remained similar to or greater than that recorded during the pre-clearance surveys. However, relative abundance in summer 2015 was lower at all sites except the Grey's Dam downstream site (Figure 4).

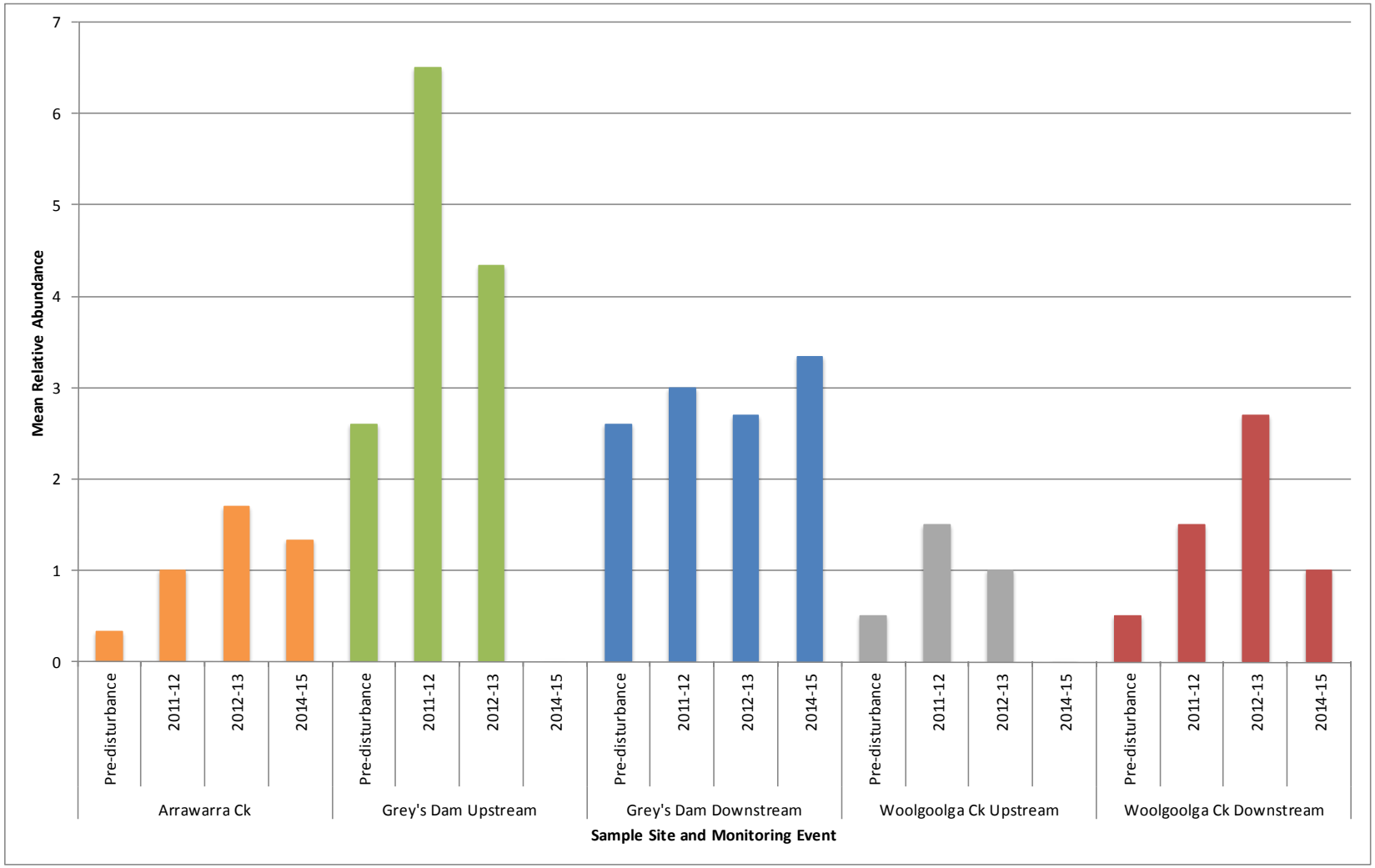

Figure 4: Comparison of mean relative abundance of M. iteratus from pre-disturbance surveys, construction phase monitoring and operational phase monitoring.

3.4 Tadpoles

During the construction phase *M. iteratus* tadpoles were recorded at the Grey's Dam upstream and downstream sites and the Woolgoolga Creek upstream site. Tadpoles were most frequently recorded at the Grey's Dam downstream site, while the highest abundance of tadpoles was recorded at the Grey's Dam upstream site (Table 5).

Table 5: Tadpoles captured during construction and operational phase monitoring periods.

Site	Date	No. Tadpoles Captured	Development Stage
Arrawarra Ck	23/02/2012	0	n/a
	27/04/2012	0	n/a
	22/11/2012	0	n/a
	22/01/2013	0	n/a
	12/04/2013	0	n/a
	29/01/2015	0	n/a
	10/03/2015	0	n/a
	02/04/2015	0	n/a
Grey's Dam upstream	**27/02/2012**	**3**	**25**
	02/05/2012	0	n/a
	22/11/2012	0	n/a
	24/01/2013	0	n/a
	11/04/2013	**23**	**26-36**
	29/01/2015	0	n/a
	09/03/2015	0	n/a
	02/04/2015	0	n/a
Grey's Dam downstream	**24/02/2012**	**2**	**25 and 26**
	02/05/2012	**3**	**25 and 26**
	23/11/2012	**1**	**37**
	24/01/2013	0	n/a
	09/04/2013	**2**	**26**
	29/01/2015	0	n/a
	09/03/2015	**1**	**26-36**
	01/04/2015	0	n/a
Woolgoolga Ck upstream	**07/02/2012**	**2**	**25**
	26/04/2012	0	n/a
	21/11/2012	0	n/a
	04/02/2013	0	n/a
	10/04/2013	0	n/a
	29/01/2015	0	n/a
	10/03/2015	0	n/a
	01/04/2015	0	n/a
Woolgoolga Ck downstream	24/02/2012	0	n/a
	26/04/2012	0	n/a
	21/11/2012	0	n/a
	04/02/2013	0	n/a
	10/04/2013	0	n/a
	29/01/2015	0	n/a
	10/03/2015	0	n/a
	01/04/2015	0	n/a

Only one *M. iteratus* tadpole was recorded during the operational phase monitoring. That tadpole was recorded at the Grey's Dam downstream site during sampling undertaken in March 2015 (Table 5; Plate 4).

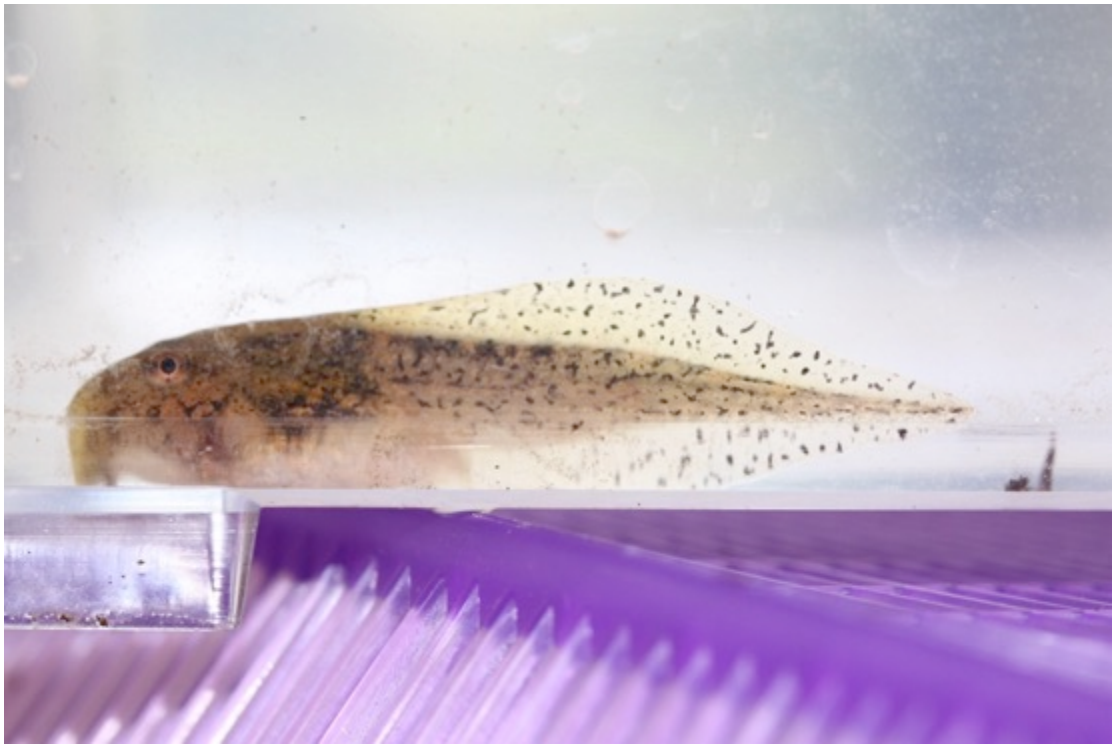

Plate 4: M. iteratus tadpole captured at the Grey's Dam downstream site in March 2015. Total length was 44.0mm. The development stage was in the range of 26 to 36. Note the high arch and angular spots on the tail fin, which are characteristic of the species.

Accurately determining the development stage of *M. iteratus* tadpole was not possible due to the formation of hind limb buds being hidden beneath a pouch of skin until stage 37. It was considered likely that closer examination to determine a more precise development stage would have been invasive and potentially harmful to the tadpole. Consequently, the development stage of the tadpole was stated as being somewhere between stage 26 and 36.

3.5 Riparian Habitat

3.5.1 Floristic Composition

Total species abundance and native species richness were clearly higher in the undisturbed areas, whilst exotic species richness was generally higher in disturbed areas (Figure 5). Higher proportions of native vine and woody species were recorded in the undisturbed areas than in the disturbed areas (Figure 6).

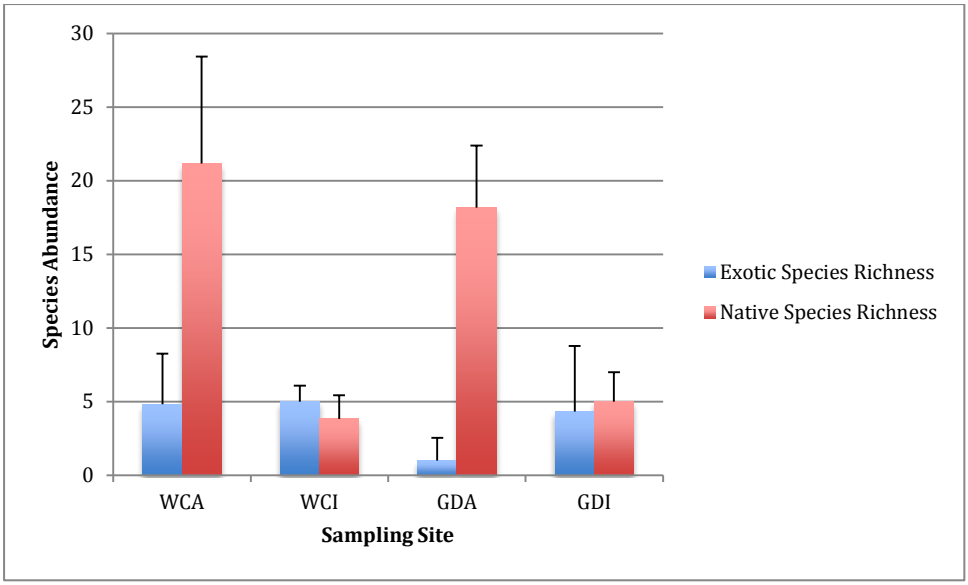

Figure 5: Comparison of native and exotic flora species richness in disturbed and undisturbed areas. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

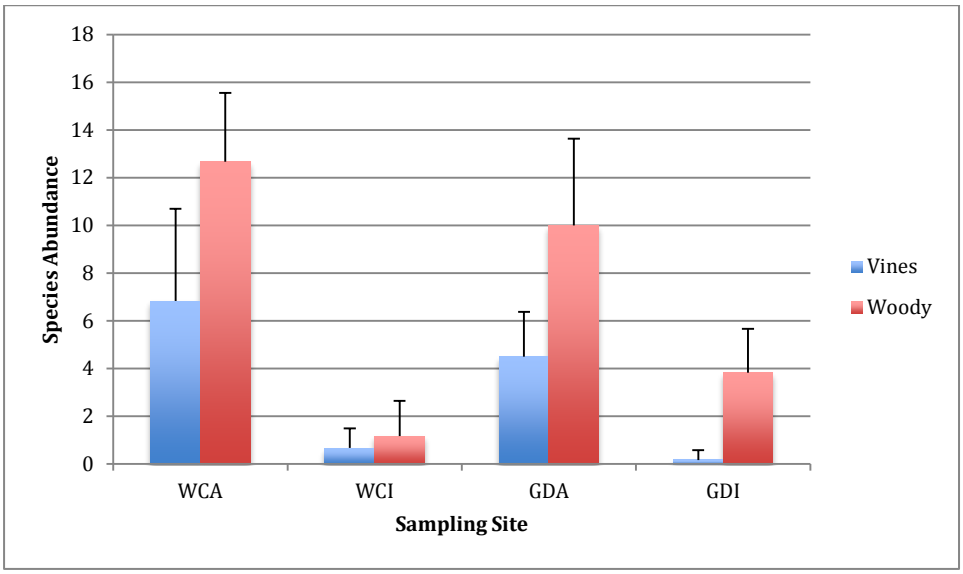

Figure 6: Comparison of abundance of vines and woody species in disturbed and undisturbed areas. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

3.5.2 Vegetation Structure

The projective cover of native vegetation was noticeably higher in adjacent undisturbed forest areas than in the disturbed riparian areas within the project alignment (Figure 7). Conversely, the cover of exotic species was substantially higher in disturbed areas within the project alignment than in adjacent undisturbed areas (Figure 7).

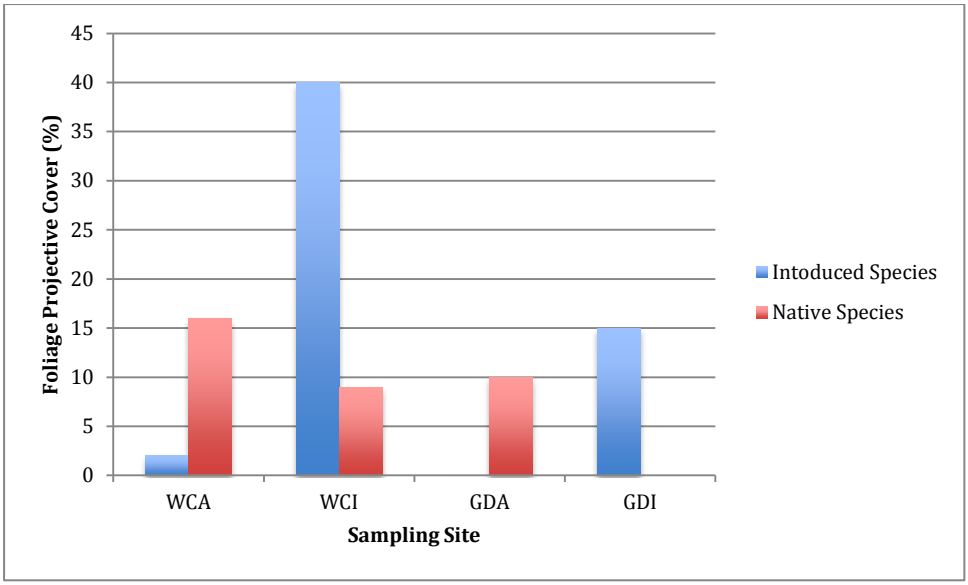

Figure 7: Comparison of foliage projective cover of native and introduced species in disturbed and undisturbed areas. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

Generally, the leaf litter cover and depth was substantially greater in undisturbed forest areas than in the disturbed riparian areas in the project corridor (Figure 8 and 9). However, leaf litter depth was highest at the greys dam impact area (Figure 9). The cover of grasses was higher in the disturbed riparian areas than in adjacent undisturbed forest areas (Figure 8).

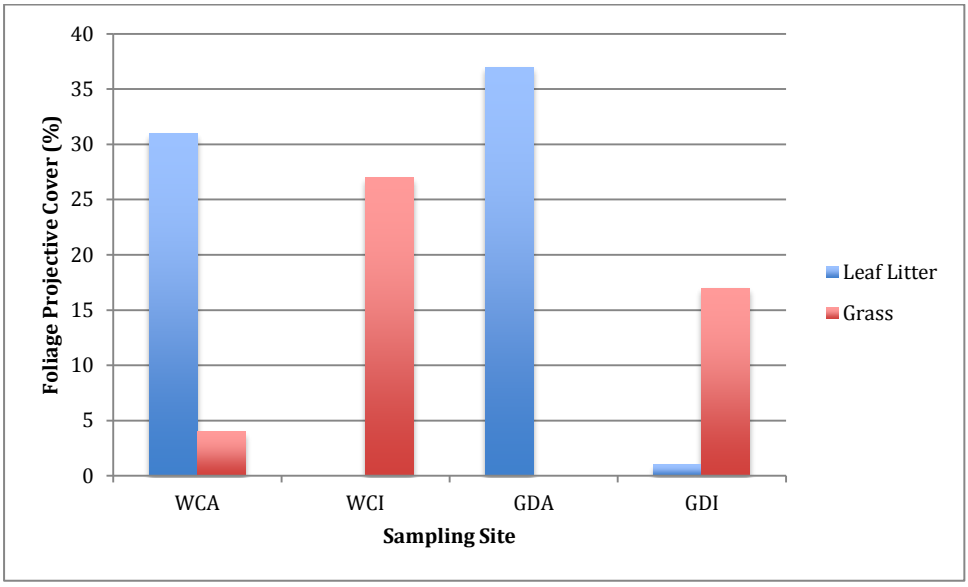

Figure 8: Comparison of projective cover of grasses and leaf litter in disturbed and undisturbed areas. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

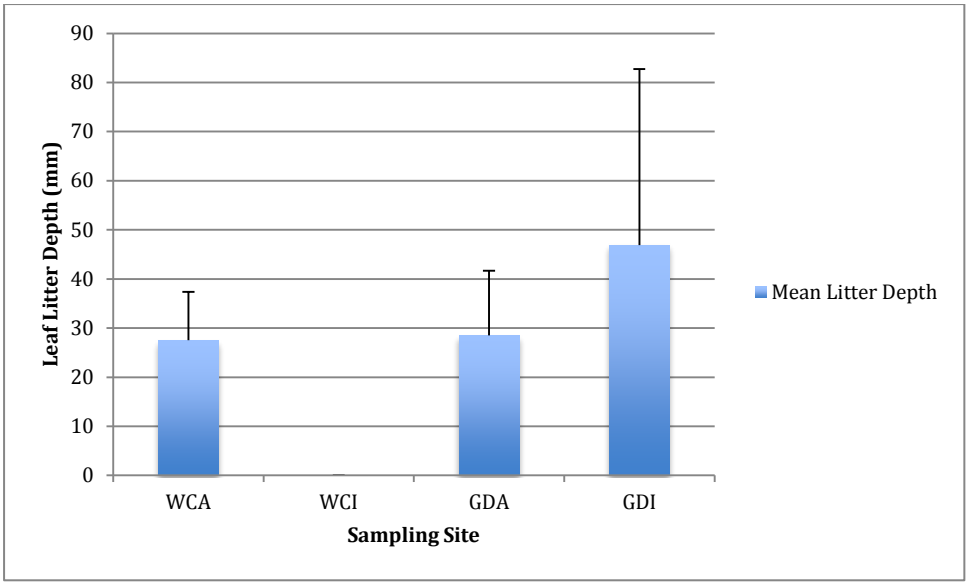

Figure 9: Comparison of mean leaf litter depth in disturbed and undisturbed areas. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Greys Dam undisturbed; GDI=grey dam impacted.

4.0 Discussion

4.1 Species Presence/Absence

The absence of *M. iteratus* from the Greys Dam upstream site could be due to a contraction of the sub-population during the extended dry period experienced during 2014. The site has always been considered to represent atypical or marginal habitat for the species, with individuals most likely colonising the area during periods of high rainfall, then contracting back to areas of higher quality habitat downstream during drier periods. The reasons for considering the Greys Dam upstream site as marginal or sub-optimal habitat for *M. iteratus* include: the lack of permanent stream flow (ie. sporadically spring fed); very few sequences of pools and riffles (i.e. site contains two dams connected by ephemeral flow) and limited width and continuity of riparian vegetation.

Absence of *M. iteratus* from the Woolgoolga Creek upstream site was also not unexpected given the consistently low abundance of individuals previously recorded at this site during construction phase monitoring. Factors that may have contributed to the poor result at this site during the 2014-15 breeding season include the delayed commencement of sampling resulting in a contracted monitoring period and the very dry conditions leading into the 2014-15 breeding season.

The dry conditions leading into the 2014-15 breeding season was also the most likely cause of the overall paucity of calling males at all sites as well as the very low abundance of tadpoles and juveniles at all sites.

4.2 Viability of Sub-populations

The apparent decline in the *M. iteratus* sub-populations recorded during the first operational phase monitoring period at the Grey's Dam and Woolgoolga Creek upstream sites was most likely due to the low annual rainfall received in the study area during 2014, which has probably resulted in a contraction of the *M. iteratus* sub-population within the wider Woolgoolga Creek catchment to areas

of optimal or higher quality habitat. This theory is supported to some extent by the increased mean relative abundance and continued presence of tadpoles and juveniles at the Grey's Dam downstream site, which contained higher quality habitat (e.g. unfragmented riparian vegetation, greater pool/riffle sequences and more reliable streamflow). Subsequent monitoring during years of higher rainfall should identify whether the sub-population is capable of re-colonising the affected upstream sites.

As mentioned in the previous section, the extended dry period experienced during 2014 was also the most likely cause for the very low abundance of tadpoles and juvenile frogs recorded at all sites during the first operational phase monitoring period. However, subsequent monitoring during years of higher rainfall should also clarify this issue.

Therefore, given the confounding influence of the extended period of below average rainfall experienced during 2014, it would be premature to conclude that the viability of the *M. iteratus* sub-population in the study area has been impacted by the construction or operation of the Upgrade project.

4.3 Effectiveness of Mitigation Measures

4.3.1 Sediment Controls

Water quality sampling recorded similar pH and turbidity levels upstream and downstream of the Upgrade corridor, which indicates that the Upgrade project has not caused any significant impact on water quality parameters likely to affect *M. iteratus* habitat quality.

4.3.2 Site Rehabilitation

There was limited evidence of site rehabilitation works in disturbed riparian areas within the project corridor. At the time of monitoring, grasses had been removed and replaced with a thick layer of wood chip mulch at the dry passage pipe at Greys Dam to encourage movement of frogs across the project corridor. This rehabilitation effort was evident in the reduced grass cover and increased litter depth recorded at this site (refer to results for site GDI in Figures 8 and 9).

The wet sclerophyll forest vegetation in undisturbed riparian areas adjacent to the project corridor was characterised by a moderately dense understorey layer of woody shrubs and vines, which was evident in the monitoring results (refer to Figure 6). Although absent from the disturbed riparian areas in the project corridor, such characteristics are expected to develop gradually in response to sustained site rehabilitation efforts.

As expected, the disturbed riparian areas had lower native plant species richness, higher exotic species richness, lower levels of leaf litter cover/depth and greater cover of grasses than the undisturbed forest sites due to the nature of recent disturbance (e.g. project construction), lack of canopy cover (i.e. lack of leaf litter generation) and increased light levels (i.e. exacerbating grass growth). However, these floristic and structural variables are expected to gradually change to more closely resemble the undisturbed forest areas in response to successful regeneration of native vegetation.

4.4 Recommendations

At the completion of the first operational phase population monitoring event there are several recommendations to be considered for inclusion in the ongoing management and monitoring of *M. iteratus* sub-populations and the species habitat within the project corridor:

- continue monitoring of site rehabilitation measures (e.g. revegetation of disturbed riparian areas at Woolgoolga Creek and Grey Dam);
- 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); and
- increase the frequency and intensity of weed monitoring and control in the disturbed riparian areas of the project corridor;
- increase the frequency of revegetation monitoring and infill plantings in the disturbed riparian areas of the project corridor.

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APPENDIX A: Nocturnal field survey results

Table A1: Raw field data - nocturnal frog surveys (Observers: DO – Don Owner; ST – Sally Townley; DR – David Rohweder; TT – Tim Thorncraft; TS – Tom St Vincent Welsh)

Date	Observers	Sex/Age	Obs. Type	Captured	Total Length (mm)	Weight (g)	Photo No.	Other Frog Species
Arrawarra Creek								
30/01/2012	DO; TT	male	visual	yes	80.6	n/a	3018-19	
29/03/2012	DO; ST	male	visual	yes	75.2	n/a	3245-46	*Mixophyes fasciolatus*
22/11/2012	DO; DR	No individuals recorded.						*Litoria tyleri; Limnodynastes peronii; Lit. fallax; Lit. gracilenta*
22/01/2013	DO; ST	male female	visual visual	yes yes	68 98.7	n/a n/a	3739-43 3744-51	*Lim. peronii*
02/04/2013	DO; ST	juvenile juvenile male	visual visual visual	yes yes yes	48 65.8 80.2	n/a n/a n/a	3825-28 3819-24 3811-18	*Lim. peronii*
21/01/2015	DD; ST	No individuals recorded.						
04/03/2015	DO; ST	female female	visual visual	yes yes	96.4 91.4	90 127	**866-868 To 872** 873-880	
01/04/2015	DO; ST	female female	visual visual	yes yes	101.5 98.7	170 92	4118-4134 **4104-4117 (same as**	

							872)	
Grey's Dam upstream								
15/02/2012	DO; ST	male	call	yes	79.3	n/a	3112	*Lit. tyleri; Lit. wilcoxii; Adelotus brevis; Lit. latopalmata; Lit. peronii; Crinia signifera*
		male	call	yes	81.9	n/a	3114-15	
		male	call	yes	78.8	n/a	3116-17	
		male	call	yes	71.4	n/a	3118	
		male	call	no	n/a	n/a	n/a	
		male	call	no	n/a	n/a	n/a	
		male	call	no	n/a	n/a	n/a	
02/04/2012	DO; ST	4 x male	call	no	n/a	n/a	n/a	*Lit. fallax; M. fasciolatus*
		male	visual	yes	81.2	n/a	3260-63	
		juvenile	visual	no		n/a		
14/12/2012	DO; TT	male	visual	yes	83.3	n/a	3690-92	*Lit. fallax; Lit. tyleri; Lit. latopalmata; A. brevis; M. fasciolatus*
		male	visual	yes	84.3	n/a	3693-95	
		juvenile	visual	yes	67.9	n/a	3696-99	
		juvenile	visual	yes	66.5	n/a	3700-05	
		male	call	no		n/a		

		male	call	no		n/a		
24/01/2013	DO; ST	male male male female	visual visual visual visual	yes yes yes yes	87.3 83.3 84.8 93.1	n/a n/a n/a n/a	3752-56 3757-62 3763-66 3767-71	*A.brevis; Lim. peronii; Lit. fallax; Lit peronii; Lit. tyleri; Lit. latopalmata*
11/04/2013	DO; TS	female female male	visual visual call	yes yes no	90 91.6	n/a n/a n/a	3902-19 3921-3928	*Lit. wilcoxii; M. fasciolatus; Lim. peronii; P. coriacea*
29/01/2015	DO; ST	No individuals recorded.						*M. fasciolatus; A. brevis; Lit. fallax; L. peronii; L. tyleri*
10/03/2015	DO; ST	No individuals recorded.						*M. fasciolatus; L. wilcoxii; A. brevis*
02/04/2015	DO; ST	No individuals recorded.						
Grey's Dam downstream								
14/02/2012	DO; ST	juvenile	visual	yes	49.2	n/a	3107-3111	*Lit. latopalmata; M. fasciolatus; Lit. wilcoxii; Lim. peronii*
02/04/2012	DO; ST	juvenile	visual	yes	48.1	n/a	3250	*Lit. fallax; Lit. wilcoxii*

		female	visual	yes	113.9	n/a	**3254-58**	
		juvenile	visual	yes	56.4	n/a	3248-49	
		female	visual	yes	96.7	n/a	3259	
		juvenile	visual	yes	53.8	n/a	3251-53	
15/02/2012	Incidental DO	juvenile	visual	no		n/a		
15/02/2012	DO; ST	4 x male	call	no	n/a	n/a		
20/12/2012	DO; TT	female	visual	yes	97.1	n/a	3706-9	*Lit. fallax; A. brevis; Lit. wilcoxii*
		female	visual	yes	109.8	n/a	**3714-25**	
		male	visual	yes	76.2	n/a	3726-28	
		male	call	no		n/a		
		juvenile	visual	yes	64.4	n/a	3729-36	
		juvenile	visual	yes	66	n/a	3737-38	
24/01/2013	DO; ST	male	call; visual	yes	77.4	n/a	3772-75	*Lit pearsoniana ; M. fasciolatus*
11/04/2013	DO; TS	female	visual	yes	111.7	n/a	**3885-3901**	*Lit. wilcoxii*
29/01/2015	DO; ST	female	V	Y	101.7	163	845, 846	
		juvenile	V	Y	36.4	5.3	847-849; 4055-56	
		male	C	N				
		male	C	N				

		female	V	Y	101.3	190	842-844	
04/03/2015	DO, ST	male M&F implexing	Visual V	Yes Observed	82.4	90	881-893	*M. fasciolatus; Lit. wilcoxii; Lit. peronei; P. coriacea*
01/04/2015	DO, ST	female male	V C; V	Y Y	107.7 83.3	198 80	4135-4154 **4155-4170**	*Lit. wilcoxii; M. fasciolatus*
Woolgoolga Creek upstream								
06/02/2012	DO; ST	juvenile male male	visual visual call	yes yes no	64.8 72.8 n/a	n/a n/a n/a	3025-26 3027-28	*Lit. latopalmata; Lit. fallax; A. brevis; M. fasciolatus; Lit. dentata*
28/03/2012	DO; ST	No individuals recorded.						
21/11/2012	DO; DR	male juvenile	call visual	no yes	 37.9	n/a n/a	 3540-44	*M. fasciolatus; A. brevis; Lit. fallax; Lim. peronii; Lit. latopalmata; Lit. tyleri; C. signifera*
31/01/2013	DO; ST	male	visual	yes	73.2	n/a	3776-81	*M. fasciolatus; A. brevis; Lim. peronii; Lit. dentata; Lit. latopalmata; Lit. pearsoniana*
03/04/2013	DO; ST	No individuals recorded.						*Lit. pearsoniana*
20/01/2015	DO; ST	No individuals recorded.						
05/03/2015	DO, ST	No individuals recorded.						*A. brevis; M. fasciolatus*

31/03/2015	DO, ST	No individuals recorded.						*M. fasciolatus; C. signifera; Lit. wilcoxii*
Woolgoolga Creek downstream								
02/02/2012	DO; ST	juvenile female	visual visual	yes yes	52.4 87	n/a n/a	3022-24 3020-21	*Lim. peronii; Lit. tyleri; Lit. latopalmata*
28/03/2012	DO; ST	juvenile	visual	yes	55.8	n/a	3219-20	*Lit. fallax*
21/11/2012	DO; DR	male juvenile	call visual	no yes	 62.6	n/a n/a	 3545-46	 *Lit. wilcoxii; Lit. pearsoniana*
31/01/2013	DO; ST	female male male	visual call call	yes no no	91.1	n/a n/a n/a	3782-88	*Lit. latopalmata; A. brevis*
04/04/2013	DO;ST	juvenile male female	visual call; visual visual	yes yes yes	59.5 72.6 94.5	n/a n/a n/a	3838-45 3829-37 3846-57	*Lit. wilcoxii*
20/01/2015	DO; ST	female	visual	yes	113	n/a	833-841; GPS 516713, 6668738	*Lit. nasuta; Lit caerulea; Lit. gracilenta*
05/03/2015	DO, ST	female male	visual visual	yes yes	102.4 86.7	158 100	899-903 904-910	
31/03/2015	DO, ST	No individuals recorded.						*Lit. wilcoxii*

Table A2: Summary of adult and juvenile M. iteratus frogs recorded during the construction and operational phase monitoring periods.

Site	Date	Males	Females	Juveniles	Recorded Sub-population 2011-12	Recorded Sub-population 2012-13	Recorded Sub-population 2014-15
Arrawarra Ck	30/01/2012	1	0	0	2 males	2 males 1 female 2 juveniles	3 females
	29/03/2012	1	0	0			
	22/11/2012	0	0	0			
	22/01/2013	1	1	0			
	02/04/2013	1	0	2			
	21/01/2015	0	0	0			
	04/03/2015	0	2	0			
	01/04/2015	0	2	0			
Grey's Dam upstream	15/02/2012	7	0	0	5 males[1] 1 juvenile	5 males[1] 3 females 2 juveniles	No frogs
	02/04/2012	5	0	1			
	14/12/2012	4	0	2			
	24/01/2013	3	1	0			
	11/04/2013	1	2	0			
	29/01/2015	0	0	0			
	10/03/2015	0	0	0			
	02/04/2015	0	0	0			
Grey's Dam downstream	14/02/2012	0	0	1	2 females	2 males[1]	3 males[1]

	02/04/2012 20/12/2012 24/01/2013 11/04/2013 29/01/2015 04/03/2015 01/04/2015	0 2 1 0 2 2 1	2 2 0 1 2 1 1	3 2 0 0 1 0 0	4 juveniles	2 females 2 juveniles	4 females 1 juvenile
Woolgoolga Ck upstream	06/02/2012 28/03/2012 21/11/2012 31/01/2013 03/04/2013 20/01/2015 05/03/2015 31/03/2015	2 0 1 1 0 0 0 0	0 0 0 0 0 0 0 0	1 0 1 0 0 0 0 0	1 male[1] 1 juvenile	1 male[1] 1 juvenile	No frogs
Woolgoolga Ck downstream	02/02/2012 28/03/2012 21/11/2012 31/01/2013	0 0 1 2	1 0 0 1	1 1 1 0	1 female 2 juveniles	1 male[1] 2 females 2 juveniles	1 male 2 females

	04/04/2013	1	1	1			
	20/01/2015	0	1	0			
	05/03/2015	1	1	0			
	31/03/2015	0	0	0			

1 = count excludes uncaptured calling males to prevent possible double-counting.

Table A3: Comparison of mean relative abundance of M. iteratus along each watercourse pre and post disturbance.

Watercourse Site	Sampling Site	Pre-disturbance[1]	2011-12 Breeding	2012-13 Breeding	2014-15 Breeding
Grey's Dam	Grey's Dam upstream	2.6 (n=5)	6.5 (n=2)	4.33 (n=3)	0 (n=3)
	Grey's Dam downstream		3 (n=2)	2.7 (n=3)	3.33 (n=3)
Woolgoolga Creek	Woolgoolga Ck upstream	0.5 (n=2)	1.5 (n=2)	1 (n=3)	0 (n=3)
	Woolgoolga Ck downstream		1.5 (n=2)	2.7 (n=3)	1 (n=3)
Arrawarra Creek	Arrawarra Creek	0.33 (n=3)	1 (n=2)	1.7 (n=3)	1.33 (n=3)

1 = sample sizes only include pre-clearing surveys with sampling effort and duration similar to that of the monitoring program.