Woolgoolga to Ballina Pacific Highway upgrade

Threatened Fish Monitoring Program Annual Report 2017

Construction Phase Annual Report 2017, Year 1

NSW GOVERNMENT

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RMS W2B Threatened Species Management – Threatened Fish

Stage 2 Aquatic Monitoring – Sections 6 - 9

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Introduction

The following report summarises the methods and results from the first year of threatened fish monitoring undertaken as part of the construction and operational phases of the Woolgoolga to Ballina Pacific Highway upgrade (W2B Upgrade).

1.1 Background

As part of the conditions of approvals required for construction of the W2B Upgrade NSW Roads and Maritime Services (Roads and Maritime) are monitoring a range of environmental factors prior to, during, and after construction, including threatened species. Formal environmental assessments undertaken during the planning phase of the W2B Upgrade revealed that a variety of threatened species listed under state and federal environmental legislation occur, or have the potential to occur, at various locations within or near the construction footprint. One species of threatened fish, Oxleyan Pygmy Perch (OPP) (*Nannoperca oxleyana*), was identified during the project EIS. As a result, a Threatened Fish Management Plan (RMS 2015) was prepared to inform monitoring and adaptive management actions for this species during all stages of the project. This report documents the results of the first year of monitoring conducted during the construction phase, with the data being assessed against comprehensive pre-construction surveys.

1.2 Objectives

The Threatened Fish Management Plan (Roads and Maritime 2015) states that monitoring will be conducted during construction and operation where known Oxleyan Pygmy Perch populations may be impacted, and for a period until such time as the mitigation measures have been proven to be effective over three consecutive monitoring periods.

Monitoring will provide information such that sound conclusions can be drawn in relation to management of threatened species. The overall monitoring objectives include:

- Evaluate the success of mitigation measures (including erosion and sediment control and pollution control measures).
- Determine the extent of secondary impacts of the project on Oxleyan Pygmy Perch populations and identify any additional mitigation measures that may minimise these impacts such as connectivity, stream mitigation, water quality and restoration of habitat.
- Determine the effectiveness of bridge design and bank rehabilitation in the management of Oxleyan Pygmy Perch.

1.3 Species Profiles

1.3.1 Oxleyan Pygmy Perch (OPP)

In NSW OPP are known to occur in Banksia-dominated coastal heath (wallum) ecosystems and coastal lakes as far south as Tick Gate Swamp (just south of Wooli). The systems where they are

usually found are dystrophic, acidic and freshwater (Knight & Arthington 2008) in addition to being shallow, slow flowing and narrow. They are mostly found over sandy and sometimes muddy benthos with high proportions of riparian cover, leaf litter and emergent aquatic plants. Typically, water depths are around 50 cm but OPP have been collected from depths of up to 130 cm. Water velocities are almost always below 0.4 m/sec, limiting occurrence to backwaters and small tributaries (Pusey, Kennard & Arthington 2004).

The predicted natural range of OPP in NSW is from the Queensland border south as far as the Manning River. In recent years, OPP have mostly been collected from the area around Evans Head NSW. OPP are known to be particularly sensitive to capture by nets. In particular, surveys using seine nets have resulted in significant mortality. The methods suggested for OPP surveys are electrofishing and setting unbaited standard fish traps. To minimise disturbances to breeding, surveys should be avoided between October and April inclusive.

Table 1.1 Summary of water quality information from NSW sites where OPP have been collected.

Measure	*Range*	*Mean ± SE*
Temp (°C)	10.9 – 28.3	16.1 ± 0.34
DO (mg/L)	2.15 – 10.02	6.42 ± 0.189
pH	3.32 – 6.9	4.47 ± 0.087
Cond (µS/cm)	68 - 2148	186 ± 22.7
Turbidity (NTU)	0 – 80	14 ± 3.6

From Knight & Arthington (2008)

2

Methods

2.1 Study Area and Monitoring Sites

The study area is located within Sections 6 – 9 of the W2B Upgrade corridor. In the first round of monitoring 27 sites were sampled. This was increased to 28 sites in the second round of monitoring. The waterways monitored included backwaters on flood-prone land, ephemeral swamps, farm drainage lines, natural creeks, dams and excavations. Of the total sites monitored nine are control sites.

The study area and location of sampling sites are displayed in **Illustrations 2.1** and **2.2**. A list of sampling locations is presented in **1Table 2.1**.

Due to the potential for construction impacts to extend along waterways, and the location of suitable habitat for the target species, some sites were located outside of the immediate W2B upgrade corridor. In most cases, the maximum distance from the highway corridor of individual impact sites was 200 m. For the same reason control sites were mostly located at a larger distance from the W2B upgrade corridor.

Table 2.1 A brief description of the significant waterways sampled during the survey.

Section	*Waterway*	*Location*	*Chainage*	*Notes*
7	Unnamed waterway south of Serendipity Rd	2	114000	Drains from headwaters approximately 1km upstream. Intermittent **Class 1** stream. OPP previously identified. **3 sites**, U/S, impact and D/S. Impact and D/S sites dry at time of sampling.
7	Tabbimoble floodway no. 1	3	115300	Drains from headwaters approximately 1.5km upstream. Intermittent **Class 1** stream. OPP previously identified. **2 sites**, impact and D/S.
8	Unnamed waterway south of MacDonalds Ck	10	134600	**Class 1** waterway, draining flood prone land connecting with Broadwater NP. OPP previously identified. **3 sites**, U/S, impact and D/S. U/S site dry at the time of survey.
8	MacDonalds Ck tributary	11	135200, 135530, 136450	Manmade drains connecting cane fields and flood prone land in Broadwater NP with a small natural **Class 1** waterway. OPP previously identified. **4 sites**, 3 at impact and 1 D/S.
8	MacDonalds Ck	12	136600	**Class 1** waterway draining flood prone land connecting with Broadwater NP. OPP previously identified. **3 sites**, U/S, impact and D/S.
8	Various dams south of Broadwater National Park	22	136700 - 137900	Four manmade dams and excavations on private property. OPP previously identified. Each individual waterbody sampled at **1 site** only. All located E (D/S) of impact.
9	Dam on western side of highway	25	138000	A dam or excavation on private property. Individual waterbody sampled at **1 site** only. Located U/S of impact.
9	Broadwater NP Swampland	16	139000	Series of wetland pools throughout protected wallum country. **Class 1** stream. OPP previously identified. **3 sites** one Impact, one E and one W.

Section	*Waterway*	*Location*	*Chainage*	*Notes*
9	Various potential refuges	27	139200 - 140500	Series of wetland pools throughout protected wallum country. **Class 1** stream. OPP previously identified. **6 sites** all located E of the impact.
9	Various dams north of Broadwater National Park	26	140900 - 142300	Five manmade dams and excavations on private property. OPP previously identified. Each individual waterbody sampled at **1 site** only. All located E (D/S) of impact.
9	Montis Gully tributary 1	13	141180 141850	Series of **Class 1** waterways and canals draining agricultural land and flood prone land. OPP previously identified. **5 sites**, 2 upstream, 2 impact and 1 D/S.

A control site was monitored for each of the locations with a confirmed population of OPP. Control sites were selected according to the methods set out in the *Threatened Fish Management Plan* (Roads and Maritime 2015) for the W2B Upgrade. The locations of control sites are presented in in **Illustrations 2.1** and **2.2**.

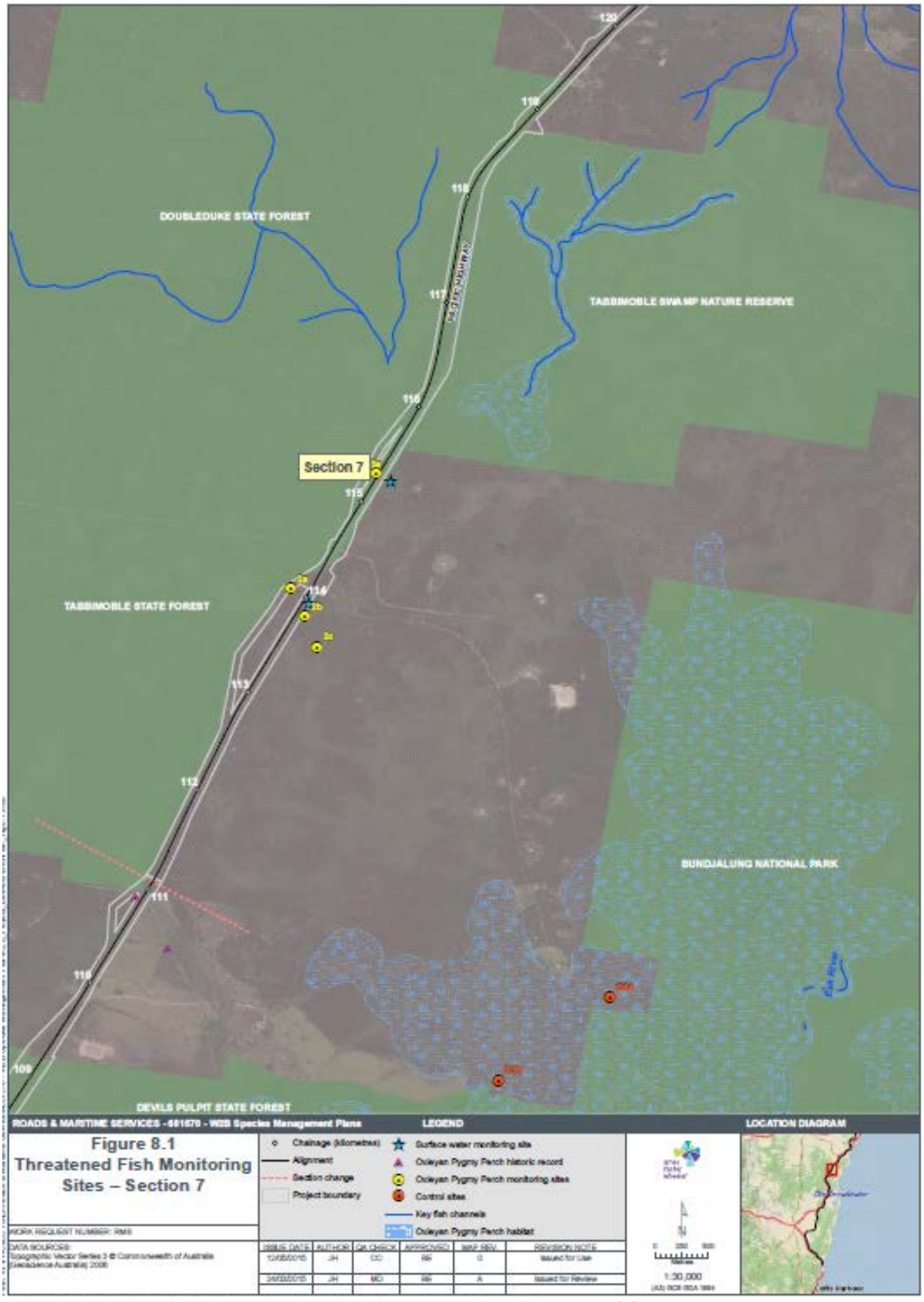


Illustration 2.1 Map of Section 7 sampling sites taken from the TFMP (RMS 2015)

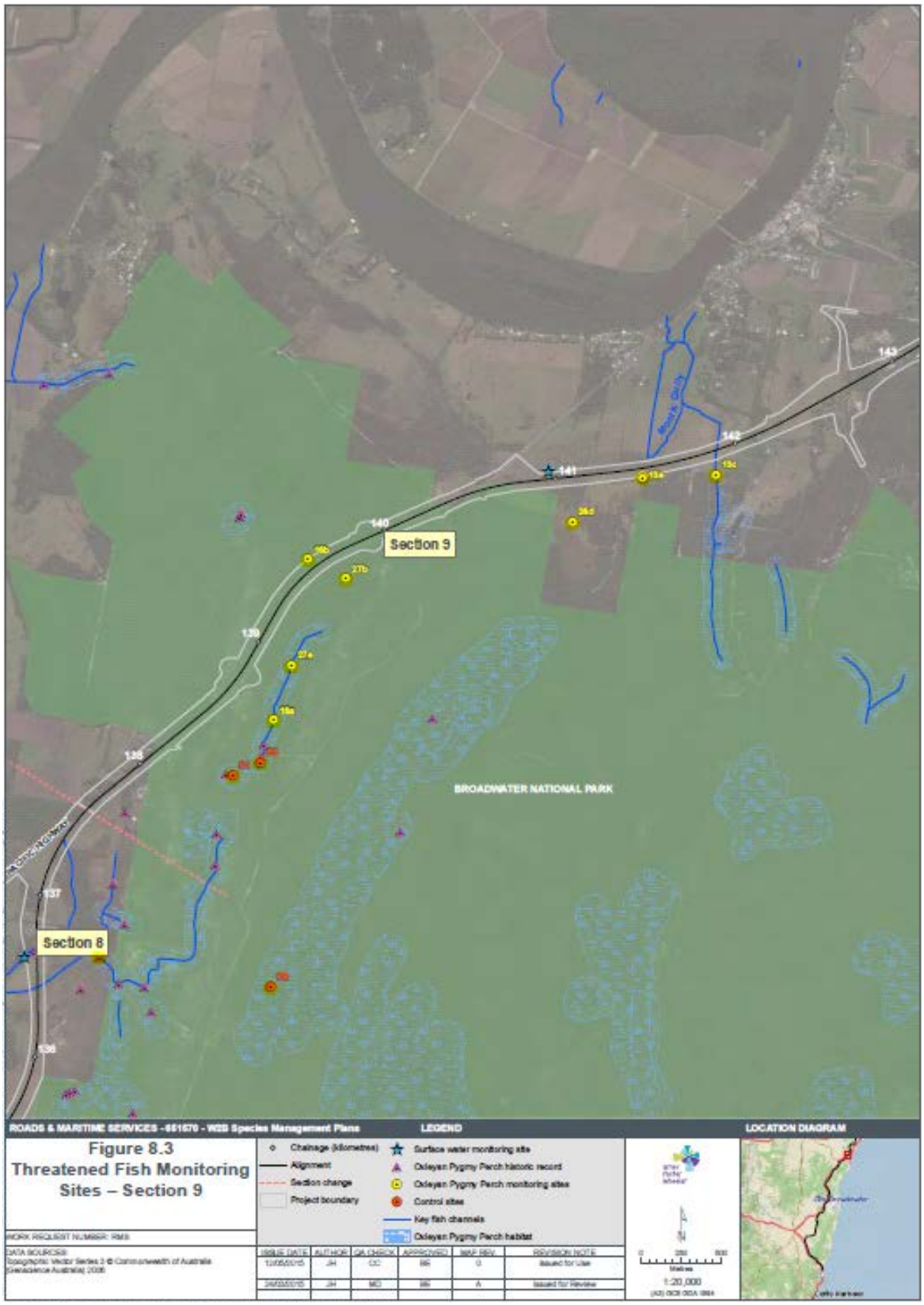


Illustration 2.2 Map of Section 8 and 9 sampling sites taken from the TFMP (RMS 2015)

2.2 Timing

Bi-annual targeted threatened fish monitoring is to occur in May/June and August/September and align with the methods undertaken for the pre-construction survey. Accordingly, the first round of surveys during the construction phase was undertaken in May and June 2017. The second round of surveys was undertaken in September 2017. Monitoring was scheduled to avoid the OPP breeding season which is thought to peak between October and April, and timed to ensure optimum conditions with respect to water levels.

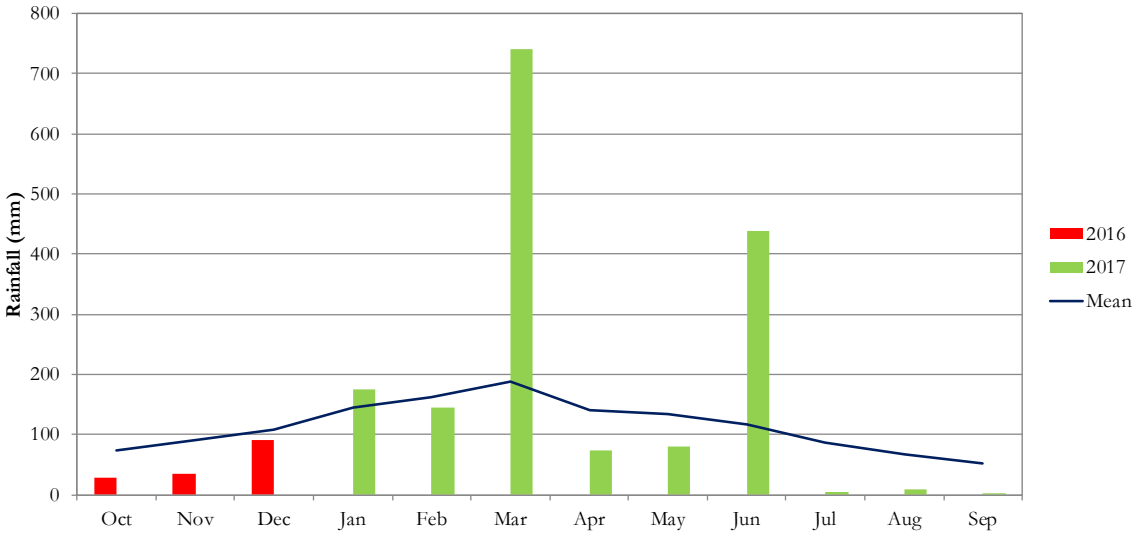


Figure 2.1 Mean monthly rainfall and total monthly rainfall from the Woodburn Bureau of Meteorology station for the 12-month period prior to and during construction sampling.

The long-term rainfall was below average for 5 of the 7 months prior to the May/June survey beginning and 8 of the 11 months prior to the September/October survey beginning (**Figure 2.1**). However, there was heavy, rainfall in March 2017 and again in June 2017. Most of the sites did not have significant flows (> 0.1 m/s) at the time of the surveys, but there was ample water to sample at the majority of sites.

2.3 Fish Survey

Fish sampling was undertaken under a Section 37 permit using a combination of back-pack electro-fisher and unbaited box traps, in accordance with procedures for Oxleyan Pygmy Perch outlined in the *Survey guidelines for Australia's Threatened Fish* (DSEWPaC, 2011), and Knight *et al.* (2007). In summary, this involved:

- The deployment of 10 unbaited standard collapsible bait traps at each site for a standard 30-minute period. Traps were redeployed for an additional 30-minute period where no Oxleyan Pygmy Perch were recorded at the sampling station in the first 30-minute period
- Undertaking back-pack electrofishing at each site, where safe to do so. Backpack electrofishing was restricted to shallow areas (e.g. <1 metre deep) due to safety issues with use in deeper water. The electrofisher settings were adjusted according to conductivity to ensure that fish were stunned temporarily. Settings were recorded at each site and are presented in **Table 2.2**. Sampling was undertaken at each site for 600 seconds of pulse time or two passes of all available habitats. Stunned fish were collected using a 5mm dip net (knotless mesh). If 30 individual OPP were captured at one site further efforts were

abandoned in order to minimise processing times and ensure that captured fish were released back into the environment in good condition.

Table 2.2 Details of electrofisher settings and effort at each site in the May 2017 sampling

Section	*Site*	*Voltage (V)*	*Pulse Freq (Hz)*	*Duty Cycle (%)*	*Passes*	*Seconds Pulsed*
7	2a	300	50	12	1.25	605
7	2b	175	50	12	1.25	602
7	2c	175	50	12	2	367
7	3a	250	50	12	1	600
8	10b	300	50	12	1	601
8	10c	175	50	12	1	589
8	11b	175	50	12	1	599
8	11d	150	50	12	1	620
8	12a	175	50	12	1	605
9	13b	Not fished				
9	13c	200	50	12	1	601
9	13e	225	50	12	1	603
9	16a*	275	50	12	0.75	521
9	16b	275	50	12	1	608
8	22b	200	50	12	1	604
8	22c	300	50	12	2	600
9	26d	300	50	12	2	600
9	27b	225	50	12	1	594
9	27e	225	50	12	1	605
Control	C1	275	50	12	1	604
Control	C2	200	50	12	1	617
Control	C3*	225	50	12	1	523
Control	C5	200	50	12	2	600
Control	C8	175	50	12	1	603
Control	C11	325	50	12	1	607
Control	C12	275	50	12	1.25	601
Control	C13	350	50	12	1	607
Control	C14	250	50	12	1	615

Table 2.3 Details of electrofisher settings and effort at each site in the September 2017 sampling

Section	*Site*	*Voltage (V)*	*Pulse Freq (Hz)*	*Duty Cycle (%)*	*Passes*	*Seconds Pulsed*
7	2a	175	50	12	2	601
7	2b	No Water				
7	2c	No Water				
7	3a	225	50	12	1	599
8	10b	Active dewatering				
8	10c	No Water				
8	11b	150	50	12	1	604
8	11d	100	50	12	1	601
8	12a	No Water				
9	13b	200	50	12	1	597

Section	*Site*	*Voltage (V)*	*Pulse Freq (Hz)*	*Duty Cycle (%)*	*Passes*	*Seconds Pulsed*
9	13c	250	50	12	1	596
9	13e	250	50	12	1	602
9	16a*	150	50	12	0.75	336
9	16b	175	50	12	1	613
8	22b	200	50	12	1	627
8	22c	200	50	12	2	599
9	26d	250	50	12	2	611
9	27b	250	50	12	1	607
9	27e	200	50	12	1	602
Control	C1	250	50	12	1	593
Control	C2	150	50	12	1	609
Control	C3*	150	50	12	0.75	317
Control	C5*	150	50	12	2	320
Control	C8*	175	50	12	1	417
Control	C11	100	50	12	2	338
Control	C12	250	50	12	1	603
Control	C13	350	50	12	1	601
Control	C14	No water				

All captured fish were retained in aerated storage buckets until all fishing at the station had been completed to avoid skewing results with recapture. Captured fish were identified, counted and measured for total length. Abnormalities including wounds or deformities were recorded at the time of capture. Exotic species captured were euthanased in accordance with approved animal ethics procedures (Barker *et al.*, 2009).

2.4 Water Quality

At each site physico-chemical water quality parameters were measured in surface water with an HORIBA U52 multimeter to determine the suitability of the site for Oxleyan Pygmy Perch in terms of water quality. The parameters measured were temperature, conductivity, dissolved oxygen, pH and turbidity.

2.5 Habitat Description

A general description of the habitat characteristics of each monitoring site was made, documenting riparian vegetation characteristics and condition, stream substrate composition and profile, areas of bank erosion and sedimentation, and overall aquatic habitat condition. The methods described in Pusey, Kennard & Arthington (2004) formed the basis of habitat descriptions.

At each monitoring site the following in-stream habitat features were recorded as key determinants of habitat suitability for the target fish species:

- average channel depth from 3 points in each site;
- average stream width from 3 points in each site;
- per cent cover of large woody debris (>150 mm stem diameter), small woody debris and leaf litter from 12 points in each site;

- per cent cover of submerged and emergent macrophytes from 12 points in each site. Species of aquatic vegetation were also recorded;
- substrate composition from 12 points in each site in per cent cover of mud, sand, fine gravel (2-16mm), coarse gravel (16-64 mm), cobble (64-128 mm), rock and bedrock;
- per cent of bank classified as undercut (20 cm overhang), or as root masses averaged from 4 transects at each site;
- per cent cover of riparian vegetation averaged from 4 transects at each site; and
- flow rates.

In order to collect this data three transects were positioned perpendicular to stream flow and the substrate composition, debris cover and vegetative cover were estimated in four 0.5 m^2 quadrats randomly positioned along each transect. Wetted width and depth were also measured at each of these transects. Additionally, 4 transects, representing a total of 20 per cent of wetted stream perimeter, were randomly positioned along each bank and estimates of root masses, bank and vegetation overhangs and riparian cover were made along each transect.

At some sites, the steepness of the banks and depth of the water combined to make it difficult to lay and interpret quadrats. On such occasions, and on others where the wetted width of the stream was less than 2.5 m, the full complement of 12 quadrats was not utilised.

In addition to the above structural habitat descriptions an inventory of aquatic plants at each site was compiled.

Photographs were taken facing upstream and downstream from a standard, central position at each site. The locations of the photographic monitoring point as well as upstream and downstream site boundaries were recorded with a GARMIN GPS map 62 handheld GPS to facilitate repeat sampling. All spatial data were collected and are reported in WGS84.

3

Results

3.1 Fish Survey

During the May 2017 survey approximately 280 hours of fish trapping and 15,901 seconds of electrofishing were used. During the September 2017 survey approximately 208 hours of fish trapping and 11,993 seconds of electrofishing were used.

In the May 2017 survey a total of 1,949 fish from eight species were captured. Of the total number of fish captured, 1,176 individuals from eight species were captured using the electrofisher and 773 individuals from seven species were captured using fish traps.

In the September 2017 survey a total of 1,803 fish from eight species were captured. Of the fish captured during the September 2017 survey 1,092 individuals from eight species were captured using the backpack electrofisher and 711 individuals from six species were captured using bait traps.

In the May 2017 survey 229 individual OPP were captured. Of these, 138 were captured using the backpack electrofisher and 91 in fish traps. In the May 2017 survey OPP were captured at 11 of the 19 impact sites and at all nine control sites.

In the September 2017 survey 425 individual OPP were captured. Of these 237 were captured using the backpack electrofisher and 188 in fish traps. In the September 2017 survey OPP were captured at 12 of the 19 impact sites and at eight of the nine control sites.

The most common species of fish captured during both surveys this year was the Firetail Gudgeon, (*Hypseleotris galii*). Individuals of this species accounted for approximately 35 per cent of the total number of fish captured in the May 2017 survey and approximately 43 per cent of the fish captured in the September 2017 survey. Overall, OPP accounted for approximately 12 per cent of the fish captured in the May 2017 survey and 24 per cent of the fish captured during the September 2017 survey.

There has been a high degree of variation at most impact sites throughout the pre-construction and ongoing monitoring in terms of fish diversity and abundance (**Figure 3.1**). In the 2 surveys this year between two and seven species have been captured at each site. In the May 2017 survey the impact sites with the highest diversity of captured fish were 13e, 11b and 13c. In the September 2017 survey the impact sites with the highest diversity of captured fish were 2a, 3a, 11b, 13c, 13e, 22b and 26d.

Between 6 and 222 individual fish were captured at each site during the two surveys this year. The impact sites where the most fish were captured during the May 2017 survey were 10b, 11b and 12a. In the September 2017 survey the impact sites where the most fish were captured were 2a, 11b, 3a and 22b.

There were some sites where fish capture was not attempted during the two surveys this year due to either a lack of water at the time of the survey, ongoing construction activities at the time of the survey or, in the case of site 13b, late addition to the monitoring program. These sites include site 13b in the May 2017 survey and sites 2b, 2c, 10c, 12a (all dry) and 10b (being

dewatered for installation of scour protection around bridge abutments) in the September 2017 survey.

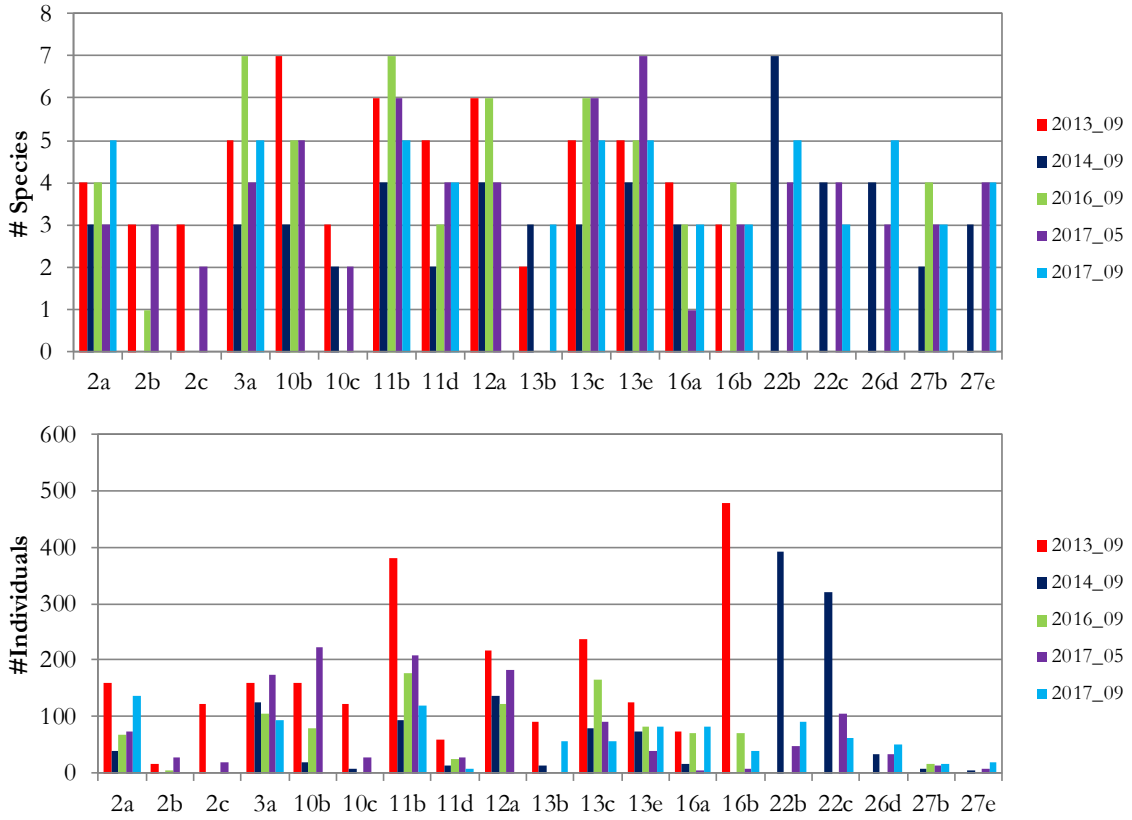


Figure 3.1 Taxonomic richness and abundance of captured fish at all impact sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

In contrast, there appears to have been less variation in both abundance and diversity detected at the control sites in the three surveys conducted there to date. (**Figure 3.2**). In the two surveys this year between two and seven species have been captured with the highest numbers of fish species observed at C13, C5 and C12.

The total number of individual fish captured varied between 14 and 221, with the largest numbers of fish captured at C8 and C12 in both the May 2017 and September 2017 surveys.

The numbers of OPP captured at each site are presented in **Figure 3.3** and **3.4**. There is a large degree of variation evident at both impact and control sites. With a few exceptions OPP have been captured at most sites in both surveys this year. The exceptions are either sites that dry out frequently (e.g. site 2c) or sites within the two subcatchments either side of Laing Hill (sites 10b, 10c, 11b, 11d and 12a).

No fish capture was attempted at control site C14 during the September 2017 survey due to a lack of water at the time of the survey.

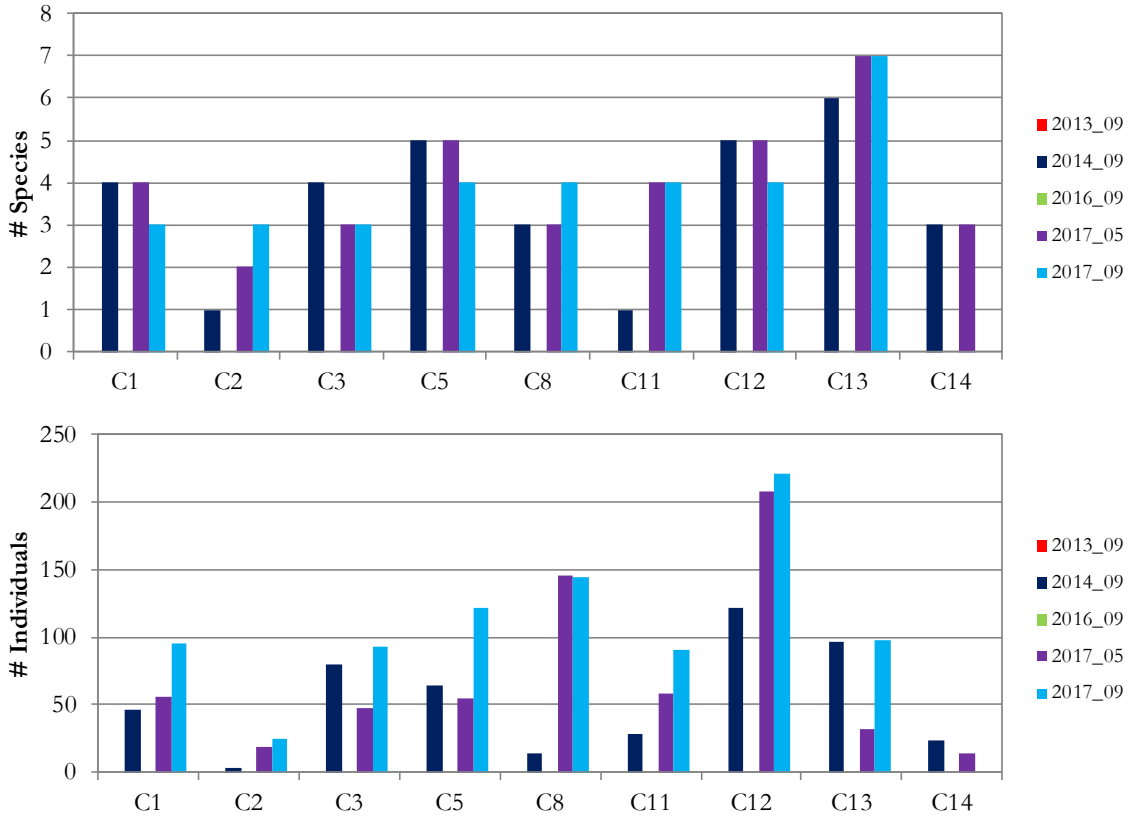


Figure 3.2 Taxonomic richness and abundance of captured fish at all control sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

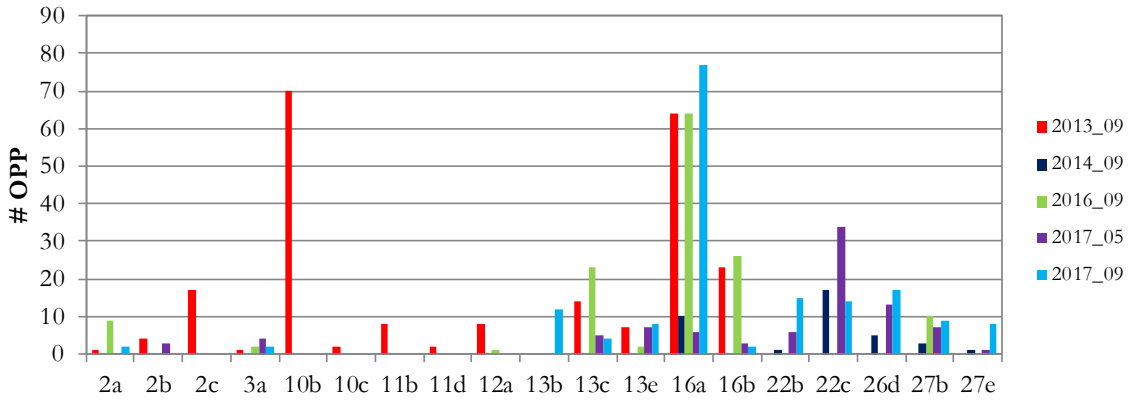


Figure 3.3 Number of OPP captured at all control sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

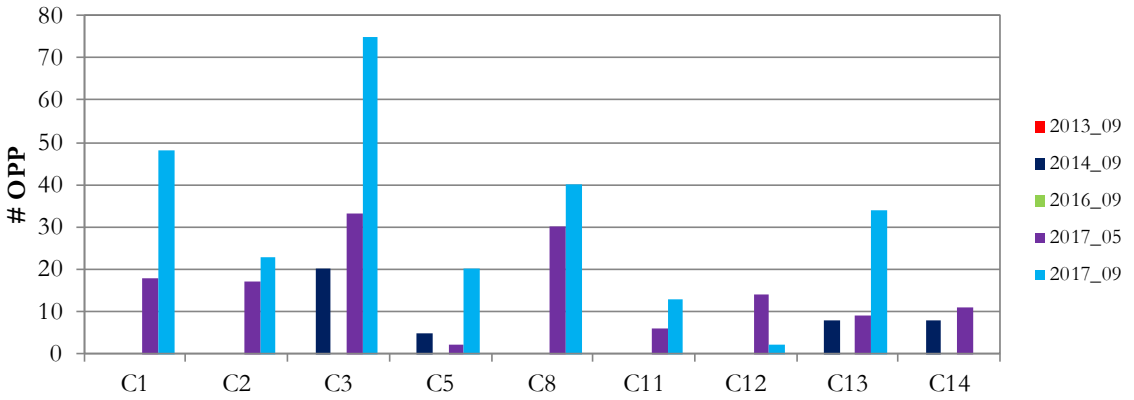


Figure 3.4 Number of OPP captured at all control sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

The full results of the May 2017 and September 2017 fish surveys are presented in **Appendix B**.

3.2 Water Quality

The results of water quality samples are presented in **1Table 3.1** and **3.2**. The results are indicative of the water quality at the time of sampling only and are likely to fluctuate considerably at each site according to weather and seasonal conditions.

Table 3.1 Results of water quality sampling from all sites for the May 2017 survey

Site	*Date*	*Temperature*	*pH*	*Conductivity*	*Turbidity*	*DO*	*DO%*
		°C		*mS/cm*	*NTU*	*mg/L*	*%*
2a	30/05/2017	16.00	**5.35**	0.105	17.4	**1.42**	14.9
2b	30/05/2017	14.38	5.64	0.146	20.8	3.15	31.8
2c	30/05/2017	13.85	**4.98**	0.275	16.5	4.58	45.8
3a	31/05/2017	13.73	**5.43**	0.089	13.5	4.61	46
10b	1/06/2017	15.55	**4.75**	0.333	3.8	**0.61**	6.4
10c	1/06/2017	12.50	**4.7**	0.249	5.7	**0.89**	8.6
11b	5/06/2017	14.95	**3.82**	0.154	0	2.69	27.6
11d	1/06/2017	14.16	**4.79**	0.137	0.1	5.74	57.7
12a	5/06/2017	13.36	**2.72**	0.25	0	**1.36**	13.4
13b		Not surveyed					
13c	6/06/2017	16.40	**3.71**	0.159	0	3.47	36.6
13e	6/06/2017	17.14	**3.8**	0.194	0	2.17	23.2
16a	2/06/2017	13.59	**3.7**	0.163	0	**2.14**	21.3
16b	1/06/2017	16.21	**4.31**	0.143	6.9	2.44	25.6
22b	7/06/2017	14.54	**3.44**	0.131	0	**0.74**	7.5
22c	7/06/2017	14.22	**3.45**	0.15	0	3.5	35.3
26d	6/06/2017	13.33	**3.39**	0.19	0	2.51	24.9
27b	6/06/2017	13.96	**3.97**	0.134	0	**0.62**	6.2
27e	2/06/2017	12.65	**3.69**	0.154	1.2	**1.26**	12.3
C1	2/06/2017	17.07	**3.96**	0.108	1	3.49	37.3
C2	7/06/2017	12.36	**3.31**	0.153	0	4.31	41.7
C3	2/06/2017	14.33	**3.56**	0.186	0	2.56	25.8
C5	5/06/2017	16.07	**3.72**	0.118	0	3.96	41.5
C8	7/06/2017	12.18	**3.21**	0.363	0	2.87	27.7
C11	31/05/2017	17.08	**4.09**	0.142	0	**1.76**	18.8
C12	31/05/2017	17.48	**3.79**	0.13	0	8.35	90
C13	30/05/2017	15.12	**4.84**	0.109	0	3.45	35.5
C14	31/05/2017	12.59	**5.27**	0.102	0.6	3.4	33.1

Red Text Outside of the known range of OPP
Blue Text Within a range thought to provide OPP with a competitive advantage

Table 3.2 Results of water quality sampling from all sites for the September 2017 survey

Site	*Date*	*Temperature*	*pH*	*Conductivity*	*Turbidity*	*DO*	*DO%*
		°C		*mS/cm*	*NTU*	*mg/L*	*%*
2a	11/09/2017	12.42	5.83	0.108	7.6	2.55	24.7
2b	11/09/2017	No water					
2c	11/09/2017	No water					
3a	11/09/2017	16.79	5.62	0.093	12.5	5.59	59.4
10b	14/09/2017	Site being dewatered for construction purposes – no water and no safe access					
10c	14/09/2017	No water					
11b	20/09/2017	19.34	5.71	0.148	5.5	2.83	31.6

Site	Date	Temperature	pH	Conductivity	Turbidity	DO	DO%
		°C		mS/cm	NTU	mg/L	%
11d	14/09/2017	24.69	5.97	0.178	5.6	7.98	97.9
12a	20/09/2017	No water					
13b	12/09/2017	15.75	**3.75**	0.172	2.1	**0.95**	9.9
13c	12/09/2017	18.82	**3.47**	0.137	3.1	2.38	26.3
13e	12/09/2017	19.27	**3.59**	0.179	0	**1.08**	12
16a	20/09/2017	20.18	**4.1**	0.161	6.9	8.3	94.1
16b	13/09/2017	21.38	**4.6**	0.23	64.2	7.15	82.9
22b	15/09/2017	21.06	**4.27**	0.135	212	8.65	99.8
22c	15/09/2017	14.96	**4.18**	0.152	6.4	4.59	47
26d	12/09/2017	13.76	**3.67**	0.206	4.1	4.23	42.2
27b	13/09/2017	13.68	**3.99**	0.116	11	4.14	41.2
27e	20/09/2017	17.09	**3.92**	0.132	4.3	2.69	28.8
C1	13/09/2017	18.74	**3.73**	0.1	0	2.45	27.1
C2	14/09/2017	19.3	**3.99**	0.183	20.2	4.7	52.5
C3	13/09/2017	23.66	**3.42**	0.201	26.4	3.77	45.4
C5	15/09/2017	12.7	**3.89**	0.113	37.6	2.74	26.7
C8	14/09/2017	18.49	**3.46**	0.315	5	3.29	36.2
C11	19/09/2017	29.36	**4.54**	0.106	6.8	4.21	55.4
C12	11/09/2017	22.92	**3.94**	0.155	0.6	5.05	60.1
C13	19/09/2017	16.47	5.51	0.112	15	3.79	40
C14	19/09/2017	No water					

Red Text Outside of the known range of OPP
Blue Text Within a range thought to provide OPP with a competitive advantage

The results of the water quality measurements show that, at the time of sampling, the water quality at most sites was within the known physico-chemical tolerances of OPP (refer to **Table 1.1**). In the majority of cases the pH values were in the range thought to provide OPP with a competitive advantage. There were some sites where the water quality was outside of the known tolerance ranges of OPP with respect to pH or dissolved oxygen concentration.

The dissolved oxygen (DO) concentrations at some sites were below the levels thought to be ideal for fish survival and function (> 4-5 mg/L). However, as stated previously, OPP are commonly associated with dystrophic (low DO concentration) waterways and the swamps and streams in the wallum country favoured by OPP are typically low in DO. During the May 2017 survey OPP were captured from water with a measured DO concentration of 0.62mg/L and during the September 2017 survey OPP were captured from water with a measured concentration of 0.95 mg/L. These values are both lower than the reported ranges for OPP (Pusey *et al.* 2004).

A comparison of baseline water quality ranges with the ranges observed during the May 2017 and September 2017 surveys is presented in **Appendix C**. The comparison indicates that DO concentrations and pH values have been lower at many of the impact and control sites in the construction phase of monitoring. However, the lowest DO concentrations were measured at impact sites, in particular sites 2a, 10b, 10c, 12a, 22b, 27b and 27e in May 2017 and sites 13b and 13e in September 2017. OPP were captured at many of these sites during those survey times.

It is unknown if the more extreme DO and pH values are reflective of persistent conditions in the waterways. Additional, more frequent water quality monitoring is being undertaken as part of the Woolgoolga to Ballina Water Quality Monitoring Program and more detailed information will be available in reports associated with that program. The more comprehensive and regularly collected data will provide a clearer picture of impacts potentially caused by the W2B upgrade.

3.3 Habitat Description

Habitat availability and condition varied across the study area. A brief description of the general habitat conditions at each location is presented in **Table 3.3**. Summary results from habitat surveys are displayed in graphical form in **Appendix A**. The two approaches, qualitative and quantitative, are intended to be used in conjunction. An inventory of aquatic plants found at each site is presented in **Table 3.4** and **Table 3.5**.

The flows were negligible (< 0.1m/s) at the majority of the sites visited.

Table 3.3 Brief descriptions of habitat features at all impact sites

Section	*Site*	*Habitat Description*
7	2a	Site 2a is located approximately 200m upstream of the upgrade corridor and consists of two pools located either side of a culvert on a dirt road. The benthic material was dominated by mud but varied across the site and included sand and gravel in some areas. Structural habitat at the site was comprised mostly of leaf litter, undercut banks and root balls, all of which were variable within the site. The riparian zone was well vegetated and continuous with adjacent forest. There was little aquatic vegetation. At the time of both surveys there was no flow.
7	2b	Site 2b is located in a shallow drainage line immediately downstream of a bank of 20 existing culverts under the Pacific Highway. There was very limited structural habitat. The benthic material was mostly mud with a small amount of gravel and sand. The riparian zone was sparsely vegetated but continuous with adjacent forest. At the time of the May 2017 survey there was no flow and at the time of the September 2017 survey there was no water.
7	2c	Site 2c is also located in a shallow drainage line approximately 300m downstream of the existing highway. Structural habitat was limited to a low proportional cover of leaf litter, other debris and grasses. The benthic material was mostly mud. The riparian zone was sparsely vegetated but continuous with adjacent forest. At the time of the May 2017 survey there was no flow and at the time of the September 2017 survey there was no water.
7	3a	Site 3a consists of a wide, shallow channel located directly upstream of an existing highway bridge. The benthic material is variable throughout the site, including mud, sand, fine gravel and coarse gravel. There is a variety of structural habitat available, including a number of fallen logs, a moderate cover of woody debris and leaf litter, dense beds of aquatic vegetation and occasional root balls and undercut banks. The aquatic vegetation is dominated by Water Ribbons (*Triglochin procerum*) and Maundia (*Maundia triglochinoides*). The margins are mostly steep. The riparian cover has been disturbed in recent times for construction. At the time of sampling there was no flow.
8	10b	Site 10b is an excavation located within the upgrade corridor at the point where a wide ephemeral wetland of variable depth drains out into open agricultural land. The benthic material was mud. Structural habitat availability varied throughout the site, although there was mostly a high proportional cover of leaf

Section	Site	Habitat Description
		litter and some emergent and submerged vegetation. The stream margins were gently sloping and grassy. There was no flow at the time of sampling. At the time of the September 2017 survey site 10b was being dewatered and part of the site was being infilled with scour protection rock.
8	10c	Site 10c consists of a shallow, broad, degraded natural drainage line through agricultural land. It is located downstream of the upgrade corridor. The stream margins were flat and grassed. Cattle access to the water was evident. Apart from submerged vegetation and occasional rushes there was very little structural habitat. The benthic material was mud. At the time of the May 2017 survey there was no flow and at the time of the September 2017 survey there was no water.
8	11b	Site 11b consists of a narrow channel, possibly modified by excavation, draining agricultural land and cane fields. The benthic material was mud, with a high proportional cover of debris. Other structural habitat included scattered rushes, regular root balls and trailing vegetation. The stream banks were relatively well vegetated with a mixture of trees, rushes and grasses. There was no flow at the time of sampling.
8	11d	Site 11d consists of a narrow, very shallow channel, probably modified by excavation, draining sugar cane fields. The benthic material was mud, with a high proportional cover of leaf litter and a regular but sparse cover of emergent aquatic plants. The stream margins were steep and grassy, with no undercutting, no trailing vegetation and very little root mass. At the time of the May 2017 survey the flow was 0.1 m/second and at the time of the September 2017 survey there was no flow.
8	12a	Site 12a consisted of a narrow channel, possibly modified by excavation, draining agricultural land. The benthic material was mud, with a high proportional cover of leaf litter and dense emergent plants, mostly Grey Rush (*Lepironia articulata*) and Jointed Twig-rush (*Baumea articulata*) in some areas. The degree of riparian cover, undercutting and root mass varied across the site. There was no perceptible flow at the time of the May 2017 survey. The site has now been significantly modified by a diversion and there was no water at the time of the September 2017 survey.
8	22b	Site 22b is an excavation located approximately 100m E of the upgrade corridor on a private property. The margins of the dam varied between gently sloping and steep and were moderately vegetated. Structural habitat was dominated by submerged vegetation and trailing vegetation with occasional debris. The benthic material was mostly sand. There was no flow.
8	22c	Site 22c is a deep excavation located in an agricultural drainage line approximately 250m E of the upgrade corridor on a private property. The margins were well vegetated and there was a high proportion of trailing vegetation, mostly Sphagnum moss and Bladderwort (*Utricularia sp.*). Structural habitat is limited in the middle but around the margins consisted of submerged vegetation and occasional debris. The benthic material was mostly sand. There was no flow.

Section	*Site*	*Habitat Description*
9	16a	Site 16a consists of a wetland pool in an old sand mining channel located within Broadwater National Park approximately 150 m to the east of the existing highway. It varied from deep to shallow along its length. The benthic material was mud and sand and the site contained little structural habitat aside from a regular but low proportional cover of leaf litter high proportional cover of submerged vegetation and scattered emergent vegetation. At the time of the May 2017 survey the pool was continuous with the surrounding swamp forest with no defined margin. There was no flow at the time of the survey.
9	16b	Site 16b consists of a wide, shallow wetland pool located approximately 50m to the west of the existing highway. The benthic material was a mixture of sand and mud. Structural habitat availability varied across the site with a dense cover of emergent aquatic plants in some areas, a moderate cover of leaf litter and small woody debris in some areas and bare sediment in others. The margins were gently sloping and have now been cleared of vegetation on the eastern margin to accommodate for construction. There was no flow at the time of the survey.
9	27b	Site 27b is a shallow, natural depression in a paperbark swamp. At the time of sampling it was continuous with the surrounding forest with no clear margin. Structural habitat was formed by a high proportional cover of submerged vegetation and leaf litter, irregular woody debris and scattered but dense stands of emergent rushes, mostly Jointed Twig-rush. The benthic material was mud with no flow evident at the time of sampling.
9	27e	Site 27e is a shallow, natural depression in a paperbark swamp. At the time of sampling it was continuous with the surrounding forest with no clear margin. Structural habitat was formed by a high proportional cover of leaf litter, regular woody debris and scattered submerged vegetation and stands of emergent rushes, mostly Jointed Twig-rush. The benthic material was mud with no flow evident at the time of sampling.
9	13b	Site 13b is located in a very shallow drain on agricultural land. The benthic material was dominated by mud, with a small proportion of sand. There was a high proportion of leaf litter and a moderate cover of emergent plants. The banks at this site were grassy with rushes and regular trees. There was no flow at the time of sampling. This site was only added for the September 2017 survey.
9	13c	Site 13c is located in a narrow, deep drain on agricultural land. The benthic material was dominated by mud, with a small proportion of sand. There was a high proportion of leaf litter and scattered small woody debris. Other structural habitat included root balls and occasional emergent vegetation. The banks at this site were grassy with rushes and regular trees. There was no flow at the time of sampling.
9	13e	Site 13e consists of a small billabong located along the path of an agricultural drain. It was approximately 15 m wide at its widest point and 1.2m deep. The margins were gently sloping and grassy. Most of the structural habitat was formed by submerged and emergent vegetation. The benthic material was dominated by mud with low percentage of sand. There was no flow.
9	26d	Site 26b is a deep pool in a shallow natural drainage line. The margins were very well vegetated and trailing vegetation was a major habitat feature. Other structural habitat included dense submerged vegetation and stands of emergent rushes. The benthic material was mostly sand and there was no flow at the time of sampling.

Plate 3.1 Site C14 was dry at the time of the September 2017 survey

Table 3.4 Aquatic plants identified at impact sites during 2017

Species Name	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Azolla spp	Azolla										x									
Bacopa monnieri	Water Hyssop		x																	
Baloskion (Restio) pallens	Zigzag Rush										x			x	x		x			
Baloskion (Restio) tetraphyllum	Feathery Rush														x	x	x	x		
Baumea articulata	Jointed Rush					x				x				x					x	x
Baumea rubiginosa	Baumea											x		x	x	x	x	x	x	x
Blechnum sp.	Fern										x							x	x	x
Carex fascicularis	Tassel Sedge	x	x		x			x		x								x	x	
Ceratophyllum demersum	Hornwort				x															
Cyperus sp.						x		x	x	x	x	x	x							
Eleocharis acuta	Common Spikerush						x	x			x		x					x		
Eleocharis pusilla	Spikerush				x		x		x				x							
Eleocharis sphacelata	Tall Spikerush											x	x							
Enteromorpha spp.					x	x	x		x	x					x			x		
Gahnia sieberana	Sawsedge	x						x		x	x			x	x	x	x	x	x	
Hydrocotyl verticilliata	Shield Pennywort		x																	
Juncus usitatus	Common Rush		x	x			x				x	x	x					x		
Lepironia articulata						x		x		x	x	x		x	x			x		x
Lomandra longifolia	Creek Mat rush	x	x	x	x															
Maundia triglchinoides	Maundia				x															x
Myriophyllum sp.	Millfoil				x															
Nymphaea sp	Waterlily					x				x		x	x			x				x
Paspalum distichum	Water Couch			x	x	x	x		x	x		x	x					x		
Persicaria deciepens.	Knotweed						x	x												
Persicaria lapathifolia	Knotweed					x	x	x		x	x	x								
Philydrum lanuginosum	Frogsmouth	x	x	x	x		x		x	x			x						x	
Schoenoplectus mucronatus	Marsh Clubrush							x												

Sphagnum sp.	Peat Moss								x		x		x	x	x	x	x	x	x	x
Triglochin procerum	Water Ribbons				x															
Utricularia sp.	Bladderwort					x						x	x	x		x	x	x	x	x

Table 3.5 Aquatic plants identified at control sites during 2017

Species Name	*Common Name*	*C1*	*C2*	*C3*	*C5*	*C8*	*C11*	*C12*	*C13*	*C14*
Baloskion (Restio) pallens	Zigzag Rush	x	x	x	x	x		x		
Baloskion (Restio) tetraphyllum	Feathery Rush	x	x	x	x	x				
Baumea articulata	Jointed Rush		x	x					x	
Baumea rubiginosa	Baumea		x	x	x	x	x	x		
Blechnum sp.	Fern								x	
Carex fascicularis	Tassel Sedge				x				x	
Cyperus sp.									x	
Eleocharis acuta	Common Spikerush							x	x	
Enteromorpha spp.						x		x		
Enydra fluctuans	Buffalo Spinach								x	
Gahnia sieberana	Sawsedge	x	x	x	x	x	x		x	
Juncus usitatus	Common Rush	x		x						x
Lepironia articulata		x	x							x
Liparophyllum exaltatum										x
Lomandra longifolia	Creek Mat rush								x	
Nymphoides indica	Water Snowflake								x	
Paspalum distichum	Water Couch								x	
Persicaria deciepens.	Knotweed								x	
Persicaria lapathifolia	Knotweed								x	
Philydrum lanuginosum	Frogsmouth								x	x
Sphagnum sp.	Peat Moss	x	x	x	x	x		x		
Triglochin procerum	Water Ribbons								x	x
Utricularia sp.	Bladderwort	x	x	x		x			x	

4

Discussion

The first two fish surveys during the construction phase for the W2B Threatened Fish monitoring were completed in May and September 2017. There were OPP captured at 13 of the 19 impact sites and all of the 9 reference locations. Habitat quality and availability varied across the sites sampled, as did water quality. At most of the sites the combination of available habitat and water quality were typical of sites that are favoured by OPP. In comparison with the results from the pre-construction threatened fish monitoring (GeoLINK 2014 & 2015) the results indicate that OPP populations have recovered in most of the areas adjacent to the future Pacific Highway following a severe period of drought in late 2013 and early 2014. More data is required to assess the impact of construction upon OPP populations but the data to date indicates that threatened fish management has been successful at this early stage of construction.

After a significant effort to identify and quantify threatened fish populations along the W2B upgrade corridor 18 impact and 9 control sites were identified for ongoing threatened fish monitoring. A further site (site 13b) was added prior to the September 2017 survey after OPP were observed there in August 2017 and changes to threatened fish management were proposed for the Montis Gully area (Chainage 140600 – 141200).

The fishing effort for the two surveys this year consisted of 488 hours of fish trapping and 27,894 seconds of electrofishing. A total of 1,949 fish were captured in May 2017 and 1,803 fish were captured in September 2017. These totals included 229 (12%) OPP and 425 (24%) OPP respectively. The OPP capture rates in the September 2013 and September 2014 surveys were 9% and 4% respectively when the same sites are considered. The sites where OPP were captured included:

- All nine control sites during both surveys, except site C14, which was dry at the time of the September 2017 survey.
- Sites 3a, 13c, 13e, 16a, 16b, 22b, 22c, 2dd, 27b, and 27e during both surveys.
- Sites 2a and 13b in the September 2017 survey only (Site 13b was not surveyed in May 2017).
- Site 2b in the May 2017 survey only (site 2b was dry at the time of the September 2017 survey).

The sites where OPP were not captured during either survey in the construction period included 2c, 10b, 10c, 11b, 11d and 12a. All of these sites except 2c are located in subcatchments either side of Laing Hill. OPP were captured at all of these sites in the first round of pre-construction monitoring (September 2013) but not in the second round of pre-construction monitoring (September 2014). Sites 2c, 10b, 10c and 12a were all dry during the September 2017 surveys. Additionally, site 10b was being actively dewatered for construction of scour protection around adjacent bridge abutments at the time of the September 2017 survey and access was not safe. Immediately prior to that dewatering process fish translocation was undertaken as per the requirements of the Environmental Work Methods Statement and the TFMP. No OPP were captured during the fish translocation effort.

There has been a high degree of variability in the numbers of OPP captured at each site during different surveys, particularly at the impact sites. Due to the opportunistic life cycle

strategies and quick responses to stochastic environmental factors displayed by OPP (Knight *et al.* 2012) it is expected that surveys conducted at different times would yield different results depending upon favourable or unfavourable breeding and dispersal conditions. It appears that breeding and dispersal conditions have been favourable in the year leading up to the commencement of construction (i.e. 2016). This is confirmed by the high proportion of juvenile OPP captured during both surveys (**Figures 4.1** through **4.4**) (Knight *et al* 2012). Approximately 70 per cent of the OPP captured in May 2017 and 73 per cent of the OPP captured in September 2017 were of a total length less than 25 mm.

Rainfall was close to average for December 2016, January 2017 and February 2017 (a significant part of the breeding season) and flooding rains in March 2017 may have aided dispersal, which happens during times of high flow when isolated, often ephemeral water bodies are connected by overland flows. This may explain the improved distribution of OPP in comparison with the results from the second pre-construction survey. The body length distribution data gives a good indication of the locations where recruitment has been strongest. In particular, recent recruitment to a number of the control sites, C2, C11, C12 and C13 appears to have been strong.

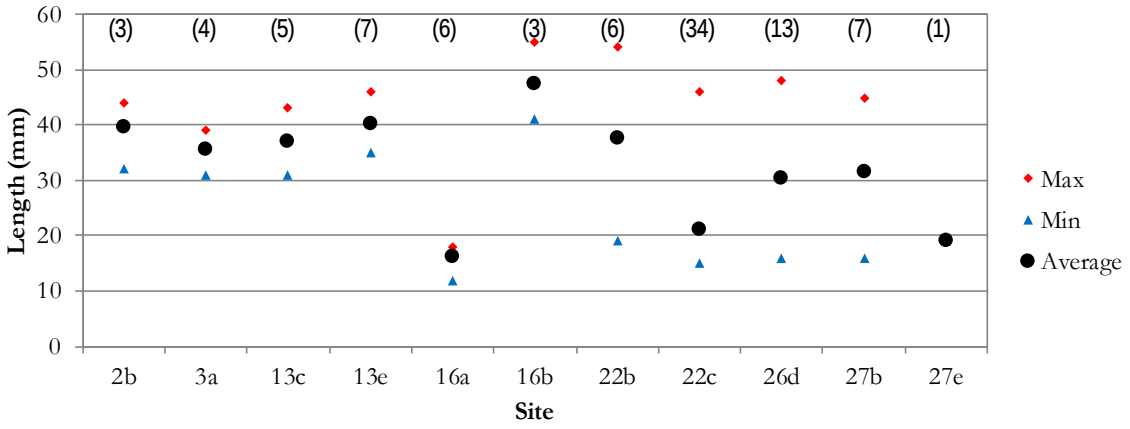


Figure 4.1 Length distribution data of all OPP captured at impact sites in the May 2017 survey (counts in brackets)

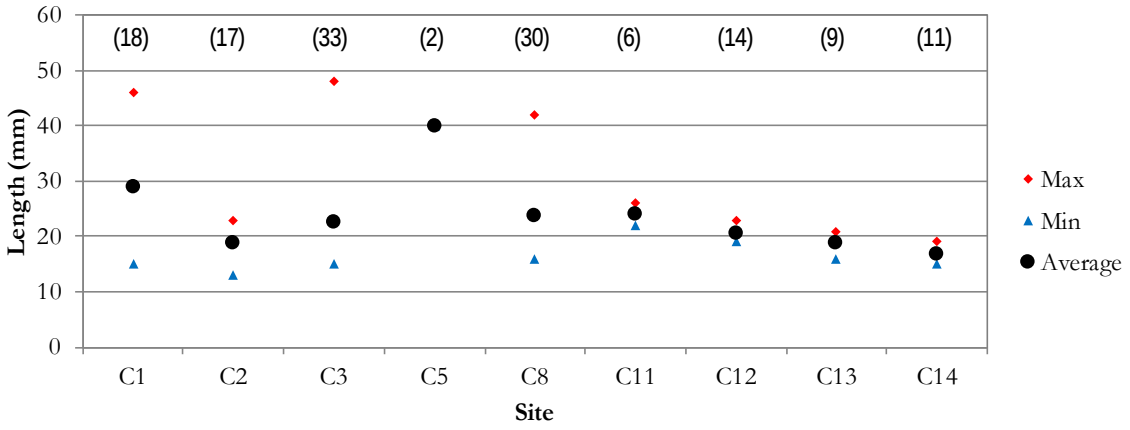


Figure 4.2 Length distribution data of all OPP captured at control sites in the May 2017 survey (counts in brackets)

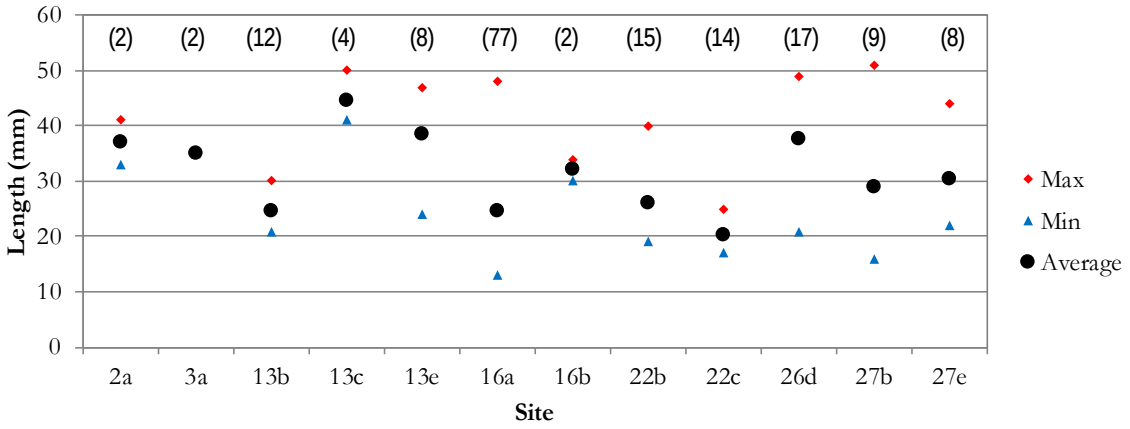


Figure 4.3 Length distribution data of all OPP captured at impact sites in the September 2017 survey (counts in brackets)

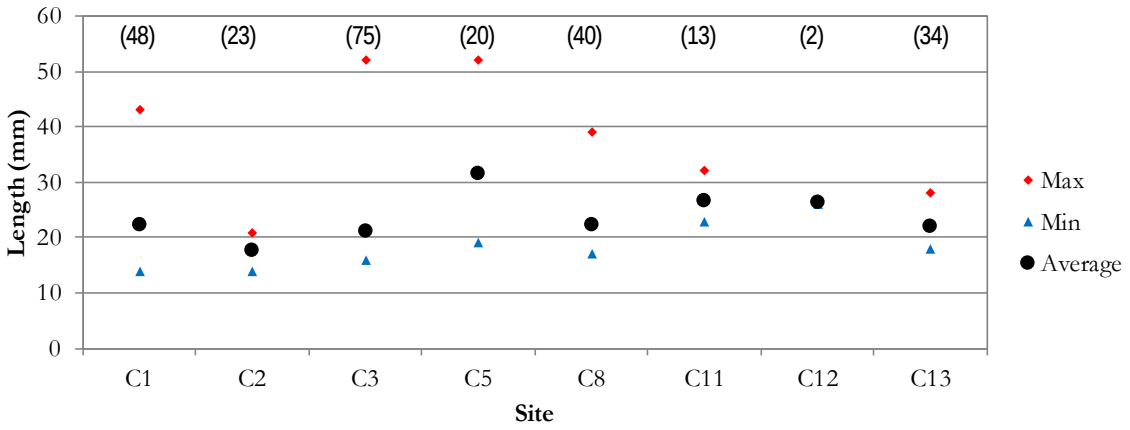


Figure 4.4 Length distribution data of all OPP captured at control sites in the September 2017 survey (counts in brackets)

There are a variety of potential reasons why OPP may not have been captured at the sites around Laing Hill during the first year of construction. These include impacts associated with construction and, potentially, with low DO concentrations measured at these sites. With the information available it is not possible to conclude whether low DO concentrations observed during the surveys in May and September 2017 are chronic or associated with construction activity. Construction activity at sites 10b, 10c, 11b, 11d and 12a was intense in the period leading up to both surveys. However, fish surveys associated with dewatering immediately prior to construction work in these waterways did not identify OPP at any of these sites. This indicates that it is likely that OPP have not yet returned to these sites following the drought conditions in late 2013 and early 2014. In the case of site 12a, OPP were found there before the September 2017 survey and after heavy rainfall in June 2017. However, the six OPP encountered there were translocated to control site C1 to avoid the direct impacts of dewatering and stream diversion associated with construction. Site 12a was dry at the time of the September 2017 survey so it is uncertain whether OPP have returned to that area following construction works, dewatering and translocation.

The conditions during both surveys this year were good for capturing fish. The May 2017 survey was undertaken after good flows, as discussed previously, but was delayed until water levels had reduced so that aquatic fauna was not dispersed over low lying ground but contained within creek banks and permanent habitats. The September survey was undertaken at a time when water levels were lower again as there had been little rain over the later parts of

the 2017 winter. The low rainfall did contribute to some sites being dry at the time of the survey.

In addition to the OPP, a large number and variety of other fish were encountered during this study. In general, the fish communities at most sites resembled those observed during pre-construction surveys. Of particular interest is the numbers of Mosquitofish (*Gambusia holbrooki*) encountered at each site. There has been variation in the numbers of Mosquitofish encountered but there is no apparent trend. However, there is no evidence at present that Mosquitofish numbers are increasing as a result of disturbances associated with construction at this early stage.

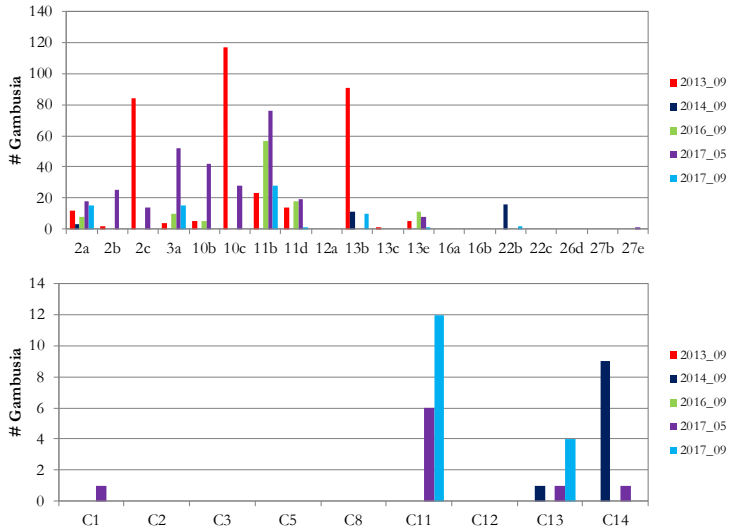
This study measured vegetative and physical habitat features including, flow, width, depth, in-stream vegetation, debris and stream bank forms. Over the course of the two surveys we have collected a large volume of information describing habitat conditions at all sites qualitatively and quantitatively. All of the sites surveyed have at least some habitat features commonly associated with OPP (Knight & Arthington 2008). The variation in habitat condition measured is generally within the ranges observed in pre-construction surveys.

This study also measured physicochemical water quality variables. Whilst water quality varied throughout the study area, at the great majority of the sites surveyed the water quality fell within the known range inhabited by OPP. There were some sites where the DO concentration was below the known range and where pH was below the known range. Sites 11b and 11d, which are downstream of an area where there was significant disturbance associated with construction this year, registered higher pH measurements in September 2017 than in May 2017. More information is required to determine whether this is part of a trend at these sites. Increased pH is of concern in OPP waterways because low pH waters are thought to provide OPP with a competitive advantage. There were no other stand-out water quality results.

The Threatened Fish Management Plan (Roads and Maritime 2015) outlines performance indicators for assessing the impacts of construction on threatened fish populations and habitats. The performance indicators, relevant notes and conclusions are listed in **Table 4.1**.

Table 4.1 Performance indicators for threatened fish management on the W2B upgrade.

Performance Indicator	*Notes*	*Conclusion*
Relative abundance of OPP in impact sites has reduced significantly when compared to control sites over three consecutive monitoring periods	There was a high degree of variation in the pre-construction monitoring results for OPP. Although OPP have not been captured at the sites located either side of Laing Hill during either of the two surveys this year they were not captured at these sites during the second round of pre-construction monitoring either. Although it is possible that construction is restricting OPP recruitment to the Laing Hill area it is likely that they have not yet returned to these sites after drought conditions in summer 2013/14 led to these sites all drying out. The most impactful construction and stream rehabilitation work at these sites should be completed in the near future. Continued monitoring will indicate whether construction is having an ongoing impact.	Continued monitoring at normal frequency.

Performance Indicator	*Notes*	*Conclusion*
Occurrence of Eastern Gambusia in waterways where they have not previously been recorded	During monitoring this year Gambusia were captured at sites 2a, 2b, 2c, 3a, 10b, 10c, 11b, 11d, 13b, 13e, 22b and 27e. They were captured at all of these sites during pre-construction monitoring with the exception of 27e. During preconstruction monitoring OPP were captured at control sites C13 and C14. In addition to these sites they were also captured at control sites C1 and C11 during monitoring this year. The capture of Gambusia at site 27e is reflected by the capture of Gambusia at the two nearby control sites. 	No corrective action required
Survey of Class 1 and 2 waterways with known or potential OPP habitat identifies additional populations of OPP.	A population of OPP were found in the Montis Gully area during the construction period. As a result, an impact site (13b) was added to the list of sites monitored prior to the September 2017 survey.	Continue monitoring at site 13b
Any change in habitat structure downstream of construction area, i.e. macrophyte and woody snag cover.	No significant changes to habitat structure have been noted to date.	No corrective action required
Any change in natural stream flow and velocity resulting in threatened fish being trapped in isolated pools	No significant changes to stream flow and velocity have been noted to date.	No corrective action required
Any weed incursion into OPP waterways	There were no new introduced species of aquatic plants observed at any of the control or impact sites during the surveys this year.	No corrective action required
No threatened fish species observed in ponds where fish have been translocated to.	OPP have been translocated from construction sites at Montis Gully (Ch 141100 - 141900) and the Woodburn to Broadwater Service Rd (Ch 139000) on several occasions in 2017 into sites 27b and C1 during the course or dewatering and stream diversion activities. OPP were captured at both of these release sites during both surveys conducted this year. OPP were also translocated from site 12a to site C1 during dewatering work. Site 12a was dry at the time of the September 2017 survey.	No corrective action required

Performance Indicator	*Notes*	*Conclusion*
Any change in water quality from baseline conditions in the vicinity of, or downstream of the construction works	The water quality results collected as part of the threatened fish monitoring gives some indication that there has been a reduction in the DO concentrations in the vicinity of construction works in comparison with baseline results. However, there was also a reduction in the DO concentrations at some of the control sites in comparison with baseline results.	Conduct an assessment of DO concentrations using data collected under the W2B Water Quality Monitoring Program
Any evidence of sediment or erosion being caused by the project	No erosion or sedimentation being caused by the project were noted during the threatened fish surveys in May or September 2017	No corrective action required
Disparity in water quality between downstream and upstream monitoring sites observed during operation of the project	Information collected under the Water Quality Monitoring Program for the W2B upgrade will be used to assess whether the W2B upgrade is meeting requirements for this performance indicator is being	This performance indicator should be assessed in the W2B upgrade water quality monitoring reports

In conclusion, the results to date indicate that the threatened fish management action adopted along the W2B upgrade during the first year of construction in Section 6-9 is successfully protecting OPP populations and habitat. OPP have been captured at most known OPP sites along the W2B upgrade, recruitment has been strong and there are mitigating factors at the known OPP sites where OPP have not been encountered. In addition, habitat and water quality remain suitable for OPP at all of the known sites. As threatened fish monitoring progresses in to the next two years of construction it is likely that the clarity of this picture will improve. At this point there are no additional adaptive management actions recommended.

Plate 4.1 OPP captured in a standard box trap.

Project Team

- Chris Thomson – Project Director
- Mathew Birch – Aquatic Ecologist: Technical leader and author
- Brenton Hays – Field Team
- Allie Cooke – Field Team

References

Allen, G. R., Midgley, S. H. and Allen, M. (2002) Field Guide to the Freshwater Fishes of Australia (Western Australian Museum, Perth).

Barker, D, Allan, G., Rowland, S., Kennedy, J. & Pickles, J. (2009) *A Guide to Acceptable Procedures and Practices for Aquaculture and Fisheries Research, 3rd Edition*. For the Primary Industries (Fisheries) Animal Care and Ethics Committee.

DSEWPaC (2011) Survey guidelines for Australia's threatened fish. Available online: http://www.environment.gov.au/epbc/publications/pubs/survey-guidelines-fish.doc

Fairfull, S. & Witheridge, G. (2003) Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings. NSW Fisheries, Cronulla, 16pp.

GeoLINK (2013) Aquatic Monitoring – RMS Woolgoolga to Ballina – Sections 6 – 11. Report prepared for NSW RMS.

GeoLINK (2014) Oxleyan Pygmy Perch Drought Refuge Assessment – RMS Woolgoolga to Ballina – Sections 7 – 9. Report prepared for NSW RMS.

GeoLINK (2015) Round 2 Aquatic Monitoring – RMS Woolgoolga to Ballina – Sections 6 – 11. Report prepared for NSW RMS.

Golder Associates (2014) Surface Water and Groundwater Monitoring Report – Pacific Highway Upgrade, Devils Pulpit to Ballina. Report No. 127622003-111-R-Rev1 Submitted to NSW RMS.

Knight, J. & Arthington, A. (2008) Distribution and habitat associations of the endangered Oxleyan pygmy perch, *Nannoperca oxleyana* Whitley, in eastern Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems.*(18) *1240-1254*

Knight, J., Arthington, A., Holder, G. & Talbot., R. (2012) Conservation biology and management of the endangered Oxleyan pygmy perch, *Nannoperca oxleyana* in Australia. *Endangered Species Research.*(17) *169-178*

Knight, J T, Butler, G. L. Smith, P. S. Wager, R. N. E. (2007) Reproductive biology of the endangered Oxleyan pygmy perch *Nannoperca oxleyana* Whitley, Journal of Fish Biology, (71) 1494-1511.

NSW DPI (2013). *Purple Spotted Gudgeon* – Mogurnda adspersa. NSW Department of Primary Industries Primefact 1275.

NSW DPI (2005). Oxleyan pygmy perch: Recovery Plan and background paper. NSW Department of Primary Industries Fisheries Management Branch, Port Stephens, NSW.

Pusey, B., Kennard, M., & Arthington, A. (2004) Freshwater Fishes of North-Eastern Australia. CSIRO Publishing, Collingwood.

Roads and Maritime Services (2015) Woolgoolga to Ballina Pacific Highway Upgrade Threatened Fish Management Plan (Version 3.0). Report prepared by NSW Roads and Maritime Services. Sinclair Knight Merz, Aurecon and Amec Foster Wheeler

Sainty, G.R. & Jacobs, S.W.L. (1994) Waterplants in Australia. CSIRO Division of Water Resources and Royal Botanic Gardens, Sydney.

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Appendix A

Aquatic Habitat Summaries

Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

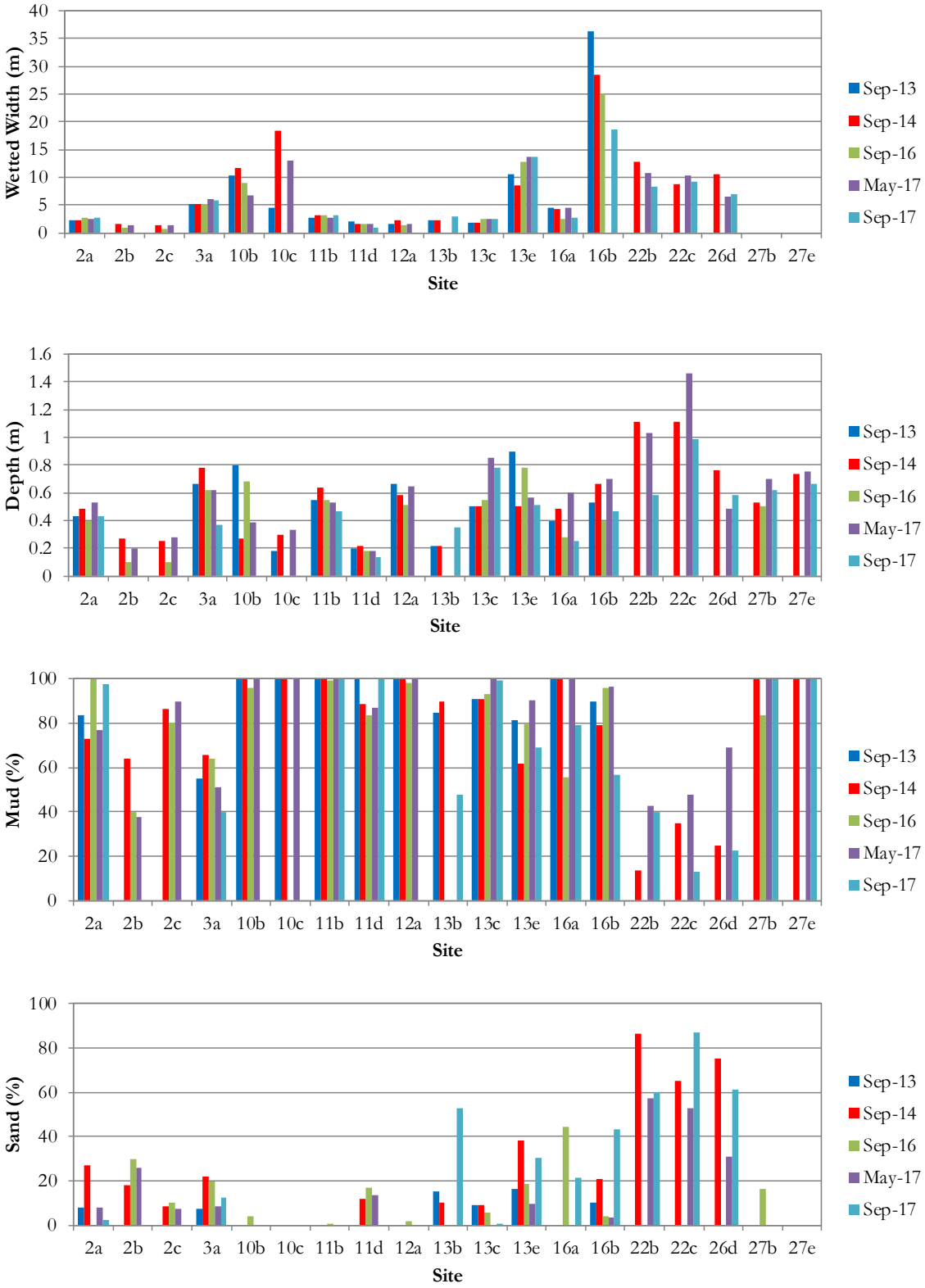


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

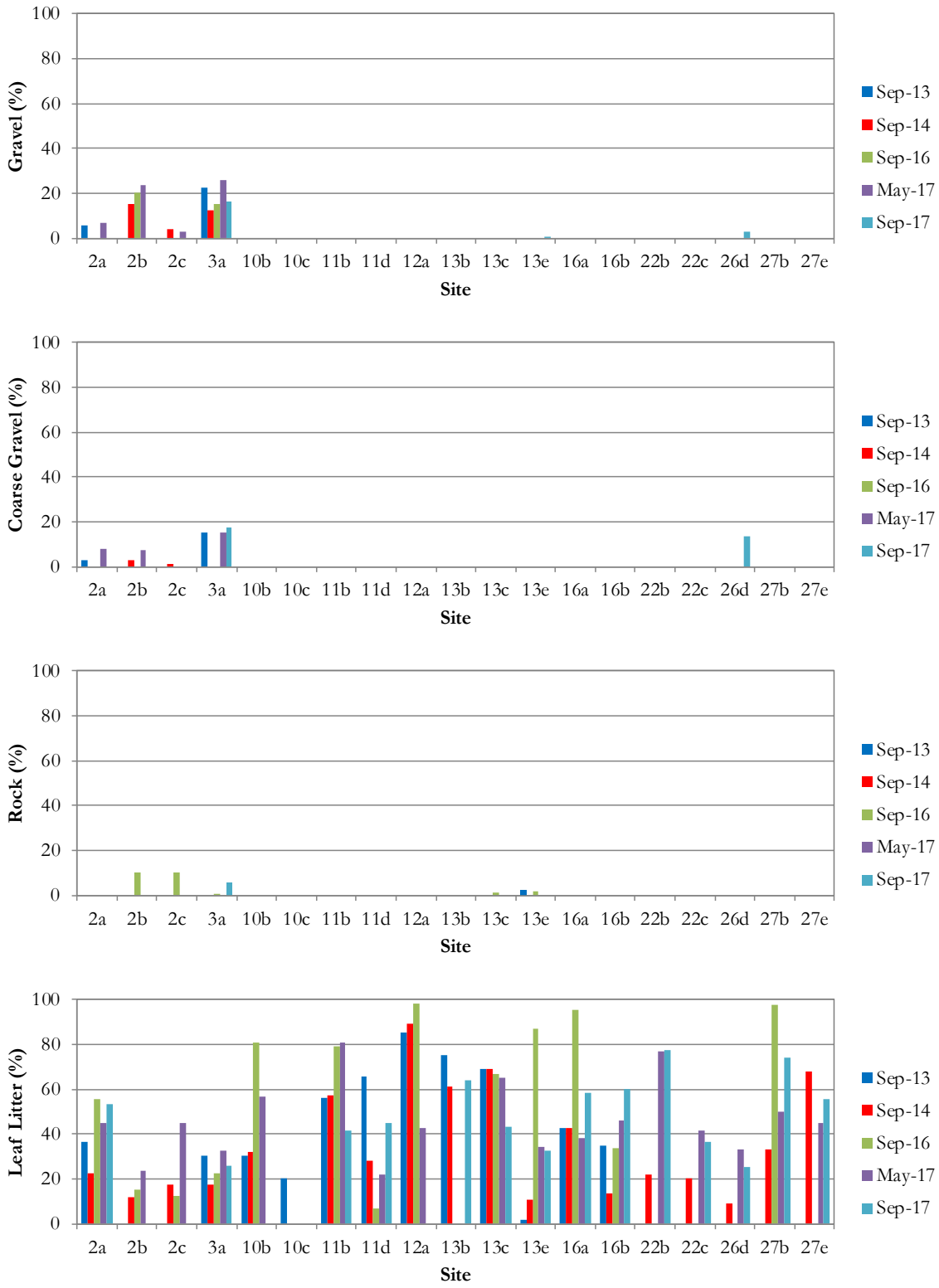


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

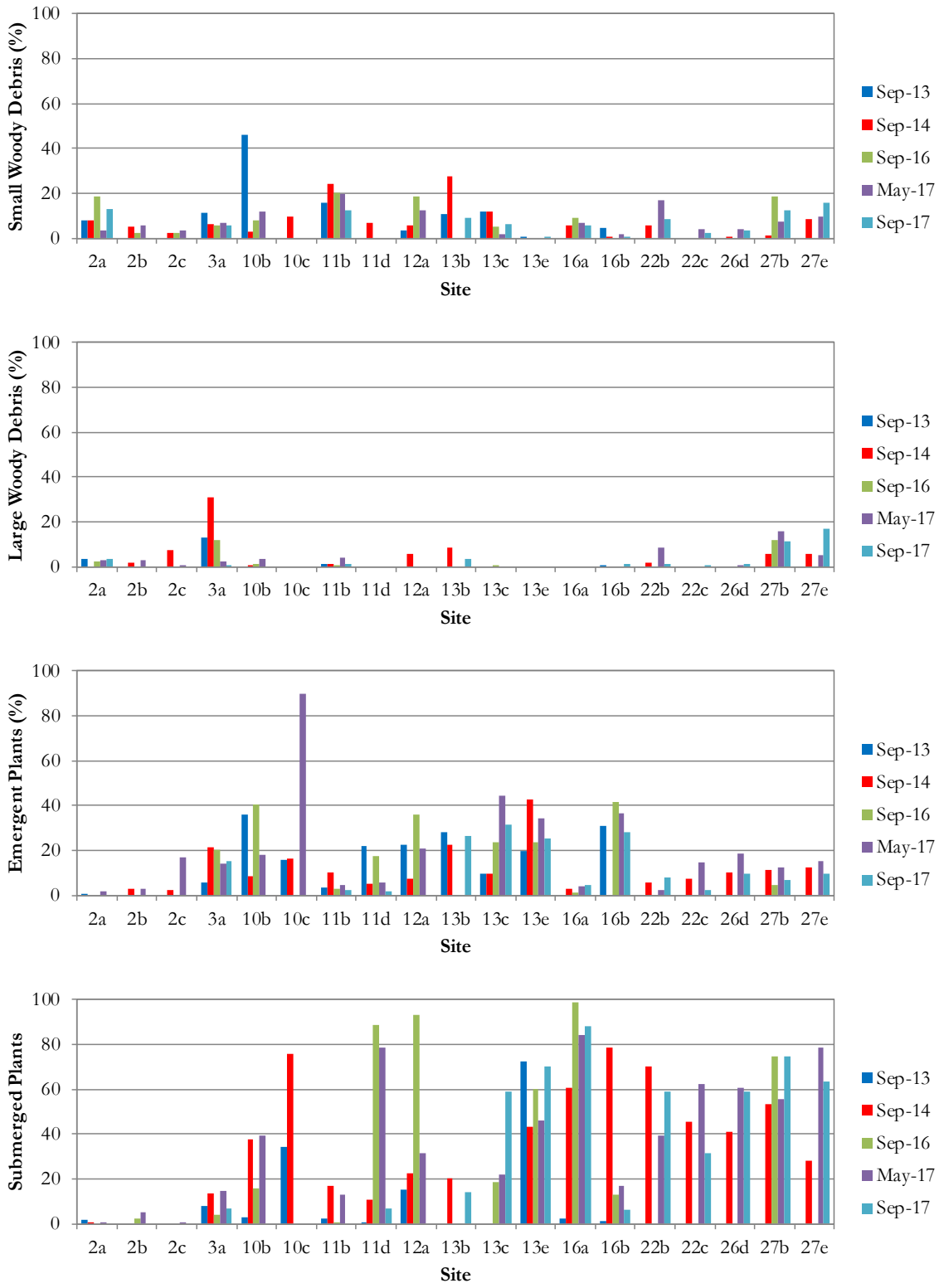


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

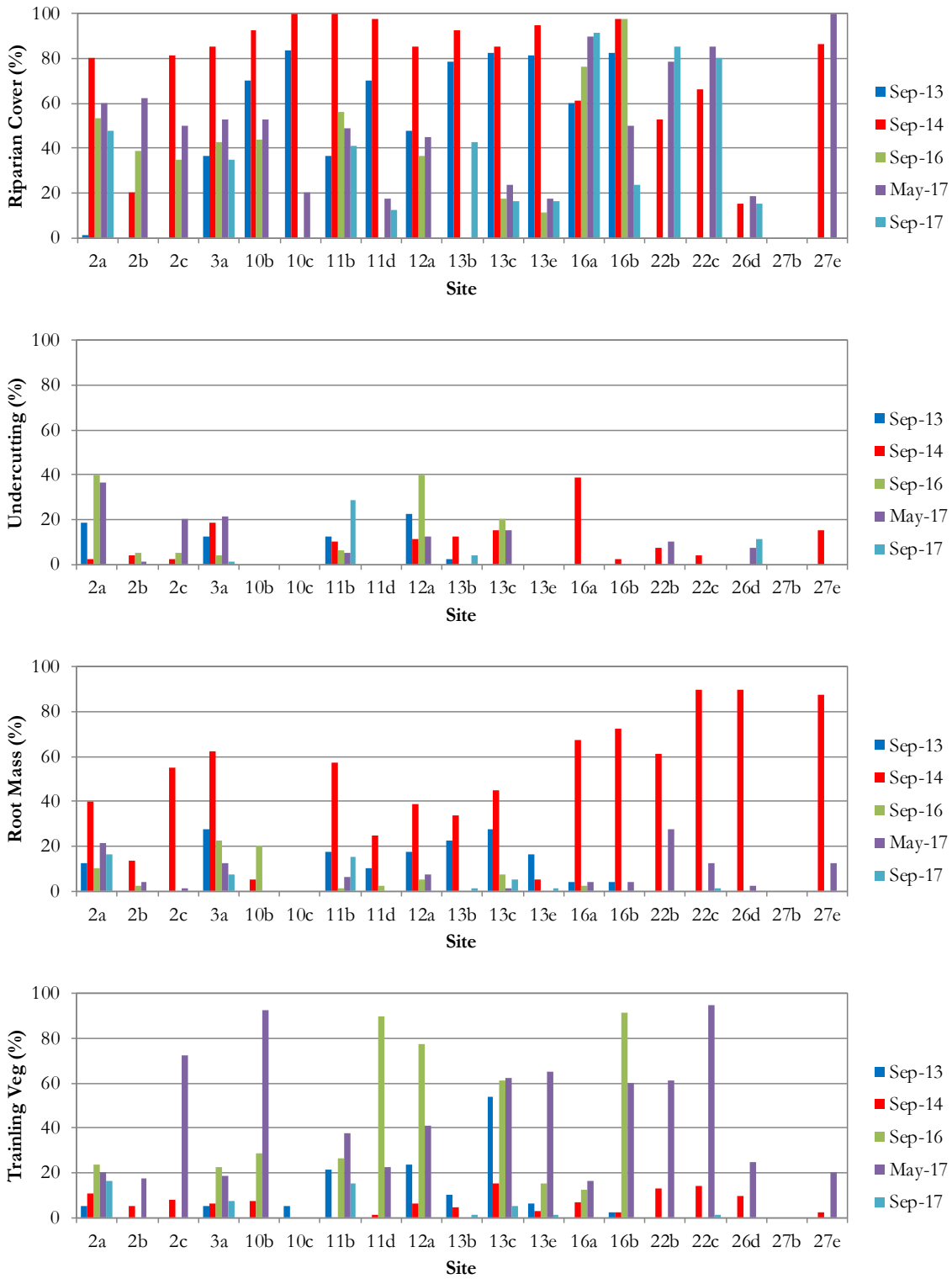


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

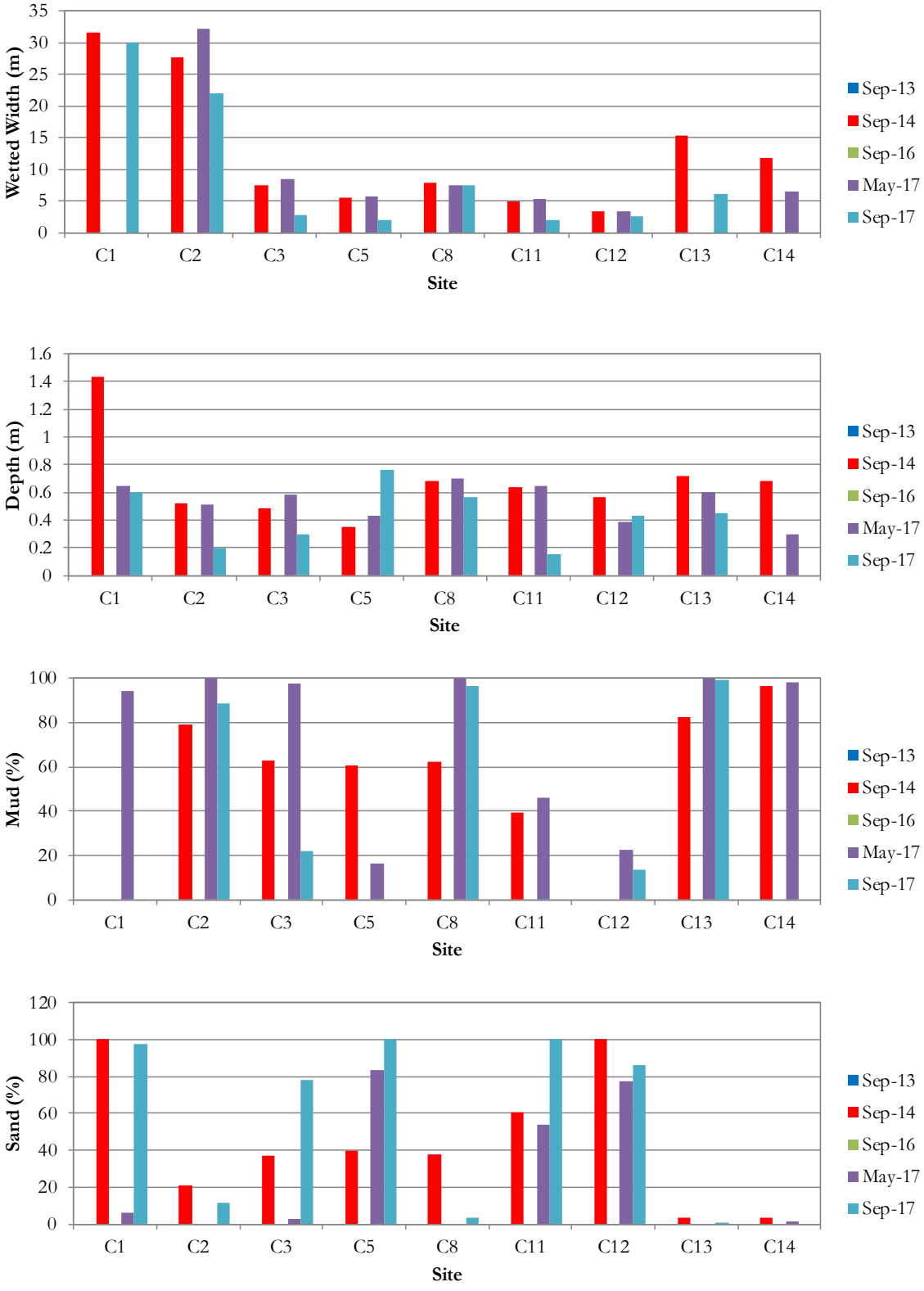


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

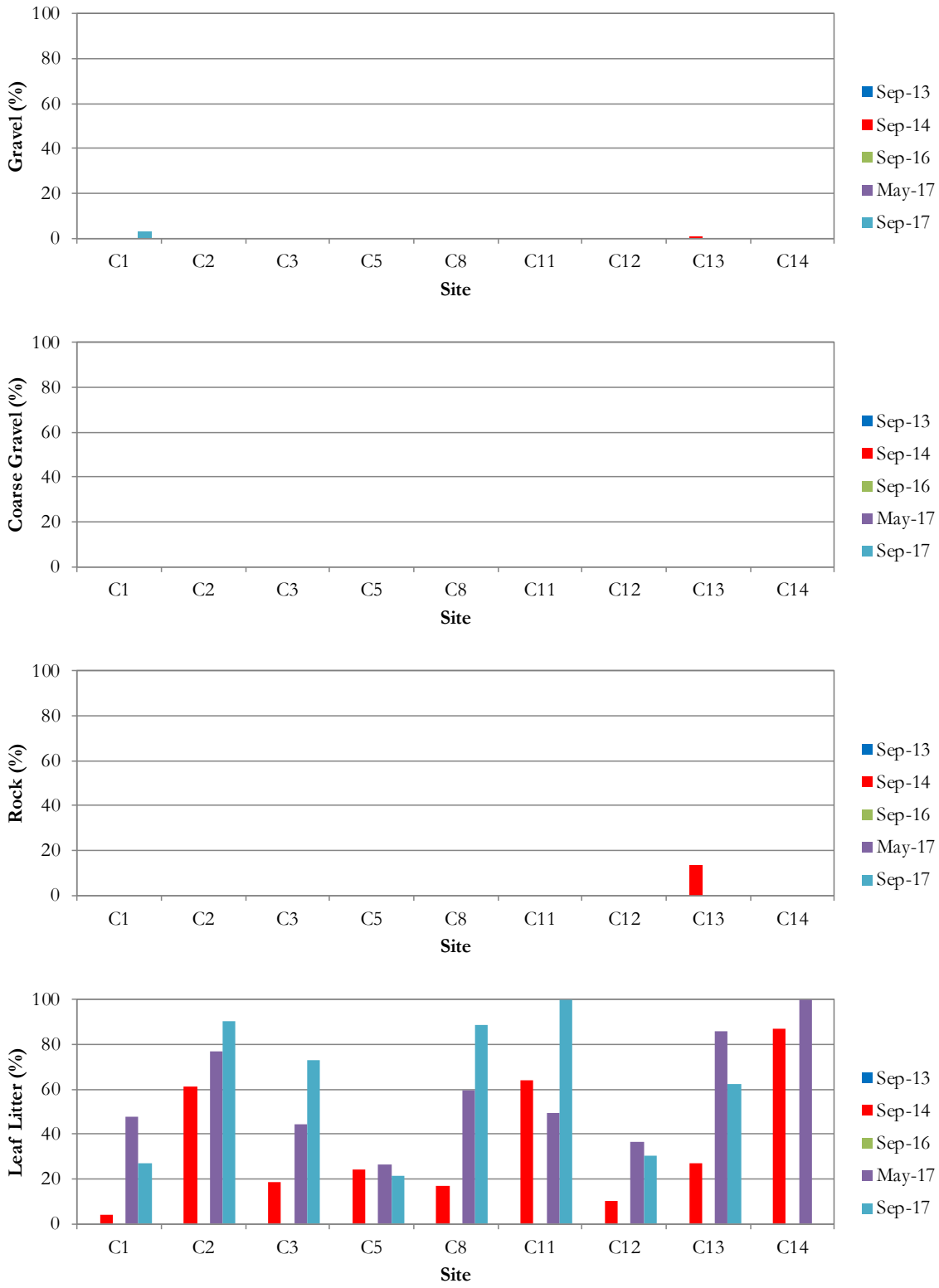


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

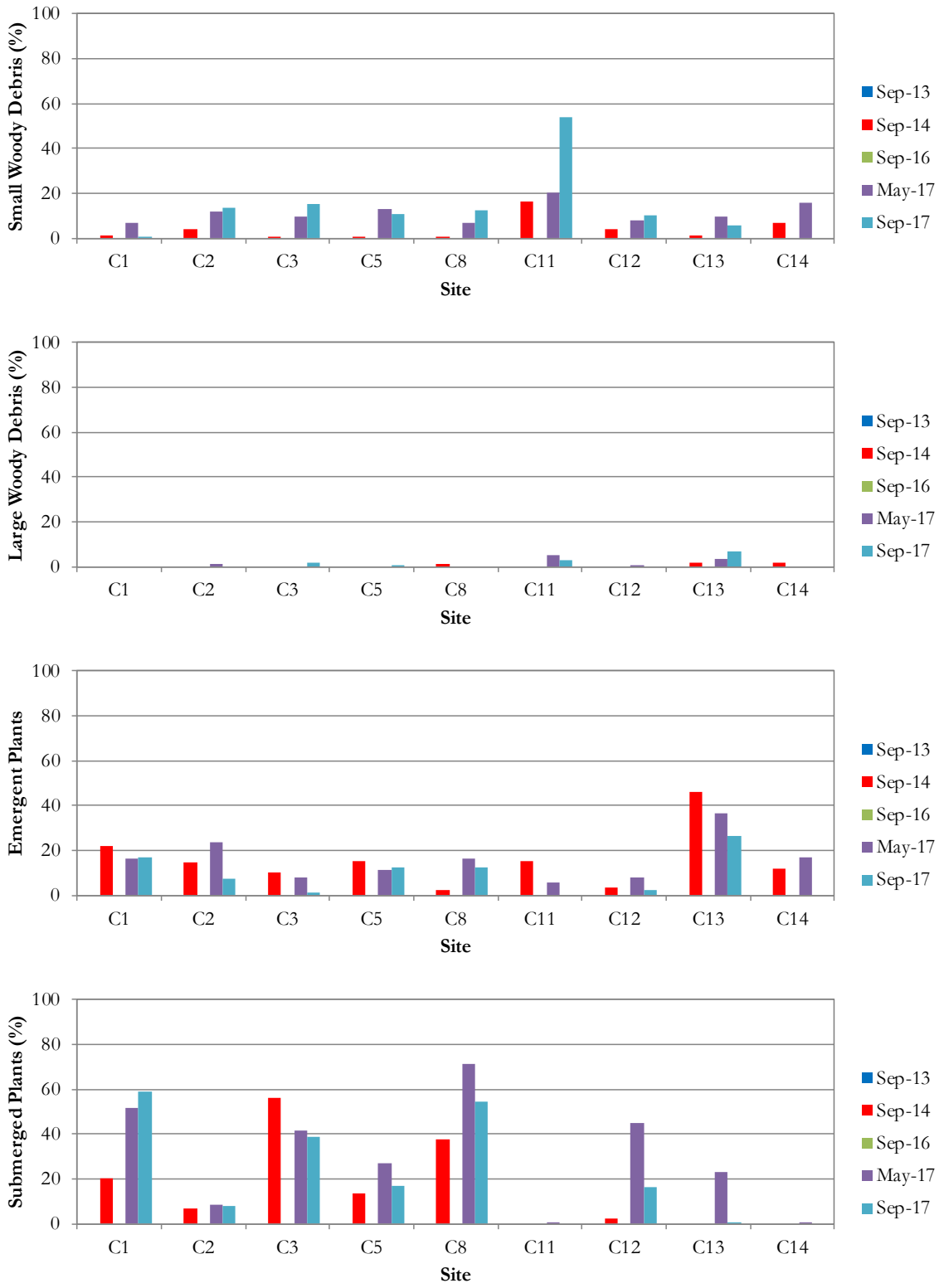
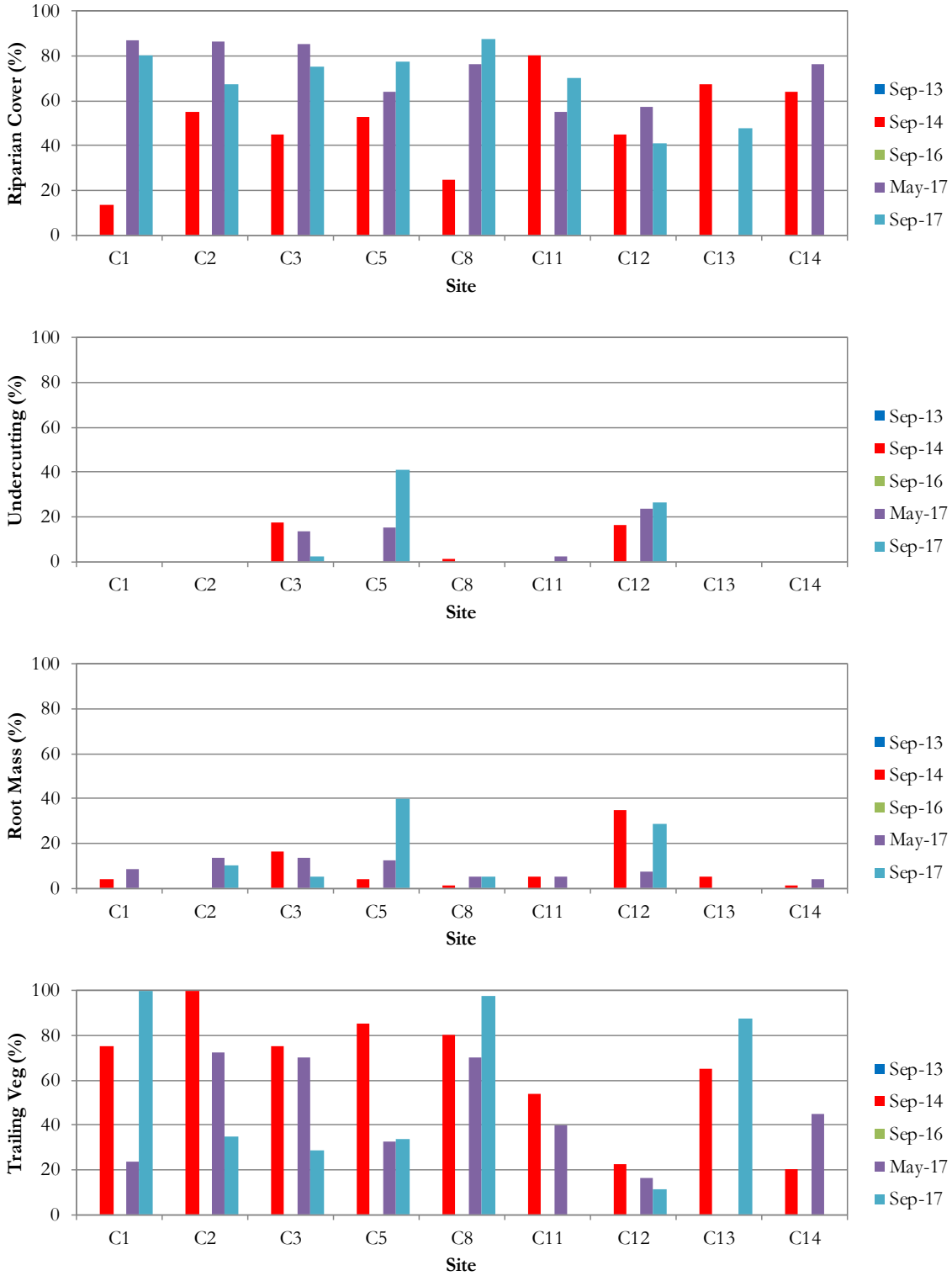


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.



Appendix B

Fish Survey Results

Table B1. Summary of captures for all fishing methods at all impact sites during the May 2017 survey

Scientific Name	*Common Name*	*Site*																		
		2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Anguilla australis	Shortfin Eel	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	1	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	7	0	0	15	92	0	61	4	60	0	20	5	0	0	13	5	14	0	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	42	0	28	0	67	0	17	1	0	0	0	0	0	1	1
Hypseleotris galii	Firetail Gudgeon	49	1	4	103	45	1	43	3	37	0	3	13	0	4	26	64	0	4	5
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	1	0	0	0	18	0	46	3	0	0	3	0	6	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	0	3	0	4	0	0	0	0	0	0	5	7	6	3	6	34	13	7	1
Gambusia	Mosquito Fish	18	25	14	52	42	28	76	19	0	0	0	8	0	0	0	0	0	0	1

Table B2. Summary of captures for all fishing methods at all control sites during the May 2017 survey

Scientific Name	*Common Name*	*Site*								
		C1	*C2*	*C3*	*C5*	*C8*	*C11*	*C12*	*C13*	*C14*
Anguilla australis	Shortfin Eel	0	0	0	1	0	0	1	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	1	0
Gobiomorphus australis	Striped Gudgeon	0	0	0	11	0	0	7	11	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	0	1	0
Hypseleotris galii	Firetail Gudgeon	9	2	8	31	97	39	90	4	0
Rhadinocentrus ornatus	Ornate Rainbowfish	18	17	33	2	30	6	14	9	11
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	28	0	7	10	18	7	96	5	2
Gambusia	Mosquito Fish	1	0	0	0	0	6	0	1	1

Table B3. Summary of captures for all fishing methods at all impact sites during the September 2017 survey

Scientific Name	*Common Name*	*Site*																		
		2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Anguilla australis	Shortfin Eel	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0
Anguilla reinhardtii	Longfin Eel	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	25	0	0	30	0	0	60	3	0	35	27	11	2	0	23	5	16	0	5
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	1	1	0	0	12	15	0	0	0	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	95	0	0	47	0	0	28	4	0	0	2	47	0	33	49	44	9	5	4
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	10	0	4	3	3	0	8	1	2
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	2	0	0	2	0	0	0	0	0	12	4	8	77	2	15	14	17	9	8
Gambusia	Mosquito Fish	15	0	0	15	0	0	28	1	0	10	0	1	0	0	2	0	0	0	0

Table B4. Summary of captures for all fishing methods at all control sites during the September 2017 survey

Scientific Name	*Common Name*	*Site*								
		C1	*C2*	*C3*	*C5*	*C8*	*C11*	*C12*	*C13*	*C14*
Anguilla australis	Shortfin Eel	0	0	0	0	1	0	0	2	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	3	0
Gobiomorphus australis	Striped Gudgeon	0	0	0	32	0	0	23	27	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	0	3	0
Hypseleotris galii	Firetail Gudgeon	25	1	16	44	84	35	180	25	0
Rhadinocentrus ornatus	Ornate Rainbowfish	22	1	2	25	19	30	16	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	48	23	75	20	40	13	2	34	0
Gambusia	Mosquito Fish	0	0	0	0	0	12	0	4	0

Appendix C

Water Quality Comparisons

Table C1. Comparison of Water Quality Ranges from pre-construction monitoring and construction phase TFMP monitoring

Location	Sites	Parameter	Units	Pre-construction range	2017 Range
Unnamed waterway south of Serendipity Rd Ch. 11400	2a, 2b, 2c	Temp	(°C)	13.3 – 23.6	12.42 - 16.00
		DO	(mg/L)	4.11 - 10	**1.42** - 4.58
		pH		5 – 6.9	4.98 - 5.83
		Conductivity	(mS/cm)	0.009 – 0.368	0.105 - 0.275
		Turbidity	(NTU)	0.9 - 118	7.6 - 20.8
Tabbimoble floodway no. 1 Ch. 115300	3a	Temp	(°C)	12.8 - 24	13.73 - 16.79
		DO	(mg/L)	1.3 - 8.07	4.61 - 5.59
		pH		4.4 – 7.2	5.43 - 5.62
		Conductivity	(mS/cm)	0.009 – 0.140	0.089 - 0.093
		Turbidity	(NTU)	18.9 – 132	12.5 - 13.5
Unnamed waterway south of MacDonalds Ck Ch. 134600	10b, 10c	Temp	(°C)	16.6 - 29	12.5 - 15.5
		DO	(mg/L)	3.17 - 10	**0.61 - 0.89**
		pH		4 – 9.3	4.7 - 4.75
		Conductivity	(mS/cm)	0.102 – 0.537	0.249 - 0.333
		Turbidity	(NTU)	1.3 - 800	3.8 - 5.7
MacDonalds Ck Tributary Ch. 135200, 135530 and 136450	11b, 11d, 22b, 22c	Temp	(°C)	15.4 – 26.7	14.16 - 24.69
		DO	(mg/L)	2.27 – 8.9	**0.74** - 8.65
		pH		3.8 – 8.9	3.44 - 5.97
		Conductivity	(mS/cm)	0.092 – 0.606	0.131 - 0.178
		Turbidity	(NTU)	2.4 - 138	0 - 212
MacDonalds Ck Ch. 136600	12a	Temp	(°C)	14.9 - 26	13.36
		DO	(mg/L)	1.7 – 8.1	**1.36**
		pH		3.6 – 6.3	**2.72**
		Conductivity	(mS/cm)	0.164 – 0.406	0.25
		Turbidity	(NTU)	0 - 14	0
Broadwater NP Swampland Ch. 139000	16a, 16b, 27b, 27e	Temp	(°C)	18.6 – 21.45	13.33 - 21.38
		DO	(mg/L)	1.83 – 5.39	**0.62** - 8.3
		pH		4.15 – 4.63	**3.7** - 4.6
		Conductivity	(mS/cm)	0.128 – 0.171	0.116 - 0.23
		Turbidity	(NTU)	0 - 703	0 - 64.2
Montis Gully Tributary 1 Ch. 141180 and 141850	13b, 13c, 13e, 26d	Temp	(°C)	17.23 – 30.9	13.33 - 19.27
		DO	(mg/L)	2.1 – 9.4	**0.95** - 4.23
		pH		3.7 - 7	**3.39** - 3.8
		Conductivity	(mS/cm)	0.026 – 0.209	0.137 - 0.206
		Turbidity	(NTU)	0 - 225	0 - 4.1
W of Bundjalung NP Approximately 4 km east of Ch. 110000	C13, C14	Temp	(°C)	18.09 – 19.11	12.59 - 16.47
		DO	(mg/L)	2.24 – 4.38	3.4 - 3.79
		pH		4.56 – 5.47	4.84 - 5.51
		Conductivity	(mS/cm)	0.086 – 0.112	0.102 - 0.112
		Turbidity	(NTU)	0 – 8.7	0 - 15
Broadwater NP	C11, C12	Temp	(°C)	15.91 – 18.49	17.08 - 29.36
		DO	(mg/L)	2.9 – 5.59	**1.76** - 8.35

6.5 km east of Ch.13000		pH		3.85 - 4	3.79 - 4.54
		Conductivity	(mS/cm)	0.124 – 0.149	0.106 - 0.155
		Turbidity	(NTU)	0 – 2.3	0 - 6.8
MacDonalds Ck Tributary 0.5 km east of 136600 and 1 km east of 137800		Temp	(°C)	16.87 – 17.78	12.36 - 19.3
		DO	(mg/L)	4.58 – 4.69	**2.74** - 4.70
		pH		3.7 – 4.22	**3.31** - 3.99
		Conductivity	(mS/cm)	0.115 – 0.158	0.113 - 0.183
	C2, C5	Turbidity	(NTU)	0 - 0	0 - 37.6
Broadwater NP 1 km east of Ch 138000	C1, C3	Temp	(°C)	17.2 - 18.91	14.33 - 23.66
		DO	(mg/L)	4.55 - 9.18	**2.45 - 3.77**
		pH		3.97 – 4.49	**3.42** - 3.96
		Conductivity	(mS/cm)	0.089 - 0.176	0.100 - 0.201
		Turbidity	(NTU)	0 – 1.4	0 - 26.4
Broadwater NP 2 km east of 136400	C8	Temp	(°C)	17.98	12.18 - 18.49
		DO	(mg/L)	5.77	**2.87 - 3.29**
		pH		3.95	**3.21 - 3.46**
		Conductivity	(mS/cm)	0.236	0.315 - 0.363
		Turbidity	(NTU)	12.1	0 - 5