

Project Name: W2B Biodiversity – Threatened Fish Monitoring

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Woolgoolga to Ballina Pacific
Highway Upgrade
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Introduction

The following report summarises the methods and results from the second 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 Woolli). 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 (DSEWPaC 2011). 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.

<i>Measure</i>	<i>Range</i>	<i>Mean $\pm$ SE</i>
Temp (°C)	10.9 – 28.3	16.1 $\pm$ 0.34
DO (mg/L)	2.15 – 10.02	6.42 $\pm$ 0.189
pH	3.32 – 6.9	4.47 $\pm$ 0.087
Cond (μ S/cm)	68 - 2148	186 $\pm$ 22.7
Turbidity (NTU)	0 – 80	14 $\pm$ 3.6

From Knight & Arthington (2008)

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 year of threatened fish monitoring 27 and 28 sites were sampled in May 2017 and September 2017 respectively. During the current monitoring period a reduced number of sites were sampled due to landholder restrictions upon access to sites 11b, 13e and 26b. 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 **Table 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.

<i>Section</i>	<i>Waterway</i>	<i>Location</i>	<i>Chainage</i>	<i>Notes</i>
7	Unnamed waterway south of Serendipity Rd	2	114000	Drains from headwaters approximately 1km upstream. Intermittent Class 1 stream. OPP previously identified. 3 sites , upstream, impact and downstream. The impact and downstream site frequently dry out.
7	Tabbimoble floodway no. 1	3	115300	Drains from headwaters approximately 1.5km upstream. Intermittent Class 1 stream. OPP previously identified. 1 site at impact.
8	Unnamed waterway south of MacDonalds Ck	10	134600	Class 1 waterway, draining flood prone land connecting with Broadwater NP. OPP previously identified. 2 sites , impact and downstream. The downstream site frequently dries out.
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. 2 sites , impact and downstream.
8	MacDonalds Ck	12	136600	Class 1 waterway draining flood prone land connecting with Broadwater NP. OPP previously identified. 1 site , at impact.
8	Various dams south of Broadwater National Park	22	136700 - 137900	Two manmade dams and excavations on private property. OPP previously identified. Each individual waterbody sampled at 1 site only. Both located E (downstream) of impact.
9	Broadwater NP Swamp land	16	139000	Series of wetland pools throughout protected wallum country. Class 1 stream. OPP previously identified. 2 sites one impact, one to the east.
9	Various potential refuges	27	139200 - 140500	Series of wetland pools throughout protected wallum country. Class 1 stream. OPP previously identified. 2 sites all located E of the impact.

<i>Section</i>	<i>Waterway</i>	<i>Location</i>	<i>Chainage</i>	<i>Notes</i>
9	Various dams north of Broadwater National Park	26	140900 - 142300	Manmade dam/excavation on private property. OPP previously identified. Located E (downstream) 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. 3 sites , 1 slightly upstream, 2 at the impact.

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 all impact and control sites are presented in in **Illustrations 2.1, 2.2 and 2.3**.

Access to some sites was restricted in 2018. Sites 13e and 26b could not be accessed for either survey in 2018 due to landholder restrictions. Site 11b could not be accessed in September 2018 due to a change of ownership.



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

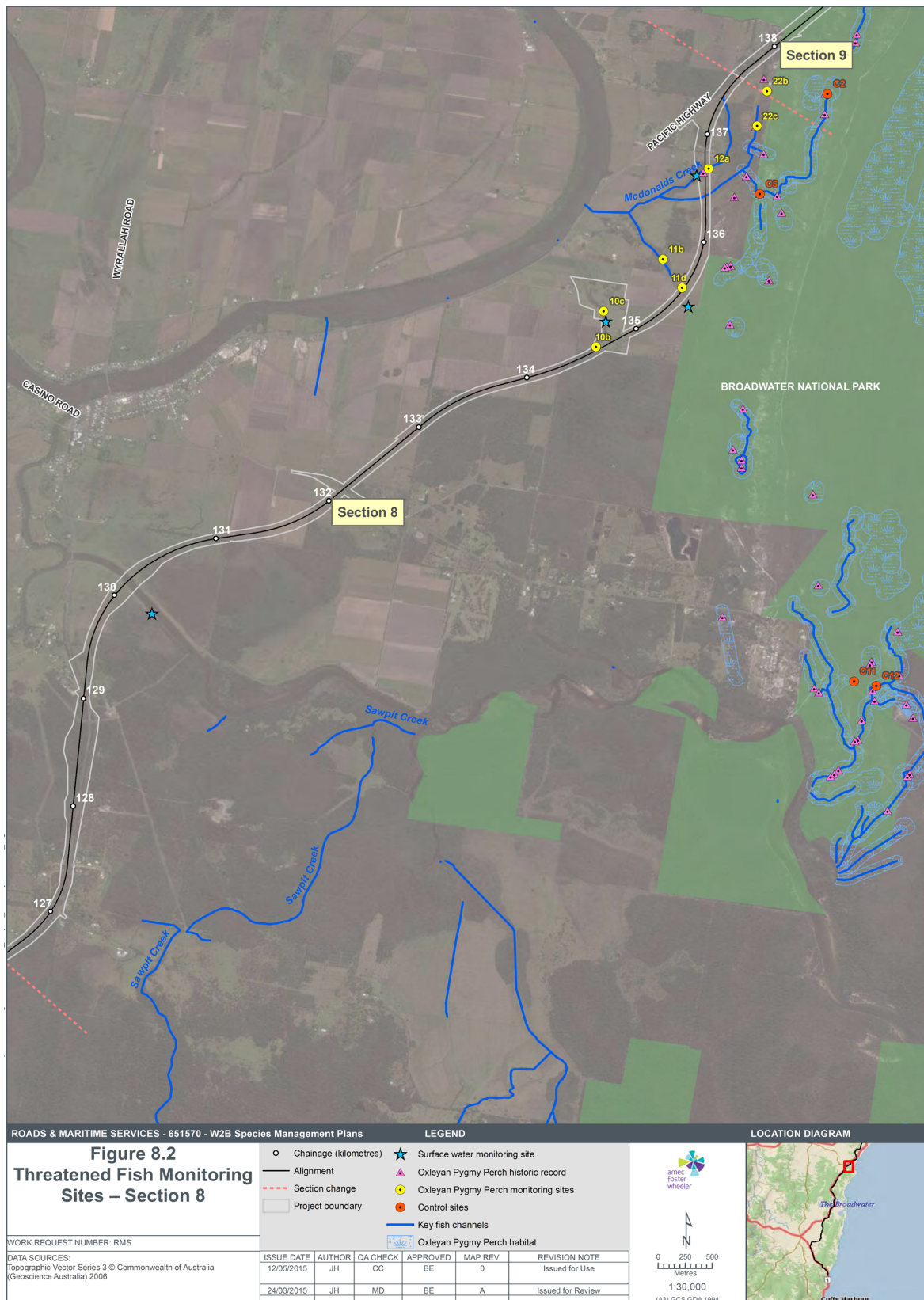


Illustration 2.2 Map of Section 8 sampling sites taken from the TFMP (RMS 2015)



Illustration 2.3 Map of Section 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 used during the pre-construction survey. During this reporting period the surveys were undertaken in May 2018 and September 2018. Monitoring was scheduled to avoid the OPP breeding season, which peaks between October and April, and timed to ensure optimum conditions with respect to water levels.

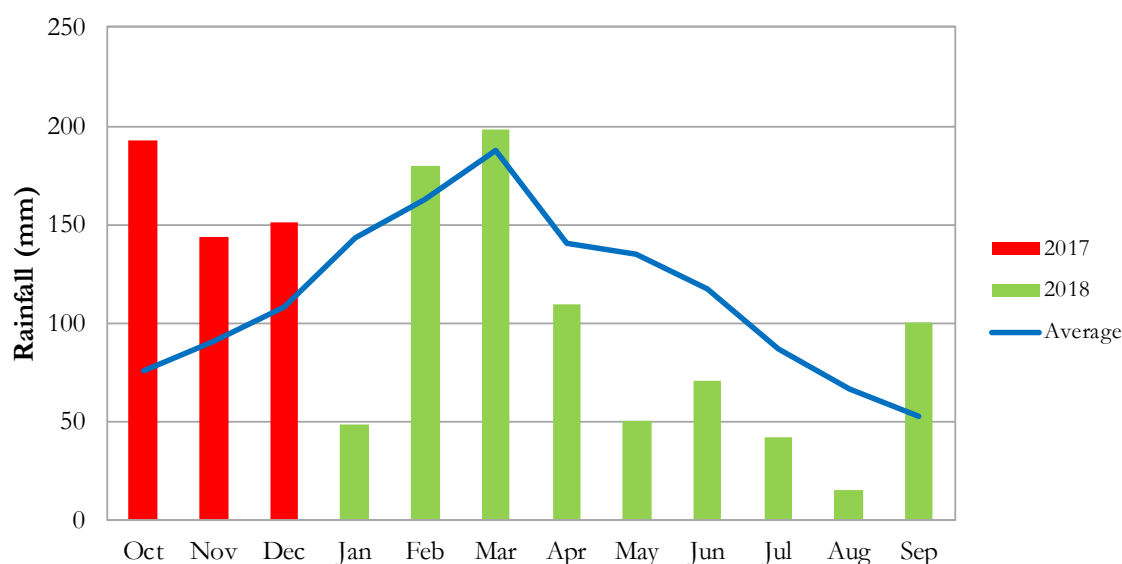


Figure 2.1 Mean monthly rainfall and total monthly rainfall from the Woodburn Bureau of Meteorology station for the current reporting period.

The long-term rainfall was above average for 4 of the 5 months prior to the May 2018 survey and below average for 5 of the 6 months prior to the September survey beginning (**Figure 2.1**). The total annual rainfall for the reporting period was approximately 10% below average. The months of actual surveys were characterised by average to slightly above average rainfall conditions. Most of the sites did not have significant flows (> 0.1 m/s) at the time of the surveys, but there was adequate water for sampling activities at most 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 m 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** and **Table 2.3**. 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 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 2018 sampling

<i>Section</i>	<i>Site</i>	<i>Voltage (V)</i>	<i>Pulse Freq (Hz)</i>	<i>Duty Cycle (%)</i>	<i>Passes</i>	<i>Seconds Pulsed</i>
7	2a	125	50	12	1	596
7	2b	75	50	12	2	73
7	2c	No Water				
7	3a	250	50	12	1	605
8	10b	250	50	12	1	540
8	10c	No Water				
8	11b	175	50	12	1	608
8	11d	100	50	12	1	447
8	12a	150	50	12	1	608
9	13b	200	50	12	1	604
9	13c	175	50	12	1	615
9	13e	No Access				
9	16a	175	50	12	1	595
9	16b	200	50	12	1	609
8	22b	150	50	12	1	627
8	22c	150	50	12	1	606
9	26d	No Access				
9	27b	225	50	12	1	604
9	27e	200	50	12	1	601
Control	C1	225	50	12	1	605
Control	C2	175	50	12	1	600
Control	C3	175	50	12	1.25	612
Control	C5	150	50	12	1	601
Control	C8	175	50	12	1	558
Control	C11	250	50	12	1	614
Control	C12	200	50	12	1	600
Control	C13	175	50	12	0.5	288
Control	C14	125	50	12	1	610

Table 2.3 Details of electrofisher settings and effort at each site in the September 2018 sampling

<i>Section</i>	<i>Site</i>	<i>Voltage (V)</i>	<i>Pulse Freq (Hz)</i>	<i>Duty Cycle (%)</i>	<i>Passes</i>	<i>Seconds Pulsed</i>
7	2a	225	50	12	2	384
7	2b	175	50	12	2	104
7	2c	No Water				
7	3a	175	50	12	1	613
8	10b	250	50	12	1	601
8	10c	250	50	12	2	185
8	11b	No Access				
8	11d	175	50	12	1.2	607
8	12a	200	50	12	1.5	603
9	13b	200	50	12	1.2	608

<i>Section</i>	<i>Site</i>	<i>Voltage (V)</i>	<i>Pulse Freq (Hz)</i>	<i>Duty Cycle (%)</i>	<i>Passes</i>	<i>Seconds Pulsed</i>
9	13c	225	50	12	1	604
9	13e	No Access				
9	16a	150	50	12	1.5	403
9	16b	200	50	12	1	604
8	22b	300	50	12	1	617
8	22c	250	50	12	2	588
9	26d	No Access				
9	27b	200	50	12	1	605
9	27c	200	50	12	1.2	615
Control	C1	200	50	12	1.75	602
Control	C2	150	50	12	1.25	620
Control	C3	175	50	12	1	615
Control	C5	150	50	12	1	602
Control	C8	225	50	12	2	601
Control	C11	250	50	12	1	621
Control	C12	200	50	12	1	464
Control	C13	175	50	12	0.5	334
Control	C14	125	50	12	1	613

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 a 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 individual 0.5 m x 0.5 m 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.

Results

3.1 Fish Survey

During the May 2018 survey approximately 238 hours of fish trapping and 13,464 seconds of electrofishing were used. During the September 2018 survey approximately 209 hours of fish trapping and 12,813 seconds of electrofishing were used.

In the May 2018 survey a total of 1,854 fish from eight species were captured. Of the total number of fish captured, 987 individuals from eight species were captured using the electrofisher and 867 individuals from seven species were captured using fish traps.

In the September 2018 survey a total of 3,096 fish from eight species were captured. Of the fish captured during the September 2017 survey 1033 individuals from eight species were captured using the backpack electrofisher and 2063 individuals from six species were captured using bait traps.

In the May 2018 survey 263 individual OPP were captured. Of these, 106 were captured using the backpack electrofisher and 157 in fish traps. In the May 2018 survey OPP were captured at 7 of the 19 impact sites and at 5 of the 9 control sites.

In the September 2018 survey 265 individual OPP were captured. Of these 136 were captured using the backpack electrofisher and 129 in fish traps. In the September 2018 survey OPP were captured at 12 of the 19 impact sites and at 7 of the 9 control sites.

The most commonly captured species of fish during both surveys this year was the Firetail Gudgeon, (*Hypseleotris galii*). Individuals of this species accounted for approximately 31 per cent of the total number of fish captured in the May 2018 survey and approximately 65 per cent of the fish captured in the September 2018 survey. Overall, OPP accounted for approximately 14 per cent of the fish captured in the May 2018 survey and 9 per cent of the fish captured during the September 2018 survey.

There has been a moderate degree of variation at most impact sites throughout the pre-construction and ongoing monitoring in terms of fish diversity and a high degree of diversity in terms of abundance (**Figure 3.1**). In the 2 surveys this year between one and six species have been captured at each site. In the May 2018 survey the impact sites with the highest diversity of captured fish were 12a, 11b and 3a and 27e. In the September 2018 survey the impact sites with the highest diversity of captured fish were 11d, 10b and 22b.

Between 3 and 529 individual fish were captured at the impact sites during the two surveys this year. The impact sites where the most fish were captured during the May 2018 survey were 3a, 13b and 11b. In the September 2018 survey the impact sites where the most individual fish were captured were 16b, 3a and 22c.

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 or changing access permission to private lands. These sites include sites 2c (dry), 10c (dry), 13e and 26d (access restrictions) in the May 2018 survey and sites 2c (dry), 11b, 13e and 26d (access restrictions) in the September 2018 survey.

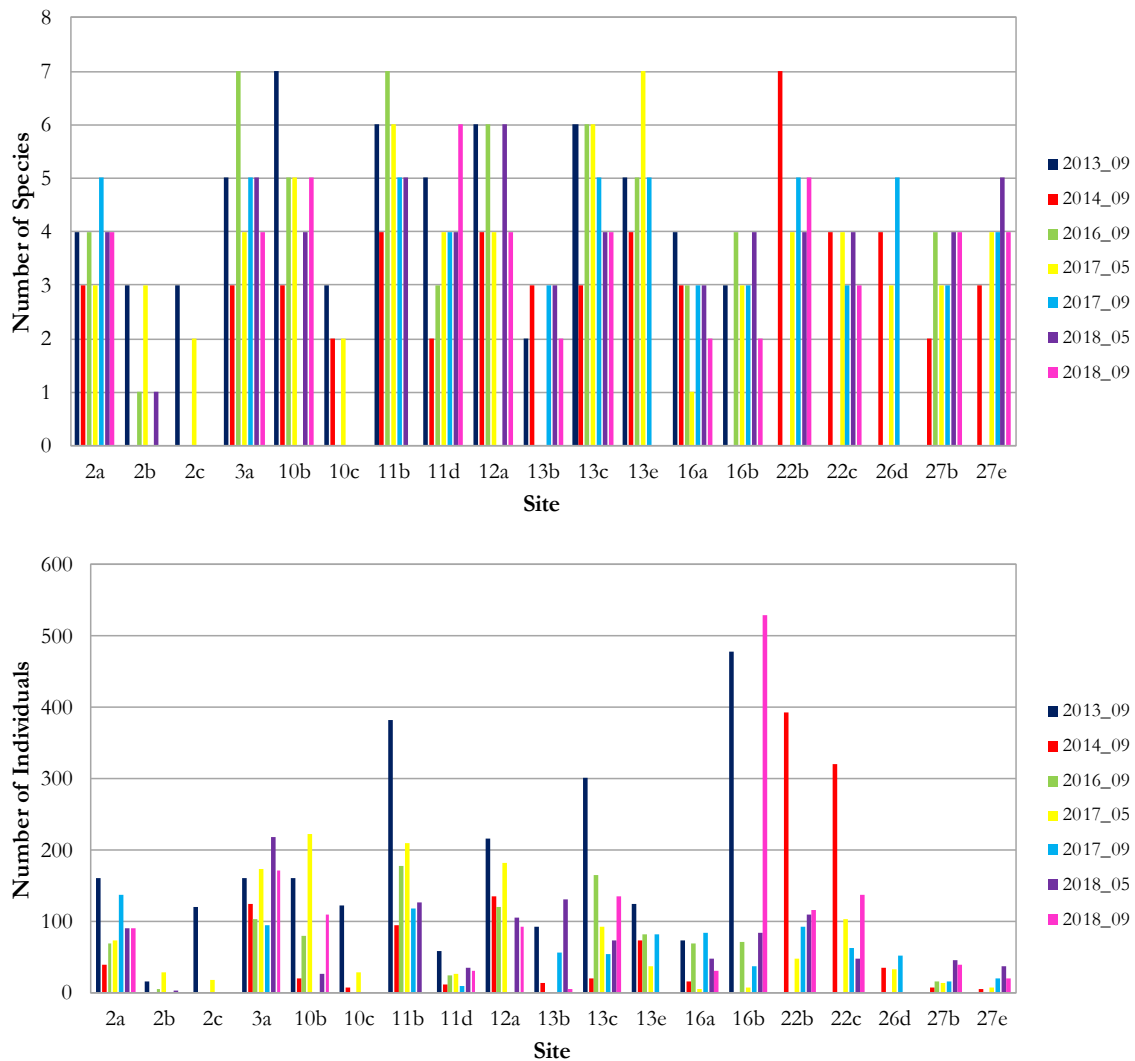


Figure 3.1 Taxonomic richness and abundance of captured fish at all impact sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

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

The total number of individual fishes captured at the control sites varied between 0 and 1033, with the largest numbers of fish captured at C12, C8 and C13 in both the May 2018 and September 2018 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 over time evident at both impact and control sites. Although OPP have been captured at most sites in both surveys this year they were captured at a lower number of sites this year than in 2017 (22 sites in 2017, 17 sites in 2018). The sites where OPP weren't captured were either sites that dry out frequently (e.g. sites 2b, 2c, 13b, C2 or C11) or sites within the two subcatchments either side of Laing Hill (sites 10b, 10c, 11b).

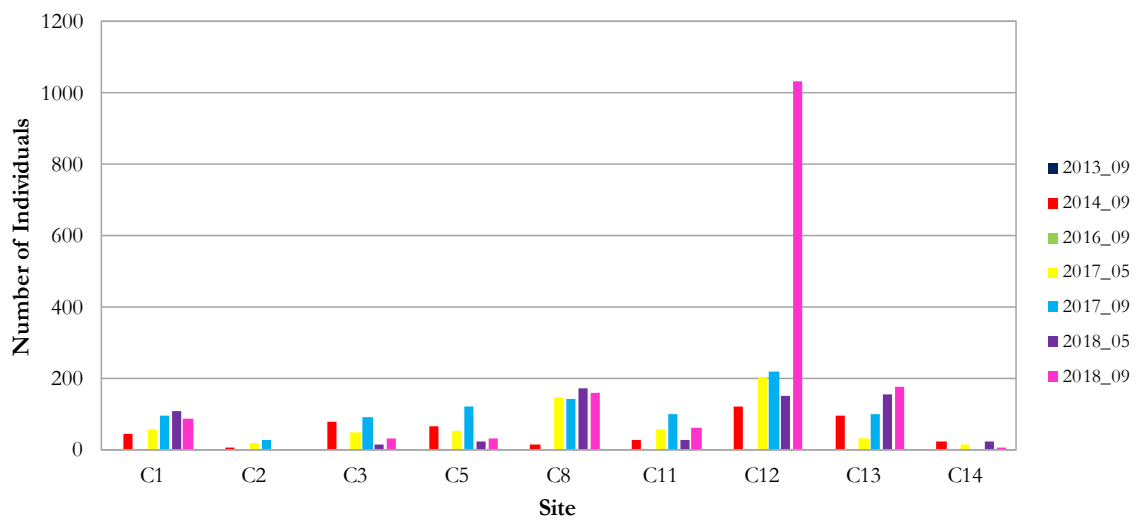
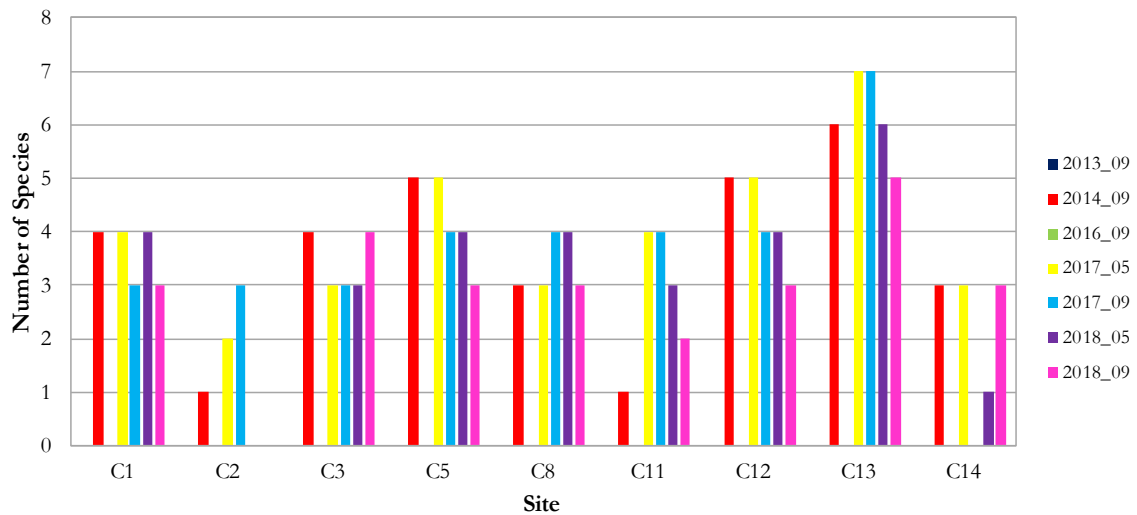


Figure 3.2 Taxonomic richness and abundance of captured fish at all control sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

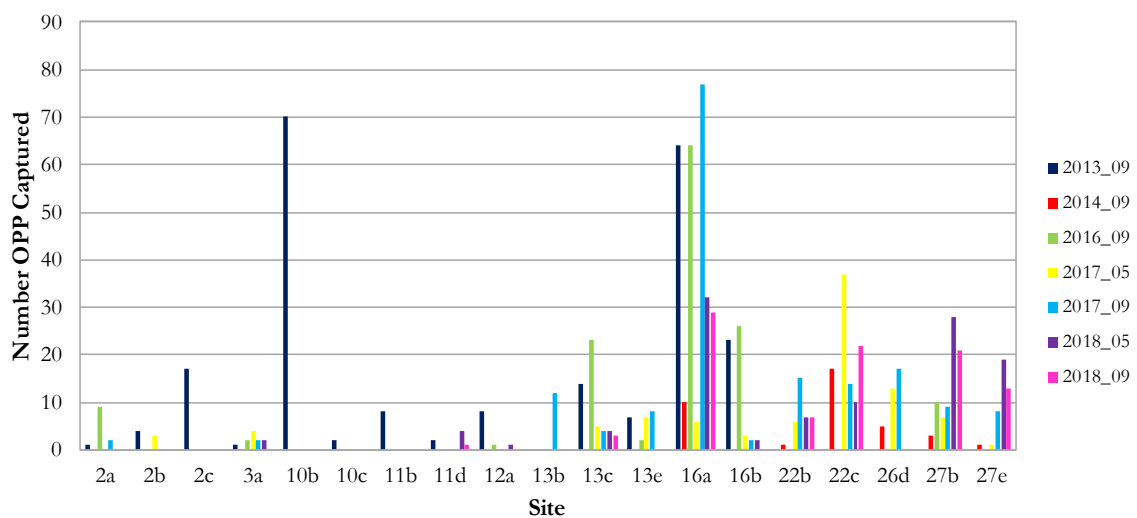


Figure 3.3 Number of OPP captured at all impact sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

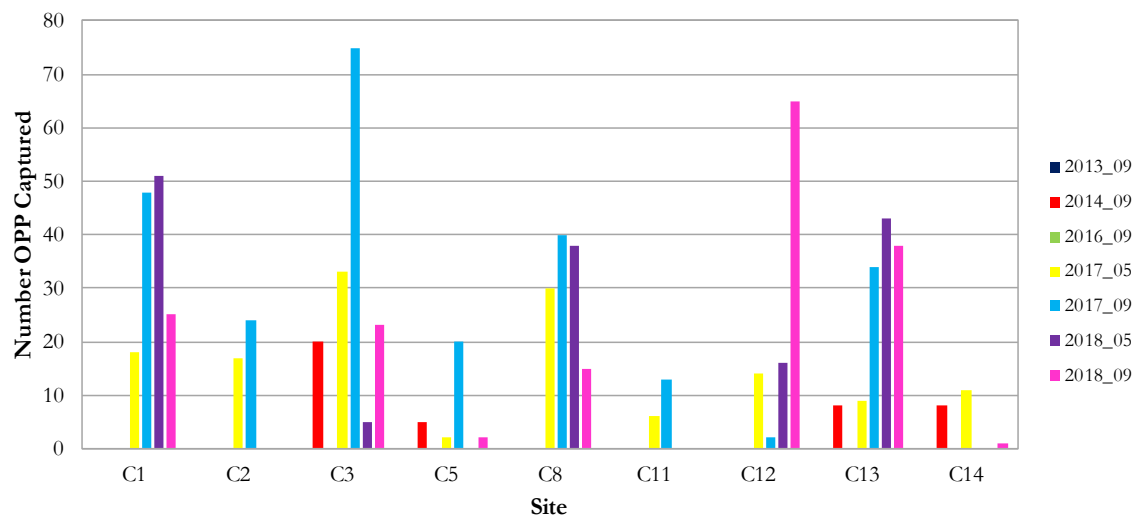


Figure 3.4 Number of OPP captured at all control sites since 2013 (pre-construction data from GeoLINK 2014 & 2015)

The full results of the May 2018 and September 2018 fish surveys are presented in **Appendix B**.

3.2 Water Quality

The results of water quality samples are presented in **Tables 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 2018 survey

<i>Site</i>	<i>Date</i>	<i>Temperature</i> °C	<i>pH</i>	<i>Conductivity</i> mS/cm	<i>Turbidity</i> NTU	<i>DO</i> mg/L	<i>DO%</i> %
2a	7/05/2018	17.02	6.13	0.093	13.1	2.79	29.8
2b	7/05/2018	16.21	6.51	0.226	37.7	2.92	30.6
2c	7/05/2018	Dry					
3a	7/05/2018	18.86	6.36	0.171	10.3	4.41	48.8
10b	8/05/2018	21.73	6.56	0.508	0	6.32	73.8
10c	8/05/2018	Dry					
11b	14/05/2018	16.68	5.26	0.163	0	9.46	100.3
11d	8/05/2018	21.02	5.01	0.193	2.8	4.68	54
12a	8/05/2018	19.08	5.82	0.28	41.6	2.08	23.2
13b	11/05/2018	16.23	4.18	0.179	2.7	3.6	37.8
13c	15/05/2018	17.88	4.18	0.18	0	4.2	45.7
13e	11/05/2018	No Access					
16a	11/05/2018	17.97	4.06	0.194	0	4.51	49.1
16b	10/05/2018	18.27	5.44	0.153	2.9	1.52	16.6
22b	9/05/2018	18.05	4.31	0.14	4.1	4.2	45.8
22c	9/05/2018	19.34	4.05	0.177	1.1	3.18	35.6
26d	11/05/2018	No Access					
27b	14/05/2018	14.83	4.08	0.176	5.7	9.02	92
27e	11/05/2018	17.2	4.24	0.166	5.3	2.1	22.5
C1	10/05/2018	21.91	3.87	0.137	2.4	9.43	110.4
C2	15/05/2018	15.34	4.29	0.185	29.2	4.11	42.4
C3	10/05/2018	18.55	4.01	0.182	1.8	3.96	43.6
C5	9/05/2018	20.2	3.96	0.133	1.2	4.1	46.6
C8	15/05/2018	13.52	3.92	0.321	5	3.8	37.8
C11	7/05/2018	23.02	4.4	0.2	0	2.91	34.8
C12	10/05/2018	23.44	3.94	0.143	0	5.61	67.4
C13	14/05/2018	15.19	5.2	0.126	2.8	10.97	112.8
C14	14/05/2018	13.92	5.68	0.063	18.9	10.84	108.5

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 2018 survey

<i>Site</i>	<i>Date</i>	<i>Temperature</i> °C	<i>pH</i>	<i>Conductivity</i> mS/cm	<i>Turbidity</i> NTU	<i>DO</i> mg/L	<i>DO%</i> %
2a	17/09/2018	15.22	6.51	0.096	35.1	1.09	11.3
2b	17/09/2018	13.31	7.1	0.472	109	4.1	40.5
2c	17/09/2018	Dry					
3a	24/09/2018	16.56	6.52	0.262	11	4.4	46.5
10b	21/09/2018	18.03	6.82	0.473	4	4.04	44.1
10c	21/09/2018	24.96	6.19	0.294	80	0.58	7.2
11b	19/09/2018	No Access					

Site	Date	Temperature	pH	Conductivity	Turbidity	DO	DO%
		°C		mS/cm	NTU	mg/L	%
11d	19/09/2018	22.64	5.49	0.159	34.8	2.67	31.7
12a	19/09/2018	19.72	5.71	0.295	2.4	0.43	4.8
13b	18/09/2018	14.29	6.43	0.338	11.5	0.47	4.7
13c	18/09/2018	16.21	3.44	0.163	3.2	1.12	11.8
13e	18/09/2018	No Access					
16a	21/09/2018	14.29	3.9	0.2	14.4	2.41	24.4
16b	24/09/2018	20.3	5.83	0.129	61.5	0.85	9.6
22b	18/09/2018	17.25	4.22	0.146	0.7	3.76	40.3
22c	20/09/2018	19.29	3.82	0.162	1.3	5.19	58
26d	18/09/2018	No Access					
27b	25/09/2018	16.48	4.24	0.179	31.3	4.55	48
27e	21/09/2018	16.24	4.44	0.143	8.3	2.24	23.6
C1	20/09/2018	17.62	4.17	0.113	3.6	1.35	14.6
C2	19/09/2018	19.33	4.09	0.185	10.6	4.26	47.6
C3	20/09/2018	16.05	3.45	0.209	28.5	3.89	40.8
C5	20/09/2018	17.89	3.76	0.115	0	2.08	22.6
C8	19/09/2018	14.71	3.73	0.291	12.2	2.46	25.1
C11	17/09/2018	24.65	4.37	0.208	4.8	5.39	66.1
C12	17/09/2018	20.09	4.22	0.154	3.4	5.69	64.5
C13	24/09/2018	16.46	5.39	0.155	5.5	2.86	30.2
C14	24/09/2018	16.51	5.46	0.094	10.3	3.59	37.9

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 September 2017 survey OPP were captured from water with a measured concentration of 1.12 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 water quality results collected during the May 2018 and September 2018 surveys is presented in **Appendix C**. The comparison indicates that DO concentrations 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 12a, 16b and 27b in May 2018 and sites 2a, 10c, 12a, 13b, 13c and 16b in September 2018. 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**, **Table 3.5**, **Table 3.6** and **Table 3.7**.

The flows were negligible ($< 0.1\text{m/s}$) at the majority of the sites visited.

Table 3.3 Brief descriptions of habitat features at all impact sites

<i>Section</i>	<i>Site</i>	<i>Habitat Description</i>
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 and September 2018 surveys there was no flow.
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 2018 survey there was no water and at the time of the September 2018 survey there was no flow.
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 (<i>Triglochin procerum</i>) and Maundia (<i>Maundia triglochinoides</i>). 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 litter and some emergent and submerged vegetation. The stream margins were gently sloping and grassy. There was no flow at the time of sampling. This site has been substantially modified during construction, including the construction of an upstream refuge pool, a deepened channel under the bridge crossing and

Section	Site	Habitat Description
		installation of rock scour protection on the northern margin of the existing excavation.
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 2018 survey there was no water and at the time of the September 2018 survey there was no flow.
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. Site 11b is located on private property with no access arrangement in place for this the September 2018 survey period.
8	11d	Site 11d consists of a narrow, 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. This site has been substantially modified during construction including revegetation and formalising of the channel. At the times of the May and September 2018 surveys there was a low flow, <0.1m/second.
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 (<i>Lepironia articulata</i>) and Jointed Twig-rush (<i>Baumea articulata</i>) in some areas. The degree of riparian cover, undercutting and root mass varies across the site. There was no perceptible flow at the time of the 2018 surveys. The site has now been significantly modified by a diversion and revegetation.
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. The site has now been significantly modified by a diversion and revegetation.
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 emergent vegetation. The banks at this site were grassy with rushes. 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. At the time of the last survey in September 2017 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. Site 13e is located on private property with no access arrangement in place for this monitoring period.

<i>Section</i>	<i>Site</i>	<i>Habitat Description</i>
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. 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. This site has been significantly modified during construction of the Woodburn-Broadwater access road by construction of a drought refuge pool, removal of some riparian vegetation and partial infilling of the eastern margin..
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 (<i>Utricularia sp.</i>). 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.
9	26d	Site 26b is a deep pool in a shallow natural drainage line. At the time of the last survey in September 2017 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. Site 26d is located on private property with no access arrangement in place for this monitoring period.
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.

Table 3.4 Aquatic plants identified at impact sites during the May 2018 survey

<i>Species Name</i>	<i>Common Name</i>	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
<i>Bacopa monnieri</i>	Water Hyssop	x	x																	
<i>Baloskion (Restio) pallens</i>	Zigzag Rush														x					
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush															x	x			
<i>Baumea articulata</i>	Jointed Rush									x	x	x								
<i>Baumea rubiginosa</i>	Baumea								x	x					x					
<i>Blechnum sp.</i>	Fern							x				x			x					x
<i>Carex fascicularis</i>	Tassel Sedge	x	x	x	x			x							x					
<i>Ceratophyllum demersum</i>	Hornwort				x															
<i>Cyperus sp.</i>	Sedge										x									
<i>Cyperus difformis</i>	Dirty Dora						x		x	x	x	x								
<i>Damasonium minus</i>	Starfruit								x											
<i>Eleocharis acuta</i>	Common Spikerush										x									
<i>Eleocharis equisetina</i>	Spikerush										x									
<i>Eleocharis pusilla</i>	Small Spike-rush								x	x										
<i>Enteromorpha spp.</i>	Green Alga						x			x		x								
<i>Gabnia sieberana</i>	Sawsedge							x		x	x			x	x	x	x			x
<i>Isolepis (Ficinia) nodosa</i>	Noddy Club Rush								x											
<i>Juncus usitatus</i>	Common Rush		x		x					x		x				x				
<i>Lepironia articulata</i>	Grey Rush					x			x	x					x		x			x
<i>Lomandra longifolia</i>	Creek Mat rush	x	x		x			x	x	x	x					x				
<i>Maundia triglochinoidea</i>	Maundia				x															
<i>Nymphaea sp.</i>	Waterlily					x				x		x				x				x
<i>Ottelia ovalifolia</i>	Swamp Lily				x															
<i>Paspalum distichum</i>	Water Couch			x	x	x	x		x	x	x									
<i>Persicaria decipiens</i>	Slender Knotweed					x	x													
<i>Persicaria hydropiper</i>	Water Pepper							x												
<i>Philydrum lanuginosum</i>	Frogsmouth	x			x	x			x		x				x					

<i>Schoenoplectus mucronatus</i>	Marsh Clubrush							x												
<i>Sphagnum</i> sp.	Peat Moss								x		x				x	x	x	x		x
<i>Triglochin procerum</i>	Water Ribbons																			x
<i>Utricularia</i> sp.	Bladderwort				x	x			x	x		x			x	x	x			x

Table 3.5 Aquatic plants identified at control sites during the May 2017 survey

<i>Species Name</i>	<i>Common Name</i>	<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>
<i>Baloskion (Restio) pallens</i>	Zigzag Rush	x	x	x	x	x	x			
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush	x			x	x		x		
<i>Baumea articulata</i>	Jointed Rush	x	x							
<i>Baumea rubiginosa</i>	Baumea		x	x		x	x	x		
<i>Blechnum</i> sp.	Fern			x					x	
<i>Carex fascicularis</i>	Tassel Sedge			x						
<i>Cyperus papyrus</i> *	Papyrus								x	
<i>Eleocharis acuta</i>	Common Spikerush						x		x	
<i>Enteromorpha</i> spp.	Green Alga								x	
<i>Gabnia sieberana</i>	Sawsedge	x		x	x	x		x	x	
<i>Juncus usitatus</i>	Common Rush				x		x			x
<i>Lepironia articulata</i>	Grey Rush	x		x			x			x
<i>Lomandra longifolia</i>	Creek Mat rush								x	
<i>Maundia triglochinoides</i>	Maundia								x	
<i>Nymphoides indica</i>	Water Snowflake								x	
<i>Ottelia ovalifolia</i>	Swamp Lily								x	
<i>Paspalum distichum</i>	Water Couch								x	
<i>Persicaria hydropiper</i>	Water Pepper								x	
<i>Philydrum lanuginosum</i>	Frogsmouth			x			x		x	x
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush								x	
<i>Sphagnum</i> sp.	Peat Moss	x	x	x	x	x	x	x		
<i>Triglochin procerum</i>	Water Ribbons								x	x

<i>Species Name</i>	<i>Common Name</i>	<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>
<i>Utricularia sp.</i>	Bladderwort	x		x	x	x	x		x	

Table 3.6 Aquatic plants identified at impact sites during the September 2018 survey

<i>Species Name</i>	<i>Common Name</i>	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
<i>Azolla spp.</i>	Azolla						x								x					
<i>Baloskion (Restio) pallens</i>	Zigzag Rush														x				x	
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush															x	x			
<i>Baumea articulata</i>	Jointed Rush								x	x	x			x					x	x
<i>Baumea rubiginosa</i>	Baumea														x					x
<i>Blechnum sp.</i>	Fern													x	x		x		x	x
<i>Carex appressa</i>	Tall Sedge					x														
<i>Carex fascicularis</i>	Tassel Sedge	x	x		x				x							x				
<i>Ceratophyllum demersum</i>	Hornwort				x															
<i>Cyperus difformis</i>	Dirty Dora					x				x	x	x			x					
<i>Drosera spatulata</i>	Spoon-leaved Sundew															x	x			
<i>Eleocharis acuta</i>	Common Spikerush										x									
<i>Eleocharis pusilla</i>	Small Spike-rush									x	x									
<i>Eleocharis sphacelata</i>	Tall Spike-rush						x					x								
<i>Enteromorpha spp.</i>	Green Alga											x								
<i>Gabnia sieberana</i>	Sawsedge									x	x			x	x	x	x		x	x
<i>Isolepis inundata</i>	Swamp Club Rush									x										
<i>Juncus usitatus</i>	Common Rush		x				x		x	x	x	x			x	x	x			
<i>Lemna sp.</i>	Duckweed														x					
<i>Lepironia articulata</i>	Grey Rush					x				x				x	x					x
<i>Lomandra longifolia</i>	Creek Mat rush	x	x			x			x	x						x				
<i>Lycopodiella cernua</i>	Scrambling Clubmoss															x	x			
<i>Maundia triglochoides</i>	Maundia				x															
<i>Nymphaea sp.</i>	Waterlily					x					x	x				x				x

<i>Ottelia ovalifolia</i>	Swamp Lily				x															
<i>Paspalum distichum</i>	Water Couch					x	x		x	x	x	x								
<i>Persicaria hydropiper</i>	Water Pepper					x														
<i>Persicaria lapathifolia</i>	Pale Knotweed											x								
<i>Philydrum lanuginosum</i>	Frogsmouth	x			x		x		x		x								x	
<i>Sphagnum sp.</i>	Peat Moss												x			x	x		x	
<i>Triglochin procerum</i>	Water Ribbons				x															x
<i>Utricularia sp.</i>	Bladderwort				x	x				x		x				x				

Table 3.7 Aquatic plants identified at control sites during the September 2017 survey

<i>Species Name</i>	<i>Common Name</i>	<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>
<i>Azolla sp.</i>	Azolla								x	
<i>Alisma plantago</i>	Common Water-plantain									x
<i>Baloskion (Restio) pallens</i>	Zigzag Rush	x	x	x	x	x	x	x		
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush	x	x		x	x				
<i>Baumea articulata</i>	Jointed Rush		x						x	
<i>Baumea rubiginosa</i>	Baumea					x	x	x		x
<i>Blechnum sp.</i>	Fern								x	
<i>Chorizandra cymbaria</i>	Heron Bristle-sedge									x
<i>Cyperus exaltatus</i>	Giant Sedge								x	
<i>Drosera spatulata</i>	Spoon-leaved Sundew	x			x			x		
<i>Enteromorpha spp.</i>	Green Alga					x				
<i>Gabnia sieberana</i>	Sawsedge			x	x	x			x	
<i>Juncus usitatus</i>	Common Rush	x	x	x		x	x	x		
<i>Lepironia articulata</i>	Grey Rush	x						x		
<i>Lycopodiella cernua</i>	Scrambling Clubmoss	x			x					
<i>Nymphaea sp.</i>	Waterlily	x							x	
<i>Ottelia ovalifolia</i>	Swamp Lily								x	
<i>Persicaria hydropiper</i>	Water Pepper								x	

<i>Species Name</i>	<i>Common Name</i>	<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>
<i>Philydrum lanuginosum</i>	Frogsmouth								x	x
<i>Potamogeton octandrus</i>	Pondweed								x	
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush							x		
<i>Sphagnum sp.</i>	Peat Moss	x	x	x	x	x		x		
<i>Triglochin procerum</i>	Water Ribbons								x	x
<i>Utricularia sp.</i>	Bladderwort	x		x				x		

Discussion and Conclusion

The two fish surveys completed during the second year of the construction phase for the W2B Threatened Fish monitoring were completed in May and September 2018. There were OPP captured at 10 of the 19 impact sites and 7 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 monitoring and the first year of construction phase threatened fish monitoring (GeoLINK 2014 & 2015, Jacobs 2018), the results collected in 2018 are moderately positive, indicating lower recruitment than the previous year but relative stability in the OPP populations over the first two years of highway construction. At least one year of continued monitoring is required to meet the aims of the Threatened Fish Management Plan.

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). Since the 2017 annual report (Jacobs 2018), there have been changes to access arrangements on some of the private properties bordering the W2B upgrade corridor. These have resulted in restricted access to some of the threatened fish monitoring sites including site 11b (September 2018 only) and sites 13e and 26d (May and September 2018).

The fishing effort for the two surveys this year consisted of 447 individual fish trapping hours and 26,277 seconds of electrofishing. A total of 1,853 fish were captured in May 2018 and 3,096 fish were captured in September 2018. These totals included 263 (14%) OPP and 265 (9%) OPP respectively. The OPP capture rates (as a percentage of total fish captured) in previous surveys have varied between 4% and 25%. The sites where OPP were captured in 2018 included:

- Seven of the nine control sites. OPP were captured at five of these during both surveys and at sites C14 and C5 in September 2018 only (C14 was dry in September 2017).
- Sites 11d, 13c, 13e, 16a, 22b, 22c, 27b, and 27e during both surveys. Significantly, the captures at Site 11d were the first at an impact site in the two subcatchments around Laing Hill since September 2013.
- Sites 3a and 12a and 16b in the May 2018 survey only.

The sites where OPP were not captured during either survey in 2018 included 2a, 2b, 2c, 10b, 10c, 11b, 13b, 13e and 26d. Of these sites, 2c was dry during both surveys and no access was permitted to 13e or 26d for either survey. Site 10c was dry at the time of the May 2018 survey but not during the September 2018 survey. Access to site 11b was restricted at the time of the September 2018 survey. No OPP have been captured at sites 10b, 10c or 11b since September 2013.

There has been significant variability in the numbers of OPP captured at each site during different surveys, at both the impact and control 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. Whilst the breeding and dispersal conditions appear to have been favourable in the year leading up to the commencement of construction (2016) they appear to have been less favourable in 2017. There was a reduced proportion of juvenile OPP captured this year compared to 2017 at both impact sites and control sites. (Table 4.1). However, there was still evidence of recruitment to some sites in the results from the current reporting period. Impact sites 16a and 27b and control sites C8 and C12 had low average lengths and strong capture numbers for both surveys, indicating good recruitment and/or breeding conditions at these sites (Figures 4.1, 4.2, 4.3 and 4.4).

Table 4.1 Proportion of juvenile OPP (<25mm total length) as a percentage of total OPP captured

Survey	Number of OPP Captured			Percentage of Juvenile OPP captured		
	Total	Impact	Control	Total	Impact	Control
May 2017	229	89	140	69.9	52.8	80.7
September 2017	425	170	255	73.4	56.5	84.7
May 2018	263	109	154	22.1	23.9	20.8
September 2018	265	96	169	27.9	18.8	33.1

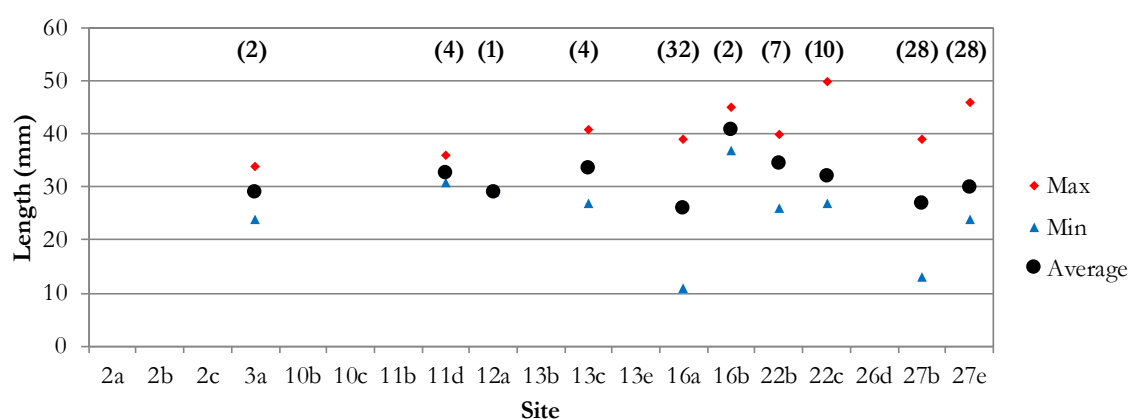


Figure 4.1 Length distribution data of all OPP captured at impact sites in the May 2018 survey (counts in brackets)

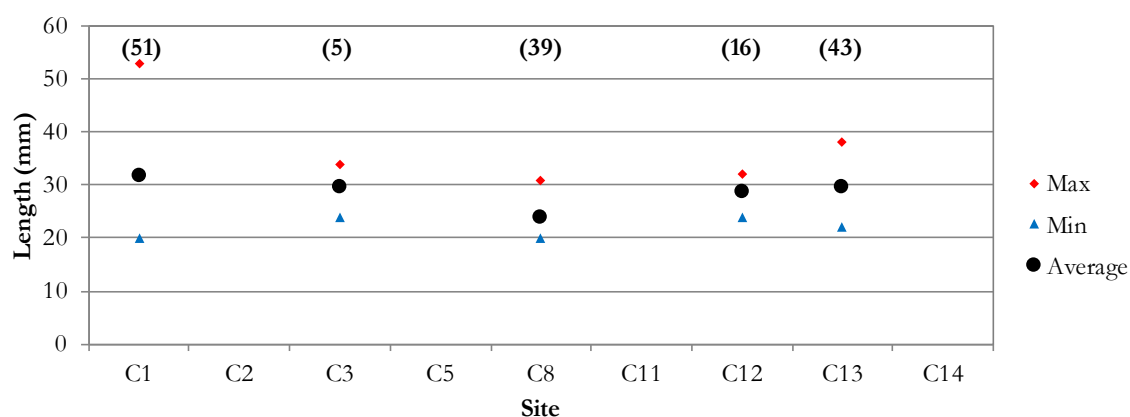


Figure 4.2 Length distribution data of all OPP captured at control sites in the May 2018 survey (counts in brackets)

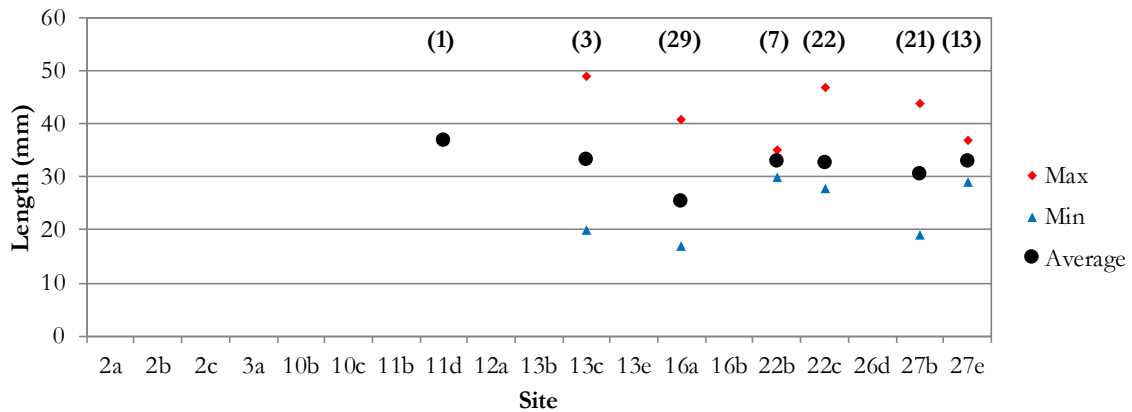


Figure 4.3 Length distribution data of all OPP captured at impact sites in the September 2018 survey (counts in brackets)

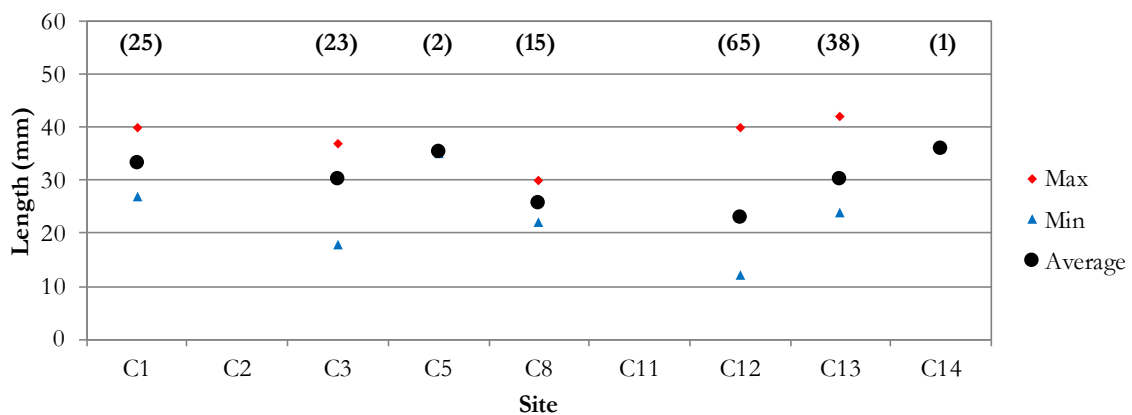


Figure 4.4 Length distribution data of all OPP captured at control sites in the September 2018 survey (counts in brackets)

Total rainfall was close to average for most months of the 2017 – 2018 OPP breeding season and relatively well spread across the months between October 2017 and April 2018. Average rainfall contributes to good breeding conditions for OPP, in terms of available breeding habitat. However, there were no flood events to aid dispersal between November 2017 and September 2018. This may, at least partially, explain the reduced proportion of juvenile OPP captured at some sites (and overall) during the 2018 surveys.

For the first time since September 2013 OPP were captured at site 11d during the 2018 surveys. This is also the first capture of OPP at any of the impact sites in the two subcatchments immediately south and north of Laing Hill (ie. sites 10b, 10c, 11b and 11d) since September 2013. This is a positive indication that the rehabilitation of the drain at this site has been successful. The capture of an individual OPP at site 12a in the May 2018 survey provides a similar positive indication.

There has still been no capture of OPP at sites 10b or 10c since September 2013. Construction activity in the immediate vicinity of sites 10b and 10c was intense throughout 2016 and 2017 but has now mostly been completed. In addition to any potential disturbance from construction it is likely that OPP have not yet returned to these sites following the drought conditions in late 2013 and early 2014, due to the lack of a large flood event. The pH measurements from site 10b, which have been in the higher part of the range known to be occupied by OPP during the two surveys in 2018, may also be indicative of a pH-based deterrent to recruitment at this site.

The conditions during both surveys this year were good for capturing fish. The May 2018 survey was undertaken after a long period of average rainfall. The September 2018 survey was undertaken after a moderately rainy few weeks, which punctuated a four-month period of below average rainfall. There were two dry sites during the May 2018 survey and one dry site during the September 2018 survey.

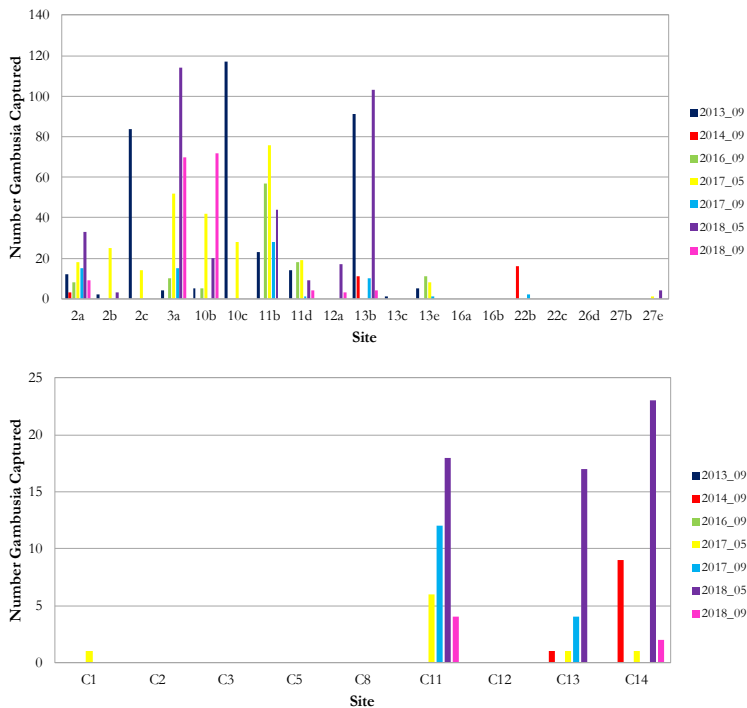
In addition to the OPP, a large number and variety of other fish have been encountered during threatened fish surveys on the W2B upgrade. In general, the fish communities at most sites resembled those observed during pre-construction surveys. No new fish species were encountered at any sites during the 2018 surveys. The numbers of Mosquitofish (*Gambusia holbrooki*) encountered at each site are of specific interest as they have been identified as a Key Threatening Process under the *Threatened Species Conservation Act 1995* and are antagonistic towards OPP. There has been variation in the numbers of Mosquitofish encountered during construction phase surveys but there is no apparent trend. There is no evidence at present that Mosquitofish numbers are increasing as a result of disturbances associated with construction.

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). There is variation in the habitat features measured at each site between surveys (**Appendix A**). The variation in habitat condition measured at the impact sites during the surveys this year is generally within the ranges observed in pre-construction surveys and mirrored by the variation in habitat condition measured at the control sites.

This study also measured physicochemical water quality variables. Whilst water quality varied throughout the study area, at the majority of the sites surveyed the water quality fell within the known ranges inhabited by OPP. There were some sites where the DO concentration was below the known range and where pH was above the known range, particularly during the September 2018 survey. Sites 2a, 10c, 12a, 13b, 13c, 16b, C1, C5 and C8 registered the lowest DO concentrations since threatened fish monitoring began during the September 2018 surveys. Sites 2a, 2b, 3a, 10b, 10c, 12a, 13b and 16b registered higher pH measurements in the 2018 surveys than in previous surveys. Notably, crossings or modifications have been installed at most of these sites during the current reporting period. Increased pH is of concern in OPP waterways because low pH waters are thought to provide OPP with a competitive advantage. More information is required to determine whether this is part of a trend at these sites. Water quality information collected as part of ongoing, regular W2B upgrade water quality monitoring may provide more details.

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 4.2**.

Table 4.2 Performance indicators for threatened fish management on the W2B upgrade.

<i>Performance Indicator</i>	<i>Notes</i>	<i>Conclusion</i>
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. OPP have now been captured at two of the five sites located either side of Laing Hill for the first time since construction phase monitoring began. Although it is possible that construction activity was restricting OPP recruitment to the Laing Hill area it is just as likely that they have not yet returned to some of the sites there after drought conditions in summer 2013/14 led to these sites all drying out. Flood activity, which aides OPP recruitment, particularly to isolated sites like 10b, has been restricted during the interim period. The most impactful construction and stream rehabilitation work at these sites has now been completed and the 2018 monitoring indicates that OPP are returning to some of these sites. Although OPP abundance has varied at several impact sites during construction phase monitoring and reduced numbers have been noted at some sites, a similar degree of variability leading to reduced numbers has also been evident at some of the control sites, particularly the sites prone to drying out, such as C14.	Continued monitoring at normal frequency.
Occurrence of Eastern Gambusia in waterways where they have not previously been recorded	During monitoring this year Gambusia were captured at sites 2a, 2b, 3a, 10b, 11b, 11d, 12a, 13b, and 27e. They were captured at all of these sites during pre-construction monitoring with the exception of site 27e, which was only surveyed once in the preconstruction phase. During preconstruction monitoring OPP were captured at control sites C13 and C14. In addition to these sites they were also captured at control site C11 during monitoring this year. The variation in Gambusia capture at the impact sites is reflected by variation in the Gambusia capture at control sites. 	No corrective action required

<i>Performance Indicator</i>	<i>Notes</i>	<i>Conclusion</i>
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 were 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 of dewatering and stream diversion activities. OPP, in relatively large numbers, were captured at both of these release sites during both surveys conducted this year and both surveys in the previous annual reporting period.	No corrective action required
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. Some of the pH measurements have indicated a potential increase in the pH around construction areas. Measurements from sites 2a, 3a, 10b, 12a 13b and 16b, while generally within background variation for those waterways (Appendix C), warrant further investigation as monitoring proceeds.	Conduct an assessment of DO concentrations and pH 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 during the construction phase monitoring to date.	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.	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 actions adopted along the W2B upgrade during the second year of construction in Section 6-9 are successfully protecting OPP populations and habitat. OPP have been captured at most known OPP sites along the W2B upgrade, recruitment was strong in 2017 and the numbers of OPP captured during surveys in 2018 were relatively large. There are some mitigating factors at the known OPP sites where OPP have not been encountered in construction phase monitoring. In effect, construction activities cannot be considered as the only variable leading to variable fish monitoring results. In addition, habitat and water quality remain suitable for OPP at most of the known sites, though some very low DO measurements have been collected and pH measurements from site 10b have been at the higher end of the known range for OPP. As threatened fish monitoring progresses in to the next year of construction it is likely that the clarity of this picture will improve. Consideration of the results presented against performance indicators from the TFMP indicate that it may be necessary to assess pH and dissolved oxygen at some sites using data from water quality monitoring undertaken as part of the W2B upgrade.



Plate 4.1 Threatened fish management measures and stream rehabilitation at site 12a, where OPP were captured during the May 2018 survey.

Project Team

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

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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.

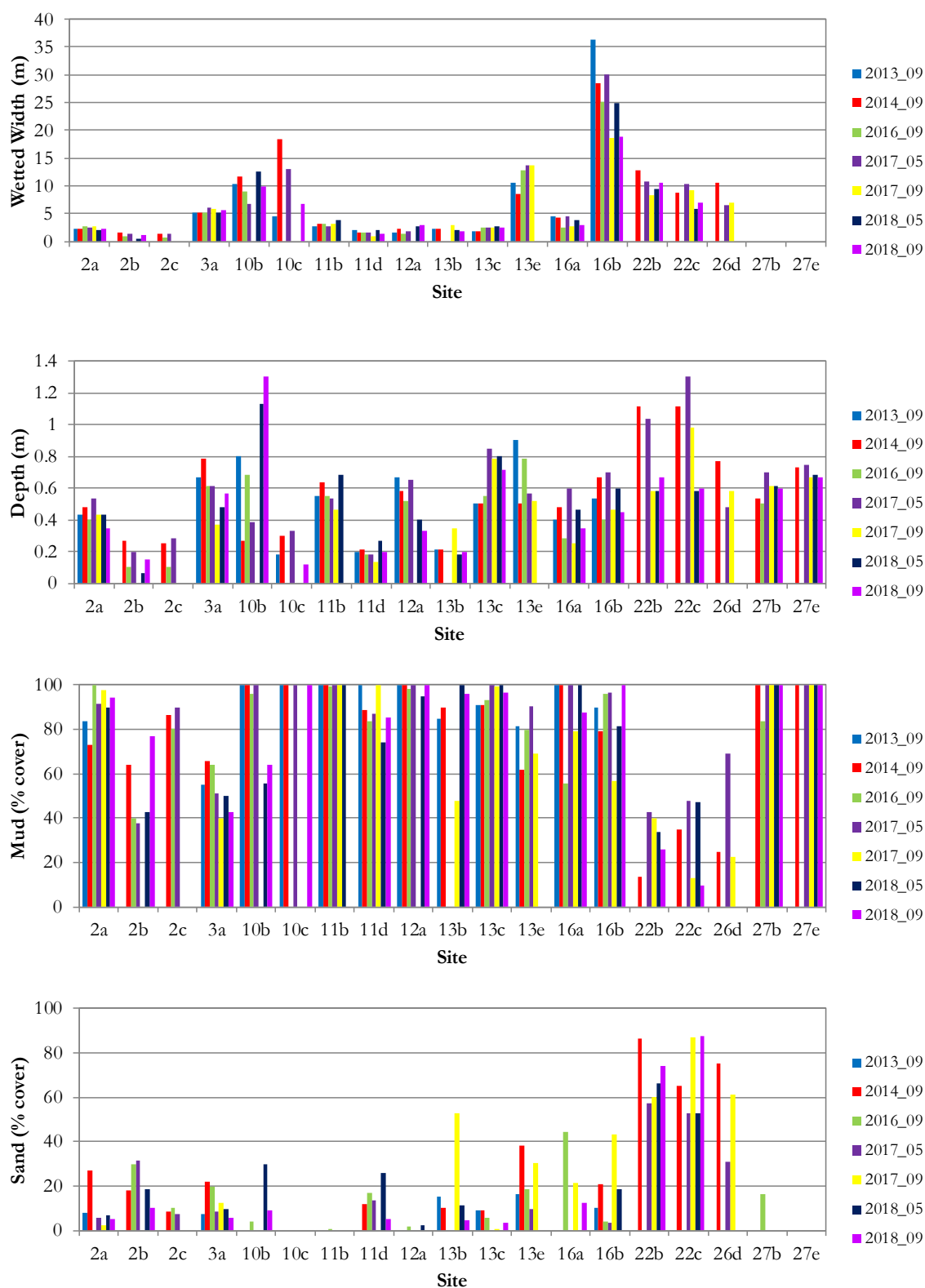


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

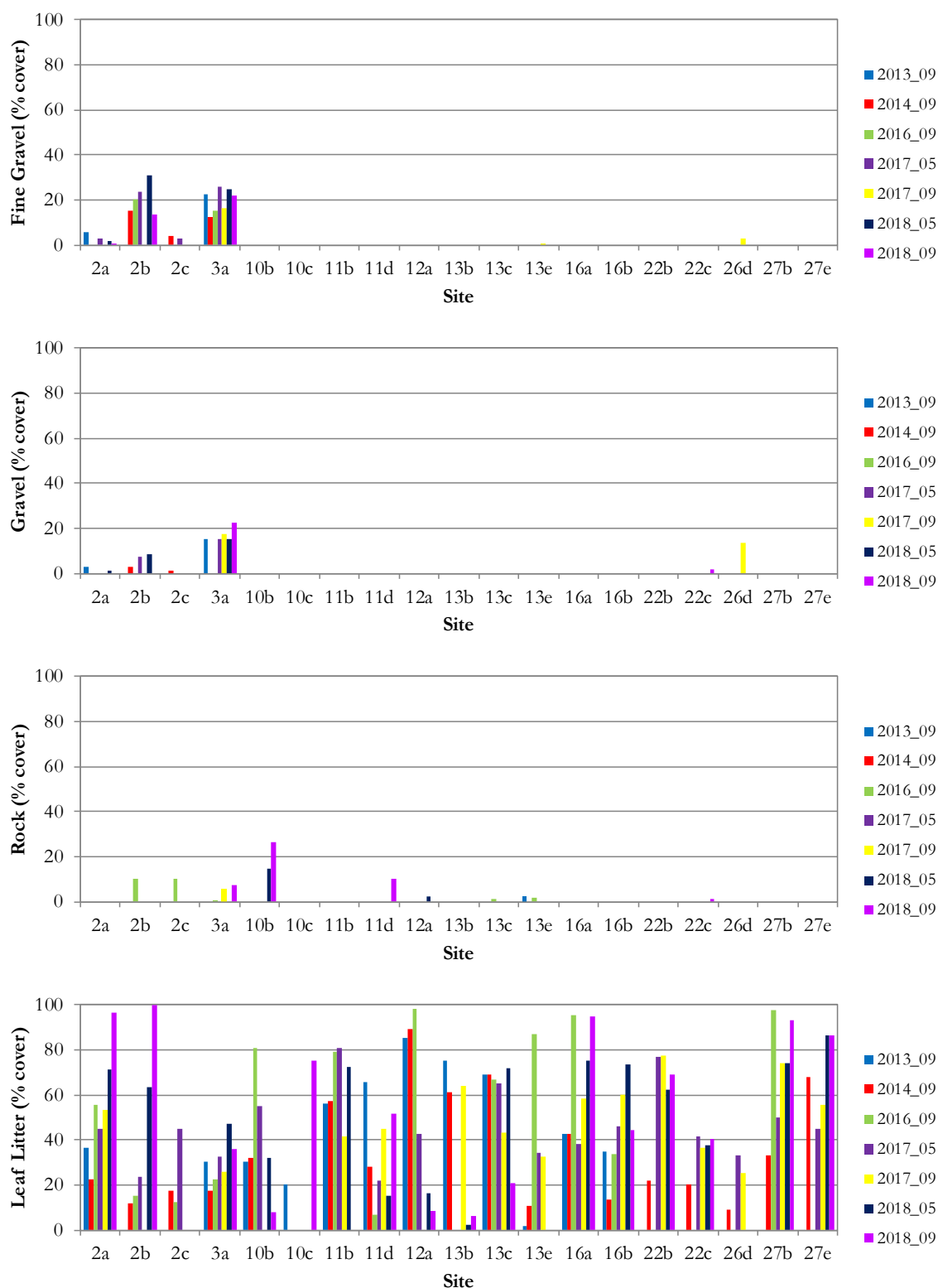


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

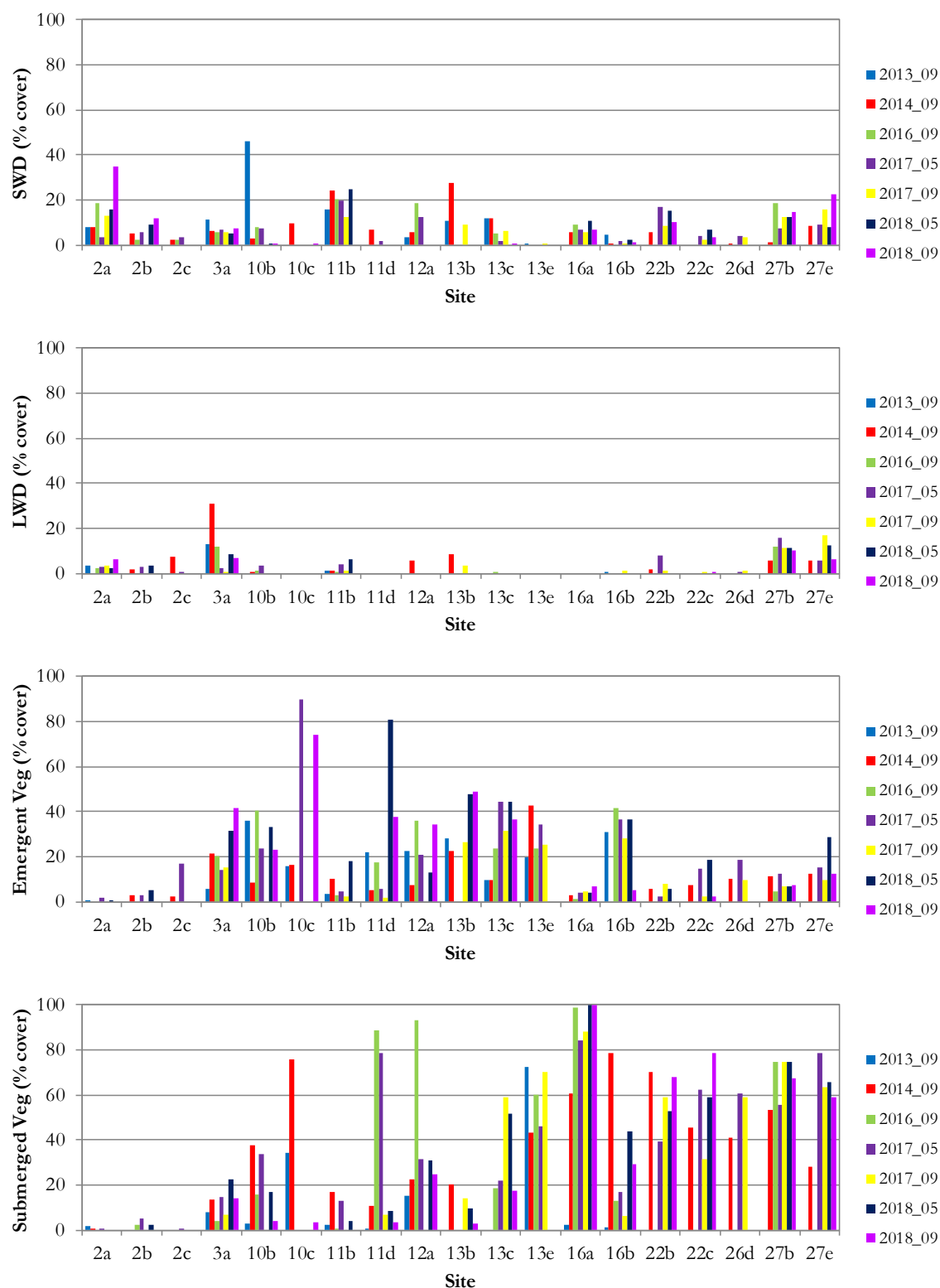


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

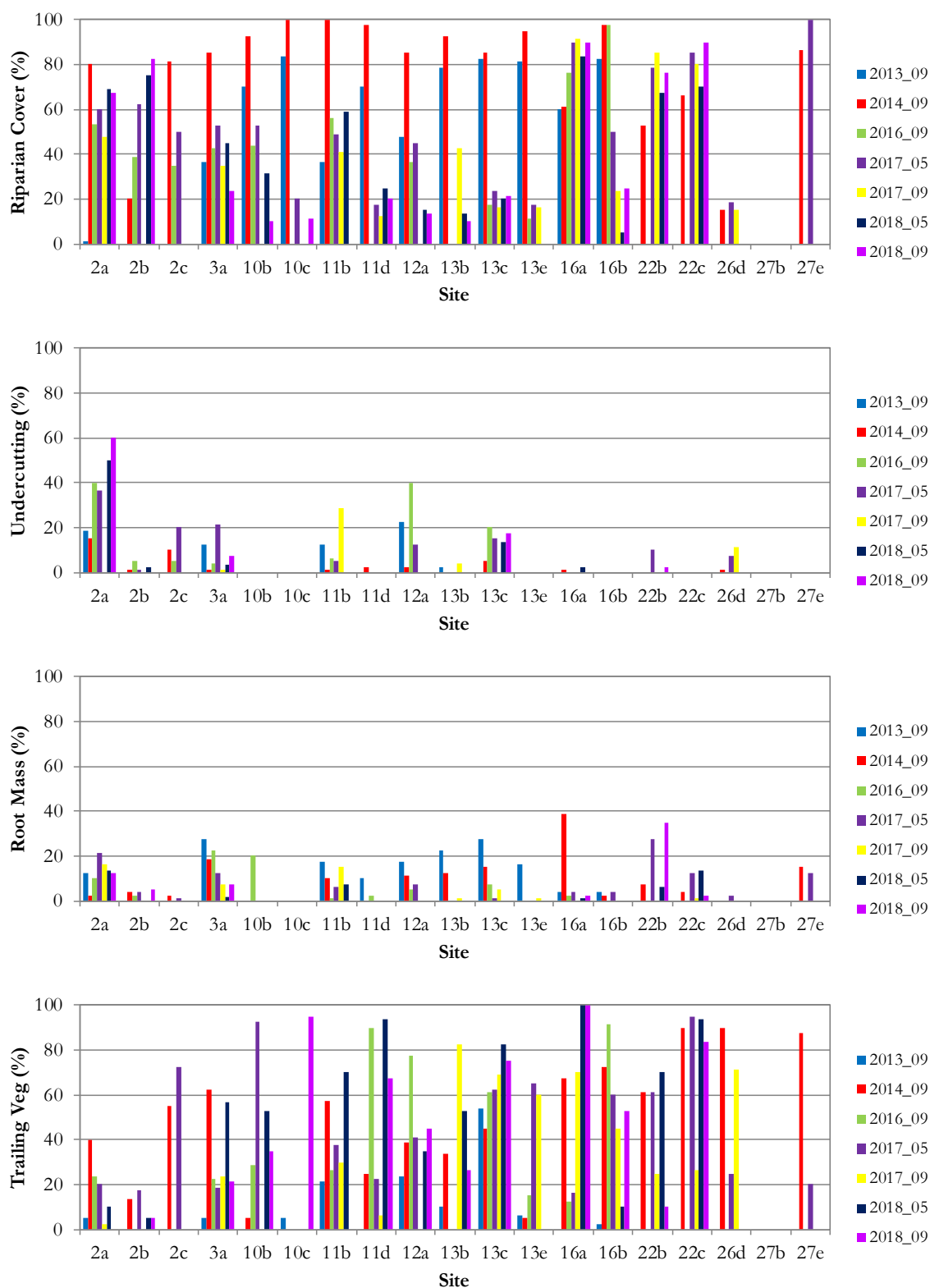


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

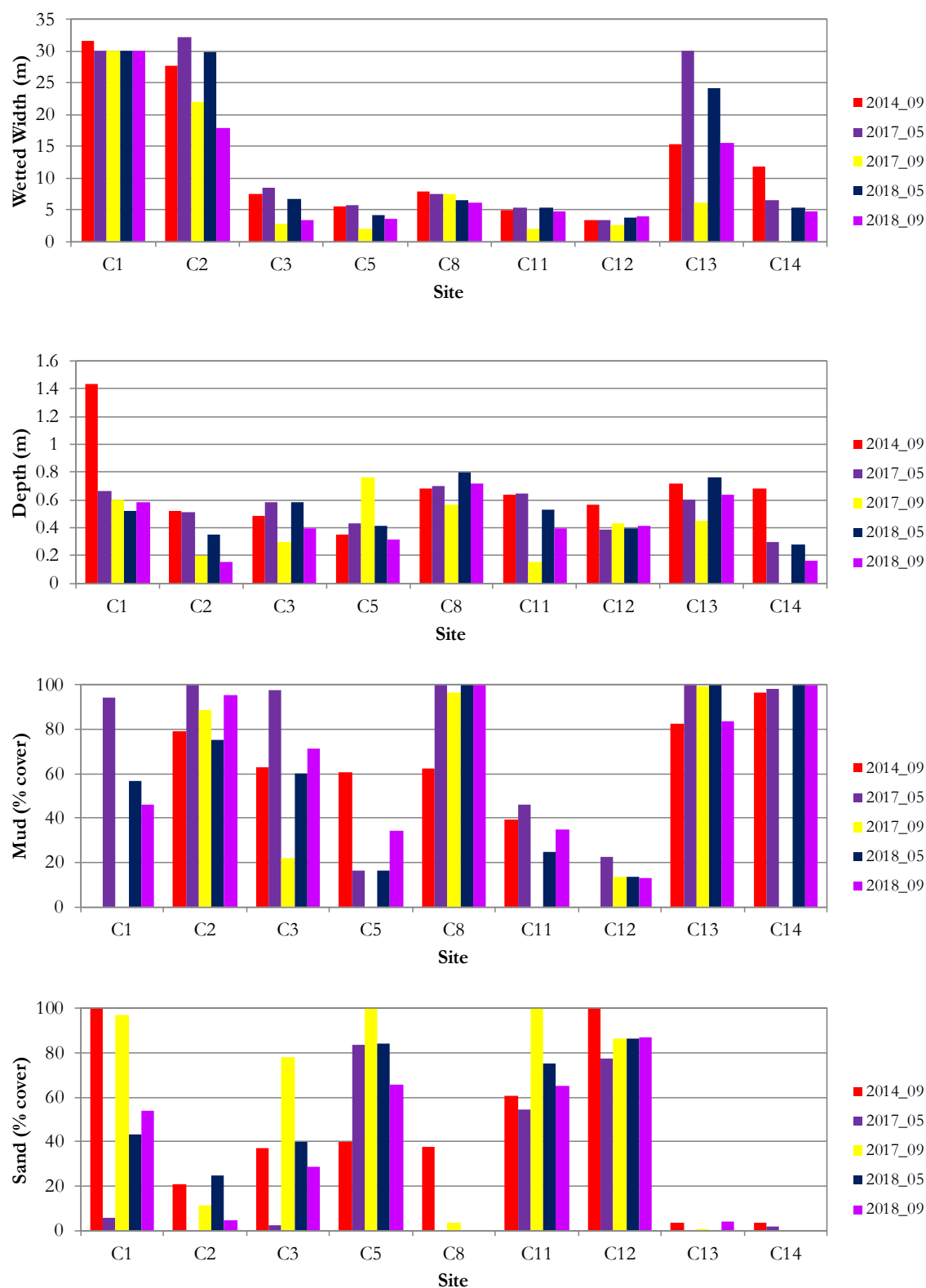


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

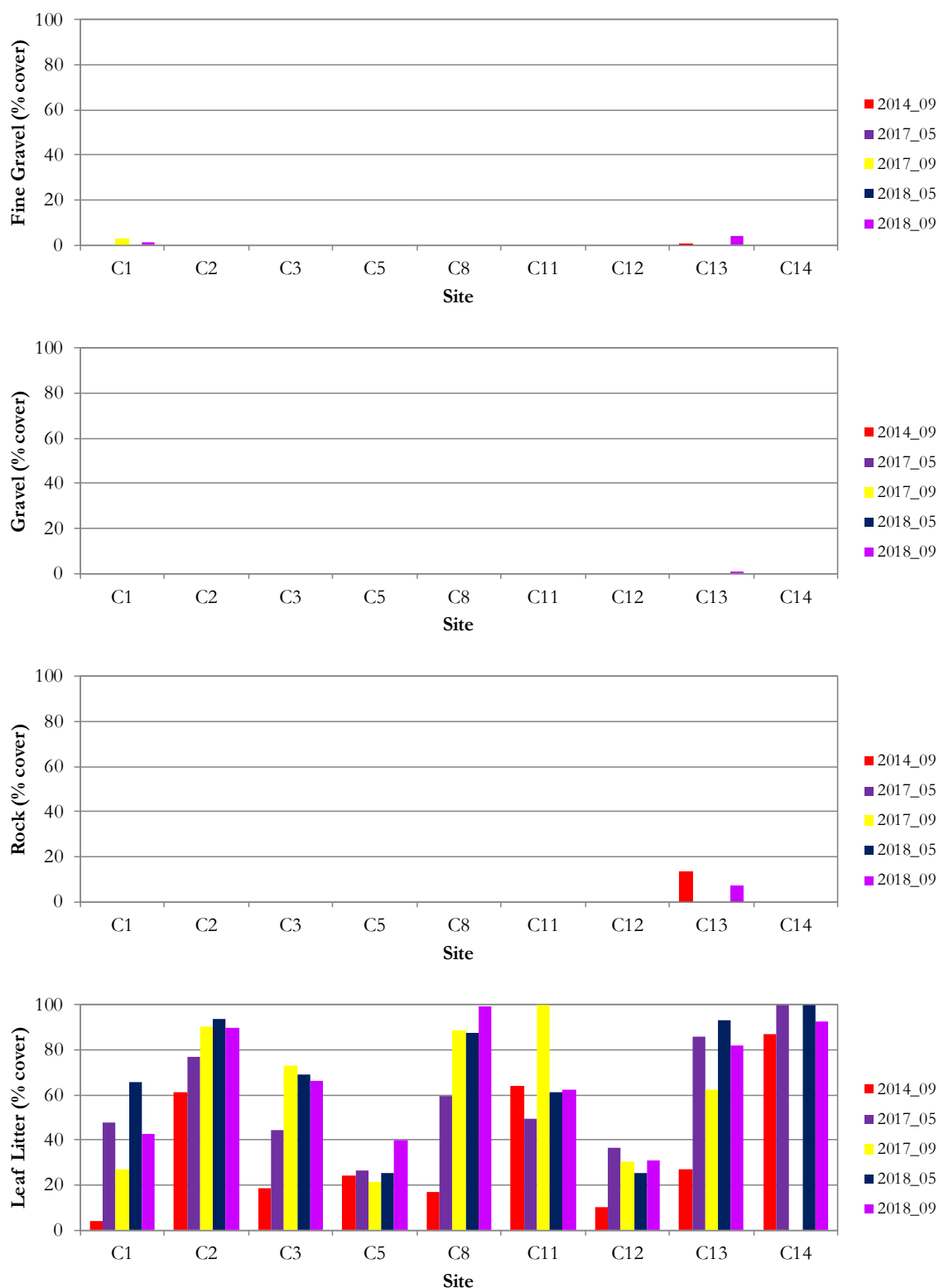


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

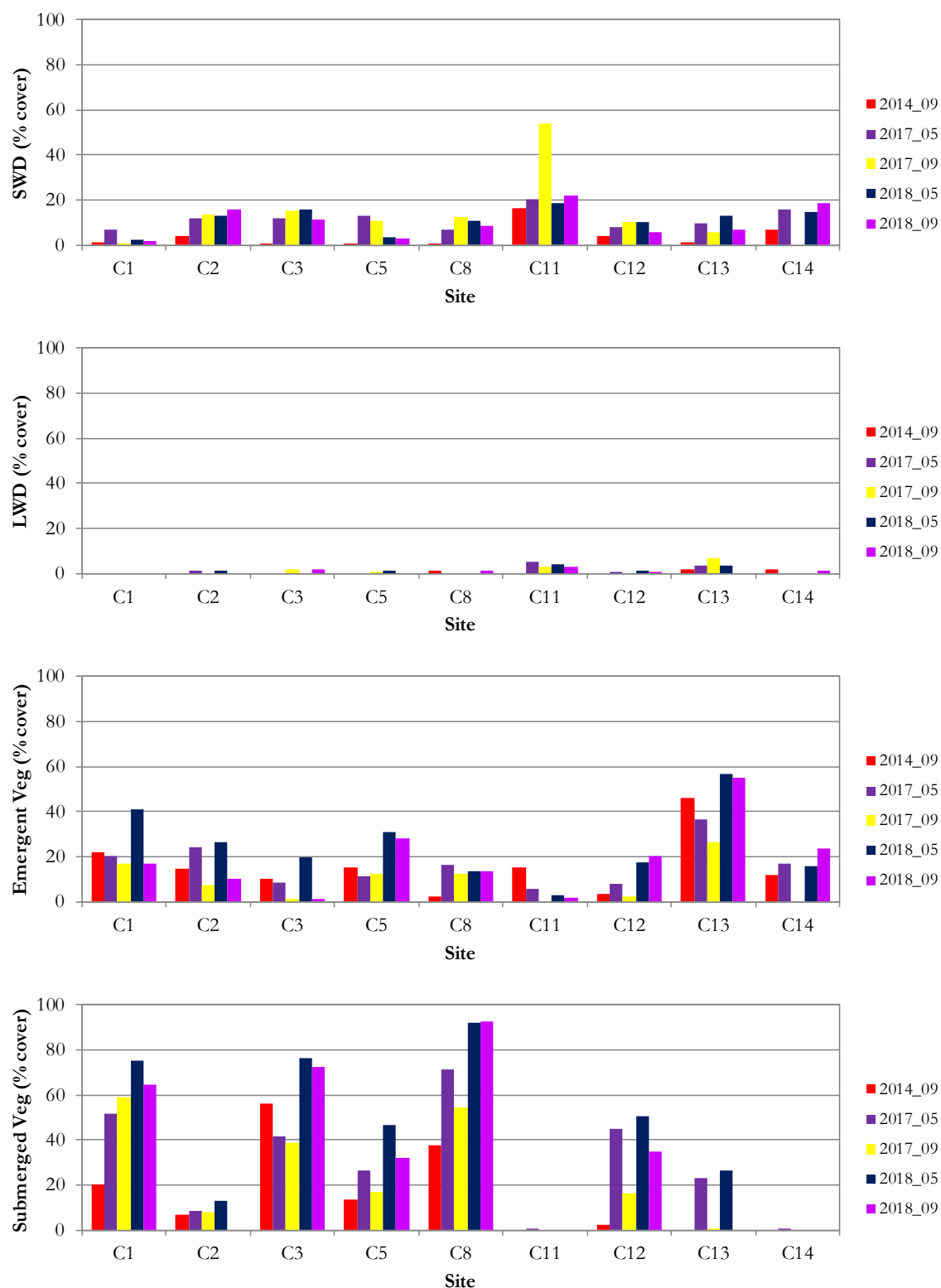
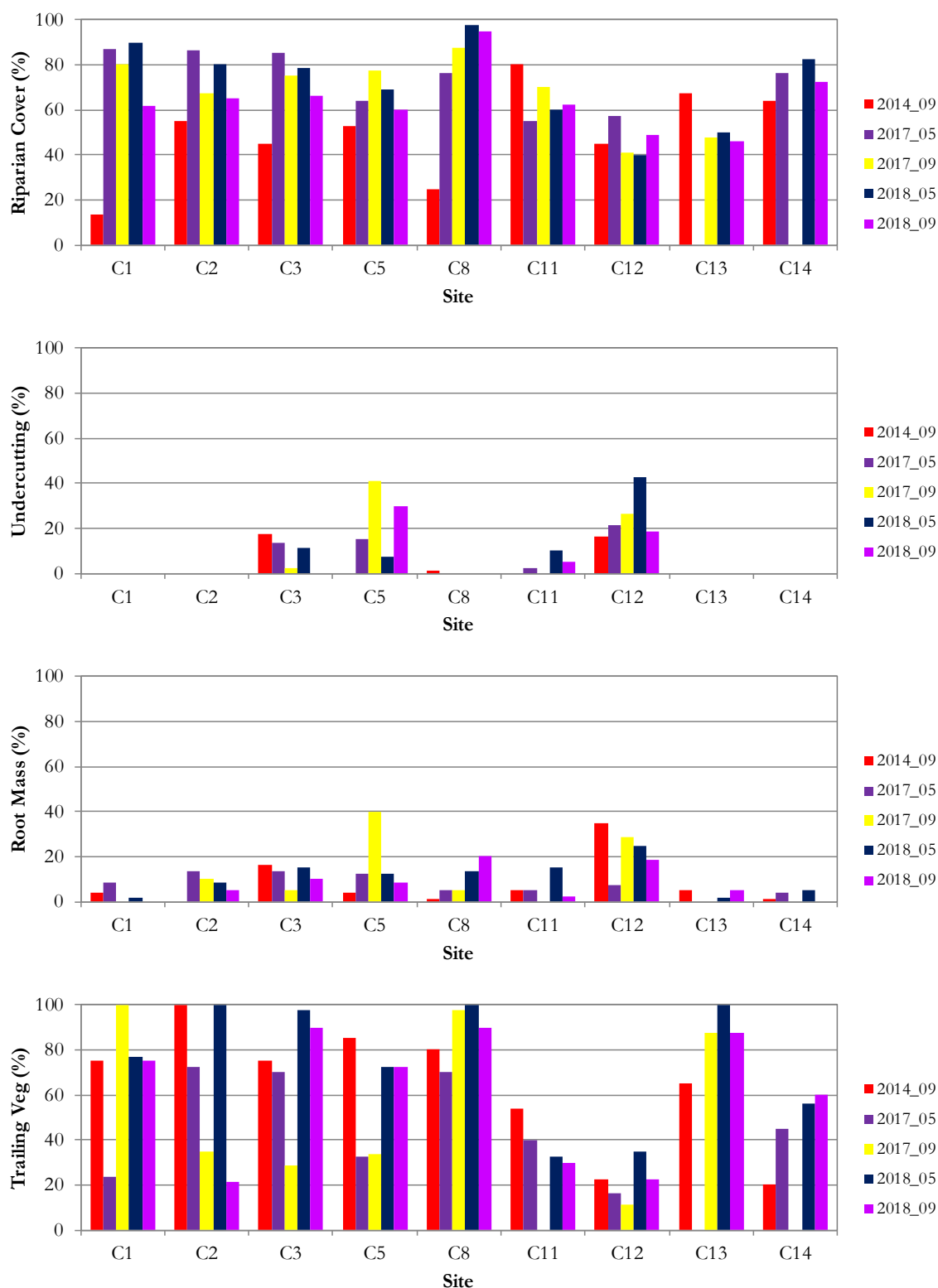


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.



Appendix B

Construction Phase Fish Monitoring Results

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

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

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

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

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

Table B5. Summary of captures for all fishing methods at all impact sites during the May 2018 survey

<i>Scientific Name</i>	<i>Common Name</i>	<i>Site</i>																		
		2a	2b	2c*	3a	10b	10c*	11b	11d	12a	13b	13c	13e*	16a	16b	22b	22c	26d*	27b	27e
<i>Anguilla australis</i>	Shortfin Eel	1	0	0	0	0	0	0	0	2	2	0	0	0	2	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	25	0	0	20	1	0	41	20	25	26	25	0	0	0	14	4	0	2	1
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	4	4	0	34	1	52	0	39	0	0	0	0	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	32	0	0	79	1	0	6	0	9	0	0	0	1	67	75	27	0	13	13
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	6	0	14	13	14	7	0	2	1
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	0	0	0	2	0	0	0	4	1	0	4	0	32	2	7	10	0	28	19
<i>Gambusia</i>	Mosquito Fish	33	3	0	114	20	0	44	9	17	103	0	0	0	0	0	0	0	0	4

* No survey due to access restrictions or dry conditions at sites 2c, 10c, 13e and 26d.

Table B6. Summary of captures for all fishing methods at all control sites during the May 2018 survey

<i>Scientific Name</i>	<i>Common Name</i>	<i>Site</i>								
		<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>
<i>Anguilla australis</i>	Shortfin Eel	0	0	1	1	1	1	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	2	0	0	7	0	0	5	8	0
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	0	0	0	9	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	26	0	0	11	96	8	96	18	0
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	28	0	9	4	37	0	32	60	0
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	51	0	5	0	39	0	16	43	0
<i>Gambusia</i>	Mosquito Fish	0	0	0	0	0	18	0	17	23

Table B7. Summary of captures for all fishing methods at all impact sites during the September 2018 survey

<i>Scientific Name</i>	<i>Common Name</i>	<i>Site</i>																		
		2a	2b	2c*	3a	10b	10c	11b*	11d	12a	13b	13c	13e*	16a	16b	22b	22c	26d*	27b	27e
<i>Anguilla australis</i>	Shortfin Eel	1	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	32	0	0	16	10	0	0	22	23	1	78	0	0	0	15	31	0	3	1
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	8	17	0	0	1	64	0	44	0	0	0	1	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	49	0	0	77	9	0	0	0	3	0	0	0	0	527	82	84	0	5	4
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	11	0	2	2	12	0	0	10	3
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	0	0	0	0	0	0	0	1	0	0	3	0	29	0	7	22	0	21	13
<i>Gambusia</i>	Mosquito Fish	9	0	0	70	72	0	0	4	3	4	0	0	0	0	0	0	0	0	0

* No survey due to access restrictions or dry conditions at sites 2c, 11b, 13e and 26d.

Table B8. Summary of captures for all fishing methods at all control sites during the September 2018 survey

<i>Scientific Name</i>	<i>Common Name</i>	<i>Site</i>								
		<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>
<i>Anguilla australis</i>	Shortfin Eel	0	0	1	0	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	0	0	0	23	0	0	0	12	0
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	0	0	0	10	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	41	0	2	8	136	56	889	35	1
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	21	0	4	0	10	0	79	83	0
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	25	0	23	2	15	0	65	38	1
<i>Gambusia</i>	Mosquito Fish	0	0	0	0	0	4	0	0	2

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	2018 Range
Unnamed waterway south of Serendipity Rd Ch. 11400	2a, 2b, 2c	Temp	(°C)	13.3 – 23.6	12.42 - 16.00	13.31 - 17.02
		DO	(mg/L)	4.11 - 10	1.42 - 4.58	1.09 - 4.10
		pH		5 – 6.9	4.98 - 5.83	6.13 – 7.1
		Conductivity	(mS/cm)	0.009 – 0.368	0.105 - 0.275	0.093 - 0.472
		Turbidity	(NTU)	0.9 - 118	7.6 - 20.8	13.1 - 109
Tabbimoble floodway no. 1 Ch. 115300	3a	Temp	(°C)	12.8 - 24	13.73 - 16.79	16.56 - 18.86
		DO	(mg/L)	1.3 - 8.07	4.61 - 5.59	4.4 – 4.41
		pH		4.4 – 7.2	5.43 - 5.62	6.36 - 6.52
		Conductivity	(mS/cm)	0.009 – 0.140	0.089 - 0.093	0.171 - 0.262
		Turbidity	(NTU)	18.9 – 132	12.5 - 13.5	10.3 - 11.0
Unnamed waterway south of MacDonalds Ck Ch. 134600	10b, 10c	Temp	(°C)	16.6 - 29	12.5 - 15.5	18.0 - 21.7
		DO	(mg/L)	3.17 - 10	0.61 - 0.89	0.58 - 6.32
		pH		4 – 9.3	4.7 - 4.75	6.19 - 6.56
		Conductivity	(mS/cm)	0.102 – 0.537	0.249 - 0.333	0.294 - 0.508
		Turbidity	(NTU)	1.3 - 800	3.8 - 5.7	4.0 - 80
MacDonalds Ck Tributary Ch. 135200, 135530 and 136450	11b, 11d, 22b, 22c	Temp	(°C)	15.4 – 26.7	14.16 - 24.69	16.68 - 22.64
		DO	(mg/L)	2.27 – 8.9	0.74 - 8.65	2.67 - 9.46
		pH		3.8 – 8.9	3.44 - 5.97	3.82 - 5.49
		Conductivity	(mS/cm)	0.092 – 0.606	0.131 - 0.178	0.14 - 0.193
		Turbidity	(NTU)	2.4 - 138	0 - 212	0.7 - 34.8
MacDonalds Ck Ch. 136600	12a	Temp	(°C)	14.9 - 26	13.36	19.08 - 19.72
		DO	(mg/L)	1.7 – 8.1	1.36	0.43 - 2.08
		pH		3.6 – 6.3	2.72	5.71 - 5.82
		Conductivity	(mS/cm)	0.164 – 0.406	0.25	0.28 - 0.295
		Turbidity	(NTU)	0 - 14	0	2.4 - 41.6
Broadwater NP Swampland Ch. 139000	16a, 16b, 27b, 27e	Temp	(°C)	18.6 – 21.45	13.33 - 21.38	14.29 - 20.3
		DO	(mg/L)	1.83 – 5.39	0.62 - 8.3	0.85 - 9.02
		pH		4.15 – 4.63	3.7 - 4.6	3.9 - 5.83
		Conductivity	(mS/cm)	0.128 – 0.171	0.116 - 0.23	0.129 - 0.200
		Turbidity	(NTU)	0 - 703	0 - 64.2	0 - 61.5
Montis Gully Tributary 1 Ch. 141180 and 141850	13b, 13c, 13e, 26d	Temp	(°C)	17.23 – 30.9	13.33 - 19.27	14.29 - 17.88
		DO	(mg/L)	2.1 – 9.4	0.95 - 4.23	0.47 – 4.2
		pH		3.7 - 7	3.39 - 3.8	3.44 - 6.43
		Conductivity	(mS/cm)	0.026 – 0.209	0.137 - 0.206	0.163 - 0.200
		Turbidity	(NTU)	0 - 225	0 - 4.1	3.2 - 14.4
W of Bundjalung NP Approximately 4 km east of Ch. 110000	C13, C14	Temp	(°C)	18.09 – 19.11	12.59 - 16.47	13.92 - 16.51
		DO	(mg/L)	2.24 – 4.38	3.4 - 3.79	2.86 - 10.97
		pH		4.56 – 5.47	4.84 - 5.51	5.20 - 5.68
		Conductivity	(mS/cm)	0.086 – 0.112	0.102 - 0.112	0.063 - 0.155
		Turbidity	(NTU)	0 – 8.7	0 - 15	2.8 - 18.9
Broadwater NP	C11, C12	Temp	(°C)	15.91 – 18.49	17.08 - 29.36	20.09 - 24.65
		DO	(mg/L)	2.9 – 5.59	1.76 - 8.35	2.91 – 5.69

Location	Sites	Parameter	Units	Pre-construction range	2017 Range	2018 Range
6.5 km east of Ch.13000		pH		3.85 - 4	3.79 - 4.54	3.94 - 4.40
		Conductivity	(mS/cm)	0.124 – 0.149	0.106 - 0.155	0.143 - 0.208
		Turbidity	(NTU)	0 – 2.3	0 - 6.8	3.4 - 4.8
MacDonalds Ck Tributary 0.5 km east of 136600 and 1 km east of 137800	C2, C5	Temp	(°C)	16.87 – 17.78	12.36 - 19.3	15.34 - 20. 2
		DO	(mg/L)	4.58 – 4.69	2.74 - 4.70	2.08 - 4.26
		pH		3.7 – 4.22	3.31 - 3.99	3.76 - 4.29
		Conductivity	(mS/cm)	0.115 – 0.158	0.113 - 0.183	0.115 - 0.185
		Turbidity	(NTU)	0 - 0	0 - 37.6	0 - 29.2
Broadwater NP 1 km east of Ch 138000	C1, C3	Temp	(°C)	17.2 - 18.91	14.33 - 23.66	16.05 - 21.91
		DO	(mg/L)	4.55 - 9.18	2.45 - 3.77	1.35 - 9.43
		pH		3.97 – 4.49	3.42 - 3.96	3.45 - 4.17
		Conductivity	(mS/cm)	0.089 - 0.176	0.100 - 0.201	0.113 - 0.209
		Turbidity	(NTU)	0 – 1.4	0 - 26.4	1.8 - 28.5
Broadwater NP 2 km east of 136400	C8	Temp	(°C)	17.98	12.18 - 18.49	13.52 - 14.71
		DO	(mg/L)	5.77	2.87 - 3.29	2.46 - 3.8
		pH		3.95	3.21 - 3.46	3.73 - 3.92
		Conductivity	(mS/cm)	0.236	0.315 - 0.363	0.291 - 0.321
		Turbidity	(NTU)	12.1	0 - 5	5 - 12.2