Woolgoolga to Ballina Pacific Highway Upgrade

Threatened Fish Monitoring Program Annual Report 2020

Final Construction Phase Report

NSW GOVERNMENT

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Woolgoolga to Ballina Pacific Highway Upgrade

Threatened Fish Monitoring Program Annual Report 2020

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Introduction

The following report summarises the methods and results from the fourth year of threatened fish monitoring undertaken during the construction phase 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 Transport for NSW (TfNSW) 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 (Roads and Maritime 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 fourth 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 Profile

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 (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.

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)

Plate 1.1 OPP captured at site 22c during the September 2020 survey.

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 year of threatened fish monitoring 27 and 28 sites were sampled in May 2017 and September 2017 respectively. In the second year of monitoring a reduced number of sites were sampled due to landholder restrictions upon access to sites 11b, 13e and 26b. In the third year of monitoring 7 sites, previously monitored as part of the Devils Pulpit Pacific Highway upgrade threatened fish monitoring (GeoLINK 2015), were added to the survey, but landholder restrictions upon access still impacted monitoring at sites 13e, 26b and OPP4. In the fourth year of monitoring but landholder restrictions upon access still impacted monitoring at sites 13e, 26b and OPP4.

The waterways monitored include backwaters on flood-prone land, ephemeral swamps, farm drainage lines, natural creeks, dams and excavations. Of the total sites monitored eleven are control sites.

The study area and location of sampling sites are displayed in **Illustrations 2.1**, **2.2**, **2.3** and **2.4**. 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.

Section	*Waterway*	*Sites*	*Chainage*	*Notes*
DP	Tabbimoble 3 Channel	OPP3, OPP7	110500	Constructed channel that drains floodwaters from the west of the Pacific Highway. Confluence with Tabbimoble 2 Channel 300m downstream of the highway. Permanent **Class 1** stream with intermittent areas and an offstream dam. OPP previously identified. **2 sites**, one upstream and one at the impact. The upstream site (OPP7) frequently dries out.
DP	Tabbimoble 2 Channel	OPP1, OPP2, OPP4, OPP6	110800	Constructed channel that drains floodwaters from the west of the Pacific Highway. Permanent **Class 1** stream with intermittent areas and an offstream dam. OPP previously identified. **4 sites**, two upstream, one at the impact and one reference site far downstream. One of the upstream sites (OPP6) frequently dries out.
7	Unnamed waterway south of Serendipity Rd	2a, 2b, 2c	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	3a	115300	Drains from headwaters approximately 1.5km upstream. Intermittent **Class 1** stream. OPP previously identified. **1 site** at impact.

Section	*Waterway*	*Sites*	*Chainage*	*Notes*
8	Unnamed waterway south of MacDonalds Ck	10b, 10c	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	11b, 11d	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	12a	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	22b, 22c	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 Swampland	16a, 16b, 27b, 27e	139000 - 140500	Series of wetland pools throughout protected wallum country. **Class 1** stream. OPP previously identified. **4 sites** one impact, three to the east.
9	Various dams north of Broadwater National Park	26d	140900 - 142300	Manmade dam/excavation on private property. OPP previously identified. Located E (downstream) of impact.
9	Montis Gully tributary 1	13b, 13c, 13e	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.
N/A	Bundjalung National Park Swampland	OPP5 C13, C14	N/A	Large coastal wetland complex. **Class 1** intermittent wetland area with a variety of natural depressions, natural drainage lines, constructed drainage lines and flooded trails. OPP previously identified. **3 reference sites**, 2 intermittent, 1 permanent.
N/A	Broadwater National Park Swampland	C1, C2, C3, C5, C8, C11, C12	N/A	Large coastal wetland complex. **Class 1** intermittent wetland area with a variety of natural depressions, natural drainage lines, constructed drainage lines and flooded trails. OPP previously identified. **7 reference sites**, 4 intermittent, 3 permanent.

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 2.3** and **2.4**.

Access to some sites was restricted in the current monitoring period. Sites 13e, 26b and OPP4 could not be accessed for either survey in 2020 due to landholder restrictions. Some sites were dry during one or both surveys in 2020. Site 2c was dry during both surveys and sites OPP6 and OPP7 were dry during the September survey only.

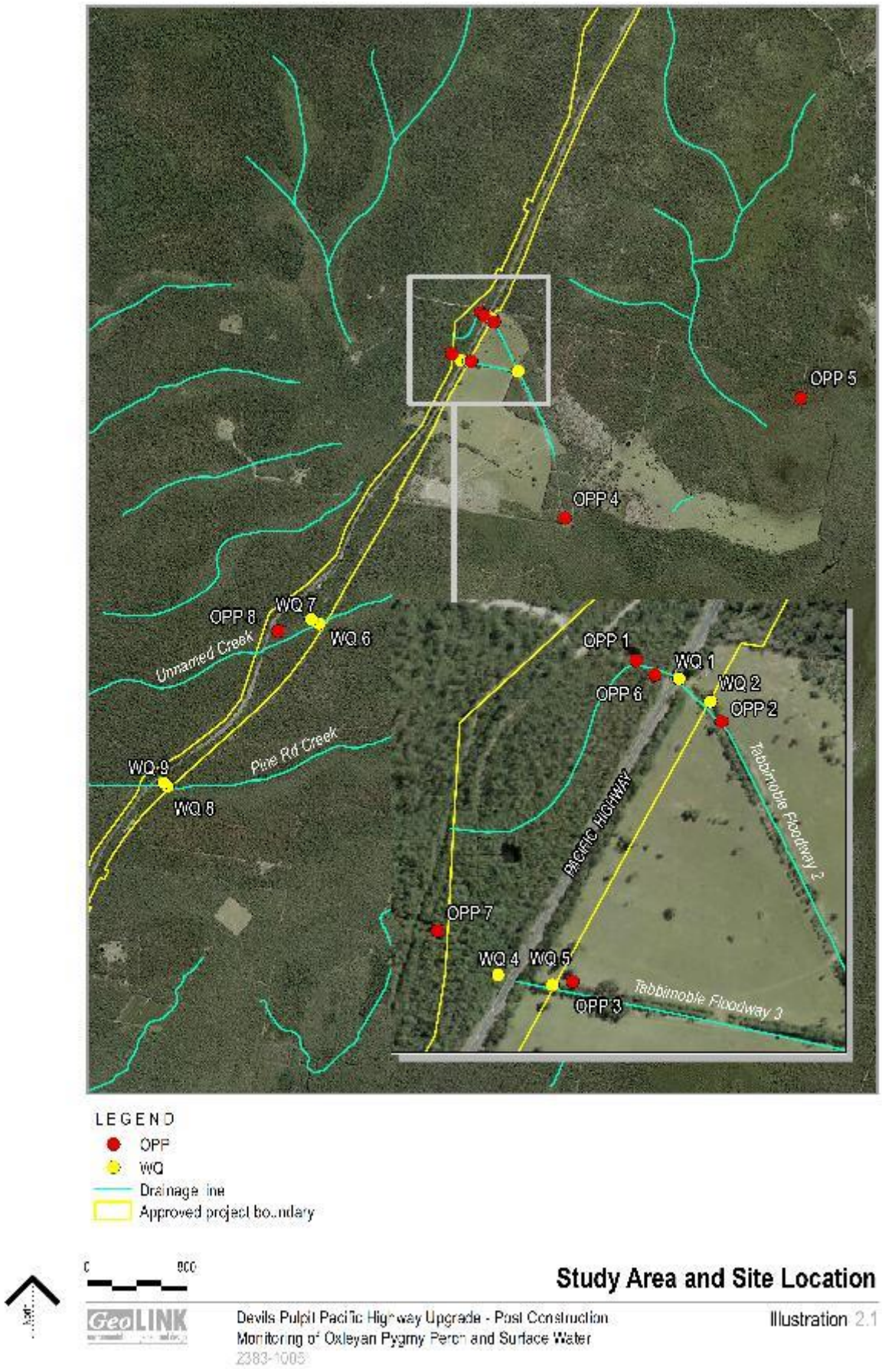


Illustration 2.1 Map of Devils Pulpit (DP) sampling sites (from GeoLINK 2015)

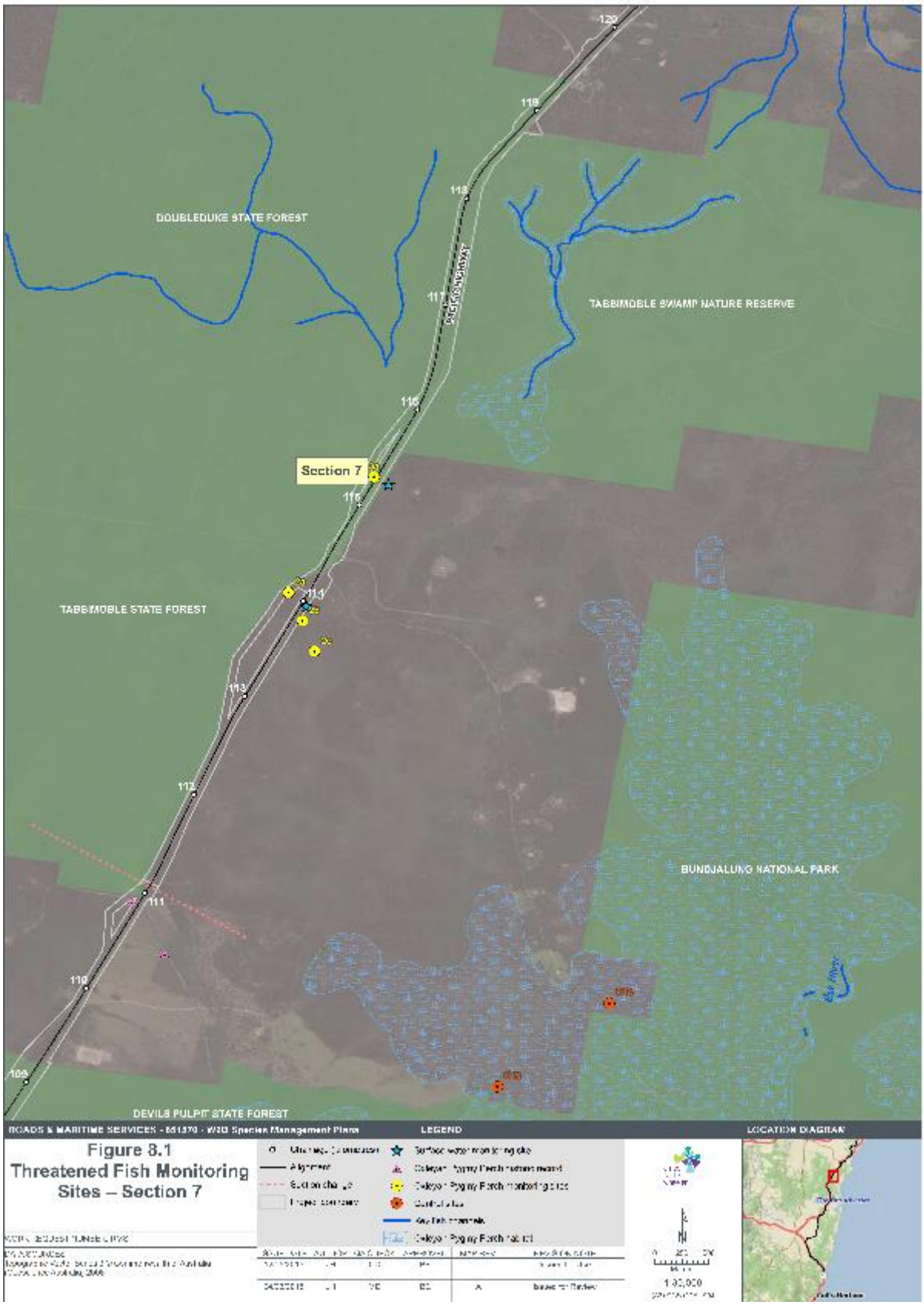


Illustration 2.2 Map of Section 7 sampling sites taken from the TFMP (RMS 2015)

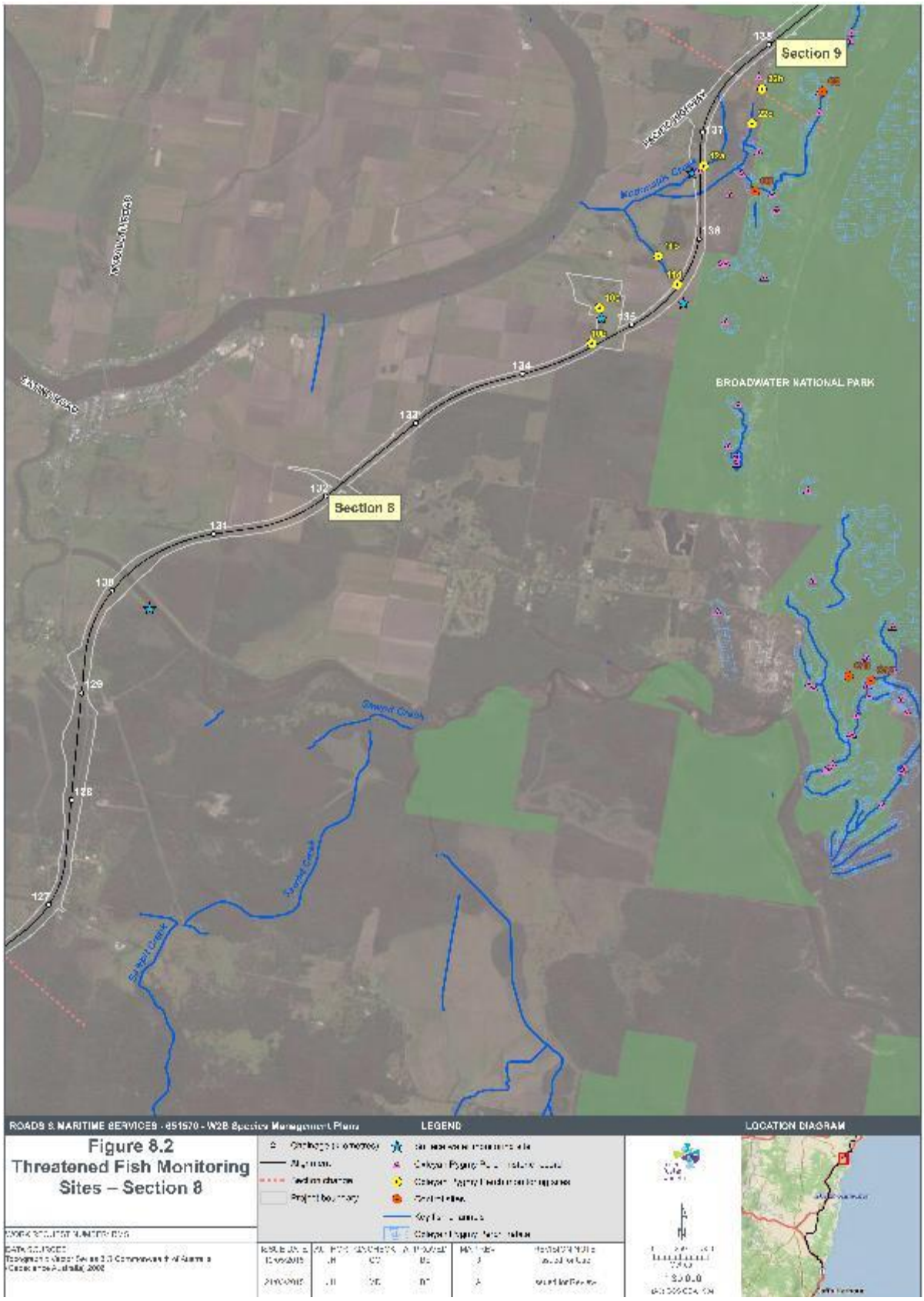


Illustration 2.3 Map of Section 8 sampling sites taken from the TFMP (RMS 2015)

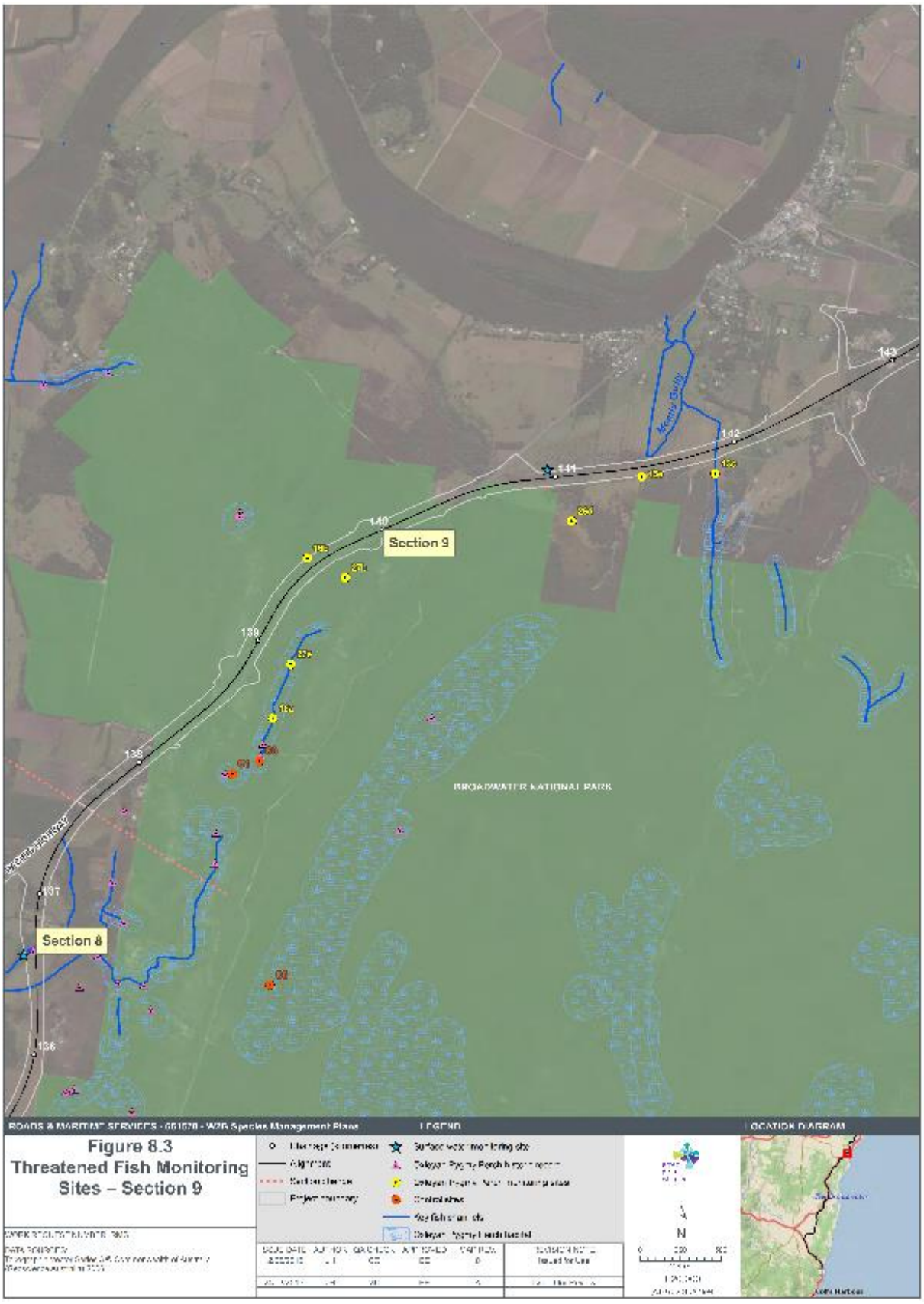


Illustration 2.4 Map of Section 9 sampling sites taken from the TFMP (RMS 2015)

2.2 Timing

Bi-annual targeted threatened fish monitoring is scheduled 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/June 2020 and September 2020.

Monitoring scheduled for May 2020 was delayed at some sites due to an interruption related to possible exposure to COVID-19. Monitoring at 4 sites was delayed until late June 2020.

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.

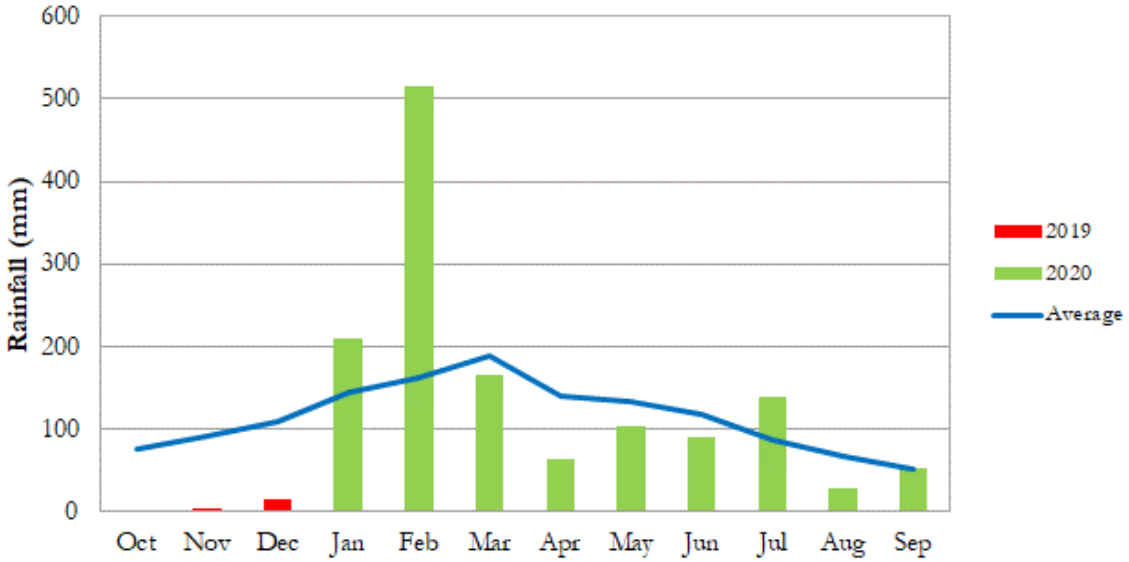


Figure 2.1 Mean monthly rainfall and total monthly rainfall from the Woodburn Bureau of Meteorology station for the current reporting period.

The total rainfall for this annual reporting period was 98% of the yearly average. However, monthly rainfall was below average for all but 3 months of this reporting period and there was very little rain recorded at Woodburn for the first 3 months of the reporting period (**Figure 2.1**). Most of the sites did not have significant flows (> 0.1 m/s) at the time of the surveys but there was water at most sites at the time of the surveys (exceptions being 2a, OPP6 and OPP7 as displayed in **Tables 2.2** and **2.3**). Water levels at some sites were very high during the surveys. Fluctuating water levels are an important consideration because they significantly change the ability to capture fish and also heavily impact the habitat measurements collected.

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 May-June 2020

Section	*Site*	*Voltage (V)*	*Pulse Freq (Hz)*	*Duty Cycle (%)*	*Passes*	*Seconds Pulsed*
6	OPP1	200	50	12	1	624
6	OPP2	225	50	12	1	606
6	OPP3	250	50	12	1	606
6	OPP4	No Access				
6	OPP5	125	50	12	1	605
6	OPP6	125	50	12	1	620
6	OPP7	100	50	12	2	466
7	2a	150	50	12	1	603
7	2b	75-250	50	12	2	441
7	2c	No Water				
7	3a	225	50	12	1	614
8	10b	275	50	12	1	617
8	10c	250	50	12	1	605
8	11b	175	50	12	1	604
8	11d	150	50	12	1	614
8	12a	200	50	12	1	599
9	13b	175	50	12	1	609
9	13c	250	50	12	1	616
9	13e	No Access				
9	16a	200	50	12	1	612
9	16b	275	50	12	1	609
8	22b	250	50	12	1	611
8	22c	175	50	12	1	616
9	26d	No Access				
9	27b	300	50	12	1	604
9	27e	175	50	12	1	599
Control	C1	200	50	12	1	603
Control	C2	175	50	12	1	612
Control	C3	200	50	12	1	606
Control	C5	175	50	12	1	605
Control	C8	225	50	12	1	612
Control	C11	275	50	12	1	654
Control	C12	175	50	12	1	603
Control	C13	250	50	12	1	608
Control	C14	150	50	12	1	618

Table 2.3 Details of electrofisher settings and effort at each site in the September 2020 sampling

Section	*Site*	*Voltage (V)*	*Pulse Freq (Hz)*	*Duty Cycle (%)*	*Passes*	*Seconds Pulsed*
6	OPP1	200-225	50	12	1	605
6	OPP2	150	50	12	1	604
6	OPP3	200	50	12	1	609
6	OPP4	No Access				
6	OPP5	100	50	12	2	307
6	OPP6	No Water				
6	OPP7	No Water				
7	2a	125	50	12	2	577
7	2b	175	50	12	2	319
7	2c	No Water				
7	3a	175	50	12	1	605
8	10b	225	50	12	1	599
8	10c	125	50	12	2	604
8	11b	250	50	12	1	606
8	11d	100	50	12	1	601
8	12a	150	50	12	1	624
9	13b	125	50	12	1	605
9	13c	200-250	50	12	1	602
9	13e	No Access				
9	16a	150-175	50	12	1	627
9	16b	225	50	12	1	601
8	22b	250	50	12	1	607
8	22c	250	50	12	1	624
9	26d	No Access				
9	27b	250-300	50	12	1	610
9	27e	225	50	12	1	609
Control	C1	250	50	12	1	605
Control	C2	200	50	12	1	607
Control	C3	175	50	12	1	624
Control	C5	175	50	12	1	603
Control	C8	175	50	12	1	616
Control	C11	175	50	12	1	602
Control	C12	175	50	12	1	606
Control	C13	175	50	12	1	596
Control	C14	100	50	12	1	599

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.

3

Results

3.1 Fish Survey

During the May-June 2020 survey approximately 258 hours of fish trapping and 18,621 seconds of electrofishing were used. During the September 2020 survey approximately 260 hours of fish trapping and 17,003 seconds of electrofishing were used.

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:

- Site 2, which was dry at the time of the May-June 2020 survey.
- Sites OPP4, 13e and 26d, which had access restrictions at the time of the May-June 2020 survey.
- Sites OPP6, OPP7 and 2c, which were dry at the time of the September 2020 survey.
- Sites OPP4, 13e and 26d, which had access restrictions at the time of the September 2020 survey.

In the May-June 2020 survey a total of 2,288 fish from eleven species were captured. Of the total number of fish captured, 1504 individuals from eleven species were captured using the electrofisher and 784 individuals from eight species were captured using fish traps.

In the September 2020 survey a total of 3,718 fish from eleven species were captured. Of the fish captured during the September 2020 survey 2,336 individuals from eleven species were captured using the backpack electrofisher and 1,382 individuals from eight species were captured using bait traps.

In the May-June 2020 survey 27 individual OPP were captured. Of these, 19 were captured using the backpack electrofisher and 8 in fish traps. In the May-June 2020 survey OPP were captured at 1 of the 24 impact sites and at 4 of the 11 control sites.

In the September 2020 survey 56 individual OPP were captured. Of these 26 were captured using the backpack electrofisher and 30 in fish traps. In the September 2020 survey OPP were captured at 2 of the 24 impact sites and at 5 of the 11 control sites.

The most commonly captured species of fish during the May-June 2020 survey was the Mosquitofish (*Gambusia holbrooki*). Individuals of this species accounted for approximately 49 per cent of the total number of fish captured in the May-June 2020 survey. The most commonly captured species of fish during the September 2020 survey was also the Mosquitofish, accounting for approximately 48 per cent of the fish captured. Overall, OPP accounted for approximately 1 per cent of the fish captured in the May-June 2020 survey and approximately 2 per cent of the fish captured during the September 2020 survey.

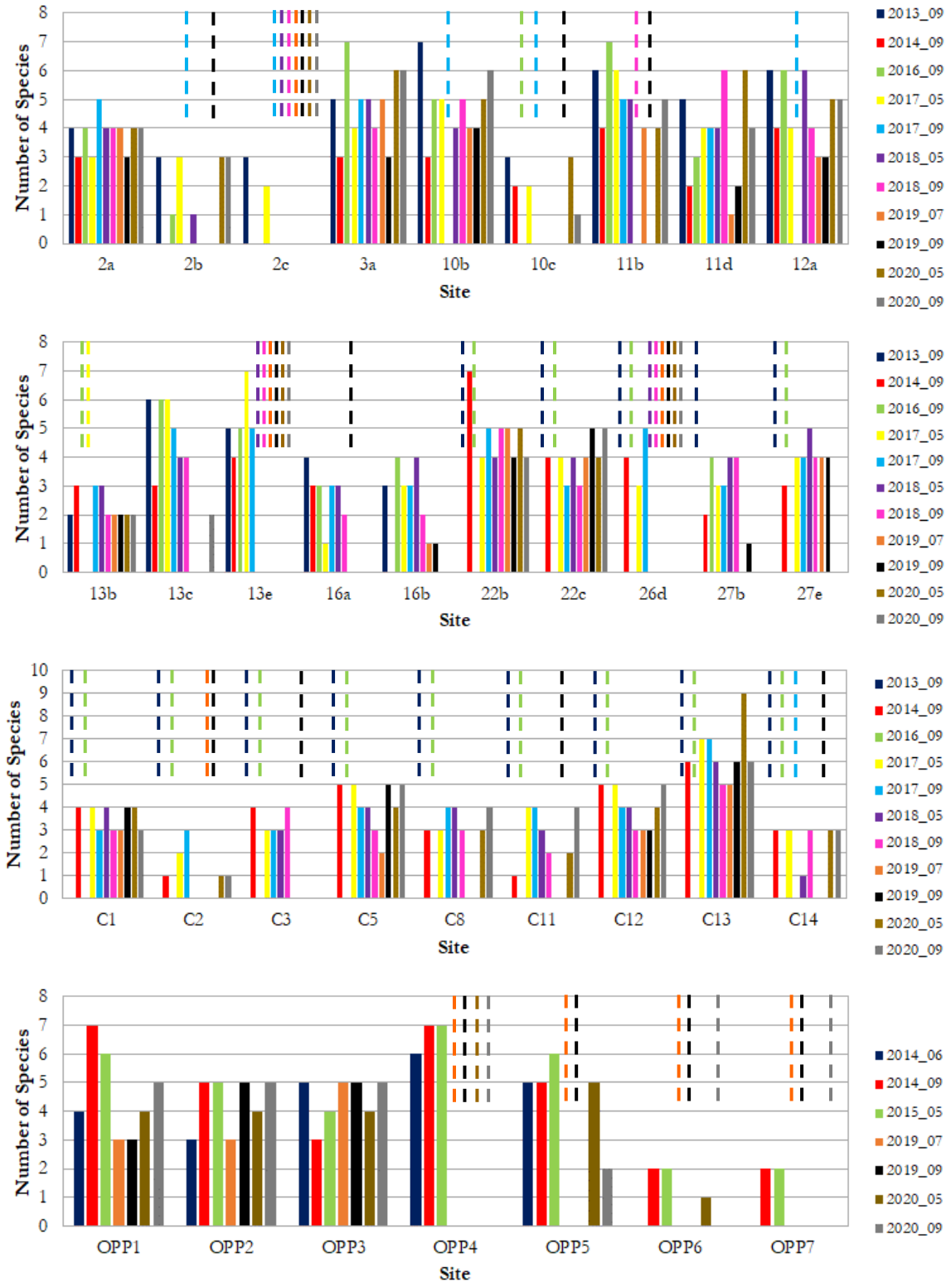


Figure 3.1 Taxonomic richness of captured fish at all sites since 2013 (pre-construction data from GeoLINK 2014, 2015a & 2015b)

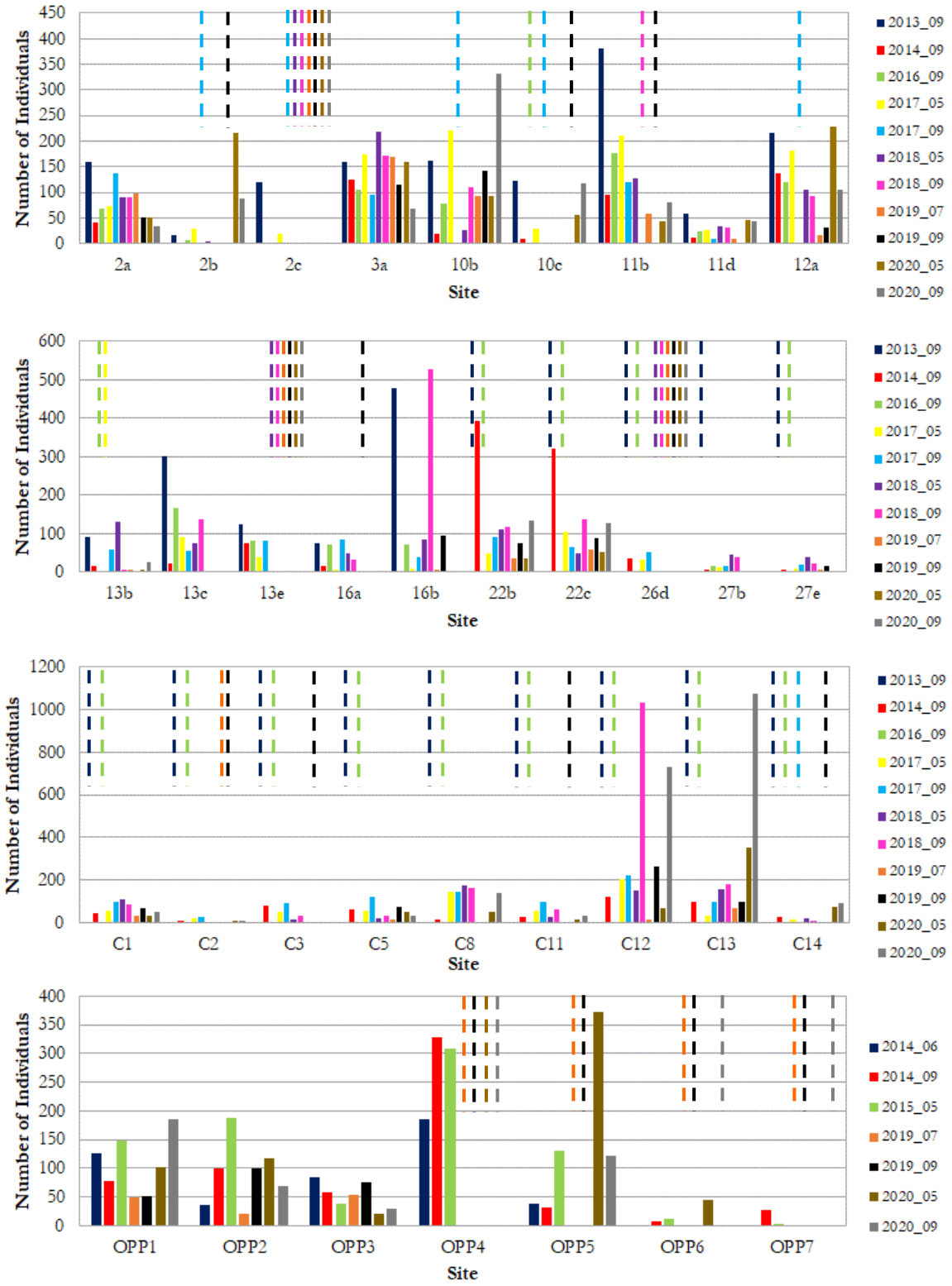


Figure 3.2 Abundance of captured fish at all sites since 2013 (pre-construction data from GeoLINK 2014, 2015a & 2015b)

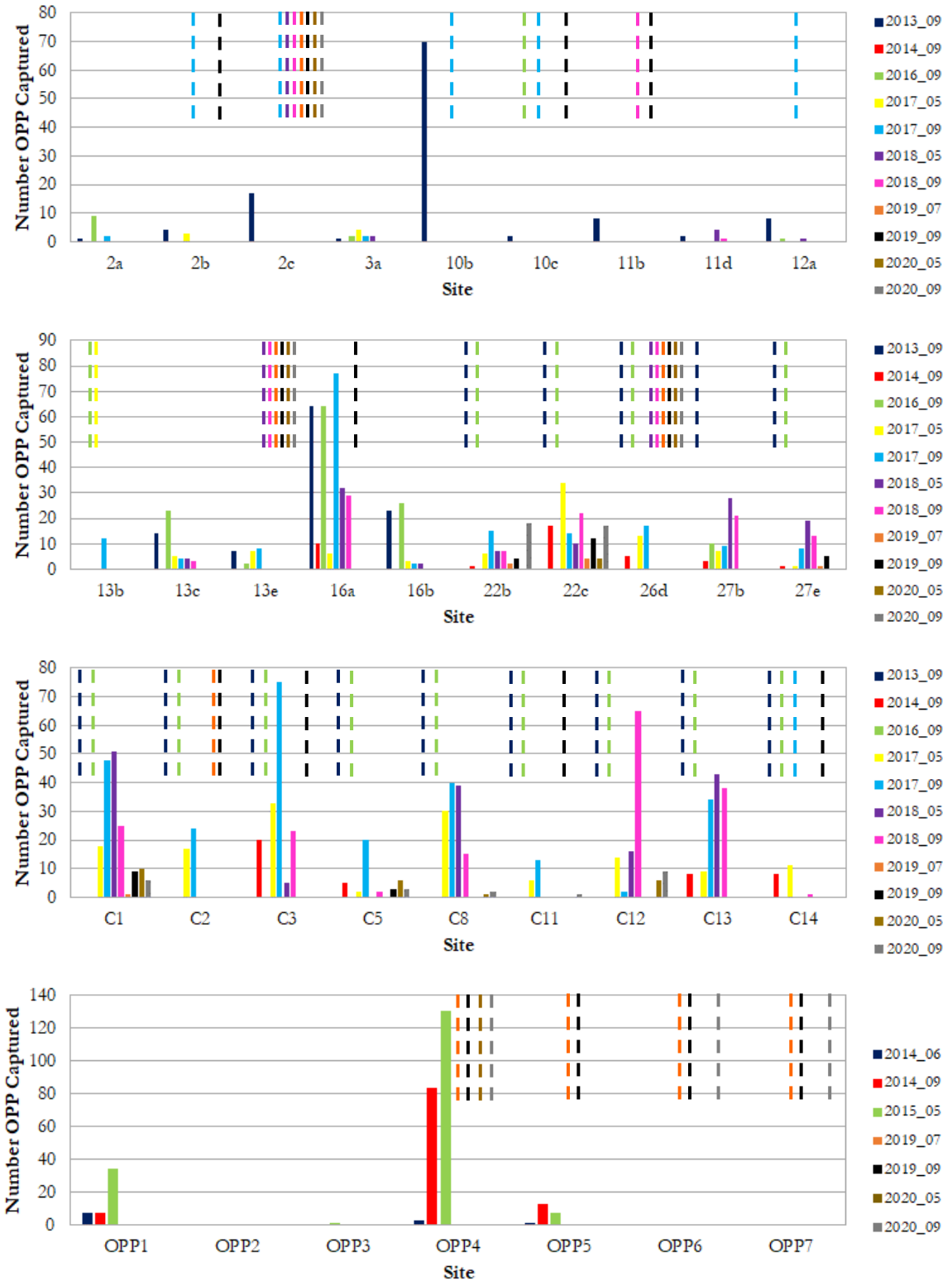


Figure 3.3 Number of OPP captured at all sites since 2013 (pre-construction data from GeoLINK 2014, 2015a & 2015b)

There has been a moderate degree of variation at most impact and control sites throughout the pre-construction and ongoing monitoring in terms of fish diversity and a high degree of variation in terms of abundance (**Figures 3.1**, **3.2** and **3.3**). In the 2 surveys this year between one and nine species were captured at each site where surveys were possible, with the exception of sites 13c, 16a, 16b, 27b, 27e, C3 and OPP7, where no fish were captured in May - June 2020, and sites 16a, 16b, 27b, 27e and C3, where no fish were captured in September 2020. In the May - June 2020 survey the sites with the highest diversity of captured fish were C13, 3a, and 11d. In the September 2020 survey the sites with the highest diversity of captured fish were 3a, 10b and C13.

Between 0 and 332 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 – June 2020 survey were 12a, 2b and 3a. In the September 2020 survey the impact sites where the most individual fish were captured were 10b, OPP1 and 22b.

The total number of individual fishes captured at the control sites varied between 0 and 1073, with the largest numbers of fish captured at OPP5 and C13 in the May – June 2020 survey and C13 and C12 in the September 2020 survey.

The numbers of OPP captured at each site are presented in **Figure 3.3**. There is a large degree of variation over time evident at both impact and control sites. The numbers of OPP captured during this reporting period were moderately low and OPP were only captured at 7 sites in the two surveys this year (compared to 22 sites in 2017, 17 sites in 2018 and 5 sites in 2019). Many of the sites where OPP weren't captured were either sites that were found to be dry in March 2019 (Birch 2019) or sites that were dry during the surveys. This included sites 2b, 2c, 10c, 11d, 13b, 16a, 27b, C2, C3, C8, C11 and C14). It is a reasonable presumption that these sites, and possibly others, dried out again in the more severe drought (see **Table 4.3**) leading up to January 2020. Additional impacts would have occurred at some sites (particularly those in the Tabbimoble Swamp catchment) as a result of bushfires in December 2019 and January 2020. A related consideration is that when so many sites dry out the overall OPP population reduces significantly and the population available to re-colonise sites when appropriate flow conditions eventuate (such as the moderate flooding event in February 2020) is less. Furthermore, the breeding habitat availability, even in sites that do retain some water, is reduced significantly when water levels fall during drought conditions such as those experienced over summer 2018-2019 and summer 2019-2020.

The full results of the May – June 2020 and September 2020 fish surveys are presented in **Appendix B**.

The capture of OPP has varied significantly between sites and over time since monitoring along the W2B upgrade began in 2013. The average capture per survey at each site during pre-construction and construction phase monitoring is presented in **Figure 3.4**. The figures indicate that pre-construction captures were significantly larger at several impact sites, including sites 2c, 10b, 10c, and 11b. However, they also indicate that construction phase captures were significantly larger at some sites, including 22b, 26d, 27b and 27e. Captures at the control sites were mostly either equivalent or larger during the construction phase monitoring, the exception being site C14.

When the control and impact sites are considered as a group, the pre-construction and construction phase average captures per site show a minor reduction in the average capture at impact sites in the construction phase monitoring and an increase in the average capture at control sites in the construction phase monitoring (**Figure 3.5**).

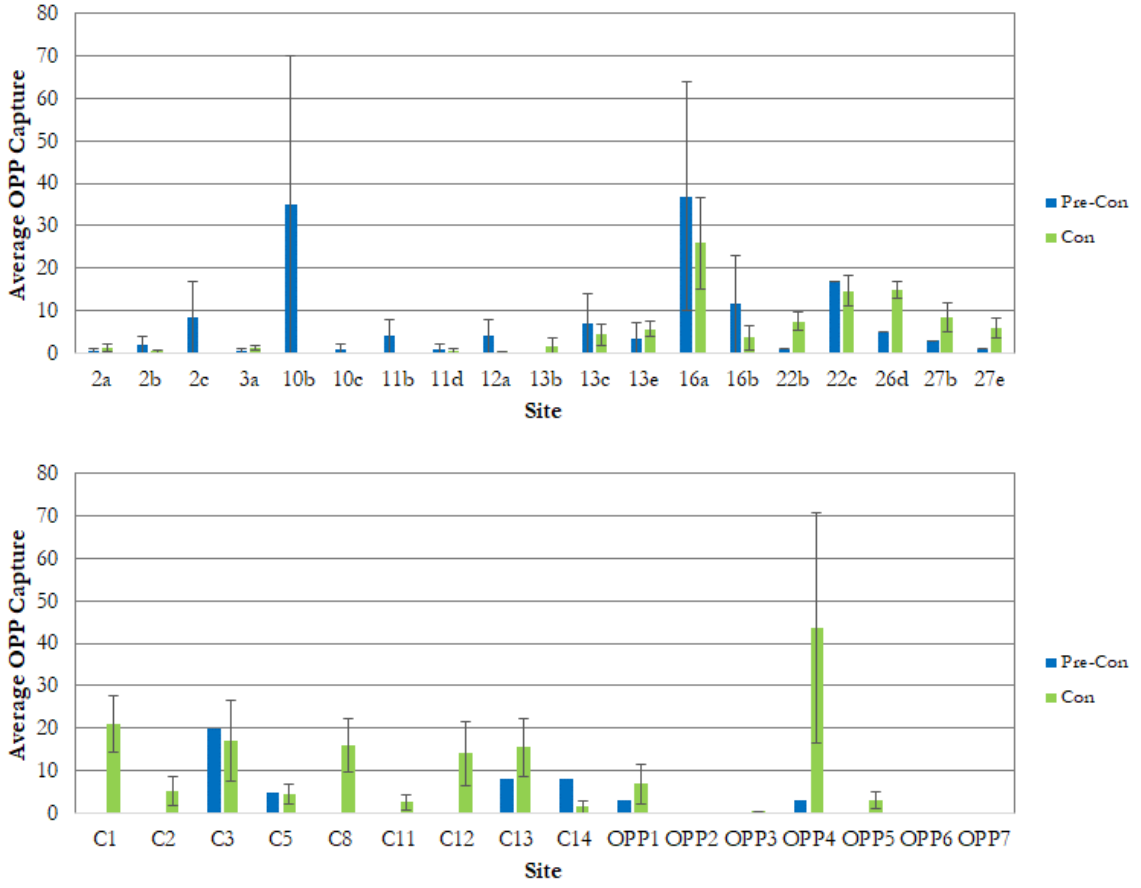


Figure 3.4 Average OPP capture per survey at all sites in pre-construction and construction phase monitoring (pre-construction data from GeoLINK 2014, 2015a & 2015b, Hyder 2012)

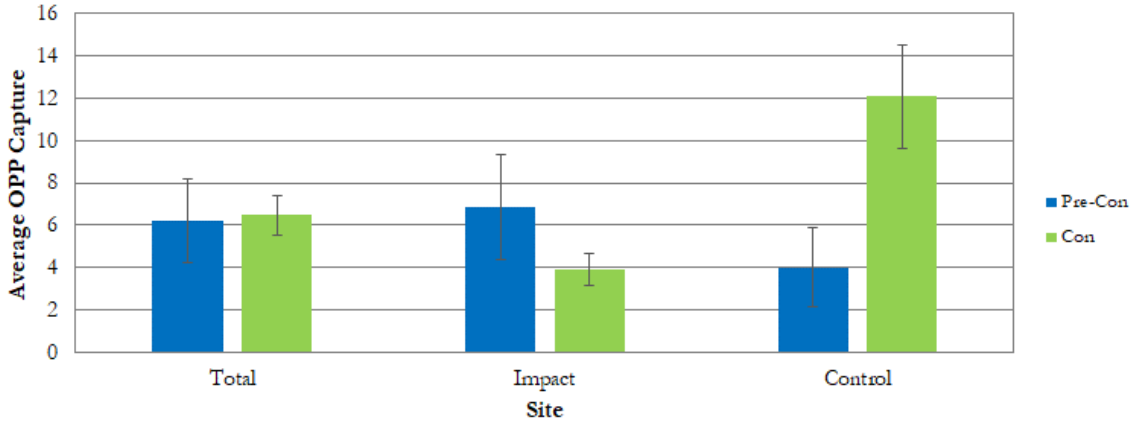


Figure 3.5 Average OPP capture at combined control and impact sites in pre-construction and construction phase monitoring (pre-construction data from GeoLINK 2014, 2015a & 2015b, Hyder 2012)

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 – June 2020 survey

Site	*Date*	*Temperature*	*pH*	*Conductivity*	*Turbidity*	*DO*	*DO%*
		°C		*mS/cm*	*NTU*	*mg/L*	*%*
OPP1	18/07/2019	15.72	6.32	0.145	6.4	3.74	38.9
OPP2	18/07/2019	15.91	6.49	0.178	1.8	4.4	46
OPP3	18/07/2019	16.33	6.33	0.172	0	4.42	46.6
OPP4		No Access					
OPP5	25/05/2020	14.35	5.78	0.135	0	5.61	56.7
OPP6	22/05/2020	16.16	6.14	0.171	0	5.3	55.6
OPP7	22/05/2020	14.19	5.88	0.148	12.1	4.33	43.6
2a	18/05/2020	18.27	5.97	0.103	17.1	3.22	35.3
2b	25/05/2020	14.35	6.67	0.497	0	5.64	57
2c	25/05/2020	No Water					
3a	25/05/2020	16.84	6.28	0.258	0	6.71	71.5
10b	20/05/2020	16.07	5.04	0.255	0	**2**	21
10c	20/05/2020	16.96	5.36	0.338	1.6	**2.07**	22.1
11b	21/05/2020	18.09	5.63	0.196	1.7	3.58	39.1
11d	19/05/2020	19.32	5.16	0.167	4.2	5.19	58
12a	19/05/2020	18.48	**4.78**	0.273	0	**1.59**	17.5
13b	19/05/2020	20.76	5.73	0.237	11.8	**1.7**	19.5
13c	20/05/2020	17.86	**3.53**	0.534	6.7	2.27	24.7
13e		No Access					
16a	26/05/2020	15.6	**3.85**	0.214	0	**1.9**	19.7
16b	21/05/2020	16.85	5.47	0.258	4.8	**0.98**	10.4
22b	26/05/2020	13.49	**4.67**	0.211	0	2.18	21.6
22c	21/05/2020	17.84	**4.09**	0.229	0	2.74	29.8
26d		No Access					
27b	20/05/2020	17.66	**4.5**	0.166	0	**1.63**	17.6
27e	26/05/2020	15.88	**4.39**	0.23	0	**1.16**	12.1
C1	17/06/2020	Probe Malfunction – No Data					
C2	17/06/2020	15.4	**4.13**	0.138	0	3.14	32.5
C3	26/05/2020	13.9	**3.83**	0.225	0	2.59	25.9
C5	21/05/2020	17.68	**4.01**	0.155	4.4	3.51	37.9
C8	17/06/2020	Probe Malfunction – No Data					
C11	20/05/2020	19.01	**4.23**	0.191	0	2.29	25.5
C12	26/05/2020	17.79	**4.12**	0.138	0	7.11	77.1
C13	18/05/2020	17.4	5.9	0.137	0.7	2.81	30.2
C14	18/05/2020	16.32	6.14	0.121	7.6	4.07	42.8

Red Text Outside of the known range of OPP
Blue Text Within a range thought to provide OPP with a competitive advantage
Green Text OPP captured at site during this survey

Table 3.2 Results of water quality sampling from all sites for the September 2020 survey

Site	*Date*	*Temperature*	*pH*	*Conductivity*	*Turbidity*	*DO*	*DO%*
		°C		*mS/cm*	*NTU*	*mg/L*	*%*
OPP1	9/09/2020	14.16	5.79	0.104	9	3.99	40.2
OPP2	9/09/2020	16.15	6.25	0.147	10.4	5.67	59.6
OPP3	9/09/2020	18.14	5.87	0.185	0	5.06	55.3
OPP4		No Access					
OPP5	15/09/2020	19.58	5.37	0.107	0	7.93	88.9
OPP6	15/09/2020	No Water					
OPP7	15/09/2020	No Water					
2a	9/09/2020	18.12	5.8	0.1	2.9	5.32	58
2b	15/09/2020	22.01	6.16	0.578	0	3.8	44.7
2c	15/09/2020	No Water					
3a	9/09/2020	17.65	5.98	0.129	2.1	5.86	63.3
10b	7/09/2020	16.52	5.76	0.535	28.8	**1.53**	16.2
10c	7/09/2020	16.24	5.09	0.367	18.2	**0.95**	10
11b	11/09/2020	19.27	5.25	0.217	5.5	5.89	65.8
11d	7/09/2020	19.91	**4.99**	0.164	30.1	4.63	52.3
12a	7/09/2020	18.85	5.43	0.26	2.5	**0.45**	5
13b	8/09/2020	15.77	6.14	0.301	43	**0.88**	9.2
13c	8/09/2020	21.4	**3.55**	0.346	**90**	**1.83**	21.3
13e		No Access					
16a	14/09/2020	14.63	**4.05**	0.183	0	3.28	33.3
16b	8/09/2020	16.07	**4.99**	0.371	0	**1.34**	14.1
22b	11/09/2020	17.59	**4.5**	0.19	0	5.12	55.3
22c	11/09/2020	16.41	**4.5**	0.192	0	5.27	55.6
26d		No Access					
27b	8/09/2020	15.83	**4.38**	0.157	0	**10.28**	107.1
27e	14/09/2020	15.94	**4.2**	0.182	0.3	**1.21**	12.6
C1	14/09/2020	21.78	**4.27**	0.12	3.2	6.54	76.4
C2	16/09/2020	18.07	**4.04**	0.156	0	5.42	59.1
C3	14/09/2020	19.2	**3.57**	0.206	0	4.24	47.3
C5	11/09/2020	15.79	**4.47**	0.13	0	5.4	56.3
C8	16/09/2020	15.39	**4.07**	0.269	0	5.22	54.0
C11	16/09/2020	19.83	**4.14**	0.173	0	4.71	53.1
C12	15/09/2020	22.2	**4.03**	0.13	0	6.91	81.3
C13	15/09/2020	16.86	5.84	0.136	16.3	2.81	29.9
C14	15/09/2020	15.2	5.72	0.13	4.5	**1.75**	18

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**). At approximately half of the sites 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 dissolved oxygen but none with respect to pH, concentration or temperature and only one with respect to turbidity. Notably, at all sites where OPP were captured during this reporting period the water quality

measurements were within the known tolerance ranges of OPP and pH was recorded within the range thought to provide OPP with a competitive advantage.

Although the dissolved oxygen (DO) concentrations at multiple sites were below the levels thought to be ideal for fish survival and function (> 4-5 mg/L), 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, a value lower than the reported ranges for OPP (Pusey *et al.* 2004).

A comparison of threatened fish monitoring baseline water quality ranges with the water quality results collected during the May - June 2020 and September 2020 surveys is presented in **Appendix C**. The comparison indicates that the majority of results are within the ranges measured in pre-construction monitoring.

A separate program of construction phase water quality monitoring on the W2B upgrade is undertaken at some of the sites where threatened fish monitoring occurs. A brief analysis of the key indicators (DO, pH and turbidity results) reported therein shows several results of interest at each of the sites over the construction phase monitoring period.

Table 3.3 Results of interest (as a fraction of total samples) for key parameters from W2B construction phase water quality monitoring at OPP sites (from GeoLINK 2021)

Site	*OPP site*	*Parameter*											
		pH				*DO*				*Turbidity*			
		2017	*2018*	*2019*	*2020*	*2017*	*2018*	*2019*	*2020*	*2017*	*2018*	*2019*	*2020*
SW7-02	2a, 2b, 2c	2/9	2/8	2/8	4/10	0/9	0/8	0/8	0/10	0/9	5/8	1/8	4/10
SW7-04	3a	0/20	0/23	0/16	5/12	1/20	0/23	1/16	2/12	3/20	8/23	4/16	5/12
SW8-04	10b, 10c	2/6	6/7	3/3	2/9	0/5	2/6	0/3	0/9	3/5	5/7	3/3	2/9
SW8-06	11b, 11d	3/14	7/20	5/8	2/11	2/13	10/20	3/8	0/11	1/14	3/20	2/8	2/11
SW8-08	12a	9/26	26/29	20/22	6/14	2/25	9/29	12/22	3/14	5/26	6/29	15/22	1/14
SW9-01	13c	5/7	12/12	3/9	1/6	0/7	2/11	4/9	1/6	0/7	1/6	3/9	1/6

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 **0**. 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 during this reporting period is presented in **Table 3.4, Table 3.6**, **Table 3.6** and **Table 3.7**.

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

Table 3.4 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 no aquatic vegetation and no flow at the time of either survey.
7	2b	Site 2b is located in a shallow drainage line immediately downstream of a bank of new box culverts under the Pacific Highway. There was very limited structural habitat. The benthic material was mostly mud with a small amount of gravel, sand and scour rock. The riparian zone has been cleared for construction.
7	2c	Site 2c is also located in a shallow drainage line approximately 300m downstream of the existing highway. Site 2c was dry at the time of both surveys.
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, coarse gravel and rock. 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 (*Cycnogeton procerum*) and Maundia (*Maundia triglochinoides*). The margins are mostly steep. A bridge has been built over the site and shading has affected the vegetation cover. 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 and sand. 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 vary between rock, bare sand and grass. 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 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. Vegetative and structural habitat varies across the site from emergent grasses and Spikerushes to bare unconsolidated sediments. The benthic material was mud. There was no flow at the time of either survey.
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 low flow at the time of both surveys.

Section	Site	Habitat Description
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 moderate proportional cover of leaf litter and a sparse cover of mostly senescing emergent aquatic plants. The stream margins were steep and grassy, with no undercutting, little trailing vegetation and very little root mass. This site has been substantially modified during construction including revegetation and formalising of the channel. Shading effects from the bridge are evident. There was low flow at the time of both surveys.
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 varies across the site. There was no perceptible flow at the time of the 2020 surveys. The site has now been significantly modified by a diversion and revegetation. Shading effects from the constructed bridge are evident.
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 and some scour rock. There was a high proportion of leaf litter and a moderate cover of emergent plants. The banks at this site vary across the site from grassy to bare scour rock. There was no flow at the time of either survey. The site has been significantly modified by a bridge construction, 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 dense emergent vegetation in some areas. The banks at this site were grassy and there are scattered rushes. There was no flow at the time of either survey.
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.
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. 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, a high proportional cover of submerged vegetation and scattered emergent vegetation. There was no flow at the time of either 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.

Section	Site	Habitat Description
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 during either survey.
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 during either survey.
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.
DP	OPP1	Site OPP1 is an excavation located approximately 50m to the north, and offstream of Tabbimoble Channel 2. The benthic material is mud. Structural habitat was abundant, including fallen trees and a high proportional cover of leaf litter, small woody debris and emergent aquatic plants (mostly *Maundia triglochinoides*, *Cycnogeton procerum*, and *Philydrum lanuginosum*. The riparian zone is densely covered with paperbarks and acacia. The site is very rarely subject to flow events. The site was heavily impacted by 2019 bushfires, and the benthic material had a high proportion of charcoal at the time of both surveys in 2020.
DP	OPP2	Site OPP2 is located in Tabbimoble Channel 2 immediately downstream of the upgraded Pacific Highway crossing. The site is relatively uniform in width and depth with the exception of a gravel bar running through the middle of the site. Benthic material is primarily mud with low proportional cover of gravel, sand and rock. Structural habitat included rootballs, overhanging banks and small but dense beds of emergent vegetation including *Maundia triglochinoides* and *Eleocharis sphacelata*.

Section	Site	Habitat Description
DP	OPP3	Site OPP 3 is located in Tabbimoble Floodway 3 immediately downstream of the upgraded Pacific Highway crossing. The site was relatively uniform in width and depth. Benthic material at this site was dominated by mud, with very little leaf litter and a low proportional cover of small and large woody debris. Structural habitat was limited with no aquatic vegetation recorded and limited overhanging banks and root balls. The riparian margin was continuously but narrowly vegetated. There was no flow at the time of sampling.
DP	OPP6	Site OPP 6 is immediately upstream (west) of the upgraded Pacific Highway crossing where Tabbimoble Floodway 3 opens out into an area of semi-permanent swampland. This site was dry at the time of the September 2020 survey. The site was heavily impacted by 2019 bushfires, and the benthic material had a high proportion of charcoal at the time of the May - June 2020 survey.
DP	OPP7	Site OPP 7 is immediately upstream (west) of the upgraded Pacific Highway crossing where Tabbimoble Floodway 2 opens out into an area of flood prone land/ephemeral swampland with ill-defined channels. This site was dry at the time of the September 2020 survey. The site was heavily impacted by 2019 bushfires.

A number of sites were heavily impacted by the bushfires of summer 2019 – 2020. In particular, a number of the sites around Tabbimoble were subject to high intensity bushfires that burnt the surrounding vegetation and, in some cases, the wetland vegetation itself. These sites typically had a high proportional cover of charcoal in the benthic material and included sites OPP1, OPP5, OPP6, OPP7, 2a, 2c (dry during both surveys), C13, C14 and C12. Many other sites, already impacted by the drought that led to the bushfires, would have been impacted by ash falls during the bushfires in addition to ash and burnt material inputs in rainfall runoff when rain followed in late January and early February 2020. In addition to the changes to available habitat, it is likely that bushfires directly and indirectly led to impacts upon water quality. The potential impacts of bushfire on water quality include (following Environment Protection Authority 2020):

- Increased nutrient concentrations.
- Increased particulate carbon concentrations.
- Increased metals concentrations including manganese, iron, copper and zinc.
- Increased suspended sediment concentrations and turbidity.
- Reduced dissolved oxygen concentrations as a result of decomposing organic matter and large debris flows.

Increased sulphate concentrations

Table 3.5 Aquatic plants identified at impact sites during the May – June 2020 survey

Species Name	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Alternanthera denticulata	Lesser Joyweed				x															
Azolla spp	Azolla					x	x								x					
Baloskion (Restio) pallens	Zigzag Rush													x	x	x			x	
Baloskion (Restio) tetraphyllum	Feathery Rush																x			
Baumea articulata	Jointed Rush									x	x								x	x
Baumea rubiginosa	Baumea														x					
Blechnum sp.	Fern													x					x	x
Carex appressa	Tall Sedge					x			x											
Carex fascicularis	Tassel Sedge		x		x			x		x						x				
Cladium procerum	Water Ribbons				x															
Cyperus difformis	Dirty Dora		x						x		x	x			x					
Eleocharis pusilla	Small Spike-rush		x		x				x											
Eleocharis sphacelata	Tall Spike-rush						x	x				x								
Enteromorpha spp.	Green Alga									x	x									
Gahnia sieberana	Sawsedge									x	x			x		x	x		x	x
Gleichenia dicarpa	Pouched Coral Fern								x											
Juncus usitatus	Common Rush		x		x	x			x		x	x		x		x				
Lemna spp	Duckweed						x								x					
Lepironia articulata	Grey Rush					x						x		x	x					x
Lomandra longifolia	Creek Mat rush		x		x	x			x	x	x									
Maundia triglochinoides	Maundia				x															
*Nymphaea sp**	Waterlily*					x		x		x		x				x				x
Ottelia ovalifolia	Swamp Lily						x													
Paspalum distichum	Water Couch					x	x		x		x									
Persicaria deciepens	Slender Knotweed							x	x		x				x					
Persicaria hydropiper	Water Pepper					x	x	x												
Philydrum lanuginosum	Frogsmouth	x	x		x		x	x	x		x									

Species Name	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Potomageton octandrus	Pondweed						x		x											
Schoenoplectus mucronatus	Marsh Clubrush							x												
Sphagnum sp.	Peat Moss									x				x		x			x	x
Typha orientalis	Cumbungi									x										
Utricularia sp.	Bladderwort				x	x	x								x	x	x		x	x

* Introduced Species

Grey cells indicate site not surveyed.

Table 3.6 Aquatic plants identified at control and Devils Pulpit sites during the May – June 2020 survey

Species Name	*Common Name*	*C1*	*C2*	*C3*	*C5*	*C8*	*C11*	*C12*	*C13*	*C14*	*OPP1*	*OPP2*	*OPP3*	*OPP4*	*OPP5*	*OPP6*	*OPP7*
Alisma plantago	Common Water-plantain														x		
Alternanthera denticulata	Lesser Joyweed								x								
Azolla spp	Azolla	x							x								
Baloskion (Restio) pallens	Zigzag Rush	x	x	x	x	x	x	x									
Baloskion (Restio) tetraphyllum	Feathery Rush			x	x	x											
Baumea articulata	Jointed Rush		x														
Baumea rubiginosa	Baumea		x			x	x	x									
Blechnum sp.	Fern														x		
Carex fascicularis	Tassel Sedge		x														
Chorizandra cymbaria	Heron Bristle-sedge	x								x	x				x		x
Chorixandra sphaerocephala	Round-headed Bristle-sedge														x		
Cladium procerum	Water Ribbons								x	x		x			x	x	x
Cyperus difformis	Dirty Dora								x		x						
Cyperus exaltatus	Giant Sedge															x	
Eleocharis acuta	Common Spikerush							x									
Eleocharis pusilla	Small Spike-rush																x
Eleocharis sphacelata	Tall Spike-rush								x		x	x					
Enteromorpha spp.	Green Alga												x		x		
Enydra fluctuans	Buffalo Spinach								x								

Species Name	*Common Name*	*C1*	*C2*	*C3*	*C5*	*C8*	*C11*	*C12*	*C13*	*C14*	*OPP1*	*OPP2*	*OPP3*	*OPP4*	*OPP5*	*OPP6*	*OPP7*
Gahnia sieberana	Sawsedge			x	x	x	x										
Juncus usitatus	Common Rush		x														
Leersia hexandra	Swamp Ricegrass								x								
Lepironia articulata	Grey Rush	x															
Maundia triglochinoides	Maundia										x	x			x		
*Nymphaea sp**	Waterlily*	x															
Ottelia ovalifolia	Swamp Lily								x								
Paspalum distichum	Water Couch															x	
Persicaria deciepens	Slender Knotweed										x						
Persicaria hydropiper	Water Pepper										x						
Persicaria strigosa	Prickly Knotweed								x								
Philydrum lanuginosum	Frogsmouth								x		x	x			x		x
Potomageton octandrus	Pondweed								x		x						
Schoenoplectus mucronatus	Marsh Clubrush											x					
Sphagnum sp.	Peat Moss		x	x	x	x		x									
Utricularia sp.	Bladderwort	x		x		x		x	x	x	x		x			x	

* Introduced Species

Grey cells indicate site not surveyed.

Table 3.7 Aquatic plants identified at impact sites during the September 2020 survey

Species Name	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Alisma plantago	Common Water-plantain								x											
Azolla spp	Azolla					x					x				x					
Baloskion (Restio) pallens	Zigzag Rush													x	x				x	x
Baloskion (Restio) tetraphyllum	Feathery Rush													x		x	x			
Baumea articulata	Jointed Rush									x	x								x	x
Baumea rubiginosa	Baumea										x				x	x				
Blechnum sp.	Fern																		x	
Carex appressa	Tall Sedge					x			x	x	x									

Species Name	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Carex fascicularis	Tassel Sedge	x	x		x	x		x												
Ceratophyllum demersum	Hornwort				x		x													
Chorizandra cymbaria	Heron Bristle-sedge										x									
Chorixandra sphaerocephala	Round-headed Bristle-sedge																x			
Cladium procerum	Water Ribbons				x															
Cyperus sp.	Sedge				x															
Cyperus difformis	Dirty Dora								x		x	x								
Cyperus exaltatus	Giant Sedge					x														
Eleocharis acuta	Common Spikerush				x		x				x									
Eleocharis pusilla	Small Spike-rush		x					x												
Eleocharis sphacelata	Tall Spike-rush						x	x	x			x								
Enteromorpha spp.	Green Alga		x				x					x				x	x			
Gahnia sieberana	Sawsedge									x	x			x	x	x	x		x	x
Gleichenia dicarpa	Pouched Coral Fern																x			
Isolepis inundata	Swamp Club Rush									x	x									
Isolepsis nodosa	Noddy Club Rush									x										
Juncus usitatus	Common Rush		x			x			x		x	x		x						
Leersia hexandra	Swamp Ricegrass							x												
Lemna spp	Duckweed						x													
Lepironia articulata	Grey Rush					x								x	x					x
Lomandra longifolia	Creek Mat rush								x	x	x									
Maundia triglochinoides	Maundia				x															
*Nymphaea sp**	Waterlily*							x		x		x				x				x
Ottelia ovalifolia	Swamp Lily						x													
Paspalum distichum	Water Couch					x	x	x		x	x	x								
Persicaria deciepens	Slender Knotweed						x	x	x											
Persicaria hydropiper	Water Pepper										x									
Persicaria strigosa	Prickly Knotweed					x		x		x										
Philydrum lanuginosum	Frogsmouth		x		x	x	x	x	x		x									

Species Name	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
Schoenoplectus mucronatus	Marsh Clubrush							x												
Sphagnum sp.	Peat Moss								x					x		x	x		x	x
Utricularia sp.	Bladderwort		x		x	x								x	x		x		x	x

* Introduced Species

Grey cells indicate site not surveyed.

Table 3.8 Aquatic plants identified at control and Devils Pulpit sites during the September 2020 survey

Species Name	*Common Name*	*C1*	*C2*	*C3*	*C5*	*C8*	*C11*	*C12*	*C13*	*C14*	*OPP1*	*OPP2*	*OPP3*	*OPP4*	*OPP5*	*OPP6*	*OPP7*
Alisma plantago	Common Water-plantain									x					x		
Azolla spp	Azolla								x								
Baloskion (Restio) pallens	Zigzag Rush	x	x	x	x	x	x	x									
Baloskion (Restio) tetraphyllum	Feathery Rush				x	x											
Baumea articulata	Jointed Rush		x						x								
Baumea rubiginosa	Baumea		x		x	x	x	x			x						
Carex fascicularis	Tassel Sedge								x								
Chorizandra cymbaria	Heron Bristle-sedge									x	x						
Chorixandra sphaerocephala	Round-headed Bristle-sedge									x					x		
Cladium procerum	Water Ribbons								x	x							
Cyperus difformis	Dirty Dora										x						
Eleocharis acuta	Common Spikerush								x			x					
Eleocharis sphacelata	Tall Spike-rush										x	x					
Enteromorpha spp.	Green Alga									x	x		x		x		
Gahnia sieberana	Sawsedge			x	x	x	x										
Isolepis inundata	Swamp Club Rush										x						
Leersia hexandra	Swamp Ricegrass								x			x					
Lepironia articulata	Grey Rush	x													x		
Maundia triglochinoides	Maundia								x		x	x					
*Nymphaea sp**	Waterlily*	x															
Ottelia ovalifolia	Swamp Lily								x		x						

Species Name	*Common Name*	*C1*	*C2*	*C3*	*C5*	*C8*	*C11*	*C12*	*C13*	*C14*	*OPP1*	*OPP2*	*OPP3*	*OPP4*	*OPP5*	*OPP6*	*OPP7*
Persicaria strigosa	Prickly Knotweed											x					
Philydrum lanuginosum	Frogsmouth								x		x	x			x		
Potomageton octandrus	Pondweed								x								
Schoenoplectus mucronatus	Marsh Clubrush											x					
Sphagnum sp.	Peat Moss	x	x	x	x	x		x									
Typha orientalis	Cumbungi								x								
Utricularia sp.	Bladderwort	x	x	x		x		x	x	x	x	x			x		

* Introduced Species

Grey cells indicate site not surveyed.

4

Discussion and Conclusion

The two fish surveys completed during the fourth year of the construction phase for the W2B Threatened Fish monitoring were completed in May - June and September 2020. There were OPP captured at 2 of the 24 impact sites and 5 of the 11 reference locations during this reporting period. Habitat quality and availability varied across the sites sampled, as did water quality. There was no water at 3 of the impact sites for at least one of the surveys this year. Environmental conditions in the months before the surveys were extreme. At some impact and control sites there was evidence of intense bushfire immediately around the sites and an intense drought between September 2019 and January 2020 was broken by a moderate flood in February 2020. At both impact and control sites the combination of habitat and water quality were more favourable for occupation by OPP than was recorded in the 2019 surveys, particularly in relation to structural habitat availability, pH and dissolved oxygen. In comparison with previous results (Hyder 2012, GeoLINK 2014 & 2015, Jacobs 2018, 2019, 2020), relatively few OPP were captured during the two surveys this year. Four years of construction phase monitoring required by the TFMP have now been completed. Overall, the results indicate a slight reduction in the number of OPP captured per site between the pre-construction and construction phase monitoring at impact sites and a slight increase in the same measure at control sites. Further analysis indicates that the reduced capture at impact sites over the course of the construction phase monitoring has also been observed at control sites and environmental conditions unrelated to W2B upgrade construction explain much of the variation observed in the dataset. Fish habitat data collected over the construction phase indicates that habitat changes detected at impact sites are similar to those detected at control sites with the exception of areas where construction of crossings has necessitated changes to stream morphology and benthic materials. Water quality collected over the entire construction phase indicates that there may have been some impacts to key water quality parameters at some OPP sites.

After a significant pre-construction effort to identify and quantify threatened fish populations along the W2B upgrade corridor 18 impact and 9 control sites were selected for ongoing threatened fish monitoring. Another 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). Prior to the surveys in 2019 a further 5 impact and 2 control sites (sites OPP1 to OPP7), previously monitored for the Devils Pulpit Pacific Highway upgrade, were added to the survey. Since the 2018 annual report (Jacobs 2019), there have been changes to access arrangements on some of the private properties bordering the W2B upgrade corridor. These have resulted in restrictions to access to some of the threatened fish monitoring sites including site sites OPP4, 13e and 26d (May - June and September 2020). The construction phase threatened fish monitoring along the W2B Upgrade has now been undertaken according to the TFMP for a period of four years, with the exception of monitoring at sites where access was denied by landholders and one occasion where ongoing construction activities meant that a site could not be accessed at the time of the survey.

The fishing effort for the two surveys this year consisted of 518 individual fish trapping hours and 35,624 seconds of electrofishing. A total of 2288 fish were captured in May - June 2020 and 3718 fish were captured in September 2020. These totals included 27 (1%) OPP and 56 (2%) OPP respectively. The OPP capture rates (as a percentage of total fish captured) in

previous surveys have varied between 1% and 25%. The sites where OPP were captured in 2020 included:

- Five of the eleven control sites. OPP were captured at site C1, C5, C8 and C12 during both surveys and at site C11 in September 2020 only (There was no access to OPP4 for either survey. All of these sites except C8 and C11 maintained aquatic habitat throughout the drought period.
- Two of the twenty-four impact sites. OPP were captured at 22c during both surveys and 22b during the September 2020 survey. Both of these sites maintained aquatic habitat throughout the drought period.

The sites where OPP were not captured during either survey in 2020 included 22 of the 24 impact sites and 6 of the 11 control sites. Of the impact sites where OPP were not captured, 11 were found to be dry during either a site inspection in March 2019 or during one or more of the four surveys conducted in 2019 and 2020, and 3 sites had restricted access. Of the remaining sites, no OPP have been captured at site 10b or 10c since September 2013 and no OPP have been captured at Site 16b since construction activities necessitated a translocation activity in July 2018. The only impact site where OPP were captured in 2019 but not in 2020 was site 27e. Due to the increased severity of the drought in late 2019, it is likely that a greater number of sites were dry in December 2019/January 2020 than in March 2019 when the last drought survey was undertaken. Sites becoming dry is, obviously, a key factor influencing OPP capture. OPP are not known to aestivate (bury themselves in mud to survive dry conditions), so the only way for them to recolonise dry sites is for floodwaters to connect the previously dry site with a drought refuge site. The other factor required is a large enough population at the refuge site to aid dispersal. There are two key areas where this does not appear to have happened since the summer 2019/2020 drought:

- North of the Perch Trail in Broadwater National Park. This area includes sites 16a, 27b, 27e and links hydrologically in floodwaters to the Montis Gully area which includes sites 13b, 13c, 13e and 26d. No OPP were captured at any of these sites in the 2020 surveys and no fish at all were captured at some of them.
- The Tabbimoble swamp subcatchment. This includes sites 2a, 2b, 2c, 3a, C13, C14, OPP1, OPP2, OPP3, OPP4, OPP5, OPP6 and OPP7. No OPP were captured at any of these sites in the 2020 surveys. The direct impact of bushfires were evident at some of the sites, including burnt wetland canopies, reduced vegetative cover and high proportional cover of charcoal over the benthic material.

Total rainfall was very low for most months of the 2018 – 2019 and 2019 – 2020 OPP breeding seasons and much lower than average between the months of March 2019 and December 2019. The first significant flood event since March 2017 occurred in February 2020, providing some opportunities for OPP dispersal. However, the most severe drought since the beginning of OPP monitoring occurred in the 8 months leading up to December 2019, meaning that breeding opportunities during the majority of the OPP breeding season prior to the dispersal event were poor (**Tables 4.2** and **4.3**) and that OPP populations at drought refuge sites were probably at historically low numbers. In comparison to the results from the 2019 surveys there were improved numbers of juvenile OPP captured in the surveys this year (**Table 4.1**, **Figures 4.1** and **4.2**). The higher proportion of juvenile OPP captured during the surveys this year indicate that improved conditions may have resulted in some recruitment to OPP populations.

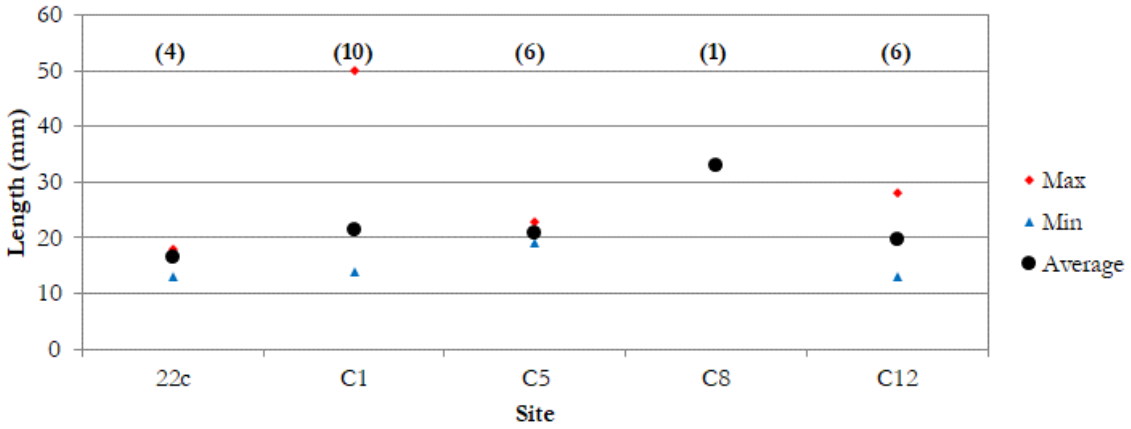


Figure 4.1 Length distribution data of OPP captured in the May – June 2020 survey (counts in brackets)

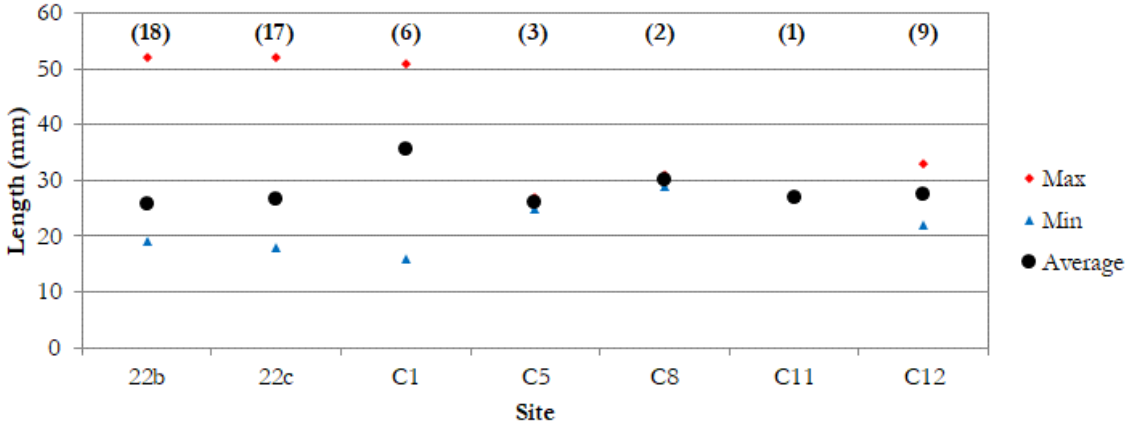


Figure 4.2 Length distribution data of OPP captured in the September 2020 survey (counts in brackets)

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

Survey	*# Sites Accessed*			*# OPP Captured*			*% Juvenile OPP captured*		
	Total	*Impact*	*Control*	*Total*	*Impact*	*Control*	*Total*	*Impact*	*Control*
September 2013	14	14	-	221	221	-	41.3	41.3	-
September 2014*	34	23	11	182	44	138	7.7	0	10.1
September 2016	13	13	-	137	137	-	12.4	12.4	-
May 2017	27	18	9	229	89	140	69.9	52.8	80.7
September 2017	28	19	9	425	170	255	73.4	56.5	84.7
May 2018	26	17	9	263	109	154	22.1	23.9	20.8
September 2018	25	16	9	265	96	169	27.9	18.8	33.1
July 2019*	32	22	10	8	7	1	0	0	0
September 2019*	31	21	10	33	21	12	0	0	0
May-June 2020*	32	22	10	27	4	23	85.2	100	83.6
September 2020*	32	22	10	56	35	21	44.6	60	19.0

* Survey included Devils Pulpit Sites

With respect to the whole OPP monitoring dataset, there has been significant variability in the numbers of OPP captured at each site since monitoring began in 2013, 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. A comparison of average OPP capture at impact and control sites in the pre-construction and construction phases of monitoring shows an increase in the average capture at control sites and a decrease in the average capture at impact sites (**Figure 3.5**). However, an analysis of trends in the average capture at control and impact sites shows a reduction at both control and impact sites over the course of construction phase monitoring and that average capture at control sites has reduced more sharply than at impact sites (**Figure 4.3**). The observed increase in average capture at control sites between the pre-construction and construction phase monitoring is likely to be driven by the fact that no control sites were monitored during pre-construction monitoring in September 2013 after breeding and dispersal conditions had been very good. Pre-construction phase monitoring at control sites was only undertaken in September 2014, after a drought that resulted in very poor breeding and dispersal conditions and many dry sites (**Tables 4.2** and **4.3**).

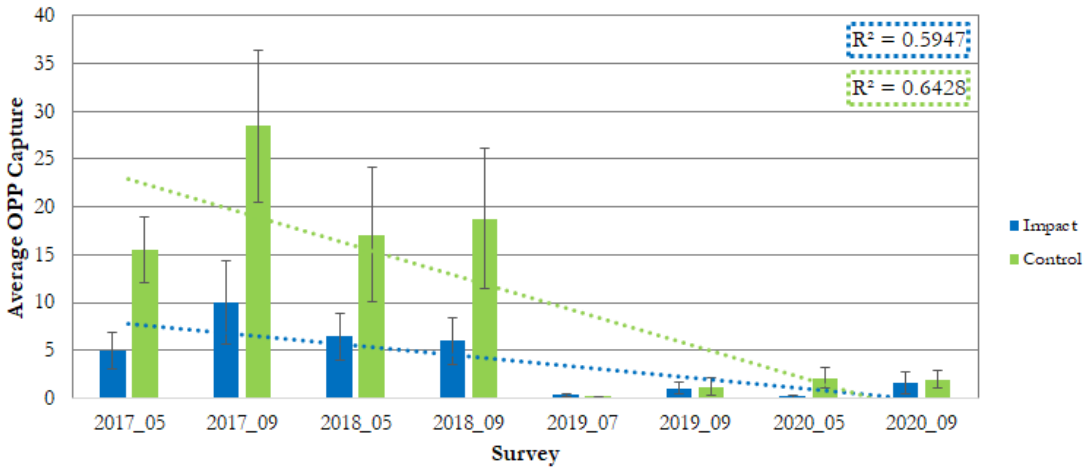


Figure 4.3 Average OPP Capture at W2B impact and control sites in the pre-construction and construction phase surveys.

Relatively good rainfall in the weeks immediately prior to the 2020 surveys meant that the conditions during both surveys this year were generally improved for capturing fish. This is reflected in the greater numbers of fish captured in comparison to the 2019 surveys. There were fewer sites that were dry during the survey periods and greater depths meant that traps were able to be set at a high proportion of sites. However, at some sites the greater water depths improve fish access to lateral habitats, reducing the likelihood of encountering the fish that are present. In general, the fish communities at most sites resembled those observed during pre-construction surveys. However, three species not previously identified during threatened fish surveys, Eel-tailed Catfish (*Tandanus tandanus*), Olive Perchlet (*Ambassis agassizii*) and Goldfish (*Carassius auratus*) were captured during this year's 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. During the surveys this year, Mosquitofish were captured in very large numbers at both control and impact sites. In comparison with the pre-construction phase, the average catch of Mosquitofish has increased slightly although there are high levels of variation in the dataset (**Figure 4.4**). However, the average capture at control sites has increased to a greater extent than at the

impact sites. There is no evidence at present that Mosquitofish numbers are increasing as a result of disturbances associated with construction.

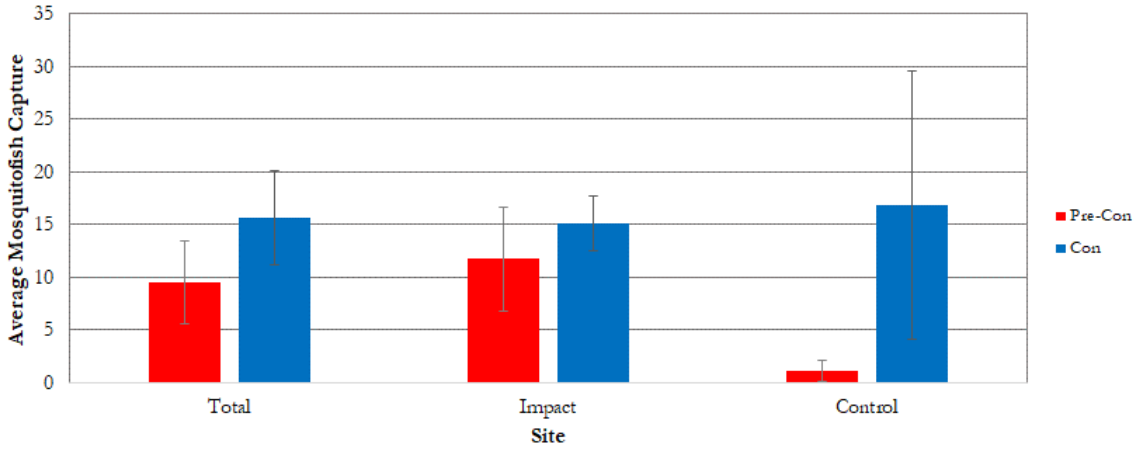


Figure 4.4 Average Mosquitofish Capture at W2B impact and control sites in the pre-construction and construction phase surveys.

This study measured vegetative and physical habitat features including, flow, width, depth, benthic material, aquatic vegetation, debris, riparian cover and stream bank forms. Over the course of the two surveys this year we have collected a large volume of information describing habitat conditions at all sites qualitatively and quantitatively. All of the sites surveyed (that weren't dry) had at least some habitat features commonly associated with OPP (Knight & Arthington 2008). Variation among habitat features collected during the May-June 2020 and September 2020 surveys was similar to previous surveys undertaken as part of construction phase monitoring.

An analysis of the habitat data collected in the pre-construction and construction phases of monitoring is presented in **Appendix A**. The analysis indicates significant differences between data collected in the pre-construction and construction phases at a relatively low number of sites and for some variables only. In general, the observed differences are evenly spread between the impact and control sites. Some of the differences observed are simply a function of hydrological condition, such as width and depth measurements or, in some cases, aquatic vegetation cover, benthic material, trailing vegetation and stream bank form, which can vary at some sites in relation to the water depth and width. Observer bias is also a significant factor, particularly in relation to variables such as riparian cover. Fixed point photographs at each site (presented in **Appendix D**) are a useful reference for determining actual differences in such cases. The observed differences between the pre-construction and construction phases that may be related to construction impacts are as follows:

- Average width and/or depth at sites 11d, 12a, 13b and 16b where construction activities changed the shape of the waterways to ensure the integrity of crossing structures (eg, installed scour protection rock, realigned sections of creek etc. Significant changes in average width and/or depth were also noted at control sites C2, C5, C11 and C14, relating specifically to antecedent hydrological conditions.
- Changes in benthic material cover at sites where rock scour protection has been installed under bridges or constructed habitat features have been lined with sand, most notably at sites 10b (increased percentage of sand and rock), 3a, 11d, 12a and 13b (scour rock placement). Significant changes in benthic material cover were also noted at control sites C1, C5, C8 and C12, where different substrates are covered with water when water levels fluctuate.

- Reduced leaf litter and/or woody debris cover at sites where riparian vegetation has been removed, including sites 3a, 10b, 11d, 12a and 13b. No reductions in debris cover were noted at control sites and most impact sites had increased average observations of debris cover in the construction phase.
- Increased cover of emergent vegetation at most impact sites in the construction phase, most notably at sites 10a, 11d and 12a where significant revegetation efforts were undertaken and fencing has reduced pressures from grazing animals. Images of these improvements to stream condition are presented in **Figures 4.x**.
- Highly variable cover of submerged vegetation at impact and control sites. Much of the submerged vegetation cover was floating species such as Bladderwort and Azolla, which are subject to boom-and-bust population cycles closely related to interactions between rainfall, temperature and season.
- Reduced riparian vegetation cover at sites where the riparian zone was cleared to install bridges or the waterway shape was otherwise modified, such as sites 3a, 10b, 11d, 12a, 13b and 16b. Reduced average riparian cover measurements were also observed at control sites C11 and C13, possibly as a result of drought conditions and/or fire. Observer bias is thought to be a strong factor in the estimation of riparian cover at sites such as 13c and 10c, which fixed point photos indicate did not change much over the course of monitoring, showed drastic reductions in average riparian cover measurements. Some of the sites where average riparian cover measures reduced also had reduced average root mass measurements in the construction phase, including sites 3a, 11d, 12a and 13b. Although root mass measurements would reduce when riparian vegetation is removed, water level also impacts the interaction between root mass and the aquatic environment.

This study also measured physicochemical water quality variables. During this reporting period several sites had very low DO concentrations in comparison with the measurements collected during threatened fish surveys since 2013. The majority of these sites were impact sites. However, after recording several high pH measurements at both impact and control sites in 2019 it is notable that all pH measurements collected during the 2020 surveys were within the reported ranges of waters known to be inhabited by OPP. Other results collected during the 2020 surveys were all within the known tolerances of OPP. Crossing installations and structural modifications made at some of the impact sites may have contributed to poor water quality results collected throughout the construction phase threatened fish surveys. Ash deposits and other impacts from bushfires may have impacted water quality during the final year of construction phase surveys.

More frequent water quality data has been collected at some of the threatened fish monitoring impact sites as part of the W2B upgrade construction phase water quality monitoring program. An analysis of the numbers of results of interest collected from threatened fish monitoring sites is presented in **Table 3.3**. It indicates that there may have been construction phase impacts to water quality at some sites and on some occasions. Of particular interest are the pH results from sites 10b and 12a in 2018 and 2019 and site 13c in 2018. It is possible that the installation of concrete structures at these sites over these times resulted in elevated pH measurements. However, the impact of the drought conditions over the same time period is also likely to have contributed and it is notable that a lower proportion of results of interest were collected in 2020 at all of these sites.

As discussed, environmental conditions are a key determinant of OPP distribution and abundance. An analysis of flood and drought intensity since monitoring began is presented in **Tables 4.2** and **4.3**. The data shows the most severe drought conditions occurring in the 5 months leading up to March 2019 and the 8 months leading up to December 2019. Both of

these droughts were of greater intensity (using these measures) than the 5-month period leading up to February 2014, when many of the impact sites were found to be dry (Birch 2014). These two most recent drought periods preceded the two years of monitoring when the least OPP were captured, measured as a total catch (**Table 4.1**) or as an average capture by site (**Figure 4.3**). Conversely, the peak flood heights were measured in January 2013 and April 2017. These floods preceded the surveys when the largest numbers of OPP were captured. The average capture per site for each survey is presented in **Figure 4.3**.

Table 4.2 Maximum river levels at the Tucombil and Bungawalbyn stations

Timing	*Approximate Maximum Levels (m)*	
	Tucombil	*Bungawalbyn*
January 2013	**3.1**	**5**
February 2013	2.8	4.9
March 2013	2.6	3.9
August 2014	2.3	2.7
February 2015	2.4	3.3
May 2015	2.7	4.3
June 2016	2.6	3.7
April 2017	**4.1**	**5.5**
June 2017	2.5	3.9
February 2020	2.7	4.3
December 2020	2.8	4.5

Table 4.3 Occurrence of 4 consecutive months of below average rainfall

Timing	*# Consecutive Months of Below Average Rainfall*	*% Average Rainfall (cumulative)*
February 2014	**5**	**42.0**
July 2014	4	61.6
July 2016	4	35.6
December 2016	4	58.1
August 2018	5	52.9
March 2019	**5**	**26.5**
December 2019	**8**	**2.8**
June 2020	4	73.3

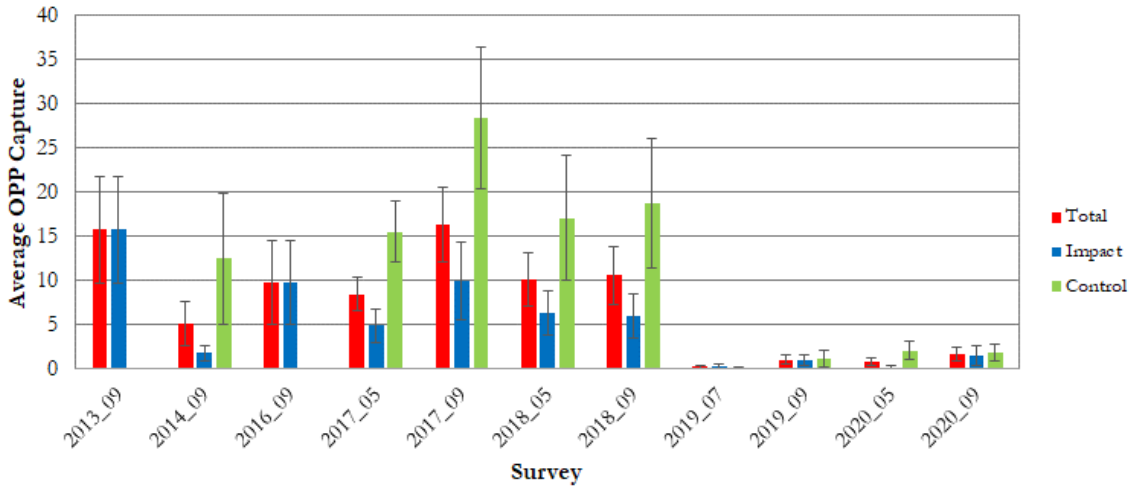
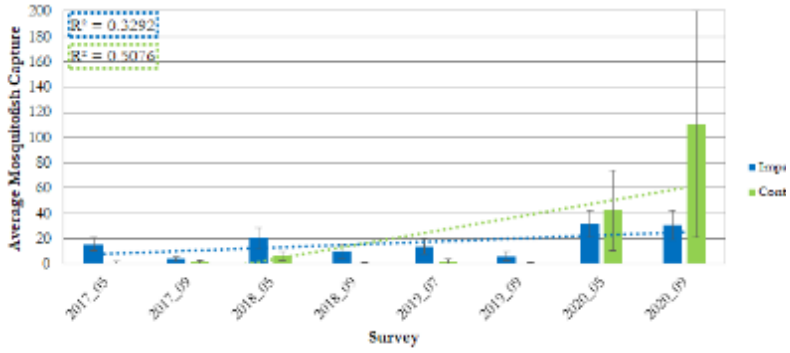


Figure 4.5 Average OPP capture (±SE) at impact and control sites for preconstruction and construction phase surveys

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**. To date, no recommendations with 'on-ground' implications have arisen from threatened fish monitoring. However, there are some performance indicators which were not met during the construction phase.

Table 4.4 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	Although OPP capture during the 2020 surveys was greater than the previous year, there were fewer OPP captured during this survey in comparison to surveys between 2013 and 2018. However, the reduced numbers of OPP captured at impact sites are accompanied by reduced numbers of OPP captured at control sites. A conclusion of this report is that drought and bushfire conditions are the key factor resulting in reduced numbers of OPP captured, not construction impacts. There was also high degree of variation in the pre-construction monitoring results for OPP due to drought conditions. **Figure 4.3** indicates a similar trend of reducing OPP capture per site at both impact and control sites over the last four years of construction phase monitoring.	Performance indicator met - No significant impact from construction activities

Performance Indicator	*Notes*	*Conclusion*
Occurrence of Eastern Gambusia in waterways where they have not previously been recorded	During monitoring this year Eastern Gambusia were captured at several control and impact sites. Eastern Gambusia were captured at all of these sites in pre-construction monitoring except sites 12a and C11. There have been high levels of variation in the numbers of Eastern Gambusia captured at sites throughout construction phase monitoring. However, the following figure indicates a similar trend of increasing Eastern Gambusia capture per site at both impact and control sites over the construction phase monitoring.  Although Eastern Gambusia capture has increased generally and they have been captured during construction at sites where they were not captured during pre-construction, this study has revealed a similar pattern at both impact and control sites. Eastern Gambusia were also captured for the first time at control site C11, during sampling this year. The following factors are more likely to have influenced Eastern Gambusia capture locations and rates: ▪ A greater number of samples collected in the construction phase. ▪ A quick response of Eastern Gambusia populations in recovery from drought conditions. ▪ The timing of drought, rainfall events and surveys.	Performance indicator not met but unlikely to be directly related to an impact from construction activities
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.	Performance indicator met
Any change in habitat structure downstream of construction area, i.e., macrophyte and woody snag cover.	Minor changes to habitat structure have been noted at some sites. This is discussed in detail in Section 4 of this report. In general, significant changes in habitat structure were evenly spread between impact and control sites. Furthermore, the changes detected at impact sites were almost all directly related to riparian vegetation removal required for bridge crossings, changes to channel width and depth directly underneath bridge crossings and/or rock placement required to protect bridge abutments and piers. Changes to macrophyte cover at impact sites were mostly positive. Reduced woody snag cover was detected at sites 3a and 12a, both sites where riparian vegetation removal was required for bridge crossings. Changes in habitat structure downstream of construction indicators were not detected.	Performance indicator met

Performance Indicator	*Notes*	*Conclusion*
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. Flow rates greater than 0.1 m/second have only been detected on a few occasions throughout monitoring.	Performance indicator met
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.	Performance indicator met
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 C1 in all annual reporting periods to date. OPP were not captured at Site 27b during surveys this year or last year. It is highly likely that the severity of the drought has impacted OPP populations at 27b and throughout the wallum country located to the North of the Perch Trail in Broadwater National Park. Site 27b was thought to be drought tolerant following a drought refuge investigation (Birch 2014).	Performance indicator not met as a result of severe and unforeseeable drought.
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**), warranted further investigation. An analysis of results from the W2B construction phase water quality monitoring indicates that several results of interest have been recorded for DO, pH and turbidity at OPP sites (**Table 3.3**). Specifically, a high number of high pH values were recorded at sites 10b & c, 12a and 13c in 2018 and/or 2019. It is not known what contribution drought conditions made to these results.	Performance indicator not met.
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.	Performance indicator met.
Disparity in water quality between downstream and upstream monitoring sites observed during operation of the project	Information collected under the operational phase Water Quality Monitoring Program for the W2B upgrade will be used to assess whether the W2B upgrade is meeting requirements for this performance indicator.	To be confirmed.

In conclusion, although significantly fewer OPP were captured during this reporting period, there is no indication that it is a result of construction impacts, because very few OPP were collected from control sites and drought conditions have clearly impacted OPP habitat in the study area, resulting in many dry sites and bushfires at some sites. Similar, though less severe, drought conditions were observed in the pre-construction monitoring and also led to lower numbers of captured OPP at fewer sites where OPP were captured.

Overall, results from the construction phase monitoring indicate that the threatened fish management actions adopted along the W2B upgrade have been successfully protecting OPP populations and habitat. In some cases there have been improvements to stream condition as a combined result of revegetation efforts and fencing to exclude grazing pressure (**Plates 4.2, 4.3, 4.4**). However, consideration of the results presented against performance indicators from the TFMP indicate that crossing construction may have had some impacts on water quality - specifically with respect to pH, a key indicator for OPP.

Plate 4.1 Threatened fish monitoring at Site 13b in May 2020.

Plate 4.2 Improved emergent vegetation cover at site 13b.

Plate 4.3 Improved emergent vegetation and riparian cover at site 12a.

Plate 4.4 Improved emergent vegetation and riparian cover at site 11d.

Project Team

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

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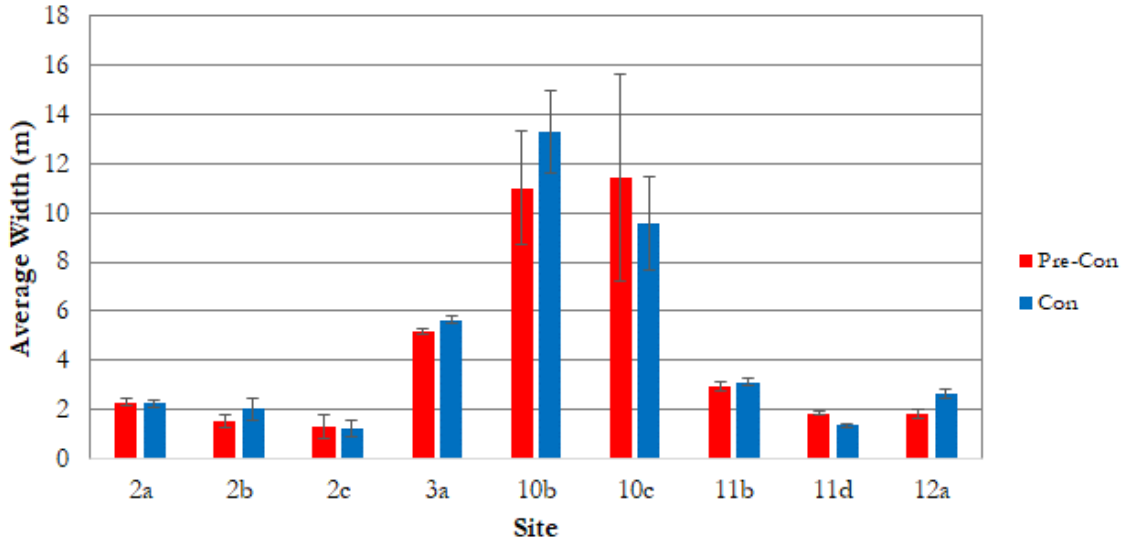
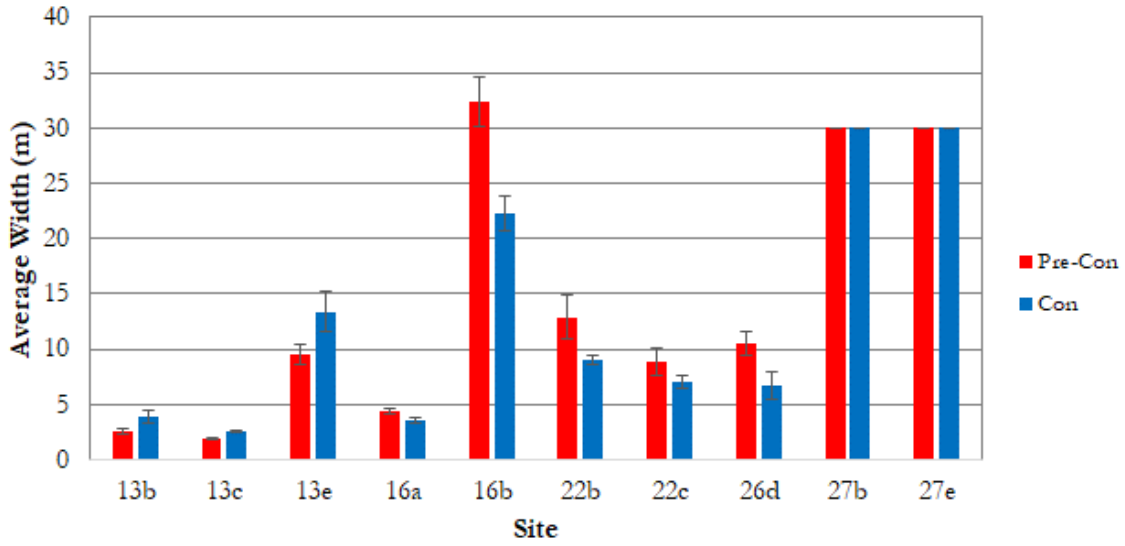
Appendix A

Aquatic Habitat Summaries

Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring





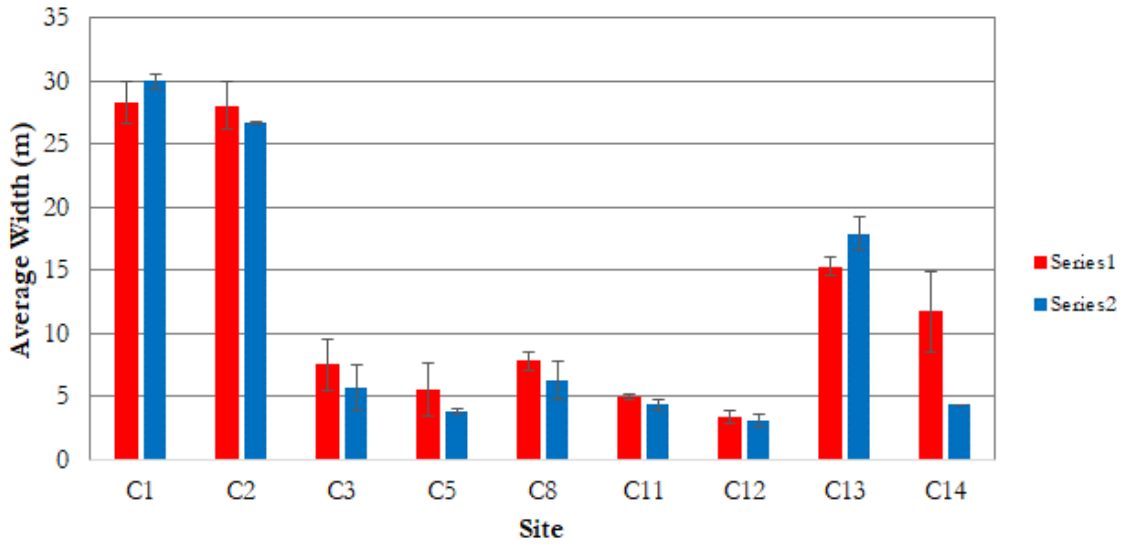


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

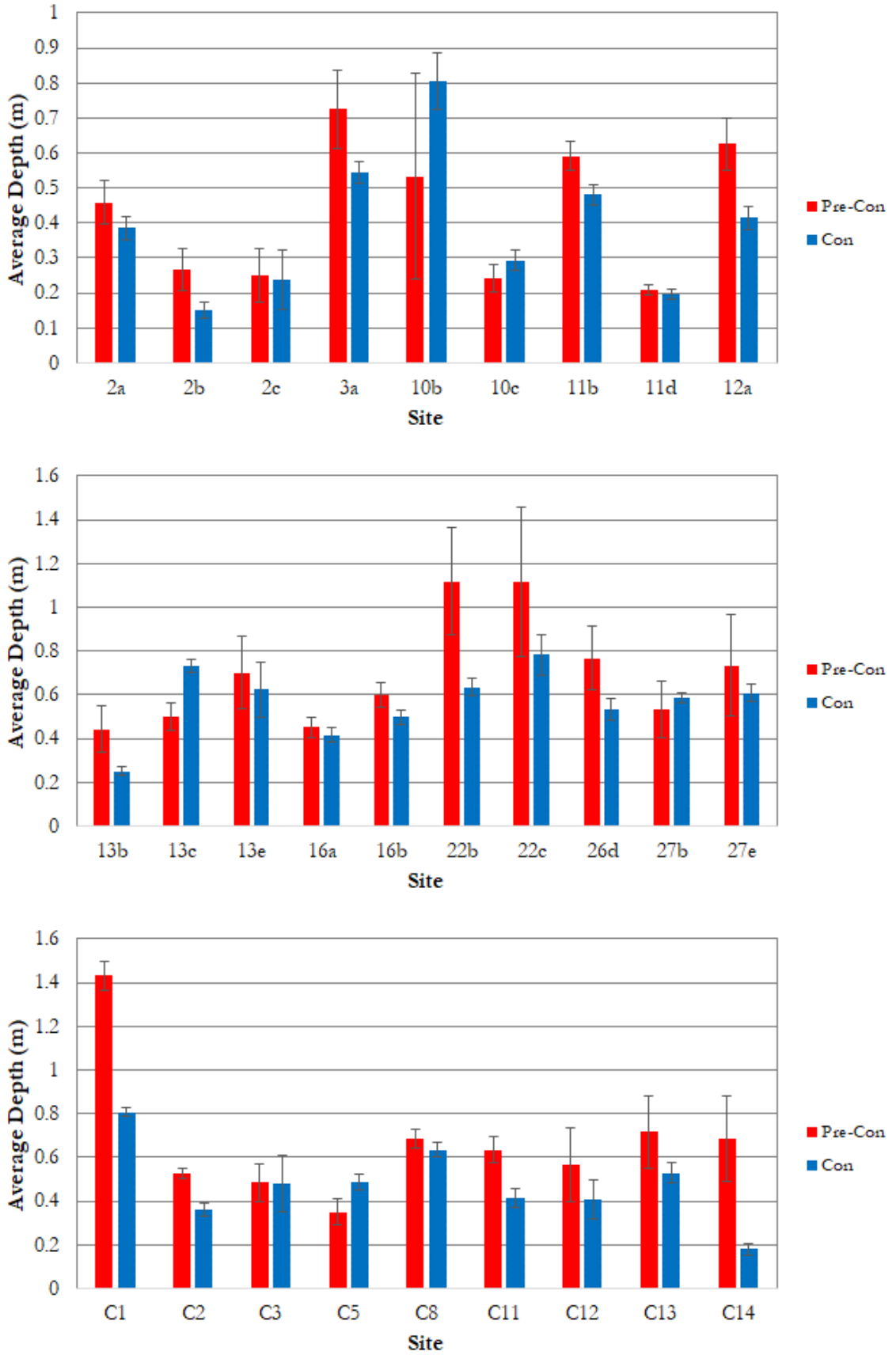
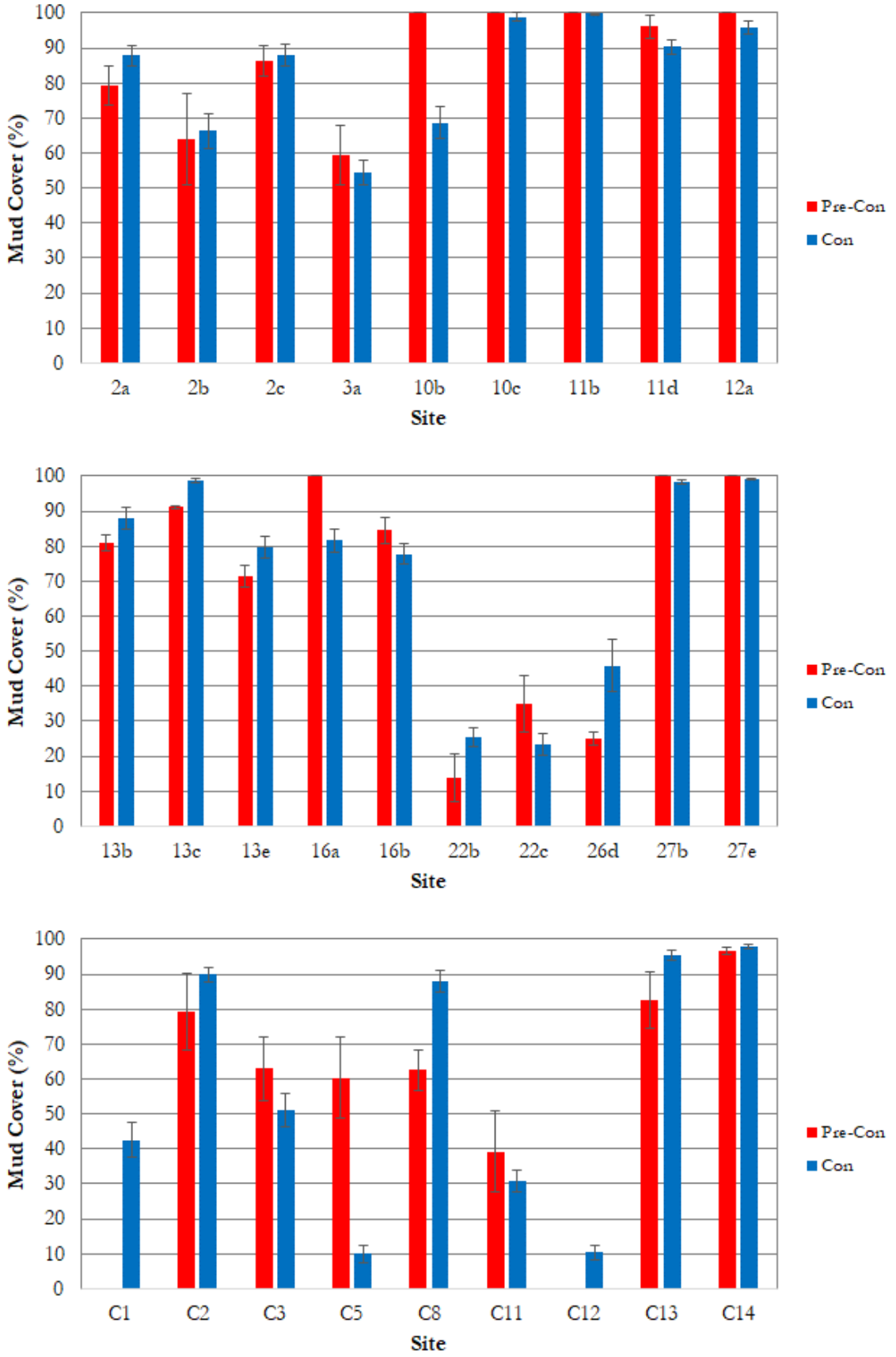


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring



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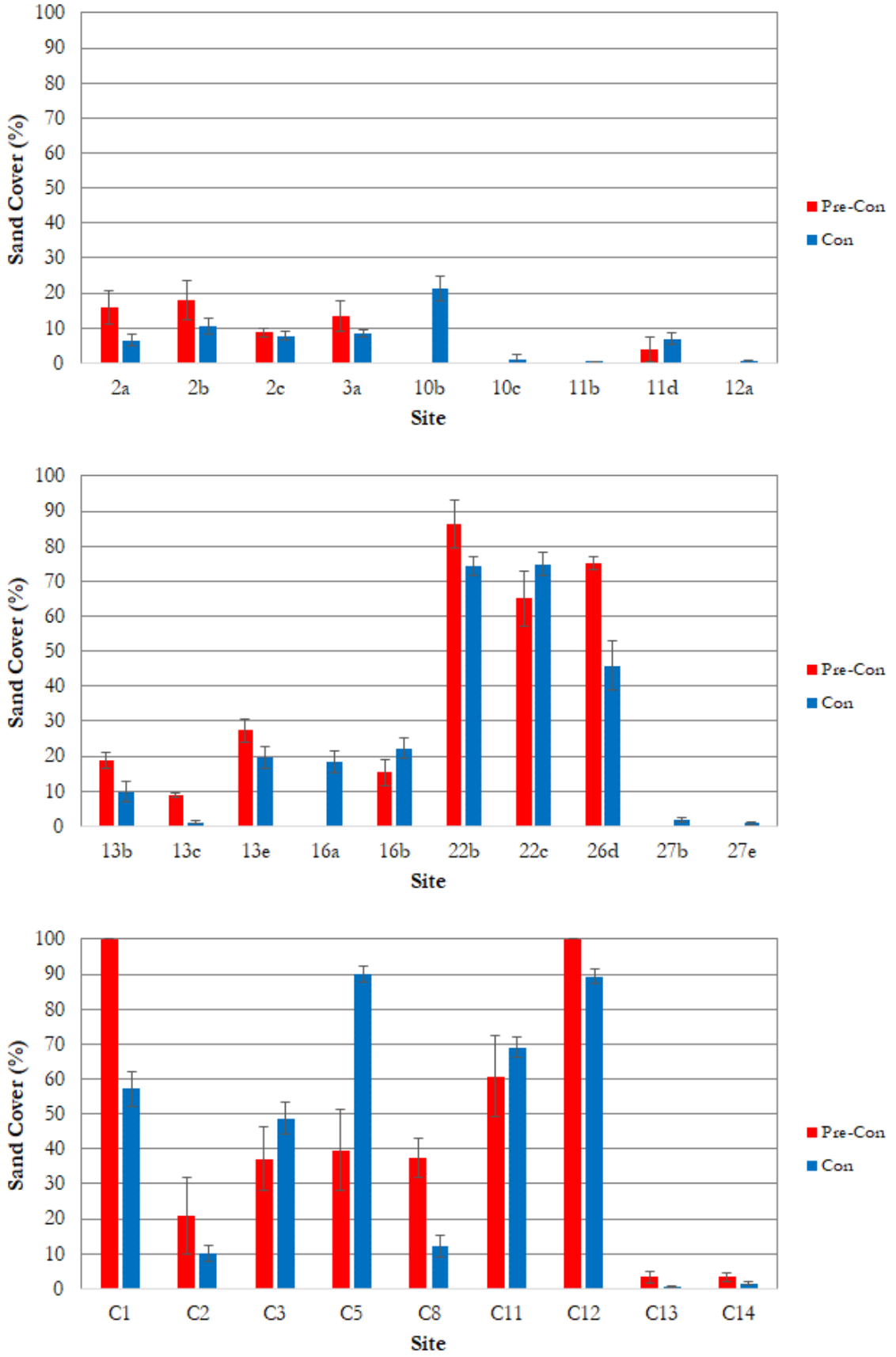
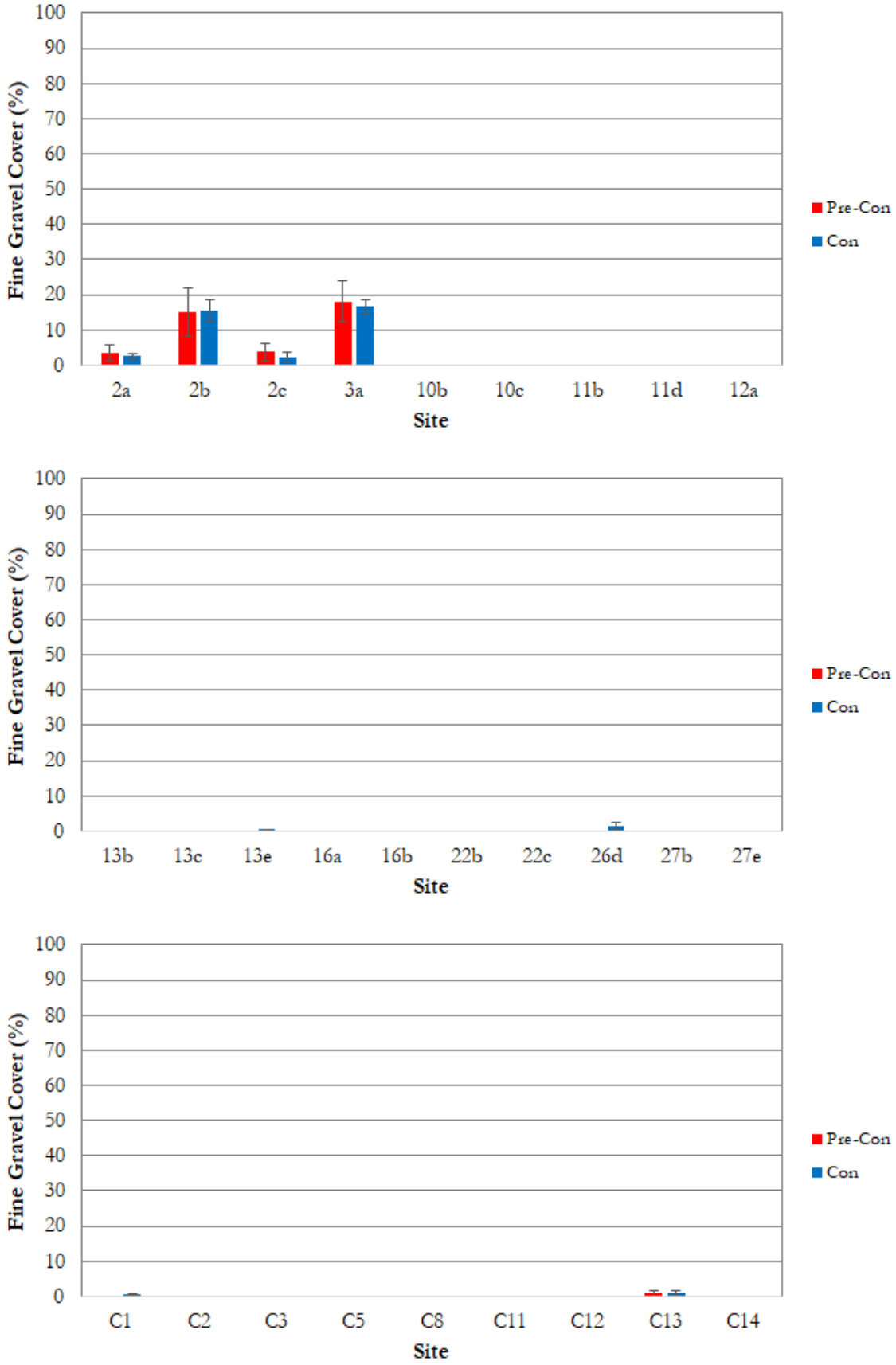


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring



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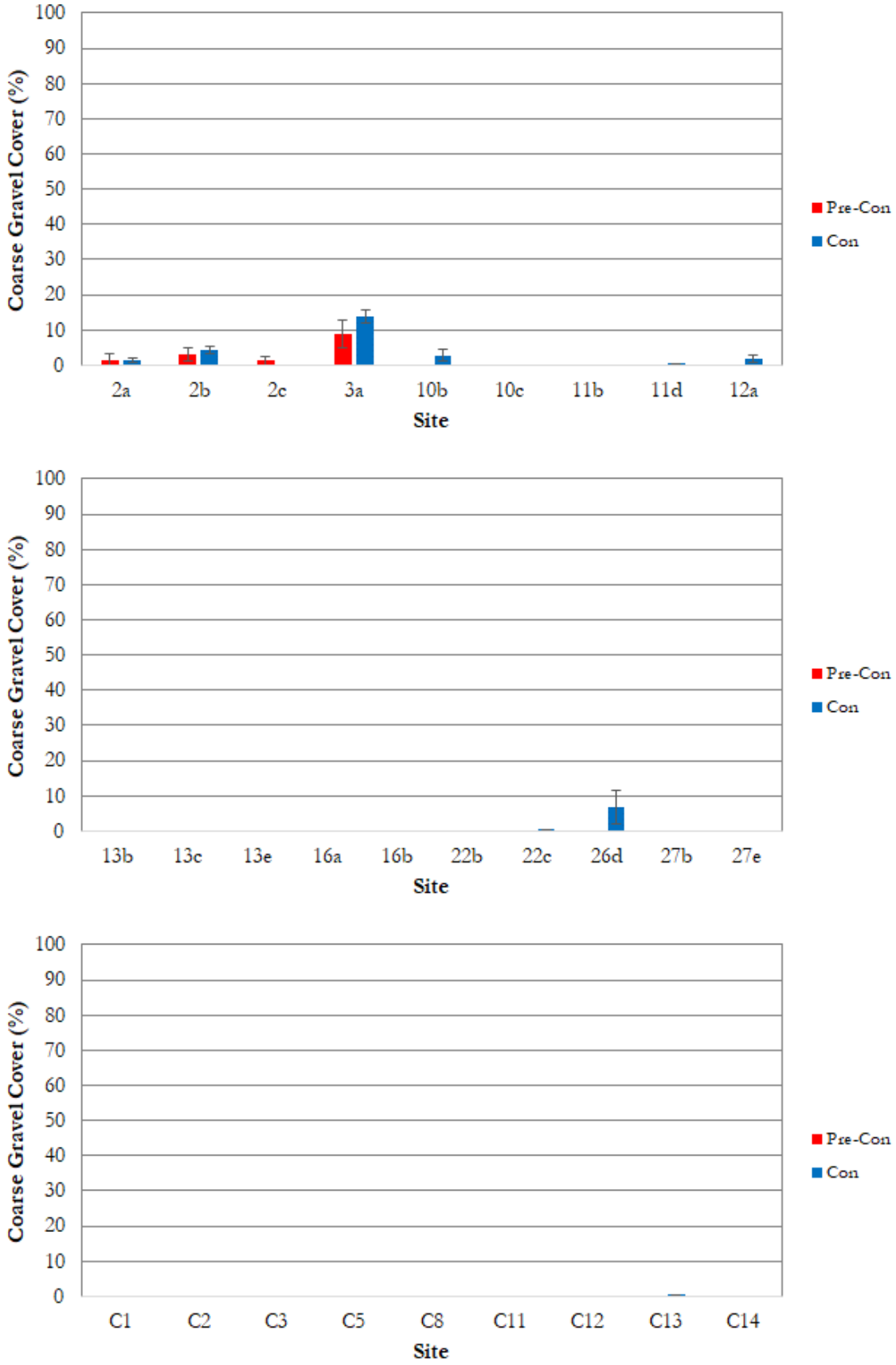

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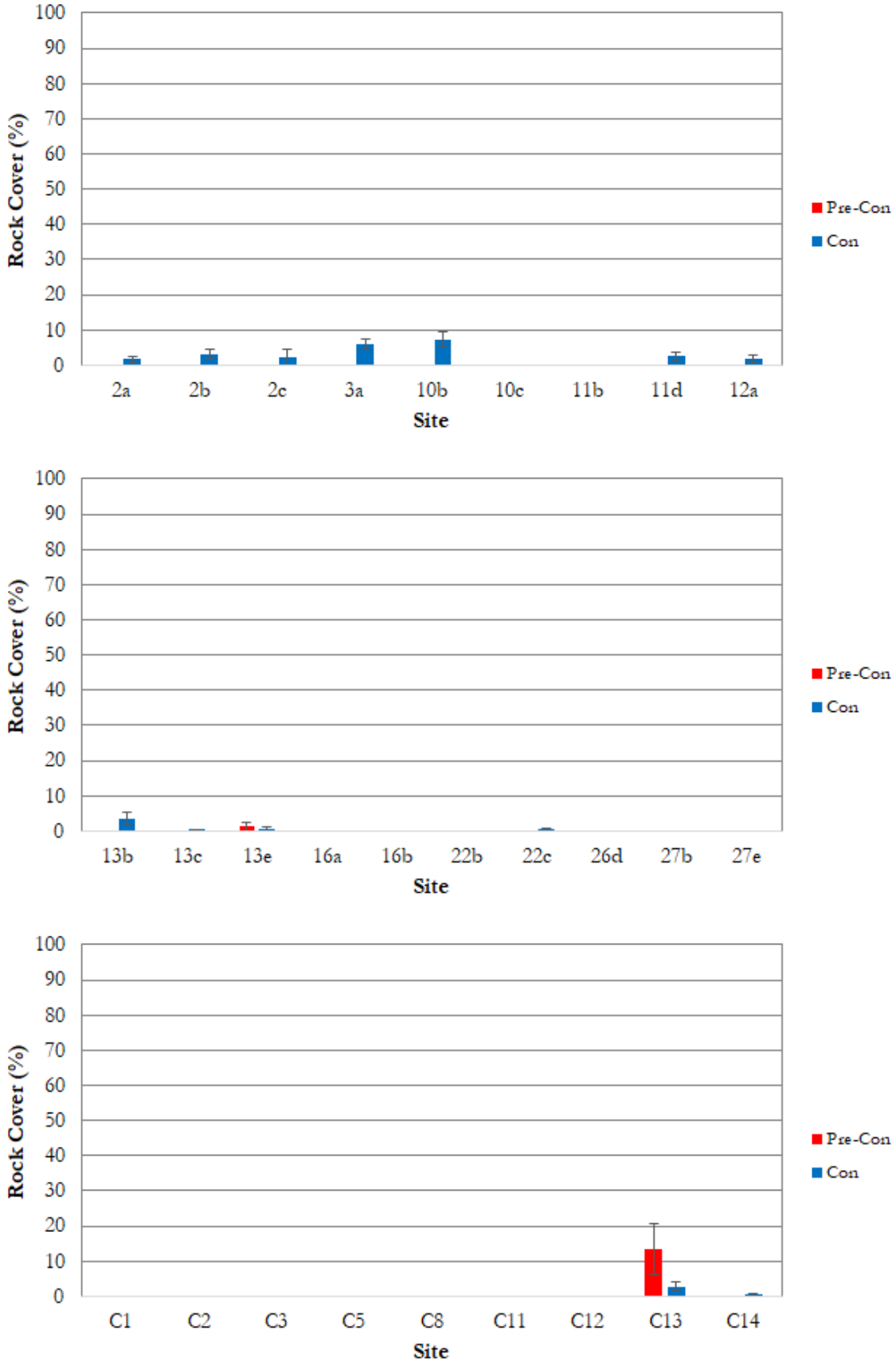

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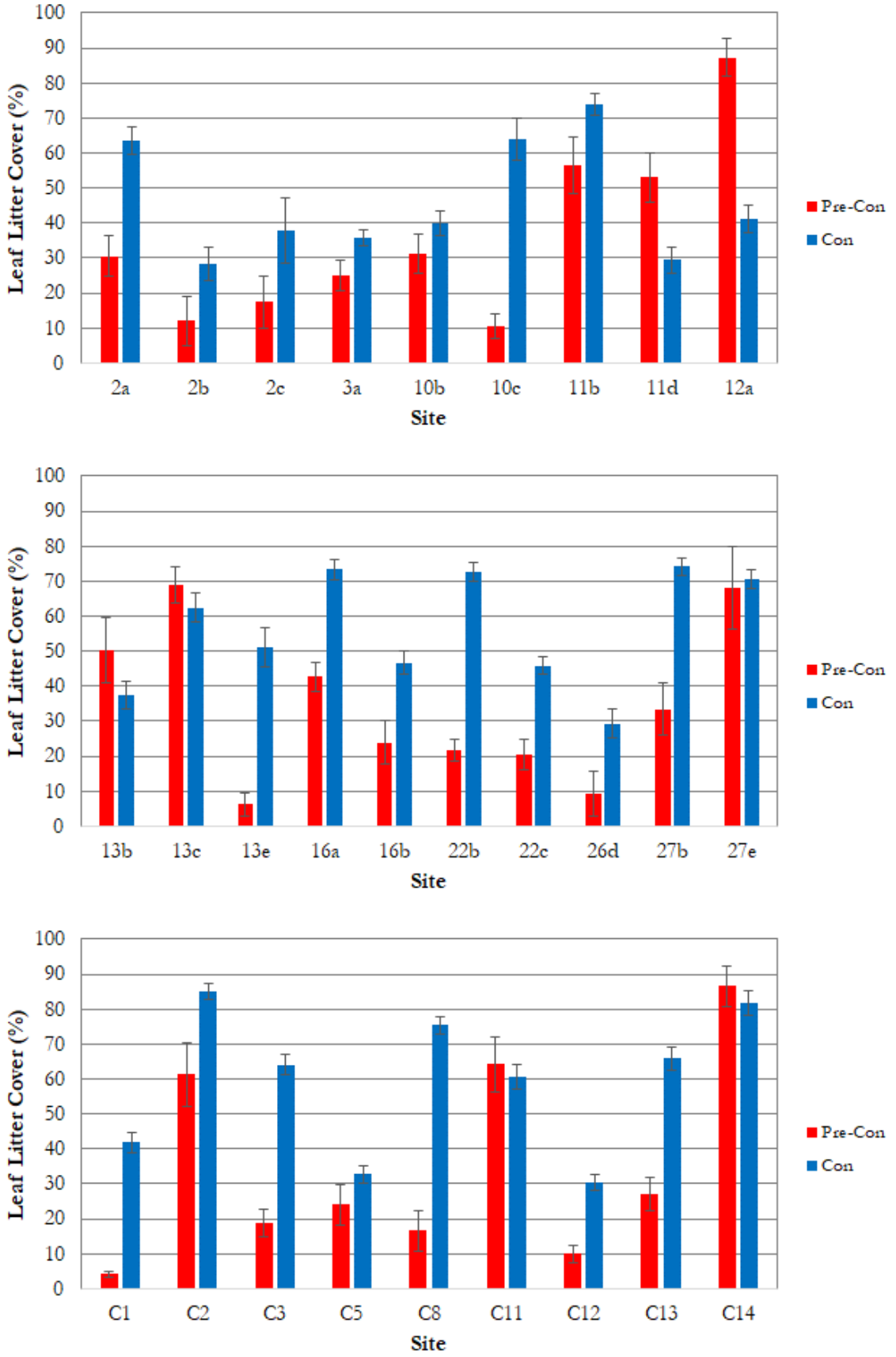

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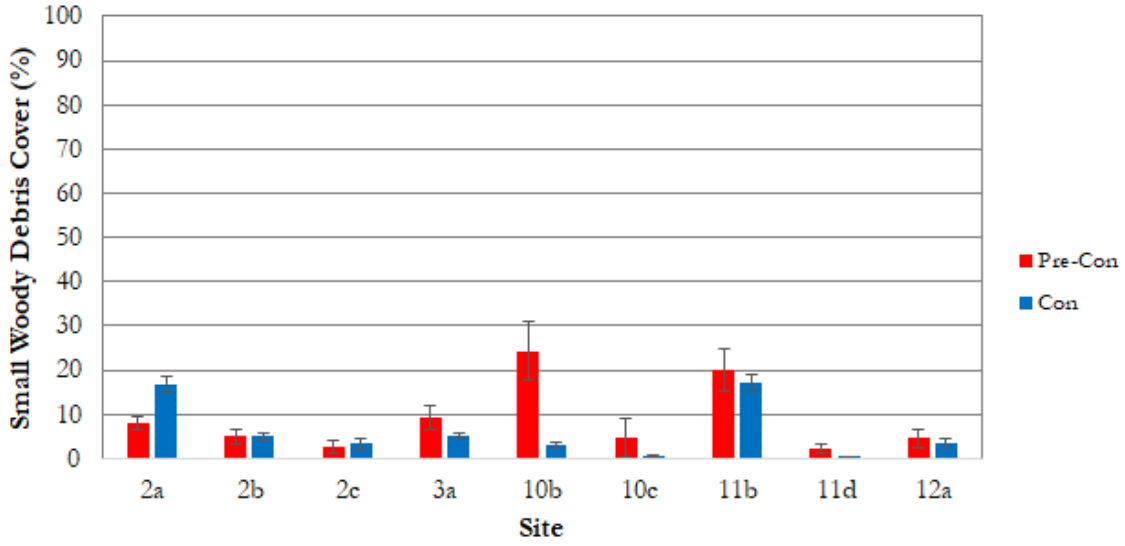
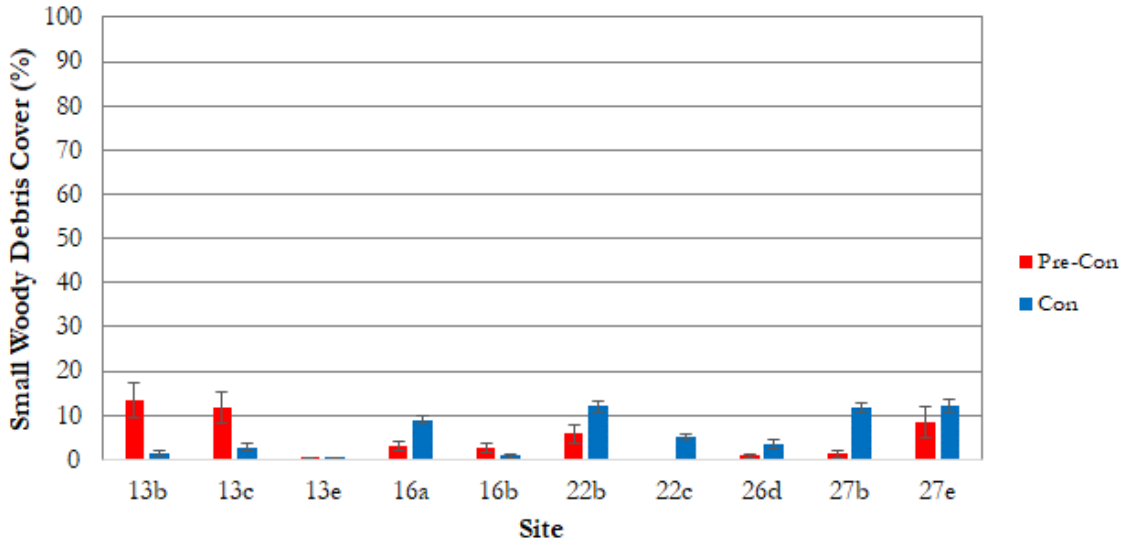




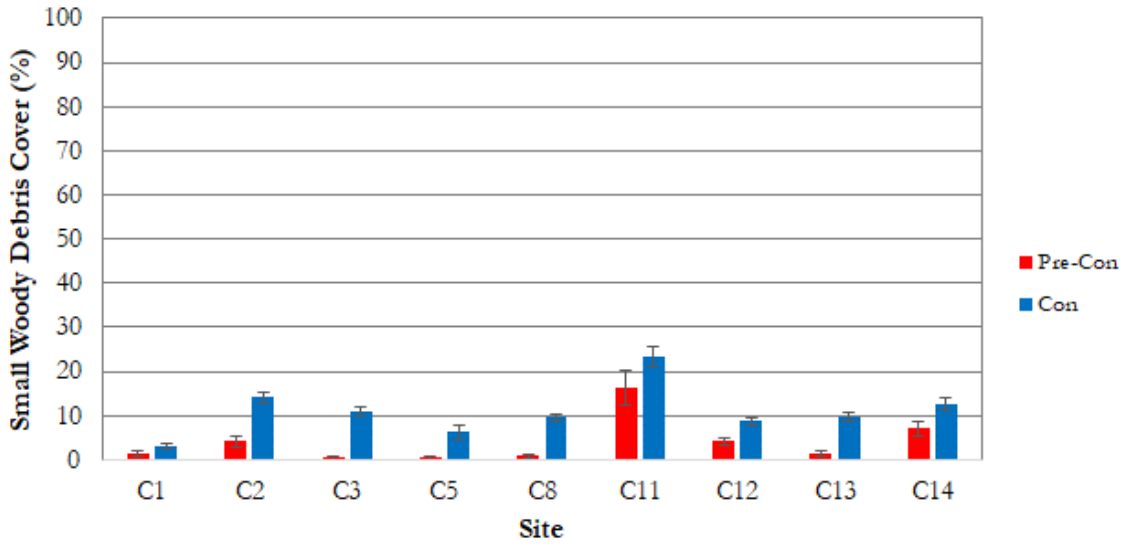


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

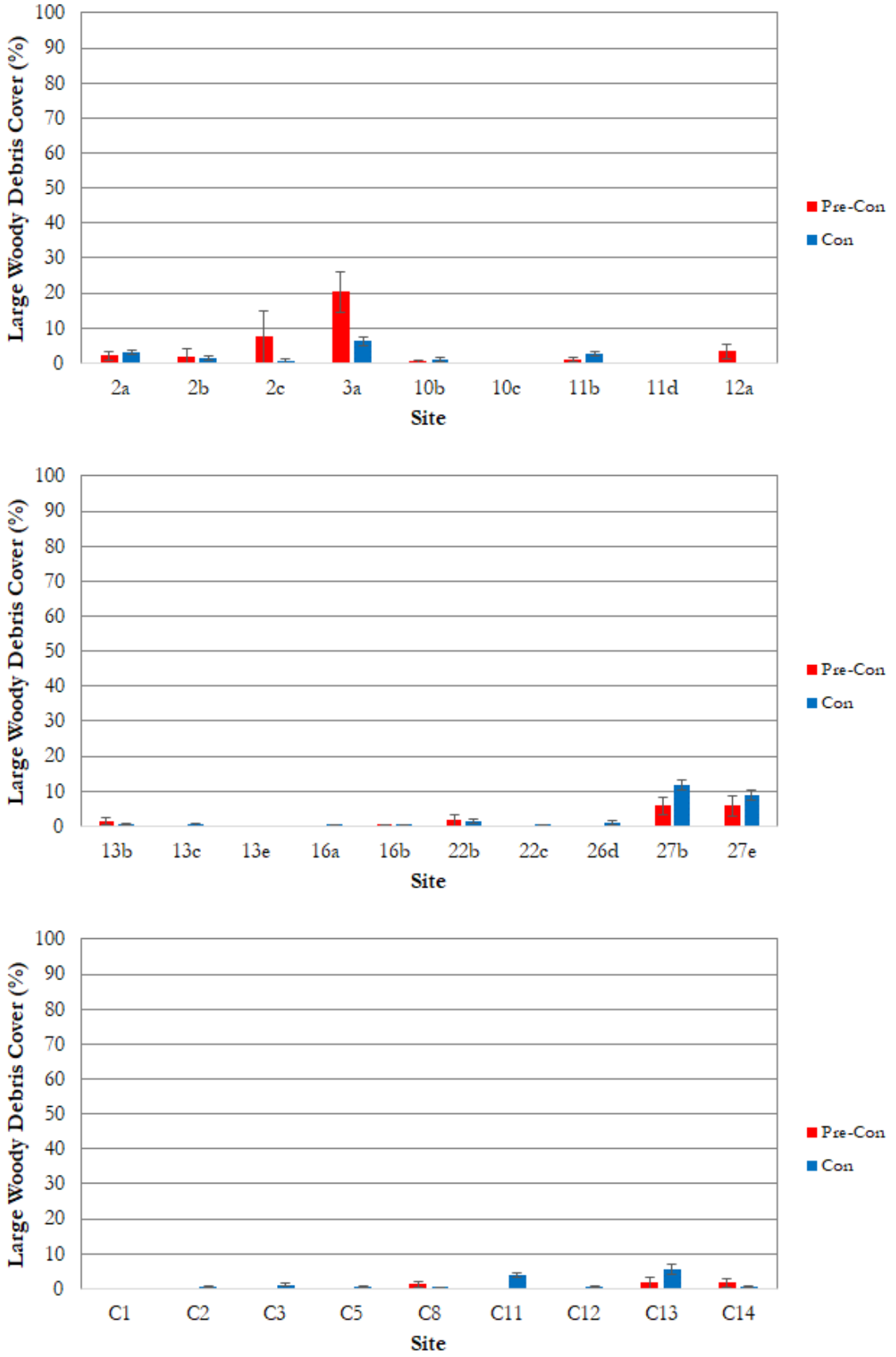


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

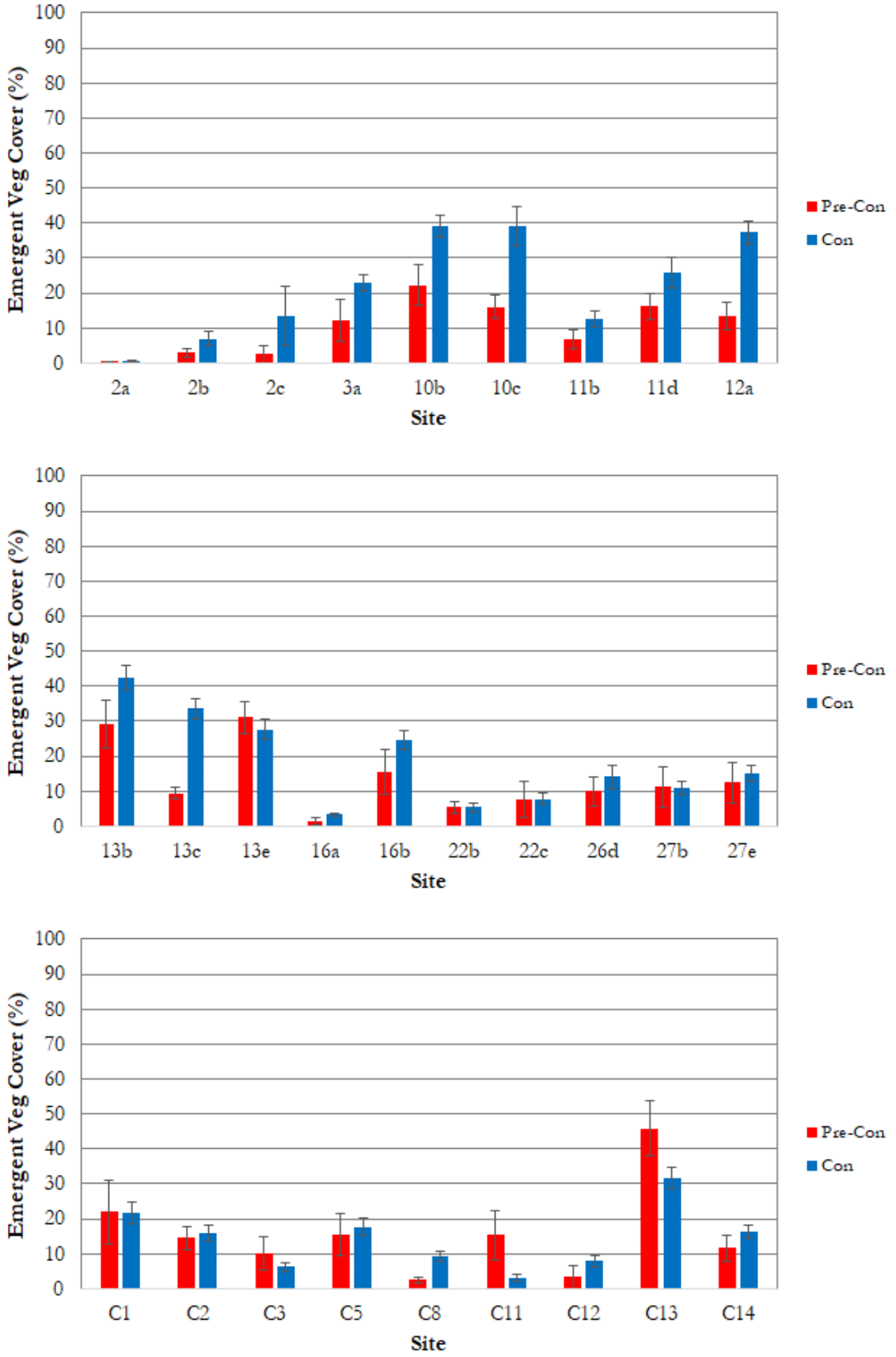


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

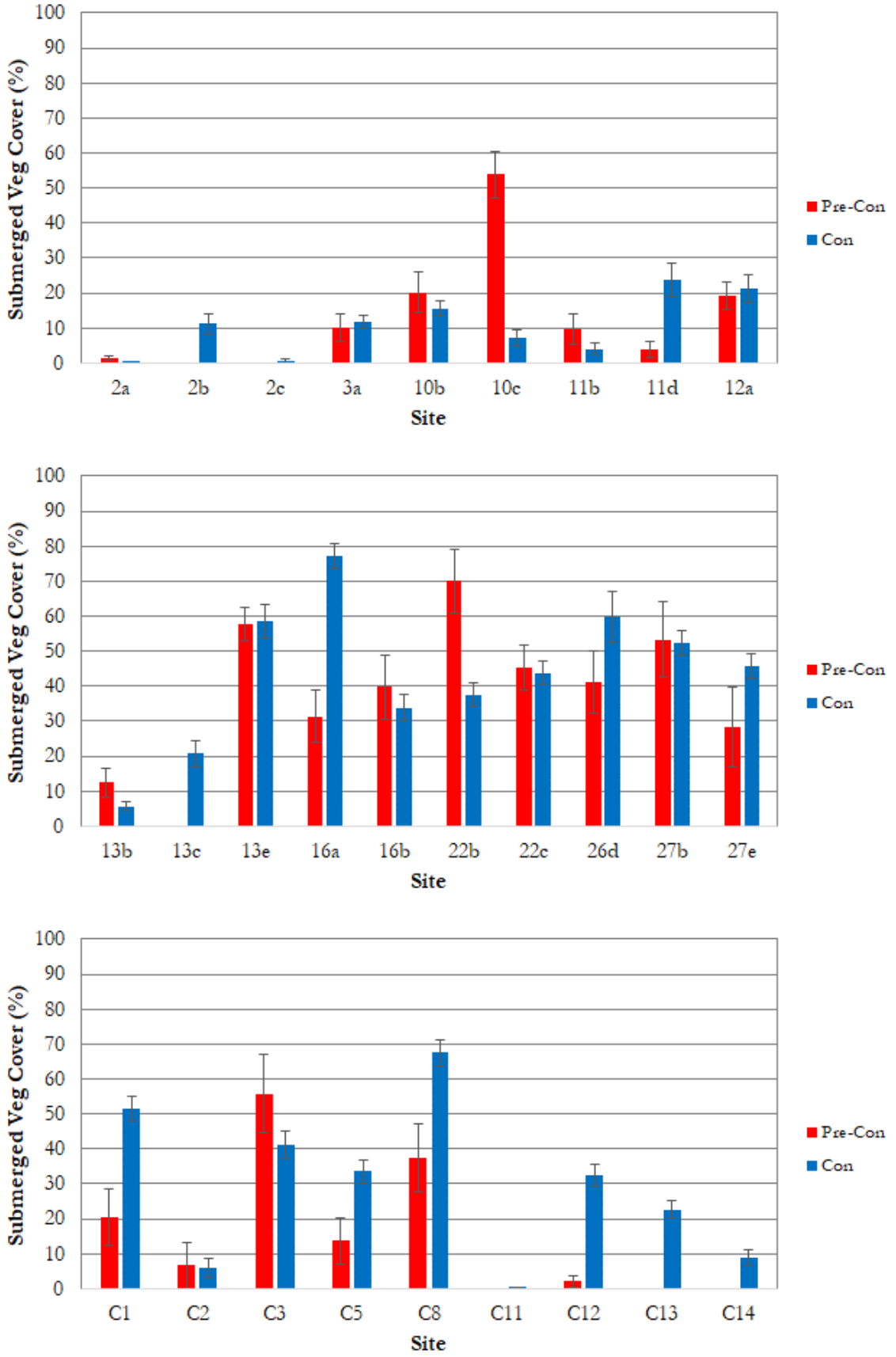


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

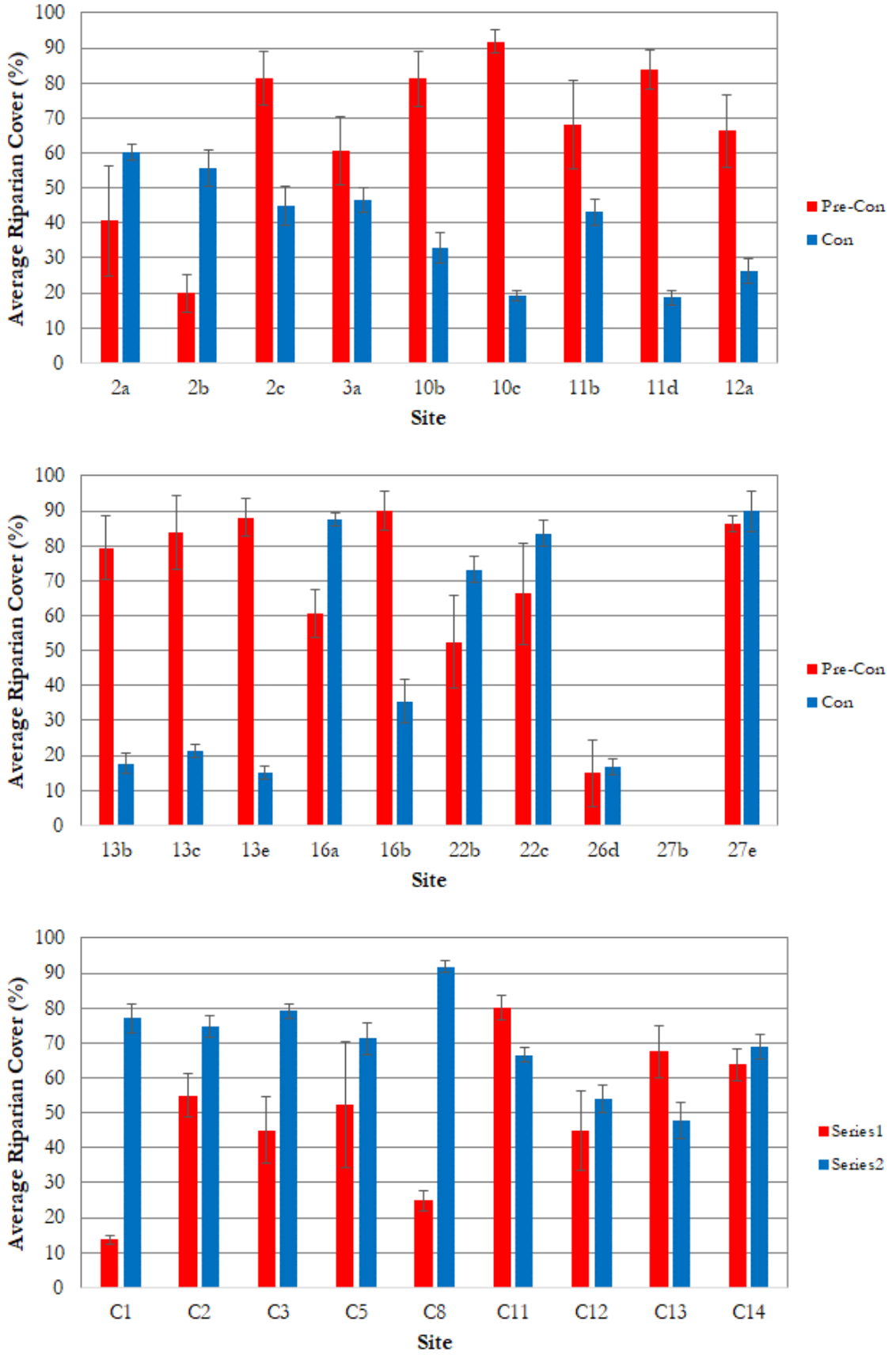


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

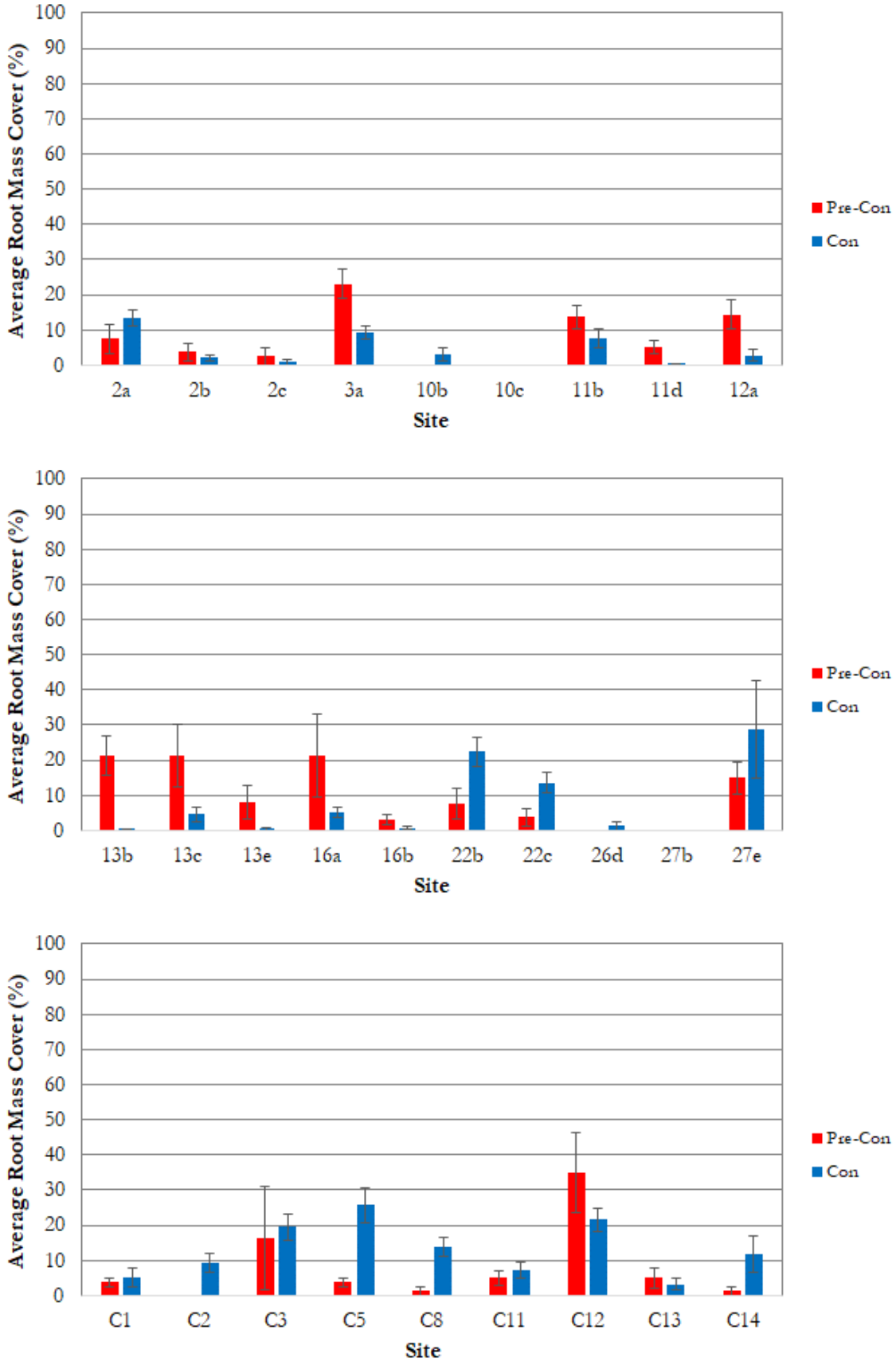
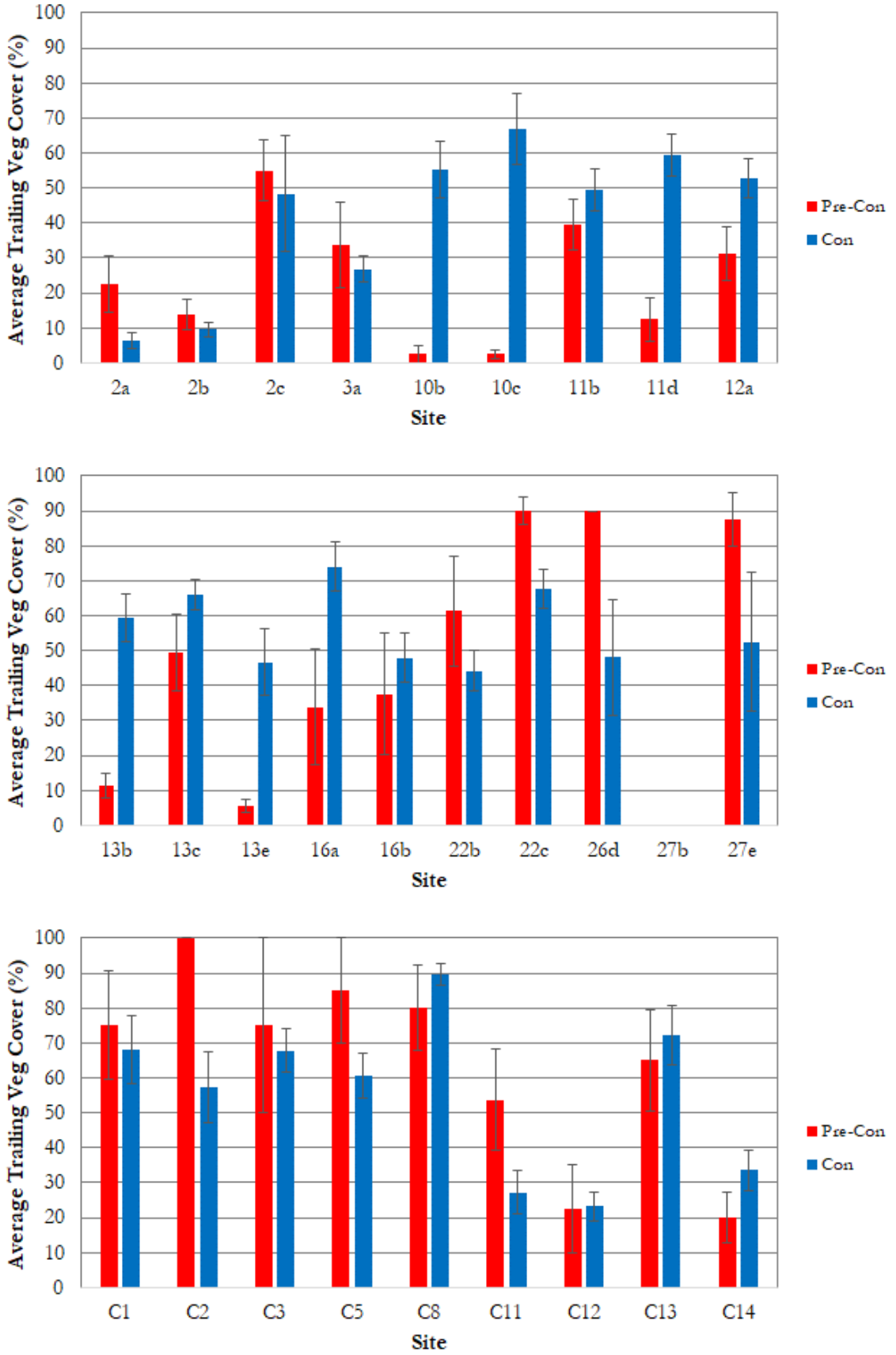


Figure A1 Average (±SE) habitat measurements at each site in the pre-construction and construction phases of monitoring



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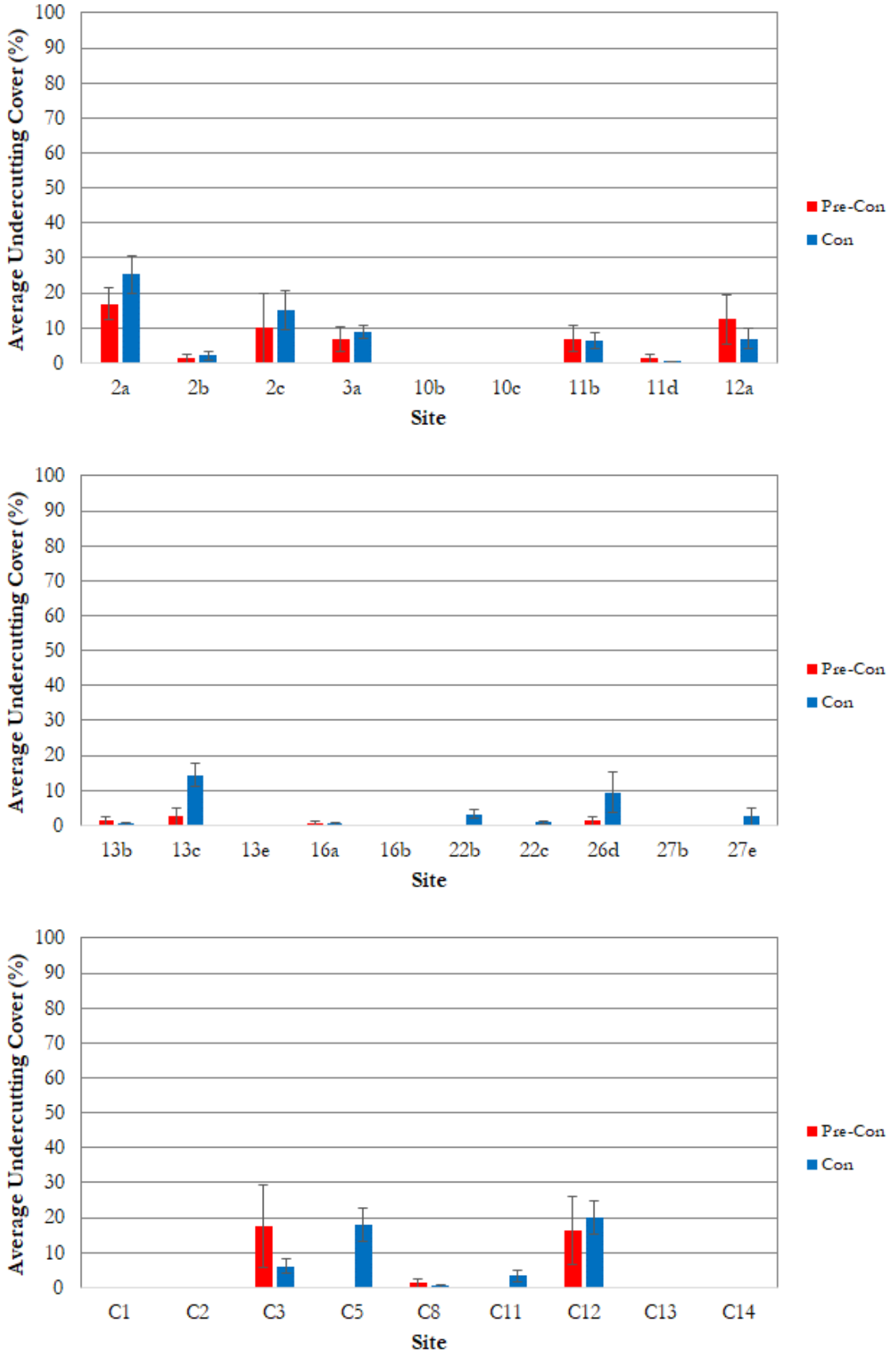

Appendix B

Construction Phase Fish Monitoring Results

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

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

Table B5. Summary of captures for all fishing methods at all impact sites during the May 2018 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	1	0	0	0	0	0	0	0	2	2	0	0	0	2	0	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	25	0	0	20	1	0	41	20	25	26	25	0	0	0	14	4	0	2	1
Hypseleotris compressa	Empire Gudgeon	0	0	0	4	4	0	34	1	52	0	39	0	0	0	0	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	32	0	0	79	1	0	6	0	9	0	0	0	1	67	75	27	0	13	13
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	6	0	14	13	14	7	0	2	1
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	0	0	0	2	0	0	0	4	1	0	4	0	32	2	7	10	0	28	19
Gambusia	Mosquito Fish	33	3	0	114	20	0	44	9	17	103	0	0	0	0	0	0	0	0	4

* No survey - access restrictions.

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

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

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	1	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	32	0	0	16	10	0	0	22	23	1	78	0	0	0	15	31	0	3	1
Hypseleotris compressa	Empire Gudgeon	0	0	0	8	17	0	0	1	64	0	44	0	0	0	1	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	49	0	0	77	9	0	0	0	3	0	0	0	0	527	82	84	0	5	4
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	11	0	2	2	12	0	0	10	3
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	0	0	0	0	0	0	0	1	0	0	3	0	29	0	7	22	0	21	13
Gambusia	Mosquito Fish	9	0	0	70	72	0	0	4	3	4	0	0	0	0	0	0	0	0	0

* No survey - access restrictions.

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

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

Table B9. Summary of captures for all fishing methods at all impact sites during the July 2019 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	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	31	0	0	9	2	0	14	9	4	3	0	0	0	0	4	10	0	0	1
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	29	0	14	0	6	0	0	0	0	0	0	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	26	0	0	45	5	0	0	0	0	0	0	0	0	5	11	12	0	0	3
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	4	0	0	0	0	0	0	0	0	0	0	18	31	0	0	1
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	1
Gambusia	Mosquito Fish	40	0	0	109	57	0	30	0	7	2	0	0	0	0	0	0	0	0	0

* No survey - access restrictions.

Table B10. Summary of captures for all fishing methods at all control and Devils Pulpit sites during the July 2019 survey

Scientific Name	*Common Name*	*Site*															
		C1	**C2**	**C3**	**C5**	**C8**	**C11**	**C12**	**C13**	**C14**	**OPP1**	**OPP2**	**OPP3**	**OPP4**	**OPP5**	**OPP6**	**OPP7**
Anguilla australis	Shortfin Eel	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	0	0	0	13	0	0	4	30	0	2	7	30	0	0	0	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	12	0	0	3	0	0	8	13	0	3	6	9	0	0	0	0
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	21	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gambusia	Mosquito Fish	0	0	0	0	0	0	0	17	0	45	8	8	0	0	0	0

Table B11. Summary of captures for all fishing methods at all impact sites during the September 2019 survey

		Site																		
Scientific Name	***Common Name***	**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	0	1	0	1	0	0	0	0	0	1	0	1	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	3	0	0	14	10	0	0	0	5	0	0	0	0	0	9	7	0	0	2
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	75	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	8	0	0	86	3	0	0	0	0	0	0	0	0	95	50	65	0	0	6
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	3	0	0	1
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	12	0	0	5
Gambusia	Mosquito Fish	40	0	0	14	54	0	0	0	19	1	0	0	0	0	0	0	0	0	0

* No survey - access restrictions.

Table B12. Summary of captures for all fishing methods at all control and Devils Pulpit sites during the September 2019 survey

		Site															
Scientific Name	***Common Name***	**C1**	**C2**	**C3**	**C5**	**C8**	**C11**	**C12**	**C13**	**C14**	**OPP1**	**OPP2**	**OPP3**	**OPP4**	**OPP5**	**OPP6**	**OPP7**
Anguilla australis	Shortfin Eel	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	1	0	0	12	0	0	6	34	0	4	70	31	0	0	0	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	0	25	0	1	0	4	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	30	0	0	13	0	0	238	32	0	46	20	36	0	0	0	0
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	28	0	0	43	0	0	22	1	0	0	1	1	0	0	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	9	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Gambusia	Mosquito Fish	0	0	0	0	0	0	0	5	0	0	5	0	0	0	0	0

Table B13. Summary of captures for all fishing methods at all impact sites during the May – June 2020 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**
Ambassis agassizii	Olive Perchlet	0	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anguilla australis	Shortfin Eel	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	5	0	0	8	12	2	19	36	47	0	0	0	0	0	7	7	0	0	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	1	40	1	1	2	154	0	0	0	0	0	1	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	18	17	0	25	6	0	2	1	8	0	0	0	0	0	20	38	0	0	0
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	1	0	0	0	13	0	0	0	0	0	3	4	0	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Tandanus tandanus	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carassius auratus	Goldfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gambusia holbrooki	Mosquito Fish	28	192	0	111	34	54	22	4	5	4	0	0	0	0	3	0	0	0	0

* No survey - access restrictions.

Table B14. Summary of captures for all fishing methods at all control and Devils Pulpit sites during the May – June 2020 survey

Scientific Name	*Common Name*	*Site*															
		C1	**C2**	**C3**	**C5**	**C8**	**C11**	**C12**	**C13**	**C14**	**OPP1**	**OPP2**	**OPP3**	**OPP4**	**OPP5**	**OPP6**	**OPP7**
Ambassis agassizii	Olive Perchlet	0	0	0	0	0	0	0	66	0	0	0	0	0	4	0	0
Anguilla australis	Shortfin Eel	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	1	0	0	4	0	0	4	13	0	4	9	17	0	0	0	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	0	18	0	1	7	1	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	12	1	0	32	23	12	37	170	31	1	3	1	0	42	0	0
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	11	0	0	8	28	0	22	9	4	0	0	0	0	2	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	10	0	0	6	1	0	6	0	0	0	0	0	0	0	0	0
Tandanus tandanus	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carassius auratus	Goldfish	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Gambusia holbrooki	Mosquito Fish	0	0	0	0	0	1	0	63	40	95	99	2	0	322	44	0

Table B15. Summary of captures for all fishing methods at all impact sites during the September 2020 survey

		Site																		
Scientific Name	***Common Name***	**2a**	**2b**	**2c***	**3a**	**10b**	**10c**	**11b**	**11d**	**12a**	**13b**	**13c**	**13e***	**16a**	**16b**	**22b**	**22c**	**26d***	**27b**	**27e**
Ambassis agassizii	Olive Perchlet	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anguilla australis	Shortfin Eel	2	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	3	1	0	15	30	0	18	34	66	0	2	0	0	0	37	25	0	0	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	2	111	0	33	0	23	0	0	0	0	0	0	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	4	17	0	26	9	0	9	1	5	0	1	0	0	0	74	78	0	0	0
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	0	0	2	6	7	0	0	0	0	0	4	7	0	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	17	0	0	0
Tandanus tandanus	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carassius auratus	Goldfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gambusia holbrooki	Mosquito Fish	25	71	0	22	179	118	18	3	3	23	0	0	0	0	0	0	0	0	0

* No survey - access restrictions.

Table B16. Summary of captures for all fishing methods at all control and Devils Pulpit sites during the September 2020 survey

		Site															
Scientific Name	***Common Name***	**C1**	**C2**	**C3**	**C5**	**C8**	**C11**	**C12**	**C13**	**C14**	**OPP1**	**OPP2**	**OPP3**	**OPP4**	**OPP5**	**OPP6**	**OPP7**
Ambassis agassizii	Olive Perchlet	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	0
Anguilla australis	Shortfin Eel	0	0	0	1	1	0	1	0	0	6	2	0	0	0	0	0
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0
Gobiomorphus australis	Striped Gudgeon	0	0	0	3	0	0	3	75	0	7	12	10	0	0	0	0
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	0	8	0	1	0	1	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	26	0	0	8	101	18	554	40	3	6	10	15	0	12	0	0
Melanotaenia duboulayi	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Rhadinocentrus ornatus	Ornate Rainbowfish	21	2	0	20	35	14	164	0	0	0	0	0	0	0	0	0
Nannoperca oxleyana	**Oxleyan Pygmy Perch**	6	0	0	3	2	1	9	0	0	0	0	0	0	0	0	0
Tandanus tandanus	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Carassius auratus	Goldfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gambusia holbrooki	Mosquito Fish	0	0	0	0	0	2	0	910	86	165	41	2	0	109	0	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	OPP Range	Pre-Con Range	2017 Range	2018 Range	2019 Range	2020 Range
Unnamed waterway south of Serendipity Rd Ch. 11400	2a, 2b, 2c	Temp	(°C)	10.9 – 28.3	13.3 – 23.6	12.42 - 16.00	13.31 - 17.02	**10.76** – 20.47	14.35 - 22.01
		DO	(mg/L)	2.15 – 10.02	4.11 - 10	**1.42** - 4.58	**1.09** - 4.10	**0** – 4.96	3.22 – 5.64
		pH		3.32 – 6.9	5 – 6.9	4.98 - 5.83	6.13 – **7.1**	6.44 – 6.92	5.8 – 6.67
		Conductivity	(mS/cm)	0.068 – 2.148	0.009 – 0.368	0.105 - 0.275	0.093 - 0.472	0.127 – 0.539	0.1 – 0.578
		Turbidity	(NTU)	0 - 80	0.9 - 118	7.6 - 20.8	13.1 - 109	22.5 - **446**	0 – 17.1
Tabbimoble floodway no. 1 Ch. 115300	3a	Temp	(°C)	10.9 – 28.3	12.8 - 24	13.73 - 16.79	16.56 - 18.86	**10.11** – 19.4	16.84 – 17.65
		DO	(mg/L)	2.15 – 10.02	1.3 - 8.07	4.61 - 5.59	4.4 – 4.41	5.44 – 7.71	5.86 – 6.71
		pH		3.32 – 6.9	4.4 – 7.2	5.43 - 5.62	6.36 - 6.52	6.42 – **7.62**	5.98 – 6.28
		Conductivity	(mS/cm)	0.068 – 2.148	0.009 – 0.140	0.089 - 0.093	0.171 - 0.262	0.324 – 0.331	0.129 – 0.258
		Turbidity	(NTU)	0 - 80	18.9 – 132	12.5 - 13.5	10.3 - 11.0	12.9 - 17	0 - 2.1
Unnamed waterway south of MacDonalds Ck Ch. 134600	10b, 10c	Temp	(°C)	10.9 – 28.3	16.6 - 29	12.5 - 15.5	18.0 - 21.7	11.11 – 16.74	16.07 – 16.96
		DO	(mg/L)	2.15 – 10.02	3.17 - 10	**0.61 - 0.89**	**0.58** - 6.32	3.08 – 6.07	**0.95 – 2.07**
		pH		3.32 – 6.9	4 – 9.3	4.7 - 4.75	6.19 - 6.56	6.08 – 7.06	5.04 – 5.76
		Conductivity	(mS/cm)	0.068 – 2.148	0.102 – 0.537	0.249 - 0.333	0.294 - 0.508	0.281 – 0.581	0.255 – 0.535
		Turbidity	(NTU)	0 - 80	1.3 - 800	3.8 - 5.7	4.0 - 80	0 – 18.3	0 – 28.8
MacDonalds Ck Tributary Ch. 135200, 135530 and 136450	11b, 11d, 22b, 22c	Temp	(°C)	10.9 – 28.3	15.4 – 26.7	14.16 - 24.69	16.68 - 22.64	**10.29** – 18.26	13.49 – 19.91
		DO	(mg/L)	2.15 – 10.02	2.27 – 8.9	**0.74** - 8.65	2.67 - 9.46	**1.77** – 6.13	2.18 – 5.89
		pH		3.32 – 6.9	3.8 – 8.9	3.44 - 5.97	3.82 - 5.49	4.10 – 6.44	4.09 – 5.63
		Conductivity	(mS/cm)	0.068 – 2.148	0.092 – 0.606	0.131 - 0.178	0.14 - 0.193	0.178 – 0.237	0.164 – 0.229
		Turbidity	(NTU)	0 - 80	2.4 - 138	0 - 212	0.7 - 34.8	0 – **104**	0 – 30.1
MacDonalds Ck Ch. 136600	12a	Temp	(°C)	10.9 – 28.3	14.9 - 26	13.36	19.08 - 19.72	12.89 – 19.58	18.48 – 18.85
		DO	(mg/L)	2.15 – 10.02	1.7 – 8.1	**1.36**	**0.43 - 2.08**	2.11 – 2.74	0.45 – 1.59
		pH		3.32 – 6.9	3.6 – 6.3	**2.72**	5.71 - 5.82	5.08 – 6.41	4.78 – 5.43
		Conductivity	(mS/cm)	0.068 – 2.148	0.164 – 0.406	0.25	0.28 - 0.295	0.374 – 0.41	0.26 – 0.273
		Turbidity	(NTU)	0 - 80	0 - 14	0	2.4 - 41.6	5.7 – 12.3	0 – 2.5
Broadwater NP Swampland	16a, 16b, 27b, 27e	Temp	(°C)	10.9 – 28.3	18.6 – 21.45	13.33 - 21.38	14.29 - 20.3	**9.92** – 21.02	14.63 – 17.66
		DO	(mg/L)	2.15 – 10.02	1.83 – 5.39	**0.62** - 8.3	0.85 - **9.02**	3.03 – 8.02	**0.98** – 10.28

Location	Sites	Parameter	Units	OPP Range	Pre-Con Range	2017 Range	2018 Range	2019 Range	2020 Range
Ch. 139000		pH		3.32 – 6.9	4.15 – 4.63	3.7 - 4.6	3.9 - 5.83	3.76 – 5.91	3.85 – 5.47
		Conductivity	(mS/cm)	0.068 – 2.148	0.128 – 0.171	0.116 - 0.23	0.129 - 0.200	0.24 – 0.347	0.157 – 0.571
		Turbidity	(NTU)	0 - 80	0 - 703	0 - 64.2	0 - 61.5	0 – 57.2	0 – 4.8
Montis Gully Tributary 1 Ch. 141180 and 141850	13b, 13c, 13e, 26d	Temp	(°C)	10.9 – 28.3	17.23 – 30.9	13.33 - 19.27	14.29 - 17.88	14.39 – 24.6	15.77 – 21.4
		DO	(mg/L)	2.15 – 10.02	2.1 – 9.4	**0.95** - 4.23	**0.47** – 4.2	**0.29** – 3.51	**0.88** – 2.27
		pH		3.32 – 6.9	3.7 - 7	3.39 - 3.8	3.44 - 6.43	3.48 – 6.8	3.53 – 6.14
		Conductivity	(mS/cm)	0.068 – 2.148	0.026 – 0.209	0.137 - 0.206	0.163 - 0.200	0.286 – 0.818	0.237 – 0.534
		Turbidity	(NTU)	0 - 80	0 - 225	0 - 4.1	3.2 - 14.4	1.9 – 54.4	6.7 - 90
W of Bundjalung NP Approximately 4 km east of Ch. 110000	C13, C14	Temp	(°C)	10.9 – 28.3	18.09 – 19.11	12.59 - 16.47	13.92 - 16.51	11.79 – 14.55	15.2 – 17.4
		DO	(mg/L)	2.15 – 10.02	2.24 – 4.38	3.4 - 3.79	2.86 - 10.97	**1.34** – 5.09	**1.75** – 4.07
		pH		3.32 – 6.9	4.56 – 5.47	4.84 - 5.51	5.20 - 5.68	5.43 – 6.92	5.72 – 6.14
		Conductivity	(mS/cm)	0.068 – 2.148	0.086 – 0.112	0.102 - 0.112	0.063 - 0.155	0.105 – 0.137	0.121 – 0.137
		Turbidity	(NTU)	0 - 80	0 – 8.7	0 - 15	2.8 - 18.9	3.5 – 4.1	0.7 – 16.3
Broadwater NP 6.5 km east of Ch.13000	C11, C12	Temp	(°C)	10.9 – 28.3	15.91 – 18.49	17.08 - 29.36	20.09 - 24.65	**9.73** – 18.66	17.79 – 22.2
		DO	(mg/L)	2.15 – 10.02	2.9 – 5.59	**1.76** - 8.35	2.91 – 5.69	3.8 – 5.09	2.29 – 7.11
		pH		3.32 – 6.9	3.85 - 4	3.79 - 4.54	3.94 - 4.40	4.21 – 4.53	4.03 – 4.23
		Conductivity	(mS/cm)	0.068 – 2.148	0.124 – 0.149	0.106 - 0.155	0.143 - 0.208	0.252 – 0.278	0.13 – 0.191
		Turbidity	(NTU)	0 - 80	0 – 2.3	0 - 6.8	3.4 - 4.8	0 – 0	0 – 0
MacDonalds Ck Tributary 0.5 km east of 136600 and 1 km east of 137800	C2, C5	Temp	(°C)	10.9 – 28.3	16.87 – 17.78	12.36 - 19.3	15.34 - 20. 2	**8.15** – 13.99	15.4 – 18.07
		DO	(mg/L)	2.15 – 10.02	4.58 – 4.69	**2.74** - 4.70	**2.08 - 4.26**	3.05 – 3.29	3.14 – 5.42
		pH		3.32 – 6.9	3.7 – 4.22	**3.31** - 3.99	3.76 - 4.29	3.73 – 3.88	4.01 – 4.47
		Conductivity	(mS/cm)	0.068 – 2.148	0.115 – 0.158	0.113 - 0.183	0.115 - 0.185	0.206 – 0.256	0.013 – 0.156
		Turbidity	(NTU)	0 - 80	0 - 0	0 - 37.6	0 - 29.2	0 – 1.8	0 – 4.4
Broadwater NP 1 km east of Ch 138000	C1, C3	Temp	(°C)	10.9 – 28.3	17.2 - 18.91	14.33 - 23.66	16.05 - 21.91	12.33 – 17.61	13.9 – 21.78
		DO	(mg/L)	2.15 – 10.02	4.55 - 9.18	**2.45 - 3.77**	**1.35** - 9.43	3.52 – 9.65	2.59 – 6.54
		pH		3.32 – 6.9	3.97 – 4.49	**3.42** - 3.96	**3.45** - 4.17	3.74 – 4.27	3.57 – 4.27
		Conductivity	(mS/cm)	0.068 – 2.148	0.089 - 0.176	0.100 - 0.201	0.113 - 0.209	0.147 – 0.306	0.12 – 0.225
		Turbidity	(NTU)	0 - 80	0 – 1.4	0 - 26.4	1.8 - 28.5	0 – 0.3	0 – 3.2

Location	Sites	Parameter	Units	OPP Range	Pre-Con Range	2017 Range	2018 Range	2019 Range	2020 Range
Broadwater NP 2 km east of 136400	C8	Temp	(°C)	10.9 – 28.3	17.98	12.18 - 18.49	13.52 - 14.71	13.33 – 19.02	15.39
		DO	(mg/L)	2.15 – 10.02	5.77	**2.87 - 3.29**	**2.46 - 3.8**	7.38 – 9.96	5.22
		pH		3.32 – 6.9	3.95	**3.21 - 3.46**	**3.73 - 3.92**	3.76 – 3.97	4.07
		Conductivity	(mS/cm)	0.068 – 2.148	0.236	0.315 - 0.363	0.291 - 0.321	0.413 – 0.458	0.269
		Turbidity	(NTU)	0 - 80	12.1	0 - 5	5 - 12.2	0 – 12.2	0
Tabbimoble Channel 2	OPP1, OPP2, OPP4, OPP7	Temp	(°C)	10.9 – 28.3	7.86 – 18.66	-	-	8.91 – 16.01	14.16 – 16.15
		DO	(mg/L)	2.15 – 10.02	3.17 – 8.74	-	-	**1.89** – 5.83	3.74 – 5.67
		pH		3.32 – 6.9	4.79 – 6.92	-	-	5.06 – 6.8	5.79 – 6.49
		Conductivity	(mS/cm)	0.068 – 2.148	0.081 – 0.194	-	-	0.148 – 0.23	0.104 – 0.178
		Turbidity	(NTU)	0 - 80	1.3 – 44.3	-	-	3.3 – 7.8	1.8 – 12.1
Tabbimoble Channel 3	OPP3, OPP6	Temp	(°C)	10.9 – 28.3	11.66 – 19.14	-	-	11.99 – 16.06	16.16 – 18.14
		DO	(mg/L)	2.15 – 10.02	4.64 – 6.53	-	-	**0.79 – 0.98**	4.42 – 5.3
		pH		3.32 – 6.9	4.99 – 6.11	-	-	6.41 – 6.56	5.87 – 6.33
		Conductivity	(mS/cm)	0.068 – 2.148	0.128 – 0.215	-	-	0.173 – 0.185	0.171 – 0.185
		Turbidity	(NTU)	0 - 80	0 – 6.5	-	-	0 - 0	0 - 0

Appendix D

Site Photographs

Table D1. Site photographs from selected surveys since September 2013

		
Site 2a 2013_09	**Site 2a 2014_09**	**Site 2a 2017_09**
		
Site 2a 2018_09	**Site 2a 2019_09**	**Site 2a 2020_09**

		
Site 2b 2013_09	**Site 2b 2014_09**	**Site 2b 2017_09**
		
Site 2b 2018_09	**Site 2b 2019_09**	**Site 2b 2020_09**

		
Site 2c 2013_09	**Site 2c 2014_09**	**Site 2c 2017_09**
		
Site 2c 2018_09	**Site 2c 2019_09**	**Site 2c 2020_09**

		
Site 3a 2013_09	**Site 3a 2014_09**	**Site 3a 2017_09**
		
Site 3a 2018_09	**Site 3a 2019_09**	**Site 3a 2020_09**

		
Site 10b 2013_09	**Site 10b 2014_09**	**Site 10b 2017_09**
		
Site 10b 2018_05	**Site 10b 2019_09**	**Site 10b 2020_09**

		
Site 10c 2013_09	**Site 10c 2014_09**	**Site 10c 2017_09**
		
Site 10c 2018_05	**Site 10c 2019_09**	**Site 10c 2020_09**

		
Site 11b 2013_09	**Site 11b 2014_09**	**Site 11b 2017_09**
		
Site 11b 2018_05	**Site 11b 2019_07**	**Site 11b 2020_09**

		
Site 11d 2013_09	**Site 11d 2014_09**	**Site 11d 2017_09**
		
Site 11d 2018_05	**Site 11d 2019_09**	**Site 11d 2020_09**

		
Site 12a 2013_09	**Site 12a 2014_09**	**Site 12a 2017_09**
		
Site 12a 2018_09	**Site 12a 2019_09**	**Site 12a 2020_09**

		**No Survey**
Site 13b 2013_09	**Site 13b 2014_09**	**Site 13b 2017_09**
		
Site 13b 2018_09	**Site 13b 2019_09**	**Site 13b 2020_09**

		
Site 13c 2013_09	**Site 13c 2014_09**	**Site 13c 2017_09**
		
Site 13c 2018_09	**Site 13c 2019_09**	**Site 13c 2020_09**

		
Site 13e 2013_09	**Site 13e 2014_09**	**Site 13e 2017_09**
No Access	**No Access**	**No Access**
Site 13e 2018_09	**Site 13e 2019_09**	**Site 13e 2020_09**

		
Site 16a 2013_09	**Site 16a 2014_09**	**Site 16a 2017_09**
		
Site 16a 2018_05	**Site 16a 2019_09**	**Site 16a 2020_05**

		
Site 16b 2013_09	**Site 16b 2014_09**	**Site 16b 2017_09**
		
Site 16b 2018_09	**Site 16b 2019_05**	**Site 16b 2020_09**

		
Site 22b 2013_09	**Site 22b 2014_09**	**Site 22b 2017_09**
		
Site 22b 2018_09	**Site 22b 2019_05**	**Site 22b 2020_05**

		
Site 22c 2013_09	**Site 22c 2014_09**	**Site 22c 2017_09**
		
Site 22c 2018_09	**Site 22c 2019_09**	**Site 22c 2020_05**

		
Site 26d 2013_09	**Site 26d 2014_09**	**Site 26d 2017_09**
No Access	**No Access**	**No Access**
Site 26d 2018_09	**Site 26d 2019_09**	**Site 26d 2020_05**

		
Site 27b 2013_09	**Site 27b 2014_09**	**Site 27b 2017_09**
		
Site 27b 2018_09	**Site 27b 2019_09**	**Site 27b 2020_09**

		
Site 27e 2013_09	**Site 27e 2014_09**	**Site 27e 2017_09**
		
Site 27e 2018_05	**Site 27e 2019_09**	**Site 27e 2020_05**

		
Site C1 2013_09	**Site C1 2014_09**	**Site C1 2017_09**
		
Site C1 2018_09	**Site C1 2019_09**	**Site C1 2020_05**

		
Site C2 2013_09	**Site C2 2014_09**	**Site C2 2017_09**
		
Site C2 2018_09	**Site C2 2019_09**	**Site C2 2020_05**

		
Site C3 2013_09	**Site C3 2014_09**	**Site C3 2017_09**
		
Site C3 2018_09	**Site C3 2019_09**	**Site C3 2020_05**

		
Site C5 2013_09	**Site C5 2014_09**	**Site C5 2017_09**
		
Site C5 2018_09	**Site C5 2019_09**	**Site C5 2020_05**

		
Site C8 2013_09	**Site C8 2014_09**	**Site C8 2017_09**
		
Site C8 2018_09	**Site C8 2019_09**	**Site C8 2020_05**

		
Site C11 2013_09	**Site C11 2014_09**	**Site C11 2017_09**
		
Site C11 2018_09	**Site C11 2019_09**	**Site C11 2020_05**

		
Site C12 2013_09	**Site C12 2014_09**	**Site C12 2017_09**
		
Site C12 2018_09	**Site C12 2019_09**	**Site C12 2020_05**

		
Site C13 2013_09	**Site C13 2014_09**	**Site C13 2017_09**
		
Site C13 2018_09	**Site C13 2019_09**	**Site C13 2020_05**

		
Site C14 2013_09	**Site C14 2014_09**	**Site C14 2017_09**
		
Site C14 2018_09	**Site C14 2019_09**	**Site C14 2020_05**

		
Site OPP1 2014_09	**Site OPP1 2015_05**	**Site OPP1 2019_09**
		
Site OPP1 2020_09		

		
Site OPP2 2014_09	**Site OPP2 2015_05**	**Site OPP2 2019_09**
		
Site OPP2 2020_09		

		
Site OPP3 2014_09	**Site OPP3 2015_05**	**Site OPP3 2019_09**
		
Site OPP3 2020_09		

		**No Access**
Site OPP4 2014_09	**Site OPP4 2015_05**	**Site OPP4 2019_09**
No Access		
Site OPP4 2020_09		

		
Site OPP5 2014_09	**Site OPP5 2015_05**	**Site OPP5 2019_09**
		
Site OPP5 2020_05		

		
Site OPP6 2014_09	**Site OPP6 2015_05**	**Site OPP6 2019_09**
		
Site OPP6 2020_09		

		
Site OPP7 2014_09	**Site OPP7 2015_05**	**Site OPP7 2019_09**
		
Site OPP7 2020_09		