

Woolgoolga to Ballina Pacific Highway Upgrade

Threatened Fish Monitoring Program Annual Report 2021

Year 1 Operational Phase Report



Project Name: W2B Biodiversity – Threatened Fish Monitoring

Client Name: TfNSW

Project Manager: Chris Thomson

Author: Mathew Birch

Version Log:

<i>Date</i>	<i>Author</i>	<i>Notes</i>
06/01/2021	MB	Draftv1 report provided to Jacobs (.docx)
03/03/2022	MB	Finalv1 report provided to Jacobs (.docx, .pdf)

Woolgoolga to Ballina Pacific
Highway Upgrade
Threatened Fish Monitoring Program Annual
Report 2021

Contents

1. Introduction	1
1.1 Background.....	1
1.2 Objectives	1
1.3 Species Profile	1
1.3.1 Oxleyan Pygmy Perch (OPP).....	1
2. Methods	3
2.1 Study Area and Monitoring Sites.....	3
2.2 Timing.....	9
2.3 Fish Survey.....	9
2.4 Water Quality.....	12
2.5 Habitat Description.....	12
3. Results	13
3.1 Fish Survey.....	13
3.2 Water Quality.....	19
3.3 Habitat Description.....	21
4. Discussion and Conclusion	31

Tables

Table 1.1	Summary of water quality information from NSW sites where OPP have been collected.	2
Table 2.1	A brief description of the significant waterways sampled during the survey.	3
Table 2.2	Details of electrofisher settings and effort at each site in May 2021	10
Table 2.3	Details of electrofisher settings and effort at each site in September 2021	11
Table 3.1	Results of water quality sampling from all sites for the May 2021 survey	19
Table 3.2	Results of water quality sampling from all sites for the September 2021 survey.....	20
Table 3.3	Brief descriptions of habitat features at all impact sites.....	21
Table 3.4	Aquatic plants identified at impact sites during the May 2021 survey.....	26
Table 3.5	Aquatic plants identified at control and Devils Pulpit sites during the May 2021 survey	27
Table 3.6	Aquatic plants identified at impact sites during the September 2021 survey	28

Table 3.7	Aquatic plants identified at control and Devils Pulpit sites during the September 2021 survey.....	30
Table 4.1	Proportion of juvenile OPP (<25mm total length) as a percentage of total OPP captured.....	33
Table 4.2	Performance indicators for threatened fish management on the W2B upgrade.	35

Figures

Figure 2.1	Mean monthly rainfall and total monthly rainfall from the New Italy Bureau of Meteorology station for the current reporting period.	9
Figure 3.1	Taxonomic richness of captured fish at all sites during the May 2021 and September 2021 surveys (plotted against Mean \pm SE in preconstruction and construction phase surveys).....	14
Figure 3.2	Number of captured fish at all sites during the May 2021 and September 2021 surveys (plotted against Mean \pm SE in preconstruction and construction phase surveys).....	15
Figure 3.3	OPP captured at all sites during the May 2021 and September 2021 surveys (plotted against Mean \pm SE in preconstruction and construction phase surveys).....	16
Figure 3.4	Average OPP capture per survey at all sites in pre-construction, construction and operational phase monitoring (pre-construction data from GeoLINK 2014, 2015a & 2015b, Hyder 2012).....	18
Figure 3.5	Average OPP capture at combined control and impact sites in pre-construction, construction and operational phase monitoring to date (pre-construction data from GeoLINK 2014, 2015a & 2015b, Hyder 2012).....	18
Figure 4.1	Length distribution data of OPP captured in the May 2021 survey (counts in brackets)	32
Figure 4.2	Length distribution data of OPP captured in the September 2021 survey (counts in brackets)	32
Figure 4.3	Average Mosquitofish Capture at W2B impact and control sites in the pre-construction, construction and operational phase surveys.	34

Appendices

Appendix A Aquatic Habitat Summaries

Appendix B Fish Survey Results

Appendix C Water Quality Ranges

Introduction

The following report summarises the methods and results from the first year of threatened fish monitoring undertaken during the operational 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 first year of monitoring conducted during the operational phase, with the data being assessed against results from three pre-construction surveys and seven construction phase 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 annual 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 Woolli). The systems where they are

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

The predicted natural range of OPP in NSW is from the Queensland border south as far as the Manning River. In recent years, OPP have mostly been collected from the area around Evans Head NSW. OPP are known to be particularly sensitive to capture by nets. In particular, surveys using seine nets have resulted in significant mortality. The methods suggested for OPP surveys are electrofishing and setting unbaited standard fish traps (DSEWPaC 2011). To minimise disturbances to breeding, surveys should be avoided between October and April inclusive.

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

<i>Measure</i>	<i>Range</i>	<i>Mean ± SE</i>
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 22b during the September 2021 survey.

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 construction phase 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 have continued to impact 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 currently 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.

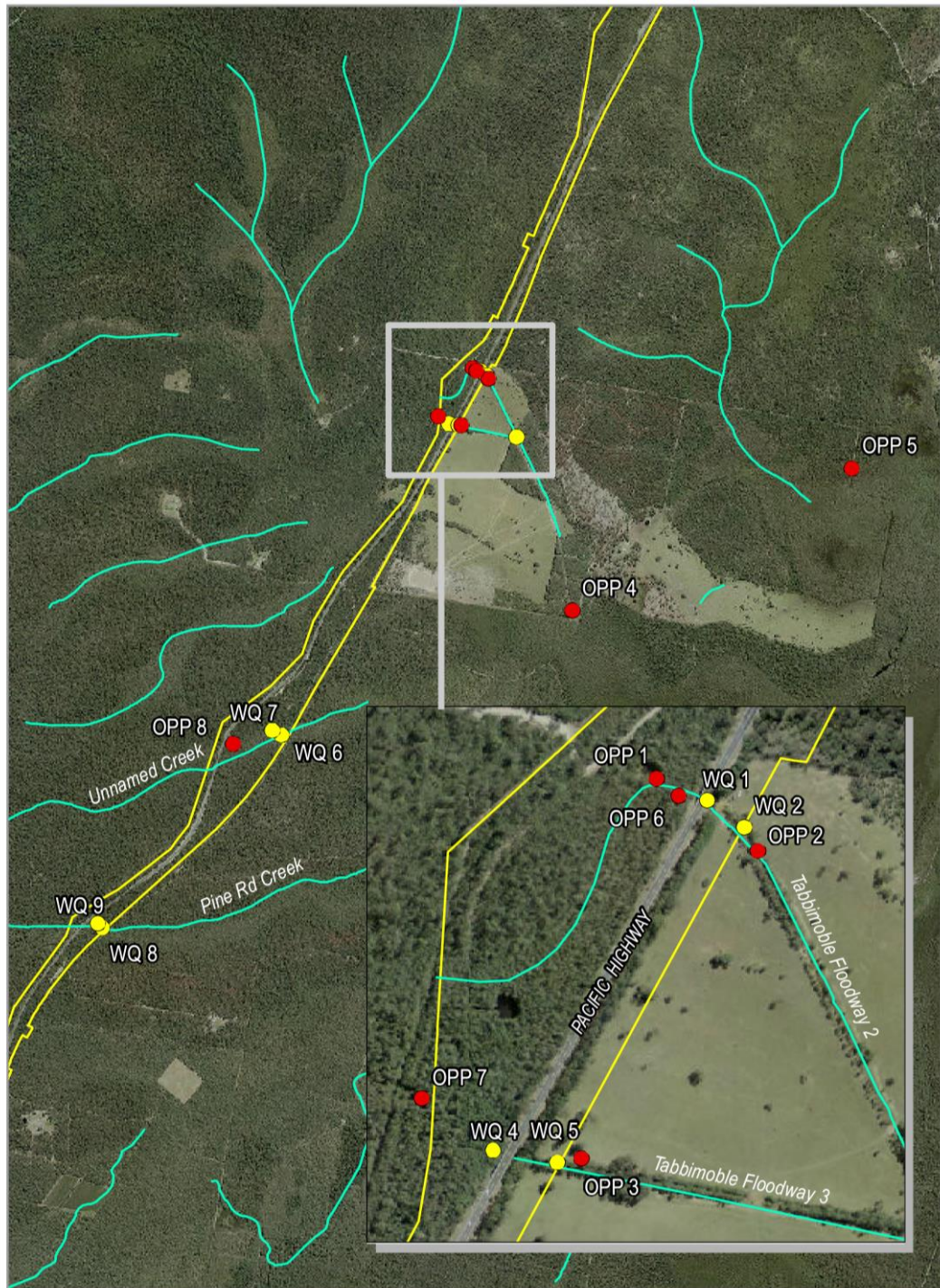
Table 2.1 A brief description of the significant waterways sampled during the survey.

<i>Section</i>	<i>Waterway</i>	<i>Sites</i>	<i>Chainage</i>	<i>Notes</i>
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.

<i>Section</i>	<i>Waterway</i>	<i>Sites</i>	<i>Chainage</i>	<i>Notes</i>
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.
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 2021 due to landholder restrictions. Site OPP 5 could not be accessed in the May 2021 survey due to extreme wet conditions on the access track more than 2 km away from the site. Some sites were also dry during the September 2021 survey including sites 2c, C11, C14, OPP5, OPP6 and OPP7.



LEGEND

- OPP
- WQ
- Drainage line
- Approved project boundary



0 800



Devils Pulpit Pacific Highway Upgrade - Post Construction
Monitoring of Oxleyan Pygmy Perch and Surface Water
2383-1005

Study Area and Site Location

Illustration 2.1

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

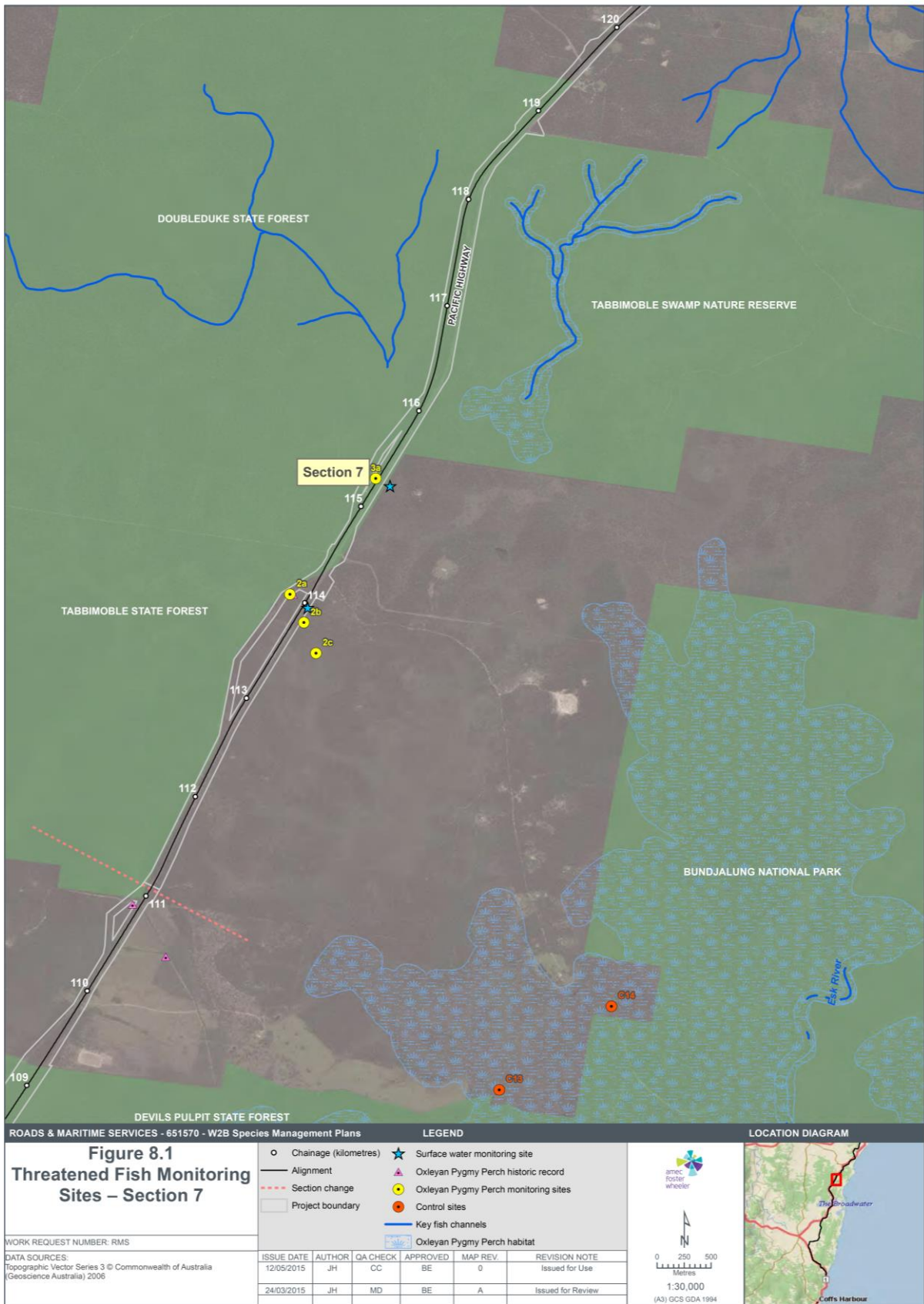


Illustration 2.2 Map of Section 7 sampling sites taken from the TFMP (RMS 2015)

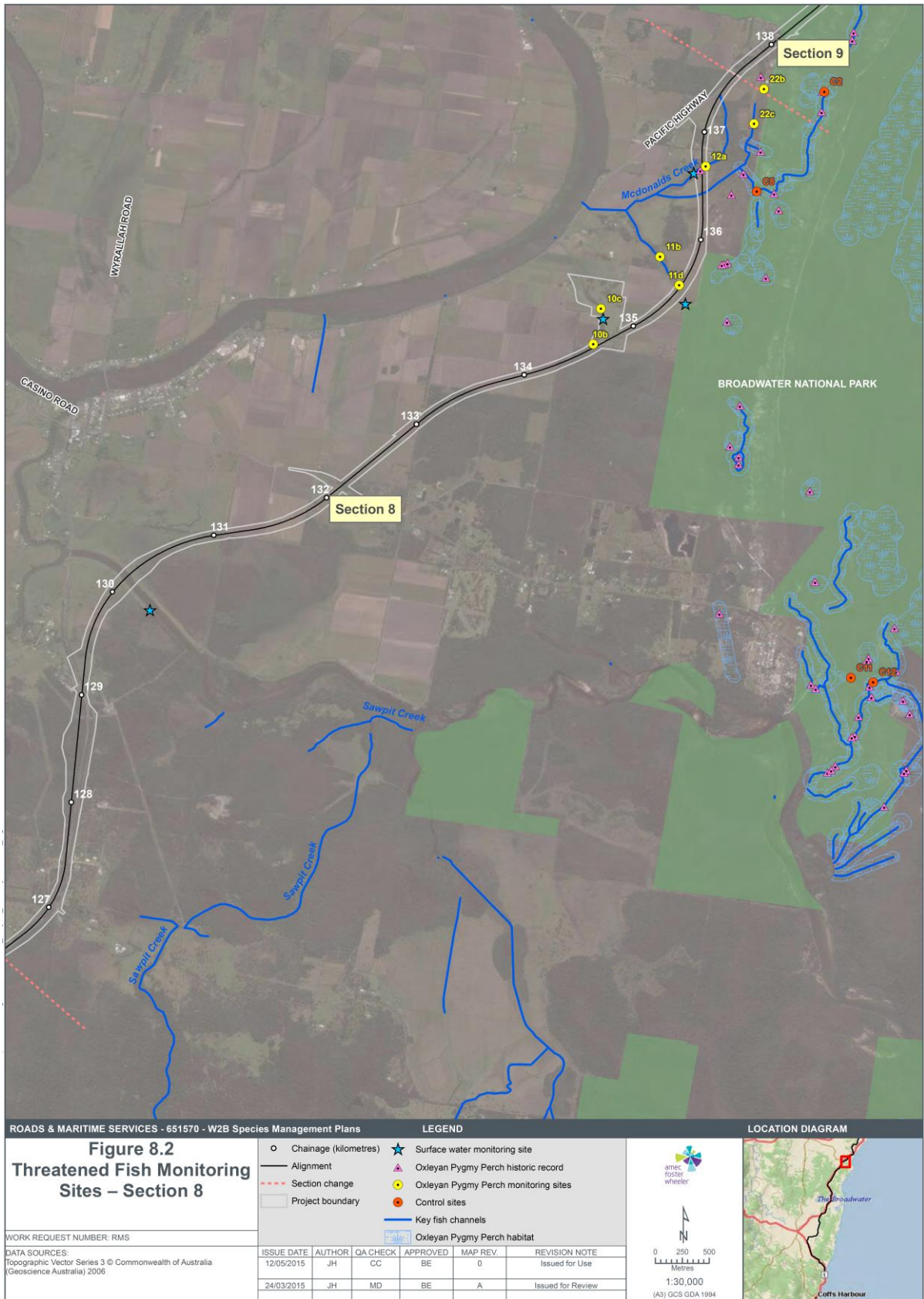


Illustration 2.3 Map of Section 8 sampling sites taken from the TFMP (RMS 2015)



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 2021 and September 2021.

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.

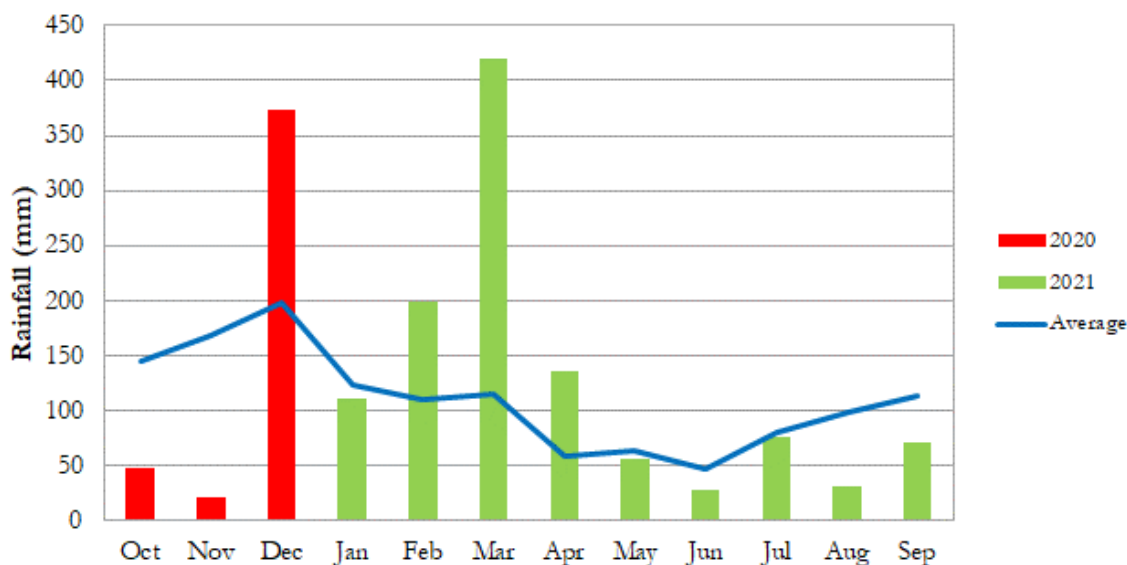


Figure 2.1 Mean monthly rainfall and total monthly rainfall from the New Italy Bureau of Meteorology station for the current reporting period.

The total rainfall for this annual reporting period was approximately 114% of the yearly average. However, approximately half of the annual rainfall was concentrated into two months, December 2020 and March 2021. (**Figure 2.1**). At the time of the May 2021 survey most sites were very wet, with water overtopping the banks at some sites. Five months of below average rainfall prior to the September 2021 survey meant that some sites were dry and most sites did not have any flow.

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 2021

<i>Section</i>	<i>Site</i>	<i>Voltage (V)</i>	<i>Pulse Freq (Hz)</i>	<i>Duty Cycle (%)</i>	<i>Passes</i>	<i>Seconds Pulsed</i>
6	OPP1	225	50	12	1	604
6	OPP2	200	50	12	1	611
6	OPP3	200	50	12	2	590
6	OPP4	No Access				
6	OPP5	No Access				
6	OPP6	125	50	12	1	602
6	OPP7	200	50	12	1	608
7	2a	200	50	12	2	600
7	2b	100	50	12	2	198
7	2c	100	50	12	2	304
7	3a	225	50	12	1	638
8	10b	300	50	12	1	607
8	10c	200	50	12	1	604
8	11b	175	50	12	1	608
8	11d	150	50	12	1	600
8	12a	200	50	12	1	600
9	13b	125	50	12	1	629
9	13c	150	50	12	1	600
9	13e	No Access				
9	16a	175	50	12	1	620
9	16b	275	50	12	2	511
8	22b	275	50	12	1	614
8	22c	275	50	12	1	609
9	26d	No Access				
9	27b	225	50	12	1	600
9	27e	225	50	12	1	604
Control	C1	250	50	12	1	618
Control	C2	175	50	12	1	615
Control	C3	175	50	12	2	511
Control	C5	200	50	12	1	614
Control	C8	175	50	12	1	606
Control	C11	250	50	12	1	624
Control	C12	225	50	12	1	601
Control	C13	250	50	12	1	642
Control	C14	225	50	12	1	614

Table 2.3 Details of electrofisher settings and effort at each site in September 2021

<i>Section</i>	<i>Site</i>	<i>Voltage (V)</i>	<i>Pulse Freq (Hz)</i>	<i>Duty Cycle (%)</i>	<i>Passes</i>	<i>Seconds Pulsed</i>
6	OPP1	175	50	12	2	497
6	OPP2	150	50	12	1	605
6	OPP3	200	50	12	1	600
6	OPP4	No Access				
6	OPP5	No Water				
6	OPP6	No Water				
6	OPP7	No Water				
7	2a	100	50	12	2	354
7	2b	125 - 150	50	12	2	360
7	2c	No Water				
7	3a	100	50	12	1	600
8	10b	200	50	12	1	600
8	10c	75	50	12	2	364
8	11b	150	50	12	1	600
8	11d	100	50	12	1	600
8	12a	75 - 100	50	12	1.25	601
9	13b	75	50	12	1.5	607
9	13c	125	50	12	1	605
9	13e	No Access				
9	16a	125	50	12	1	609
9	16b	125	50	12	1	611
8	22b	125	50	12	1	618
8	22c	200	50	12	2	424
9	26d	No Access				
9	27b	175 - 225	50	12	1	605
9	27e	150	50	12	1	606
Control	C1	200	50	12	1	616
Control	C2	75	50	12	1	386
Control	C3	75	50	12	1	620
Control	C5	100	50	12	2	217
Control	C8	150	50	12	1	614
Control	C11	No Water				
Control	C12	100	50	12	1	641
Control	C13	200	50	12	1	604
Control	C14	No Water				

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

2.4 Water Quality

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

2.5 Habitat Description

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

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

- average channel depth from 3 points in each site;
- average stream width from 3 points in each site;
- per cent cover of large woody debris (>150 mm stem diameter), small woody debris and leaf litter from 12 points in each site;
- per cent cover of submerged and emergent macrophytes from 12 points in each site. Species of aquatic vegetation were also recorded;
- substrate composition from 12 points in each site in per cent cover of mud, sand, fine gravel (2-16mm), coarse gravel (16-64 mm), cobble (64-128 mm), rock and bedrock;
- per cent of bank classified as undercut (20 cm overhang), or as root masses averaged from 4 transects at each site;
- per cent cover of riparian vegetation averaged from 4 transects at each site; and
- flow rates.

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

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

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

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

Results

3.1 Fish Survey

During the May 2021 survey approximately 284 hours of fish trapping and 18,006 seconds of electrofishing were used. During the September 2021 survey approximately 223 hours of fish trapping and 14,164 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 were:

- Sites OPP4, 13e and 26d, which had access restrictions at the time of the May 2021 and September 2021 surveys.
- Site OPP5, which could not be accessed due to an unsafe access track at the time of the May 2021 survey.
- Sites OPP5, OPP6, OPP7, 2c, C11 and C14, which were dry at the time of the September 2021 survey.

In the May 2021 survey a total of 2,771 fish from twelve species were captured. Of the total number of fish captured, 1904 individuals from twelve species were captured using the electrofisher and 867 individuals from eight species were captured using fish traps.

In the September 2021 survey a total of 4,135 fish from eleven species were captured. Of the fish captured during the September 2021 survey 1,960 individuals from eleven species were captured using the backpack electrofisher and 2,175 individuals from eight species were captured using bait traps.

In the May 2021 survey 102 individual OPP were captured. Of these, 44 were captured using the backpack electrofisher and 58 in fish traps. In the May 2021 survey OPP were captured at 2 of the 24 impact sites and at 6 of the 11 control sites.

In the September 2021 survey 200 individual OPP were captured. Of these 103 were captured using the backpack electrofisher and 97 in fish traps. In the September 2021 survey OPP were captured at 5 of the 24 impact sites and at 6 of the 11 control sites.

The most commonly captured species of fish during the May 2021 survey was the Firetail Gudgeon (*Hypseleotris galii*). Individuals of this species accounted for approximately 31 per cent of the total number of fish captured in the May 2021 survey. The most commonly captured species of fish during the September 2021 survey was also the Firetail Gudgeon, accounting for approximately 40 per cent of the fish captured. Overall, OPP accounted for approximately 3 per cent of the fish captured in the May 2021 survey and approximately 5 per cent of the fish captured during the September 2021 survey.

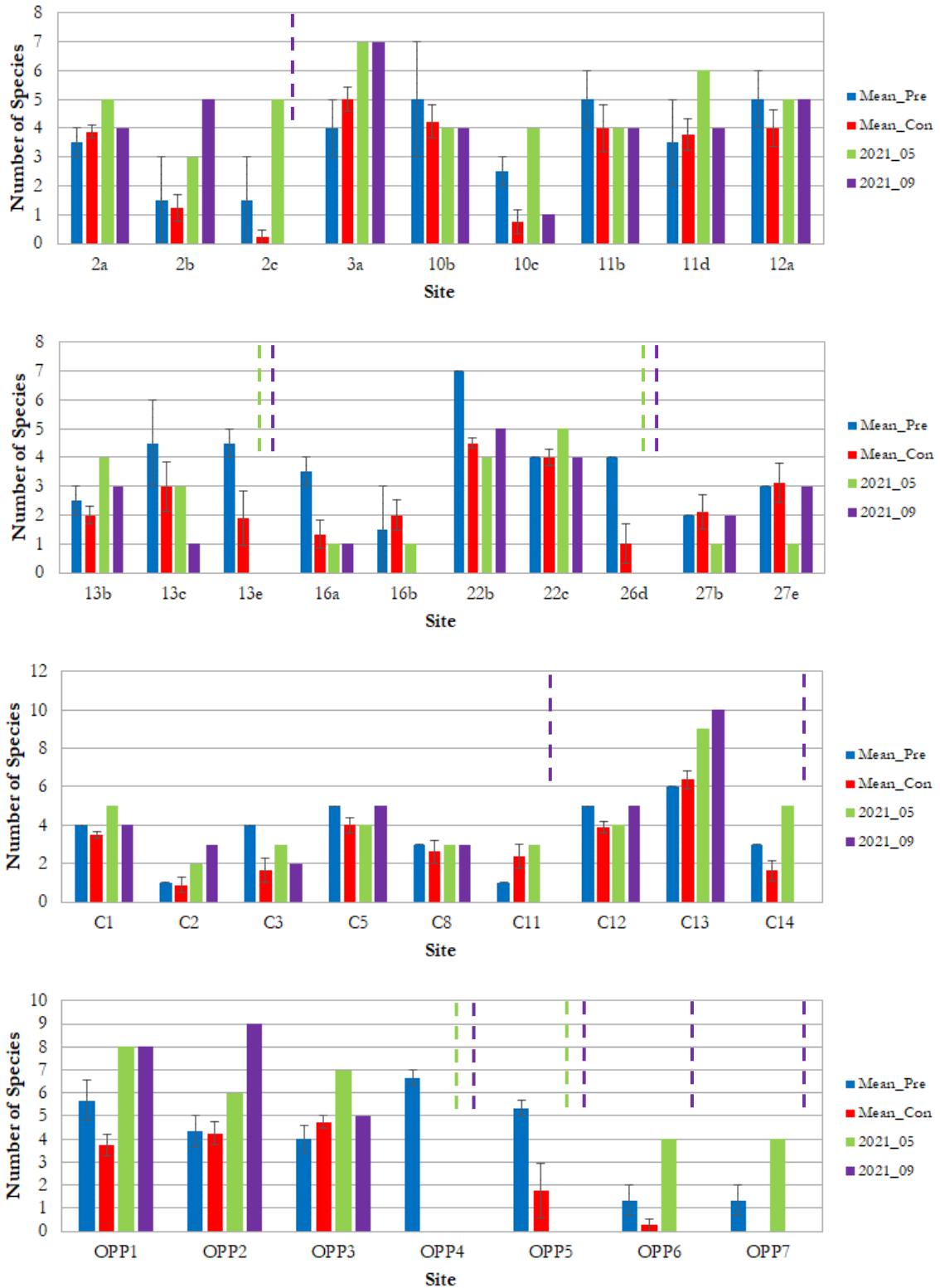


Figure 3.1 Taxonomic richness of captured fish at all sites during the May 2021 and September 2021 operational phase surveys (plotted against Mean \pm SE in preconstruction and construction phase surveys)

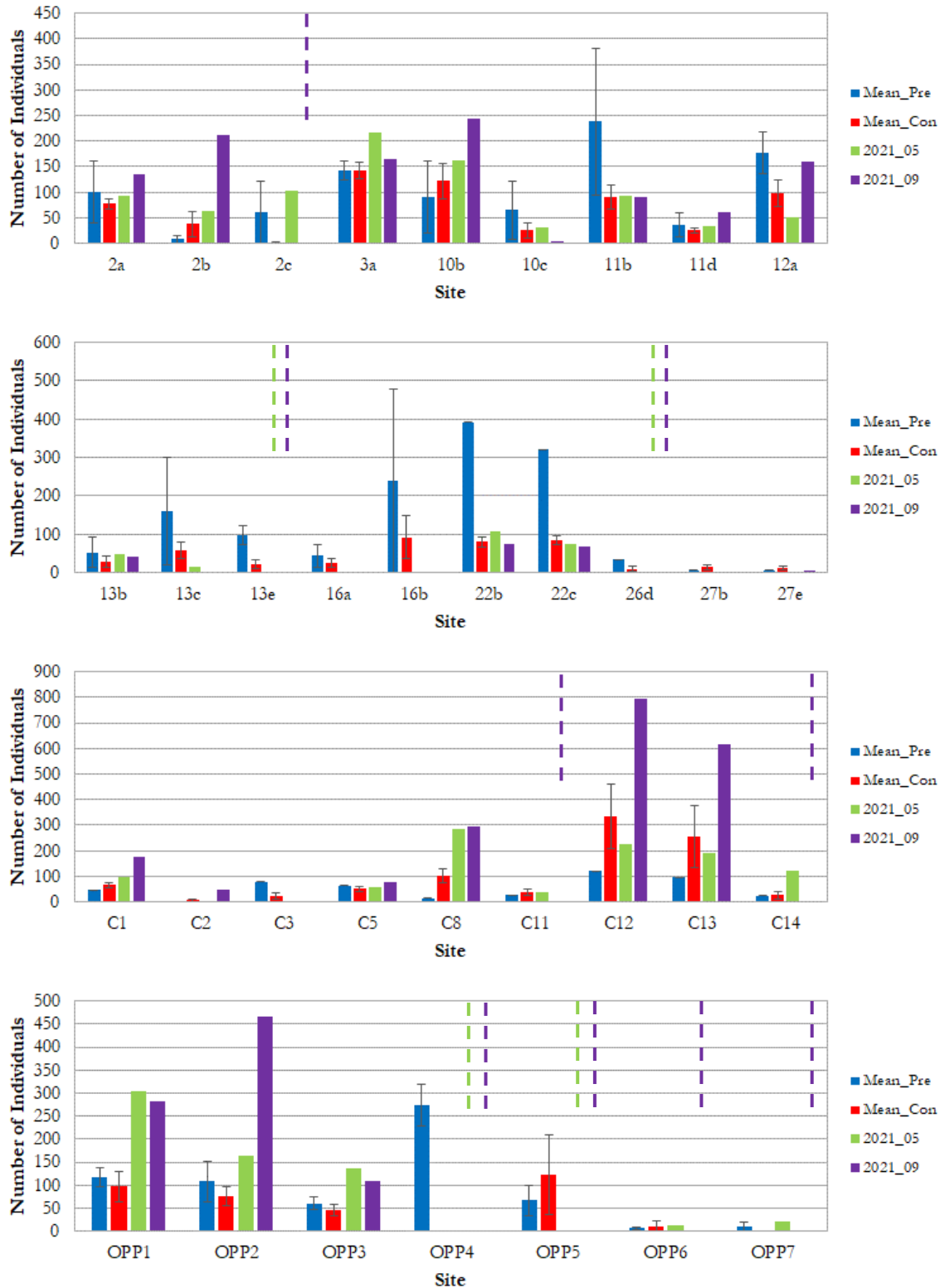


Figure 3.2 Number of captured fish at all sites during the May 2021 and September 2021 operational phase surveys (plotted against Mean \pm SE in preconstruction and construction phase surveys)

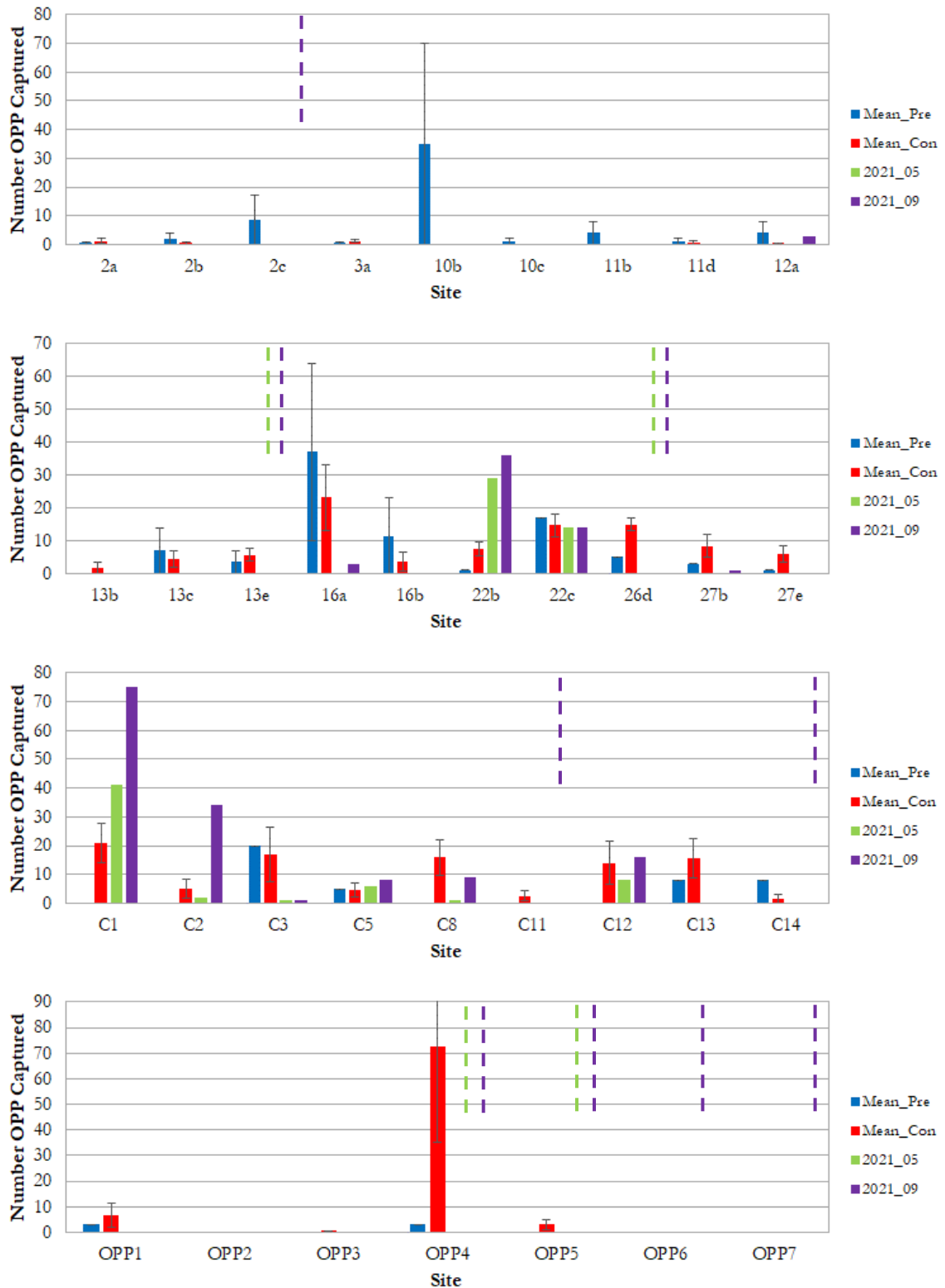


Figure 3.3 OPP captured at all sites during the May 2021 and September 2021 operational phase surveys (plotted against Mean \pm SE in preconstruction and construction phase surveys)

The results during this reporting period have been moderately variable at most impact and control sites in terms of fish diversity and abundance (Figures 3.1, 3.2 and 3.3). With very few exceptions the variation was consistent with the variability identified during the pre-

construction and construction phase surveys. In the 2 surveys this year between one and ten species were captured at each site where surveys were possible, with the exception of site 16b, where no fish were captured in September 2021. In the May 2021 survey the sites with the highest diversity of captured fish were C13, OPP1, 3a, and OPP3. In the September 2021 survey the sites with the highest diversity of captured fish were C13, OPP2 and OPP1.

Between 0 and 465 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 2021 survey were OPP1, 3a, 10b and OPP2. In the September 2021 survey the impact sites where the most individual fish were captured were OPP2, OPP1 and 2b.

The total number of individual fishes captured at the control sites varied between 0 and 794, with the largest numbers of fish captured at C8 and C12 in the May 2021 survey and C12 and C13 in the September 2021 survey.

The numbers of OPP captured at each site are presented in **Figure 3.3**. The numbers of OPP captured during this reporting period were moderate in May 2021 and moderately high in September 2021. There were more OPP captured in September 2021 than in May 2021 at all sites where OPP were captured. OPP were captured at 11 sites in the two surveys this year (compared to 22 sites in 2017, 17 sites in 2018, 5 sites in 2019 and 7 sites in 2020). 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 (see TfNSW 2021 for a discussion of drought and flood intensity). The increased number of sites where OPP were captured and the increased numbers of OPP captured, in comparison to the previous 2 years, is an indication of the improved breeding and dispersal conditions associated with rainfall in December 2020 and March 2021 and also a general recovery of the OPP population from the severe drought conditions in December 2019 and January 2020.

The full results of the May 2021 and September 2021 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, construction and operational phase (to date) monitoring is presented in **Figure 3.4**. The figures indicate that pre-construction captures were significantly larger than construction and operational phase captures 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, and that operational phase captures to date have been higher at 22b. Average captures at the control sites during the operational phase monitoring to date have mostly been larger than or equivalent to captures during the pre-construction phase monitoring, the exceptions being sites C3, C13 and C14.

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

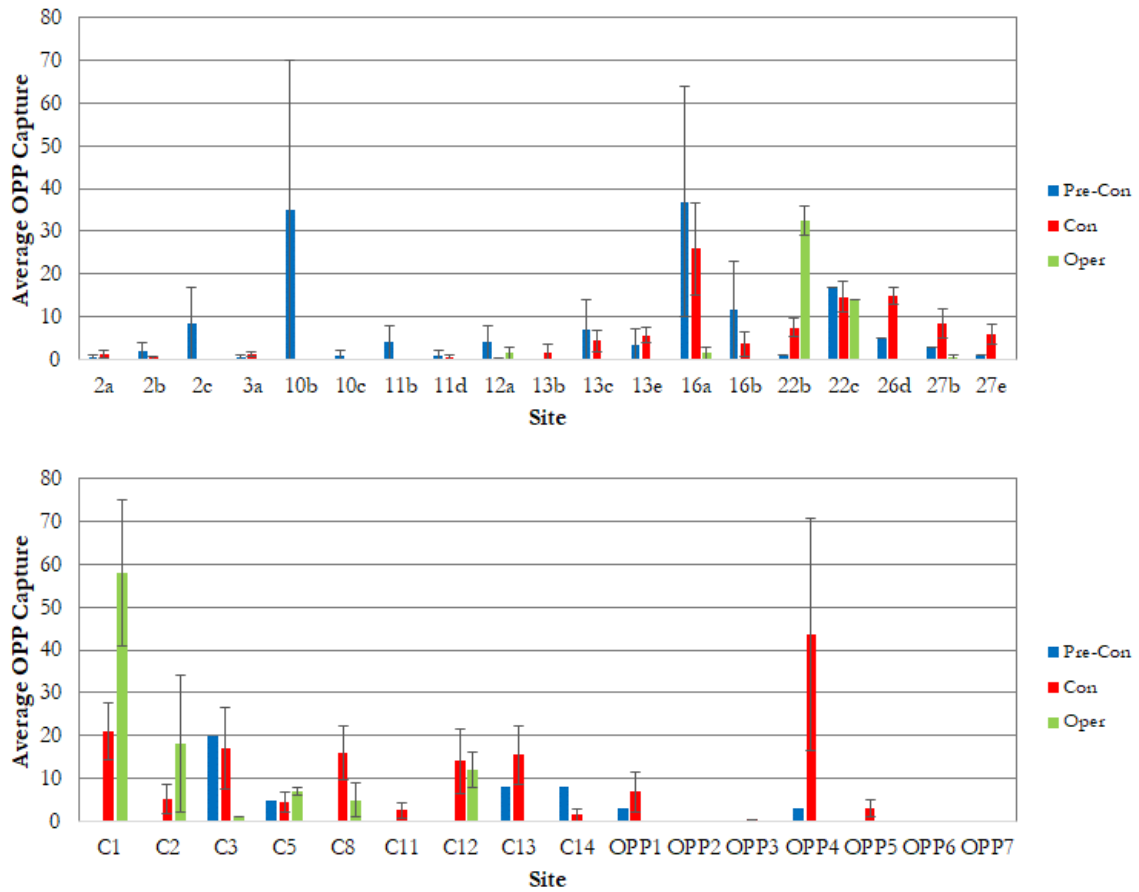


Figure 3.4 Average OPP capture per survey at all sites in pre-construction, construction and operational phase monitoring (pre-construction data from GeoLINK 2014, 2015a & 2015b, Hyder 2012)

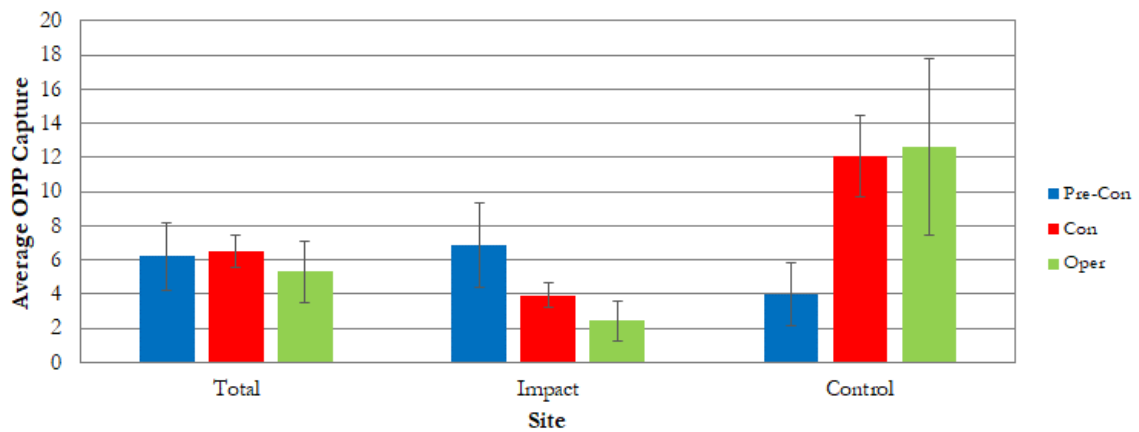


Figure 3.5 Average OPP capture at combined control and impact sites in pre-construction, construction and operational phase monitoring to date (pre-construction data from GeoLINK 2014, 2015a & 2015b, Hyder 2012). Note operational phase data is from a single year of monitoring

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 2021 survey

<i>Site</i>	<i>Date</i>	<i>Temperature</i>	<i>pH</i>	<i>Conductivity</i>	<i>Turbidity</i>	<i>DO</i>	<i>DO%</i>
		<i>°C</i>		<i>mS/cm</i>	<i>NTU</i>	<i>mg/L</i>	<i>%</i>
OPP1	7/04/2021	16.04	5.39	0.072	13.4	4.64	48.5
OPP2	7/05/2021	17.42	5.35	0.095	10.3	5.4	58.1
OPP3	10/05/2021	17.09	5.78	0.041	44.7	8.61	92.1
OPP4		No Access					
OPP5	10/05/2021	No Safe Access					
OPP6	7/05/2021	16.59	5.4	0.098	5.3	7.31	77.4
OPP7	10/05/2021	17.09	5.66	0.039	58.5	8.2	87.7
2a	3/05/2021	19.57	5.48	0.089	7.9	3.12	35.1
2b	3/05/2021	22.27	6.36	0.348	20.8	10.57	124.5
2c	3/05/2021	20	5.44	0.135	32.5	6.67	75.5
3a	10/05/2021	18.38	5.51	0.112	11	5.55	60.8
10b	4/05/2021	19.75	5.3	0.153	0	0.09	1
10c	4/05/2021	23.96	5.77	0.13	3.8	14.33	173.7
11b	10/05/2021	20.81	4.75	0.136	0	3.79	43.5
11d	4/05/2021	19.36	4.48	0.129	1.8	3.66	40.9
12a	4/05/2021	17.76	4.48	0.148	0	2.03	22
13b	4/05/2021	18.64	5.56	0.138	7.6	0.82	9
13c	10/05/2021	19.06	3.67	0.157	9.1	1.1	12.2
13e		No Access					
16a	11/05/2021	17.9	3.71	0.137	2.6	1.03	11.2
16b	5/05/2021	17.47	5.81	0.344	18.8	0.2	2.2
22b	6/05/2021	19.14	3.82	0.115	0	4.22	47
22c	6/05/2021	15.89	4.04	0.13	6.7	2.44	25.4
26d		No Access					
27b	11/05/2021	18.61	3.86	0.098	0.6	1.08	11.9
27e	11/05/2021	17.85	3.96	0.136	0	1.65	18
C1	6/05/2021	19.3	3.87	0.091	0	7.88	88
C2	11/05/2021	18	3.83	0.12	0	4.35	47.4
C3	6/05/2021	17.74	3.46	0.133	3	2.82	30.5
C5	6/05/2021	15.11	4.07	0.089	0	3.99	41
C8	11/05/2021	17.51	3.57	0.176	0	1.36	14.7
C11	5/05/2021	17.83	4.11	0.143	0	2.28	24.7
C12	5/05/2021	17.48	4.23	0.081	0.8	4.04	43.5
C13	3/05/2021	18	5.62	0.065	0	5.38	58.6
C14	3/05/2021	17.65	5.84	0.071	0	3.57	38.6

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 2021 survey

<i>Site</i>	<i>Date</i>	<i>Temperature</i>	<i>pH</i>	<i>Conductivity</i>	<i>Turbidity</i>	<i>DO</i>	<i>DO%</i>
		°C		mS/cm	NTU	mg/L	%
OPP1	27/09/2021	17.04	6.19	0.126	-	3.72	39.7
OPP2	27/09/2021	17.54	6.93	0.215	-	7.23	78.1
OPP3	27/09/2021	18.46	6.28	0.2	-	3.89	42.8
OPP4		No Access					
OPP5	27/09/2021	No Water					
OPP6	27/09/2021	No Water					
OPP7	27/09/2021	No Water					
2a	21/09/2021	17.88	6.76	0.1	-	10.5	114.1
2b	21/09/2021	21.64	7.51	0.597	-	6.49	75.7
2c	21/09/2021	No Water					
3a	29/09/2021	16.93	5.86	0.163	-	5.8	61.8
10b	22/09/2021	17.04	6.02	0.458	-	7.53	80.5
10c	22/09/2021	17.42	4.9	0.474	-	2.83	30.5
11b	24/09/2021	20.02	5.08	0.227	-	1.31	14.9
11d	22/09/2021	21.79	5.63	0.136	-	5.28	61.7
12a	22/09/2021	16.26	5.58	0.331	-	2.48	26.1
13b	22/09/2021	13.7	6.36	0.274	-	0.04	0.4
13c	24/09/2021	24.5	3.83	0.293	-	1.01	12.3
13e		No Access					
16a	28/09/2021	16.14	4.21	0.164	-	1.19	12.5
16b	24/09/2021	21.75	6.24	0.412	-	4.28	50
22b	23/09/2021	22.03	4.49	0.182	-	5.45	64
22c	23/09/2021	15.36	4.28	0.165	-	2.95	30.5
26d		No Access					
27b	24/09/2021	14.2	4.43	0.125	-	10.95	110.2
27e	28/09/2021	15.2	4.77	0.163	-	0.84	8.7
C1	28/09/2021	18.23	4.15	0.107	-	5.14	56.2
C2	28/09/2021	23.71	4.1	0.254	-	5.5	66.4
C3	23/09/2021	20.76	3.76	0.231	-	3.62	41.6
C5	23/09/2021	13.36	4.39	0.109	-	0.96	9.5
C8	28/09/2021	22.33	3.93	0.263	-	4.56	53.8
C11	29/09/2021	No Water					
C12	29/09/2021	17.08	4.33	0.145	-	3.02	32.3
C13	21/09/2021	19.5	6.22	0.134	-	0.89	10
C14	21/09/2021	No Water					

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

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, conductivity and pH but none with respect to turbidity or temperature. Notably, at most of

the 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 pre-construction and construction phase water quality ranges with the water quality results collected during the May 2021 and September 2021 surveys is presented in **Appendix C**. The great majority of results are within the ranges measured in pre-construction and construction phase monitoring.

3.3 Habitat Description

Habitat availability and condition varied across the study area. A brief description of the general habitat conditions at each location is presented in **Table 3.3**. Summary results from habitat surveys are displayed in graphical form in **Appendix A**. The two approaches, qualitative and quantitative, are intended to be used in conjunction. An inventory of aquatic plants found at each site during this reporting period is presented in **Table 3.4**, **Table 3.5**, **Table 3.6** and **Table 3.7**.

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

Table 3.3 Brief descriptions of habitat features at all impact sites

<i>Section</i>	<i>Site</i>	<i>Habitat Description</i>
7	2a	Site 2a is located approximately 200m upstream of the upgrade corridor and consists of two pools located either side of a culvert on a dirt road. The benthic material was dominated by mud but varied across the site and included sand and gravel in some areas. Structural habitat at the site was comprised mostly of leaf litter, undercut banks and root balls, all of which were variable within the site. The riparian zone was well vegetated and continuous with adjacent forest. There was no aquatic vegetation and no flow at the time of either survey. There was evidence of bushfire around the site.
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 the September 2021 survey. There was evidence of bushfire around the site.

<i>Section</i>	<i>Site</i>	<i>Habitat Description</i>
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 (<i>Cyanogeton procerum</i>) and Maundia (<i>Maundia triglochoides</i>). 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 included mud and sand and scour rock when water levels are high. 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.
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 (<i>Lepironia articulata</i>) and Jointed Twig-rush (<i>Baumea articulata</i>), in some areas. The degree of riparian cover, undercutting and root mass varies across the site. There was no perceptible flow at the time of the 2021 surveys. The site has now been significantly modified by a diversion and revegetation. Shading effects from the constructed bridge are evident.

Section	Site	Habitat Description
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 approximately 20m upstream of the new highway crossing. 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.
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 (<i>Utricularia sp.</i>). Structural habitat is limited in the middle but around the margins consisted of submerged vegetation and occasional debris. The benthic material was mostly sand. There was no flow during either survey.

Section	Site	Habitat Description
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 <i>Maundia triglochinooides</i> , <i>Cyanogeton procerum</i> , and <i>Philydrum lanuginosum</i>). 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 <i>Maundia triglochinooides</i> and <i>Eleocharis sphacelata</i> .
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 2021 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 2021 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 2021 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, C13 and C14. 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 3.4 Aquatic plants identified at impact sites during the May 2021 survey

<i>Species Name</i>	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
<i>Alternanthera denticulata</i>	Lesser Joyweed				x			x												
<i>Azolla spp.</i>	Azolla														x					
<i>Baloskion (Restio) pallens</i>	Zigzag Rush													x	x	x	x			
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush															x	x			
<i>Baumea articulata</i>	Jointed Rush									x	x								x	
<i>Baumea rubiginosa</i>	Baumea													x	x	x			x	x
<i>Blechnum sp.</i>	Fern							x						x			x		x	x
<i>Carex appressa</i>	Tall Sedge					x			x	x										
<i>Carex fascicularis</i>	Tassel Sedge	x			x			x												
<i>Ceratophyllum demersum</i>	Hornwort				x															
<i>Chorizanandra cymbaria</i>	Heron Bristle-sedge		x																	
<i>Cyanogeton procerum</i>	Water Ribbons				x															
<i>Cyperus sp.</i>	Sedge								x	x				x						
<i>Cyperus difformis</i>	Dirty Dora			x		x				x	x	x								
<i>Drosera spatulata</i>	Spoon-leaved Sundew															x				
<i>Eleocharis pusilla</i>	Small Spike-rush		x	x						x										
<i>Eleocharis sphacelata</i>	Tall Spike-rush						x	x			x	x								
<i>Gahnia sieberiana</i>	Sawsedge							x		x	x						x		x	x
<i>Gleichenia dicarpa</i>	Pouched Coral Fern																x			
<i>Isolepis inundata</i>	Swamp Club Rush	x																		
<i>Juncus prismatocarpus</i>	Branching rush		x																	
<i>Juncus usitatus</i>	Common Rush	x	x	x					x	x	x	x					x			
<i>Leersia hexandra</i>	Swamp Ricegrass					x	x		x	x										
<i>Lepironia articulata</i>	Grey Rush					x									x					x
<i>Lomandra longifolia</i>	Creek Mat rush	x		x				x	x	x	x									
<i>Maundia triglochinoides</i>	Maundia				x															
<i>Nymphaea sp.*</i>	Waterlily*					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
<i>Ottelia ovalifolia</i>	Swamp Lily	x			x															
<i>Paspalum distichum</i>	Water Couch			x		x	x		x	x		x								
<i>Persicaria decipiens</i>	Slender Knotweed					x	x		x											
<i>Persicaria hydropiper</i>	Water Pepper					x	x	x		x	x									
<i>Persicaria lapathifolia</i>	Pale Knotweed						x													
<i>Philydrum lanuginosum</i>	Frogsmouth	x	x	x	x	x	x	x	x	x										
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush		x			x		x												
<i>Sphagnum sp.</i>	Peat Moss													x		x	x		x	x
<i>Utricularia sp.</i>	Bladderwort					x				x				x	x	x	x		x	x

* Introduced Species

Grey cells indicate site not surveyed.

Table 3.5 Aquatic plants identified at control and Devils Pulpit sites during the May 2021 survey

Species Name	Common Name	C1	C2	C3	C5	C8	C11	C12	C13	C14	OPP1	OPP2	OPP3	OPP4	OPP5	OPP6	OPP7
<i>Alternanthera denticulata</i>	Lesser Joyweed										x						
<i>Azolla spp.</i>	Azolla								x								
<i>Balaskion (Restio) pallens</i>	Zigzag Rush	x	x	x	x	x	x	x									
<i>Balaskion (Restio) tetraphyllum</i>	Feathery Rush				x	x											
<i>Baumea articulata</i>	Jointed Rush		x														
<i>Baumea rubiginosa</i>	Baumea	x	x	x	x	x	x	x			x	x					
<i>Carex fascicularis</i>	Tassel Sedge		x								x						
<i>Chorizandra cymbaria</i>	Heron Bristle-sedge									x							
<i>Cygnogeton procerum</i>	Water Ribbons								x	x							x
<i>Cyperus exaltatus</i>	Giant Sedge																x
<i>Drosera spatulata</i>	Spoon-leaved Sundew							x									
<i>Eleocharis acuta</i>	Common Spikerush															x	
<i>Eleocharis sphacelata</i>	Tall Spike-rush								x		x	x					x
<i>Enhydra fluctuans</i>	Buffalo Spinach									x							
<i>Gabnia sieberiana</i>	Sawsedge		x	x	x	x				x							

Species Name	Common Name	C1	C2	C3	C5	C8	C11	C12	C13	C14	OPP1	OPP2	OPP3	OPP4	OPP5	OPP6	OPP7
<i>Isolepis inundata</i>	Swamp Club Rush										x	x				x	
<i>Juncus usitatus</i>	Common Rush									x						x	
<i>Leersia hexandra</i>	Swamp Ricegrass								x		x	x					x
<i>Lepironia articulata</i>	Grey Rush	x															
<i>Lomandra longifolia</i>	Creek Mat rush															x	
<i>Maundia triglochinooides</i>	Maundia								x		x	x					x
<i>Nymphaea sp.*</i>	Waterlily*	x															
<i>Ottelia ovalifolia</i>	Swamp Lily								x		x						
<i>Paspalum distichum</i>	Water Couch										x					x	x
<i>Persicaria decipiens</i>	Slender Knotweed																x
<i>Persicaria strigosa</i>	Prickly Knotweed								x								
<i>Philydrum lanuginosum</i>	Frogsmouth								x	x	x	x				x	x
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush											x					
<i>Sphagnum sp.</i>	Peat Moss	x	x	x	x	x		x									
<i>Utricularia sp.</i>	Bladderwort	x	x	x	x			x		x	x						

* Introduced Species

Grey cells indicate site not surveyed.

Table 3.6 Aquatic plants identified at impact sites during the September 2021 survey

Species Name	Common Name	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
<i>Alternanthera denticulata</i>	Lesser Joyweed				x															
<i>Azolla spp.</i>	Azolla										x				x					x
<i>Baloskion (Restio) pallens</i>	Zigzag Rush													x	x				x	
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush															x	x			
<i>Baumea articulata</i>	Jointed Rush									x	x								x	x
<i>Baumea rubiginosa</i>	Baumea										x									
<i>Baumea sp.</i>	A rush													x	x	x	x			
<i>Blechnum sp.</i>	Fern													x	x				x	x
<i>Bolboschoenus fluviatilis</i>	Tall Club-rush								x											
<i>Carex appressa</i>	Tall Sedge					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
<i>Carex fascicularis</i>	Tassel Sedge	x			x			x		x										
<i>Ceratophyllum demersum</i>	Hornwort				x															
<i>Chorizanthe cymbaria</i>	Heron Bristle-sedge								x										x	
<i>Cyanogeton procerum</i>	Water Ribbons				x															
<i>Cyperus sp.</i>	Sedge					x														
<i>Cyperus difformis</i>	Dirty Dora											x								
<i>Eleocharis acuta</i>	Common Spikerush				x						x									
<i>Eleocharis pusilla</i>	Small Spike-rush		x																	
<i>Eleocharis sphacelata</i>	Tall Spike-rush						x	x				x								
<i>Enteromorpha spp.</i>	Green Alga																			
<i>Gabnia sieberiana</i>	Sawsedge					x				x				x	x	x	x		x	x
<i>Hypolepis muelleri</i>	Harsh Ground Fern									x										
<i>Isolepis inundata</i>	Swamp Club Rush		x		x	x	x		x	x	x									
<i>Juncus prismatocarpus</i>	Branching Rush		x		x				x											
<i>Juncus usitatus</i>	Common Rush		x			x	x		x		x	x								
<i>Leersia hexandra</i>	Swamp Ricegrass					x		x		x										
<i>Lemna spp.</i>	Duckweed														x					
<i>Lepironia articulata</i>	Grey Rush					x								x	x					x
<i>Lomandra longifolia</i>	Creek Mat rush				x				x	x	x					x				
<i>Maundia triglochinoidea</i>	Maundia				x															
<i>Nymphaea sp.*</i>	Waterlily					x				x		x				x				x
<i>Ottelia ovalifolia</i>	Swamp Lily	x			x															
<i>Paspalum distichum</i>	Water Couch					x	x		x	x	x	x								
<i>Persicaria decipiens</i>	Slender Knotweed						x		x			x								
<i>Persicaria lapathifolia</i>	Pale Knotweed						x													
<i>Persicaria strigosa</i>	Prickly Knotweed					x		x		x	x									
<i>Philydrum lanuginosum</i>	Frogsmouth		x		x	x	x	x	x		x								x	
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush					x		x												
<i>Sphagnum sp.</i>	Peat Moss								x	x	x			x		x	x		x	x
<i>Utricularia sp.</i>	Bladderwort		x			x								x	x	x	x		x	x
<i>Viola banksii</i>	Native Violet							x												

* Introduced Species

Grey cells indicate site not surveyed.

Table 3.7 Aquatic plants identified at control and Devils Pulpit sites during the September 2021 survey

<i>Species Name</i>	<i>Common Name</i>	<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>	<i>OPP1</i>	<i>OPP2</i>	<i>OPP3</i>	<i>OPP4</i>	<i>OPP5</i>	<i>OPP6</i>	<i>OPP7</i>
<i>Azolla</i> spp.	Azolla								x								
<i>Baloskion (Restio) pallens</i>	Zigzag Rush	x	x	x	x	x		x									
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush			x	x	x											
<i>Baumea articulata</i>	Jointed Rush		x						x								
<i>Baumea rubiginosa</i>	Baumea					x		x									
<i>Baumea</i> sp.	A rush		x		x	x		x									
<i>Carex fascicularis</i>	Tassel Sedge											x					
<i>Chorizandra cymbaria</i>	Heron Bristle-sedge										x						
<i>Cygnogeton procerum</i>	Water Ribbons								x								
<i>Eleocharis sphaclata</i>	Tall Spike-rush										x	x					
<i>Gabnia sieberiana</i>	Sawsedge		x	x	x	x											
<i>Isolepis inundata</i>	Swamp Club Rush										x						
<i>Juncus prismatocarpus</i>	Branching Rush			x	x						x	x					
<i>Leersia hexandra</i>	Swamp Ricegrass								x			x					
<i>Lepironia articulata</i>	Grey Rush	x															
<i>Maundia triglochinooides</i>	Maundia										x	x					
<i>Nymphaea</i> sp.*	Waterlily	x															
<i>Ottelia ovalifolia</i>	Swamp Lily								x		x						
<i>Persicaria strigosa</i>	Prickly Knotweed								x		x	x					
<i>Philydrum lanuginosum</i>	Frogsmouth								x		x	x					
<i>Potamogeton octandrus</i>	Pondweed								x								
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush											x					
<i>Sphagnum</i> sp.	Peat Moss	x	x	x	x	x		x									
<i>Utricularia</i> sp.	Bladderwort	x			x			x	x								

* Introduced Species

Grey cells indicate site not surveyed.

Discussion and Conclusion

The two fish surveys completed during the first year of the operational phase for the W2B Threatened Fish monitoring were completed in May and September 2021. There were OPP captured at 5 of the 24 impact sites and 6 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 due to dry weather in the lead up to the September 2021 surveys. At some impact and control sites there was remnant evidence of bushfires from December 2019 and January 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 and 2020 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), a moderate number of OPP were captured during the two surveys this year. Overall, the results indicate a slight reduction in the number of OPP captured per site when compared with the average catches from the pre-construction and construction phase monitoring at impact sites and a slight increase in the same measure at control sites. However, as noted in the final construction phase Threatened Fish Monitoring Report, 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 during this reporting period indicates continued variability among both impact and control sites. Most of the variability is explained by environmental conditions unrelated to the W2B upgrade operation with the exception of sites where construction of crossings has necessitated changes to stream morphology and benthic materials. At some of those sites there are positive signs that habitat rehabilitation efforts have been successful. Water quality measurements collected during this reporting period were also variable within and between sites. Again, much of the observed variability is explained by environmental conditions unrelated to highway operation.

Operational phase monitoring is proceeding at all of the 24 impact and 11 control sites that were being monitored at the end of the construction phase threatened fish monitoring. During this monitoring period operational phase threatened fish monitoring along the W2B Upgrade was undertaken according to the TFMP, with the exception of monitoring at sites where access was denied by landholders (OPP4, 13e, 26d) and one site where unsafe conditions restricted access (OPP5, May 2021 only).

The fishing effort for the two surveys this year consisted of 507 individual fish trapping hours and 32,170 seconds of electrofishing. A total of 2,771 fish were captured in May 2021 and 4,135 fish were captured in September 2021. These totals included 102 (3%) OPP and 200 (5%) 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 2021 included:

- Six of the eleven control sites. OPP were captured at site C1, C2, C3, C5, C8 and C12 during both surveys.
- Five of the twenty-four impact sites. OPP were captured at 22b and 22c during both surveys and 12a, 16a and 27b during the September 2021 survey only. The captures at

sites 12a, 16a and 27b were the first in their respective areas since drought conditions set in in late 2019.

Notably there were two areas where no OPP were captured during this reporting period:

- 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 or 2021 surveys. The direct impact of bushfires are still evident at some of the sites, including burnt wetland canopies, reduced vegetative cover and high proportional cover of charcoal over the benthic material.
- The unnamed drain south of Laing Hill (sites 10b and 10c) where no OPP have been captured since 2013.

Plentiful rainfall between December 2020 and April 2021 including flooding conditions in March 2021 would have resulted in good breeding and dispersal conditions for OPP, the first such occurrence since 2018. This is reflected in the increased numbers of OPP captured during the current reporting period and the increased number of sites at which OPP were captured in comparison to the results from the 2019 and 2020 (**Table 4.1**). The proportion of juvenile OPP, and the overall size distributions of OPP, captured during the surveys this year indicate more stable OPP populations (**Figures 4.1 and 4.2**).

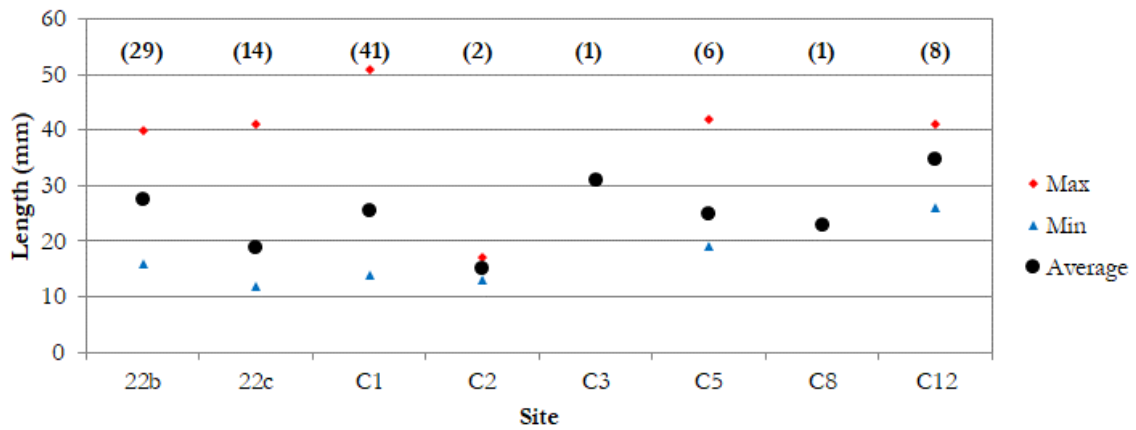


Figure 4.1 Length distribution data of OPP captured in the May 2021 survey (counts in brackets)

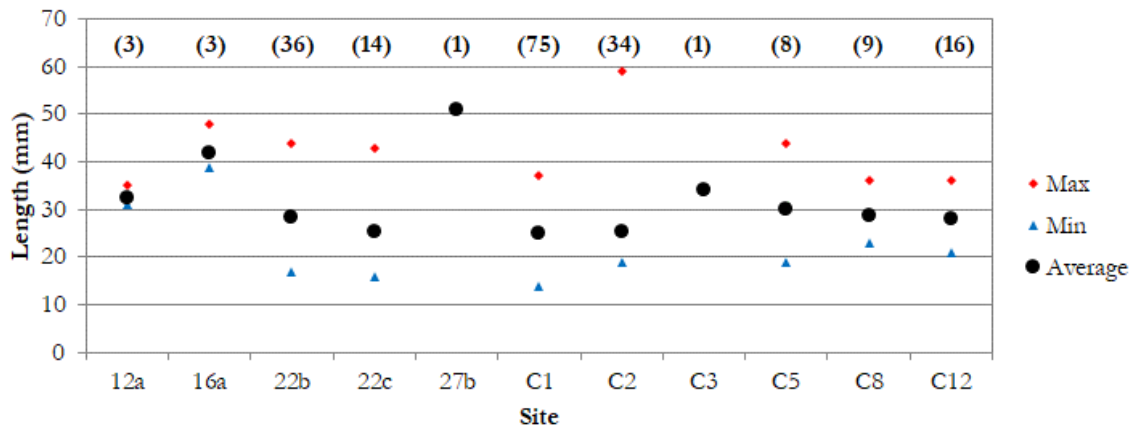


Figure 4.2 Length distribution data of OPP captured in the September 2021 survey (counts in brackets)

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
May 2021*	31	22	9	102	43	59	46.1	46.5	45.8
September 2021*	32	22	10	200	57	143	44	42.1	44.8

* Survey included Devils Pulpit Sites

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, construction and operational (to date) 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, as discussed in the previous annual Threatened Fish Monitoring Report (TfNSW 2021), trend analysis shows that throughout construction phase monitoring there was a similar trend towards reduced capture at both impact and control sites and 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.

The numbers of Mosquitofish (*Gambusia holbrooki*) encountered at each site are of specific interest as predation by this species is identified as a Key Threatening Process under the *Biodiversity Conservation Act 2016* and they are antagonistic towards OPP. There has been variation in the numbers of Mosquitofish encountered during threatened fish surveys to date. During the surveys this year, Mosquitofish were captured in very large numbers at both control and impact sites. In comparison with the pre-construction and construction phases, the average catch of Mosquitofish to date in operational phase monitoring has increased slightly although there are high levels of variation in the dataset (**Figure 4.3**). 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 Pacific Highway operation.

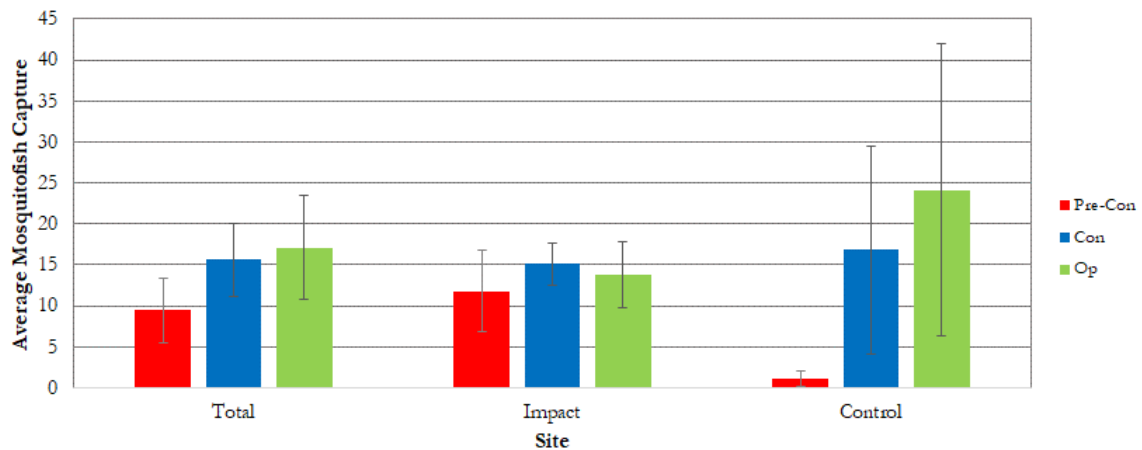


Figure 4.3 Average Mosquitofish Capture at W2B impact and control sites in the pre-construction, construction and operational phase surveys.

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 2021 and September 2021 surveys was similar to previous surveys undertaken as part of pre-construction and construction phase monitoring.

A graphical assessment of the habitat data collected in the pre-construction, construction and operational (to date) phases of monitoring is presented in **Appendix A**. The analysis indicates significant differences between data collected in the pre-construction, construction and operational (to date) 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. Many 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 the final annual report) are a useful reference for determining actual differences in such cases. Several disturbances potentially relating to construction impacts were described in the final construction phase monitoring report (TfNSW 2021). Most of these resulted from necessary changes to the shape of waterways associated with crossing designs, clearing of riparian vegetation around bridge abutments and/or material use such as rock utilised as scour protection around bridge abutments. There were also some changes in vegetative cover at crossing sites, for example, where rehabilitation efforts had successfully resulted in increased emergent vegetation cover (See **Plates 4.1 to 4.4**). The results of habitat monitoring during this first year of the operational phase are similar to those of the later years of construction phase monitoring, indicating no changes associated with operation of the highway. Due to the small size of the operational phase dataset the standard errors of the means presented in **Appendix A** are large. It is expected that continued monitoring will lead to a reduction in the variability and that any emerging trends associated with operation of the highway will become clear.

This study also measured physicochemical water quality variables. During this reporting period several sites had very low DO concentrations in comparison with the other

measurements collected during threatened fish surveys since 2013. The majority of these sites were impact sites. All but one of the pH measurements collected during the 2021 surveys were within the reported ranges of waters known to be inhabited by OPP. Other results collected during the 2021 surveys were all within the known tolerances of OPP.

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. While there are some performance indicators that were not met during this first year of operational phase monitoring, they are generally minor and acceptable in nature and there are no recommended changes to highway operation.

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

<i>Performance Indicator</i>	<i>Notes</i>	<i>Conclusion</i>
Relative abundance of OPP in impact sites has reduced significantly when compared to control sites over three consecutive monitoring periods	Using number of OPP captured as a measure of relative abundance, the relative abundance of OPP at all sites increased in comparison to the two previous years.	Performance indicator met - No significant impact from highway operation
Occurrence of Eastern Gambusia in waterways where they have not previously been recorded	Eastern Gambusia were not captured at any new sites during this monitoring period. There were high levels of variation in the numbers of Eastern Gambusia captured at sites throughout pre-construction and construction phase monitoring at both impact and control sites. Although Eastern Gambusia were captured in some sites during construction phase monitoring where they were not captured during pre-construction phase monitoring it included both control and reference sites. Trend analyses (TfNSW 2021) also indicated that detected increases in the Eastern Gambusia populations were greater at control sites than at impact sites, indicating that Eastern Gambusia population dynamics were not strongly associated with the construction of the highway.	Performance indicator met - No significant impact from highway operation
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. Monitoring is continuing at that site.	Performance indicator met
Any change in habitat structure downstream of construction area, i.e., macrophyte and woody snag cover.	Some minor changes to habitat structure around highway crossings were noted during the construction phase monitoring (discussed in TfNSW 2021). At this stage of the operational phase monitoring no new changes to habitat structure related to highway operation have been detected.	Performance indicator met

<i>Performance Indicator</i>	<i>Notes</i>	<i>Conclusion</i>
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 also captured at Site 27b during surveys this year, although capture throughout construction phase monitoring at 27b was highly variable.	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. During the construction phase monitoring some of the pH measurements collected during threatened fish monitoring and during construction phase water quality monitoring indicated a potential increase in the pH around construction areas (TfNSW 2021). During operational phase monitoring to date pH measurements have been lower at the majority of those sites (Appendix C).	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 and operational 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, the number OPP were captured during this reporting period increased in comparison to the previous two years of monitoring. The increased capture was noted at impact and control sites alike and is likely to be related to improved conditions for breeding and dispersal between December 2020 and April 2021. On a positive note, OPP were captured at Site 12a for the first time since May 2018, a good indication that the habitat rehabilitation measures at that site have been successful. The data captured during this reporting period does not indicate that highway operation is negatively impacting OPP populations or habitat in the study area.



Plate 4.1 Site 13b in September 2018 after channel realignment and initial plant out.



Plate 4.2 Site 13b in September 2021 showing dense emergent vegetation cover.



Plate 4.3 Site 12a in May 2018 after channel realignment and initial plant out.



Plate 4.4 Site 12a in September 2021 showing dense emergent vegetation cover.

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
- Dave Consterdine – Field Team

References

- Allen, G. R., Midgley, S. H. and Allen, M. (2002) Field Guide to the Freshwater Fishes of Australia (Western Australian Museum, Perth).
- Barker, D, Allan, G., Rowland, S., Kennedy, J. & Pickles, J. (2009) *A Guide to Acceptable Procedures and Practices for Aquaculture and Fisheries Research, 3rd Edition*. For the Primary Industries (Fisheries) Animal Care and Ethics Committee.
- Birch (2019) Oxleyan Pygmy Perch Drought Refuge Survey. Letter to J. Sakker, NSW DPI Fisheries.
- DSEWPac (2011) Survey guidelines for Australia's threatened fish. Available online: <http://www.environment.gov.au/epbc/publications/pubs/survey-guidelines-fish.doc>
- Fairfull, S. & Witheridge, G. (2003) Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings. NSW Fisheries, Cronulla, 16pp.
- GeoLINK (2013) Aquatic Monitoring – RMS Woolgoolga to Ballina – Sections 6 – 11. Report prepared for NSW RMS.
- GeoLINK (2014) Oxleyan Pygmy Perch Drought Refuge Assessment – RMS Woolgoolga to Ballina – Sections 7 – 9. Report prepared for NSW RMS.
- GeoLINK (2015a) Round 2 Aquatic Monitoring – RMS Woolgoolga to Ballina – Sections 6 – 11. Report prepared for NSW RMS.
- GeoLINK (2015b) RMS Devils Pulpit Pacific Highway Upgrade – Post-construction Monitoring of Oxleyan Pygmy Perch and Surface Water. Report prepared for NSW RMS.
- GeoLINK (2021) Annual Water Quality Monitoring Report – Pacific Highway Upgrade: Woolgoolga to Ballina Sections 3 to 11: July 2019 to June 2020.
- Golder Associates (2014) Surface Water and Groundwater Monitoring Report – Pacific Highway Upgrade, Devils Pulpit to Ballina. Report No. 127622003-111-R-Rev1 Submitted to NSW RMS.
- BMT WBM, Hyder (2012) NSW Roads and Maritime Services Devils Pulpit Upgrade – Ecological Monitoring Program.
- Jacobs (2018) Woolgoolga to Ballina Pacific Highway upgrade – Threatened Fish Monitoring Program Annual Report 2017
- Jacobs (2019) Woolgoolga to Ballina Pacific Highway upgrade – Threatened Fish Monitoring Program Annual Report 2018
- Jacobs (2020) Woolgoolga to Ballina Pacific Highway upgrade – Threatened Fish Monitoring Program Annual Report 2019
- Knight, J. & Arthington, A. (2008) Distribution and habitat associations of the endangered Oxleyan pygmy perch, *Nannoperca oxleyana* Whitley, in eastern Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems*.(18) 1240-1254

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

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

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

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

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

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

Transport for NSW (TfNSW) (2021) *Woolgoolga to Ballina Pacific Highway Upgrade - Threatened Fish Monitoring Program Annual Report 2020 – Final Construction Phase Report*

Copyright and Usage

© Mathew Birch/Aquatic Science and Management, January 2022

This document is copyright and cannot be reproduced in part or whole without the express permission of the author. It has been prepared for the use of Jacobs and Transport for NSW and must not be used for any other purpose, person or organisation without the prior written approval of Mathew Birch/Aquatic Science and Management.

The contents of this report are provided expressly for the named clients for their own use. No responsibility is accepted for the use of or reliance upon this report in whole or in part by any third party. This report is prepared with information supplied by the client and possibly other stakeholders. While care is taken to ensure the veracity of information sources, no responsibility is accepted for information that is withheld, incorrect or that is inaccurate. This report has been compiled at the level of detail specified in the report and no responsibility is accepted for interpretations made at more detailed levels than so indicated.

Appendix A

Aquatic Habitat Summaries

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

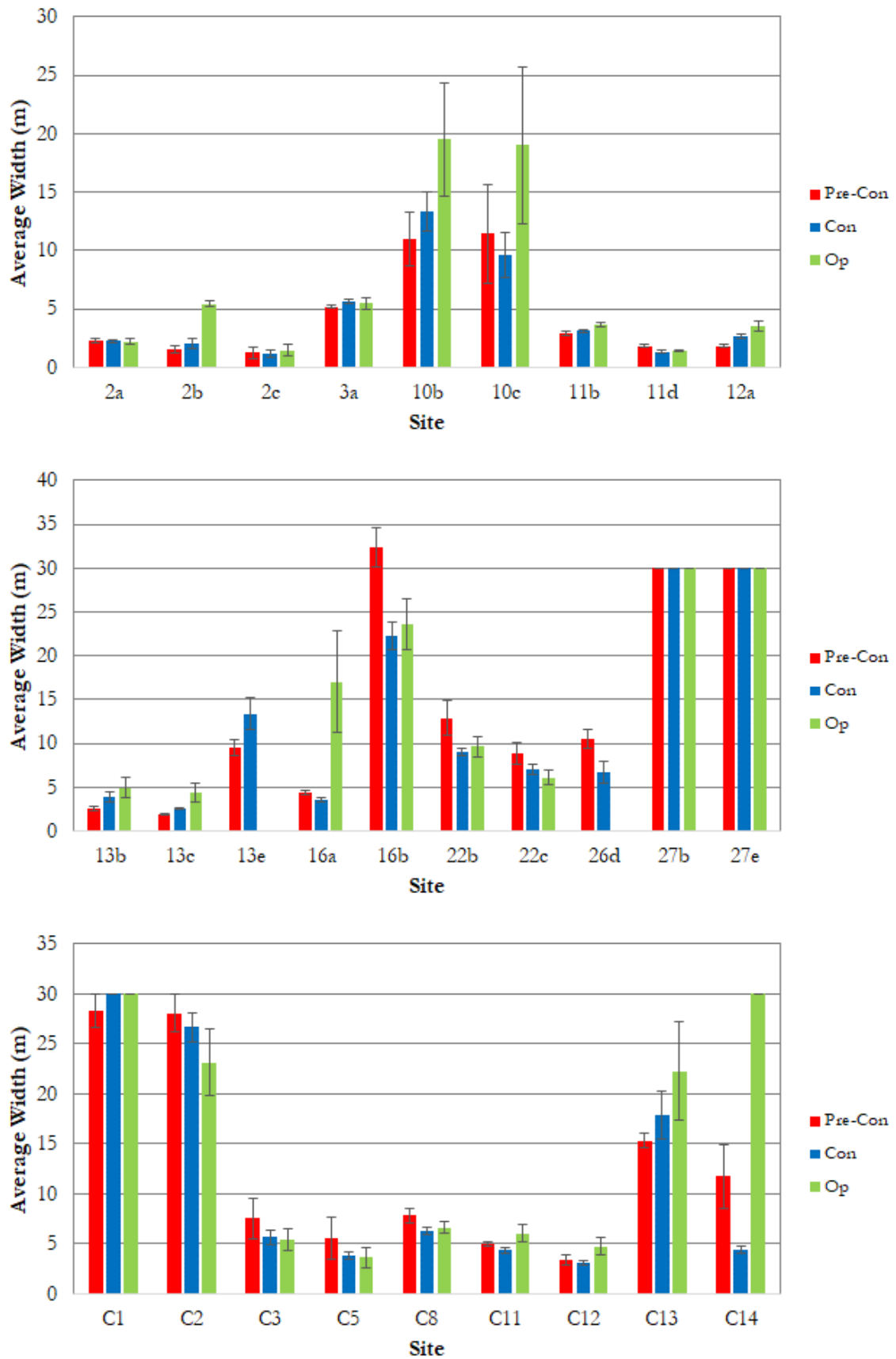


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

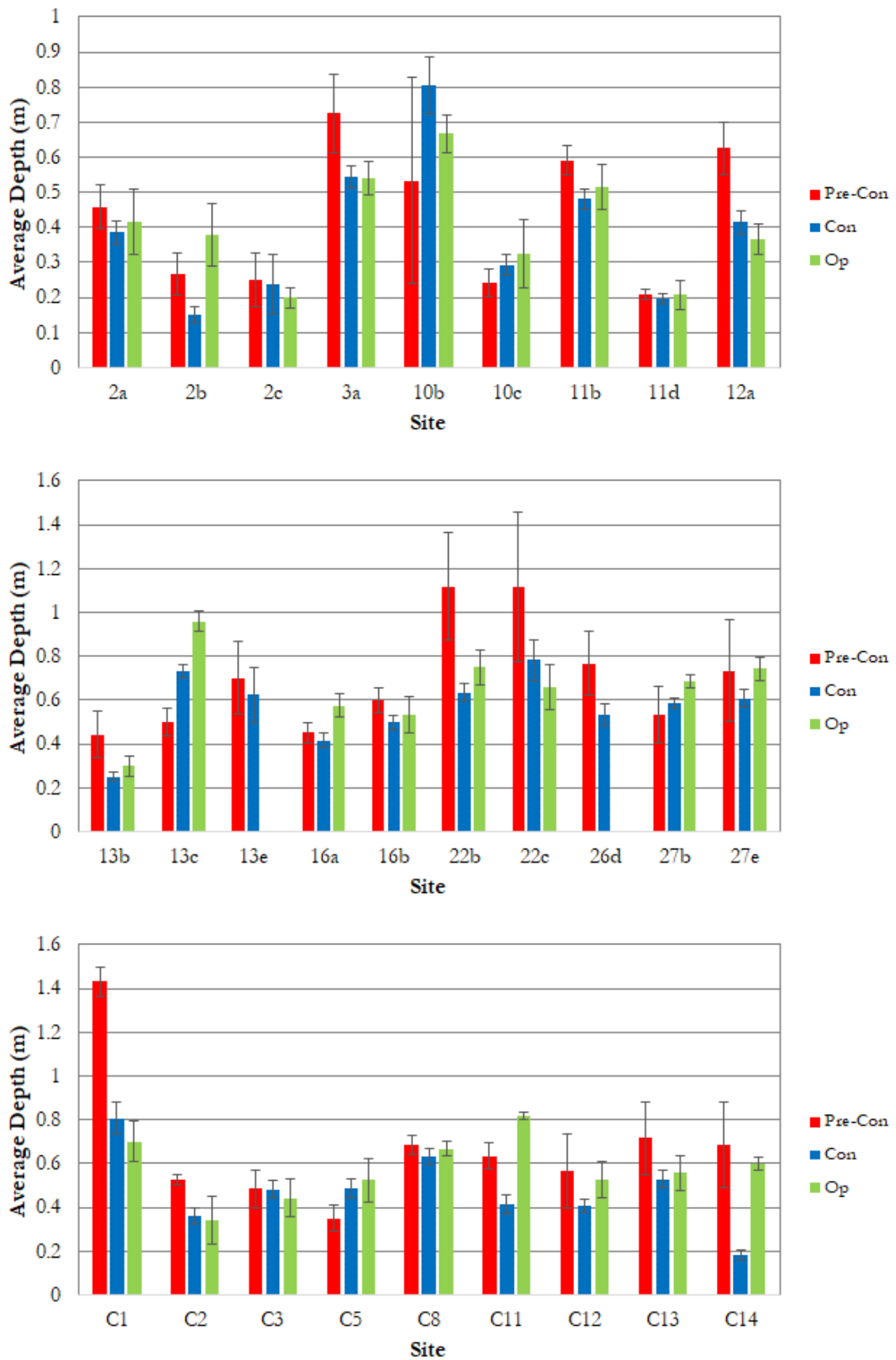


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

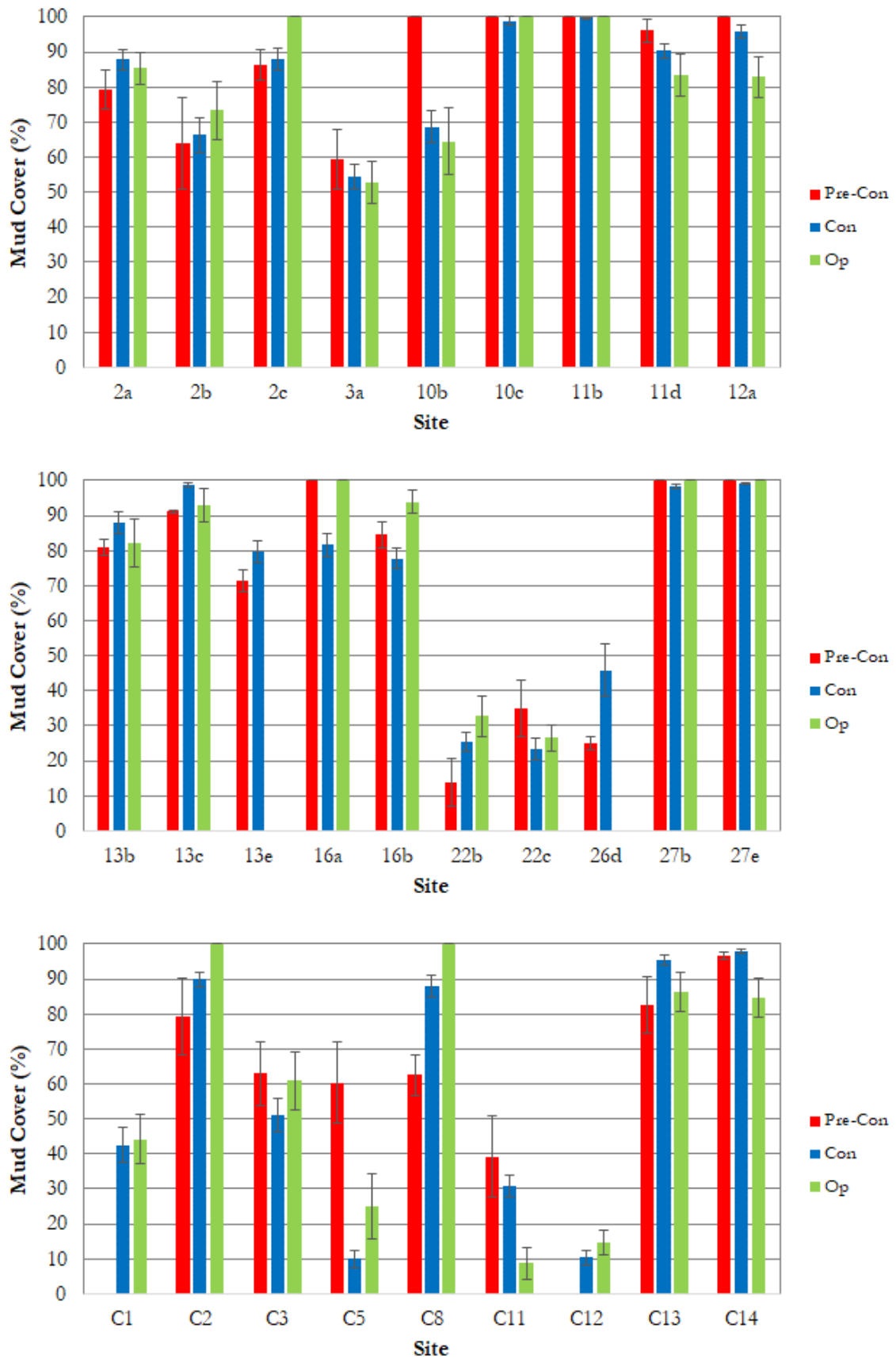


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

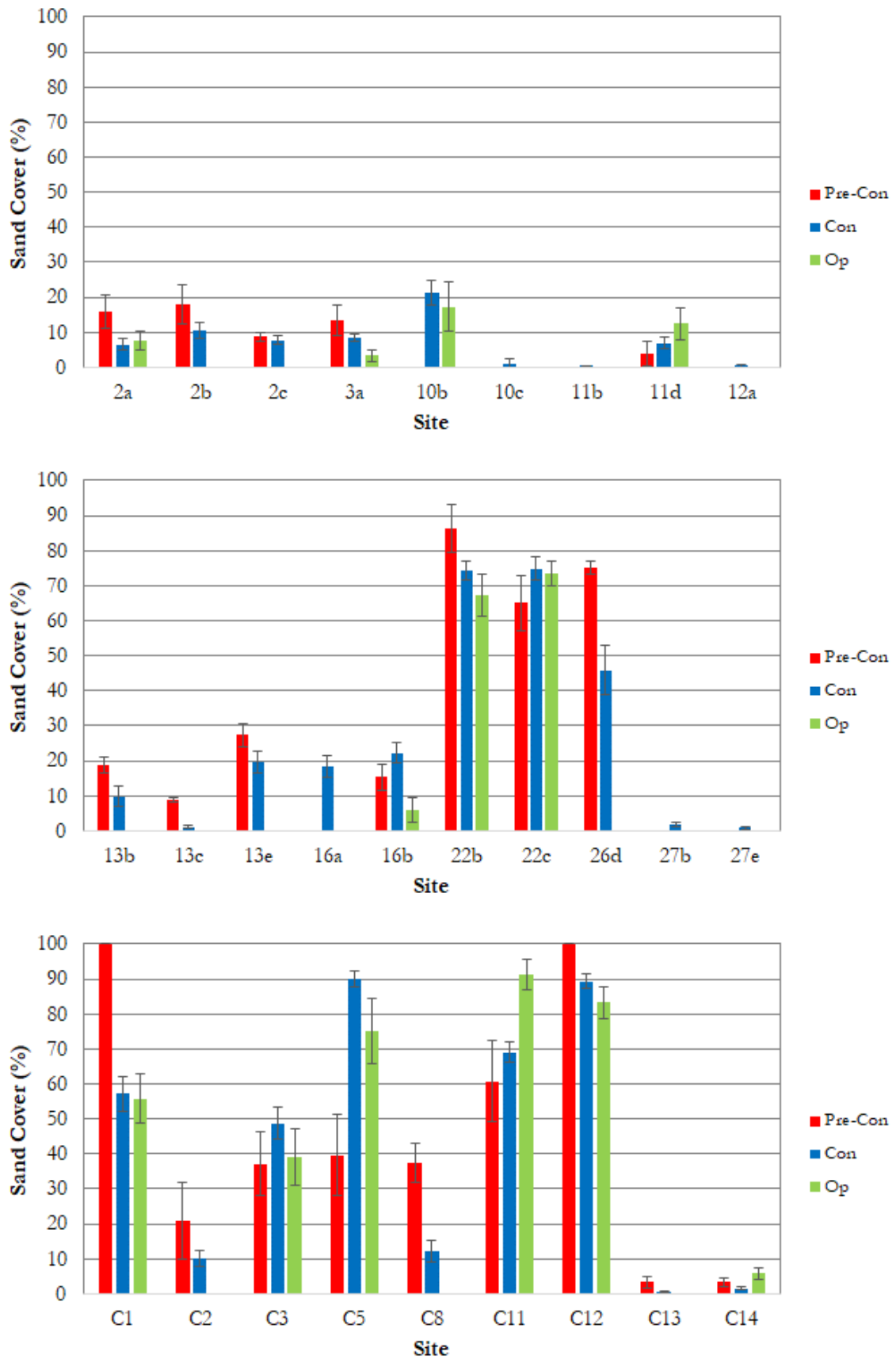


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

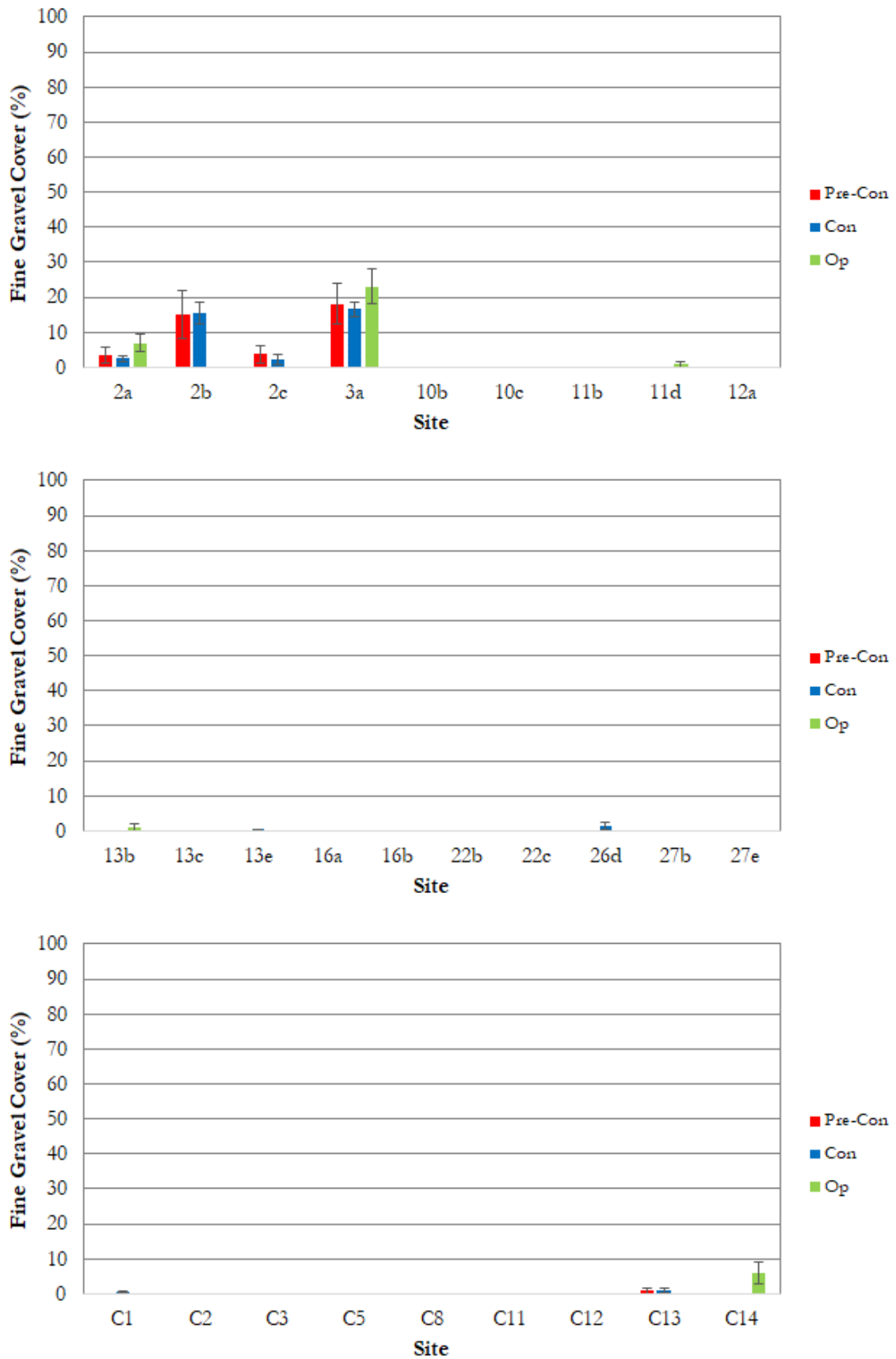


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

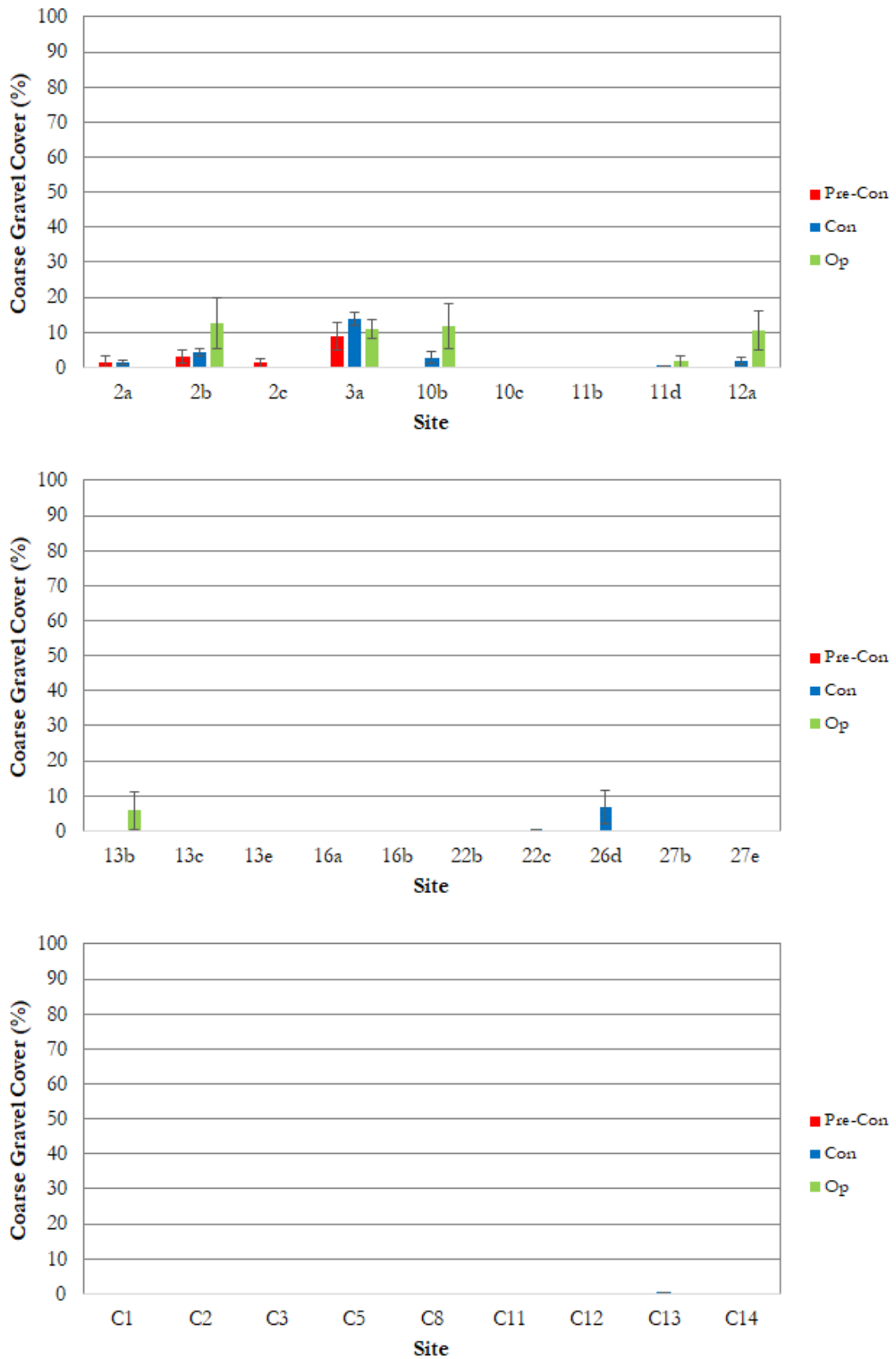


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

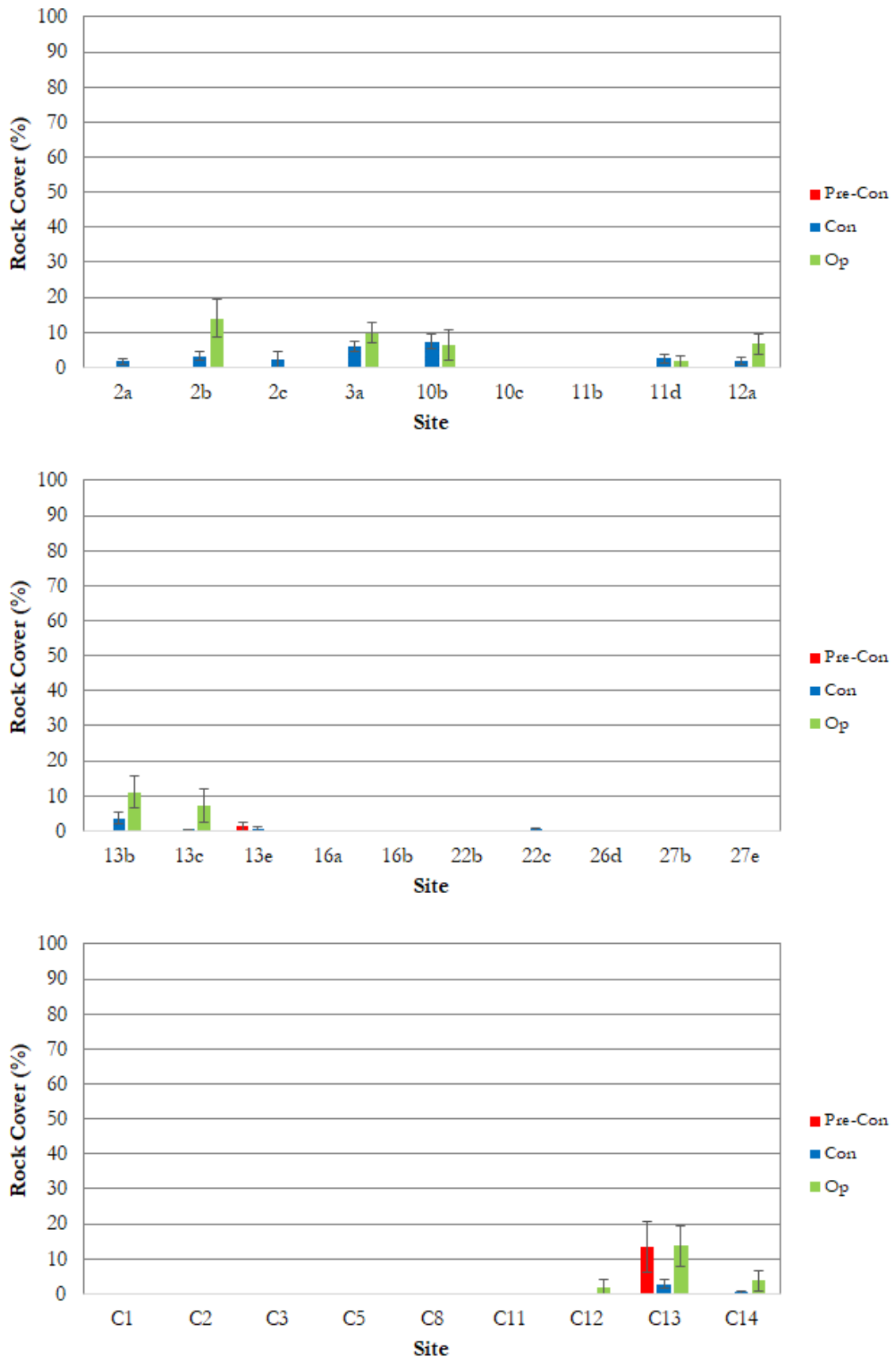


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

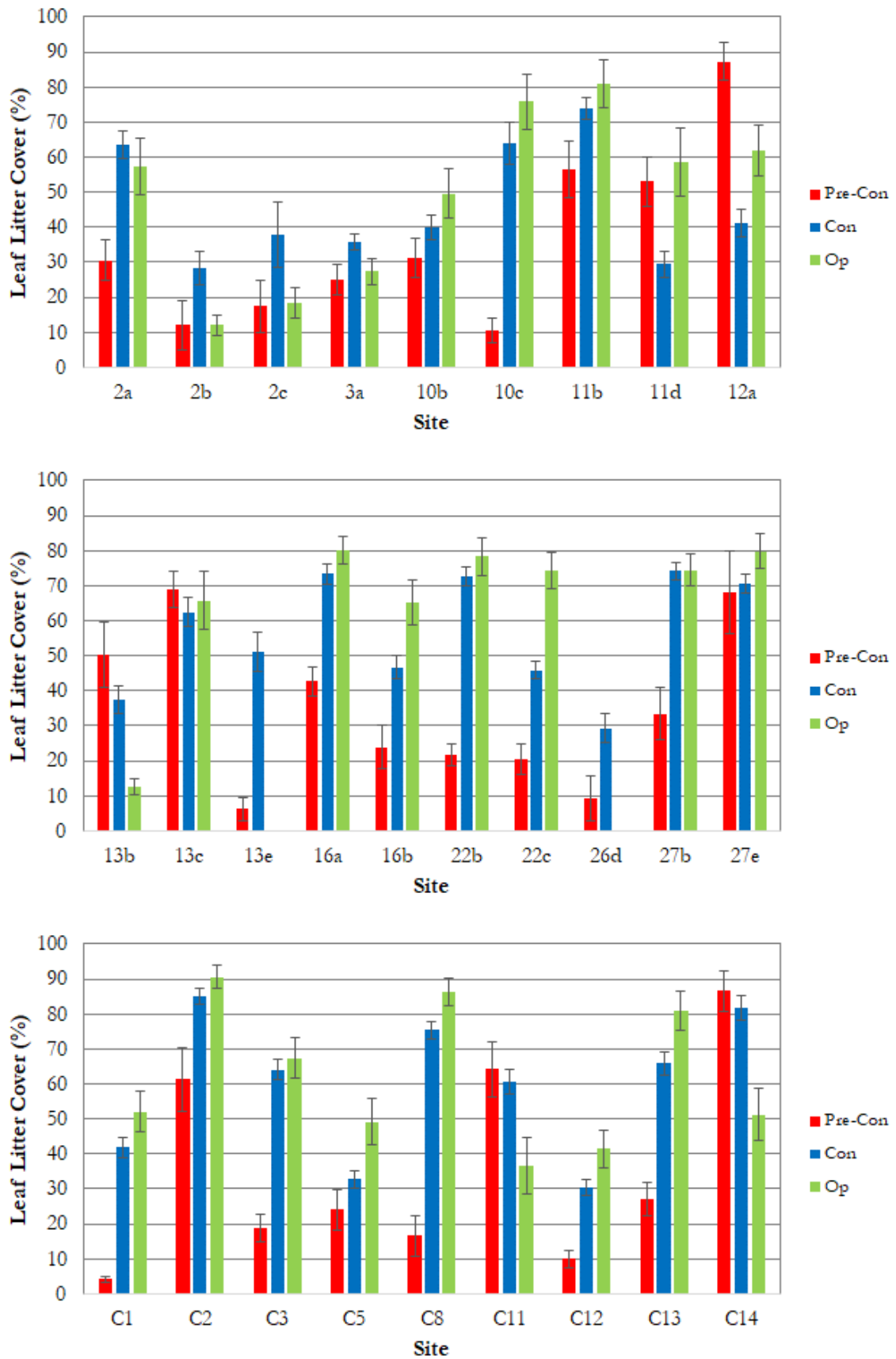


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

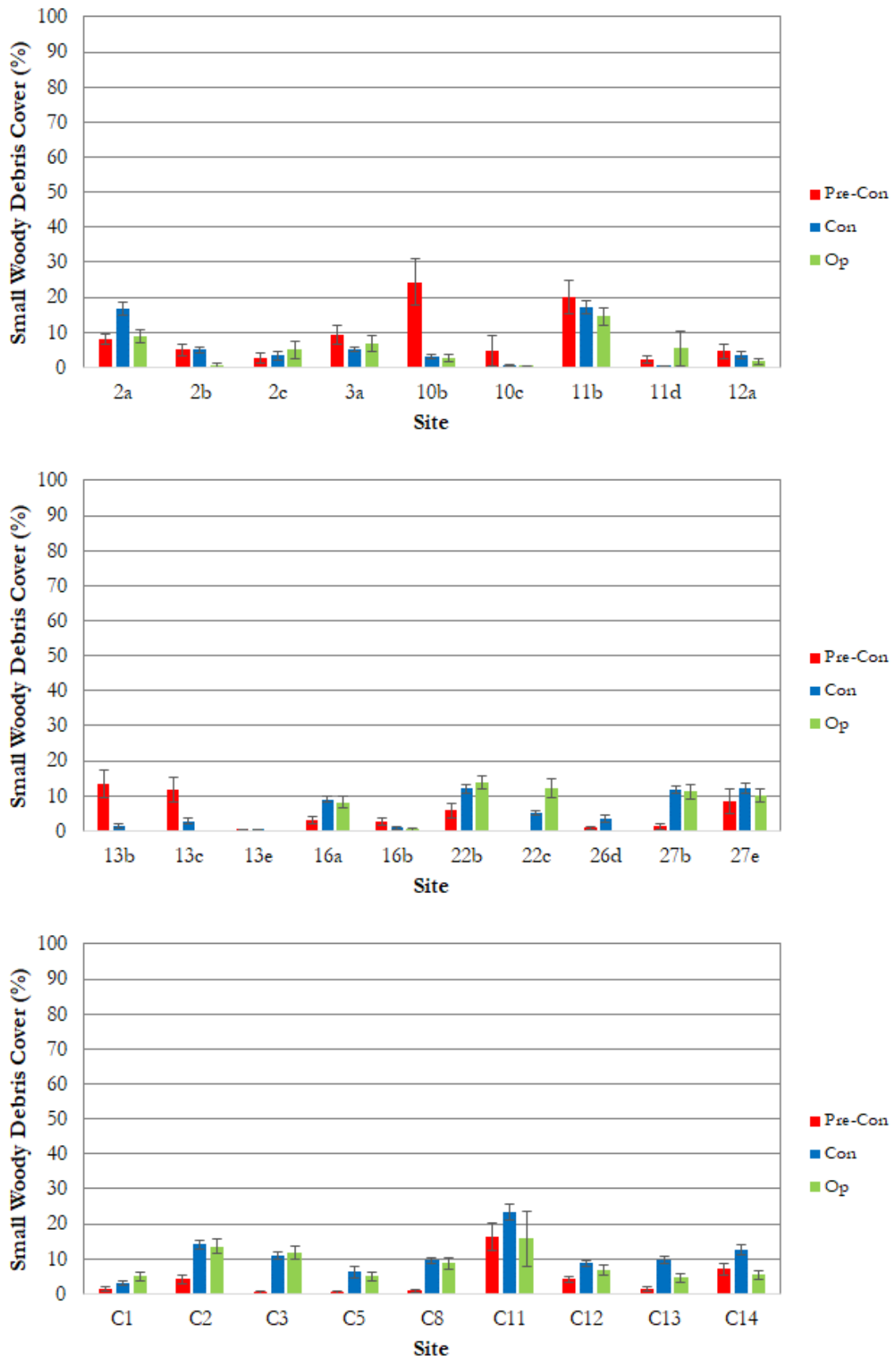


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

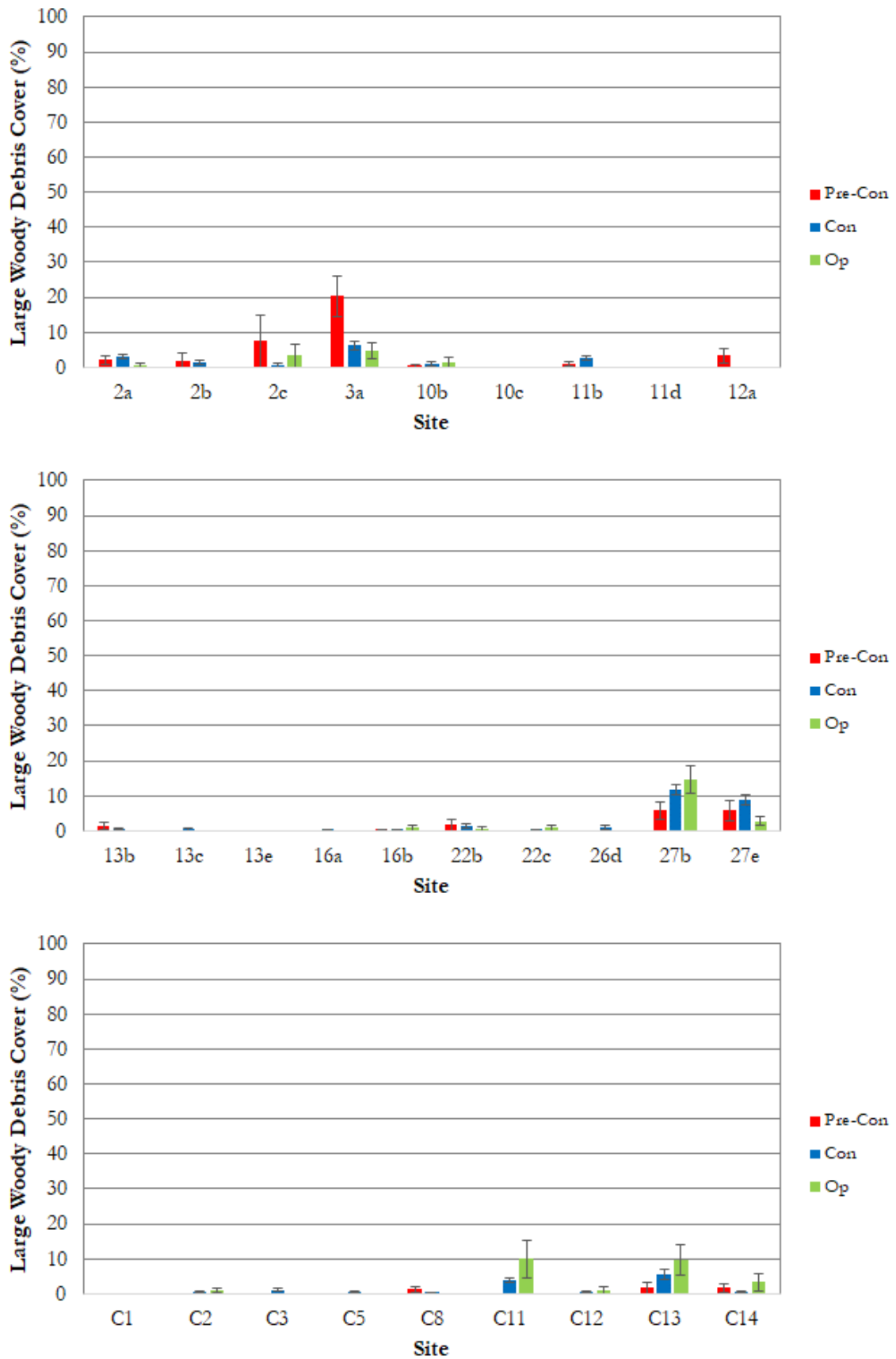


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

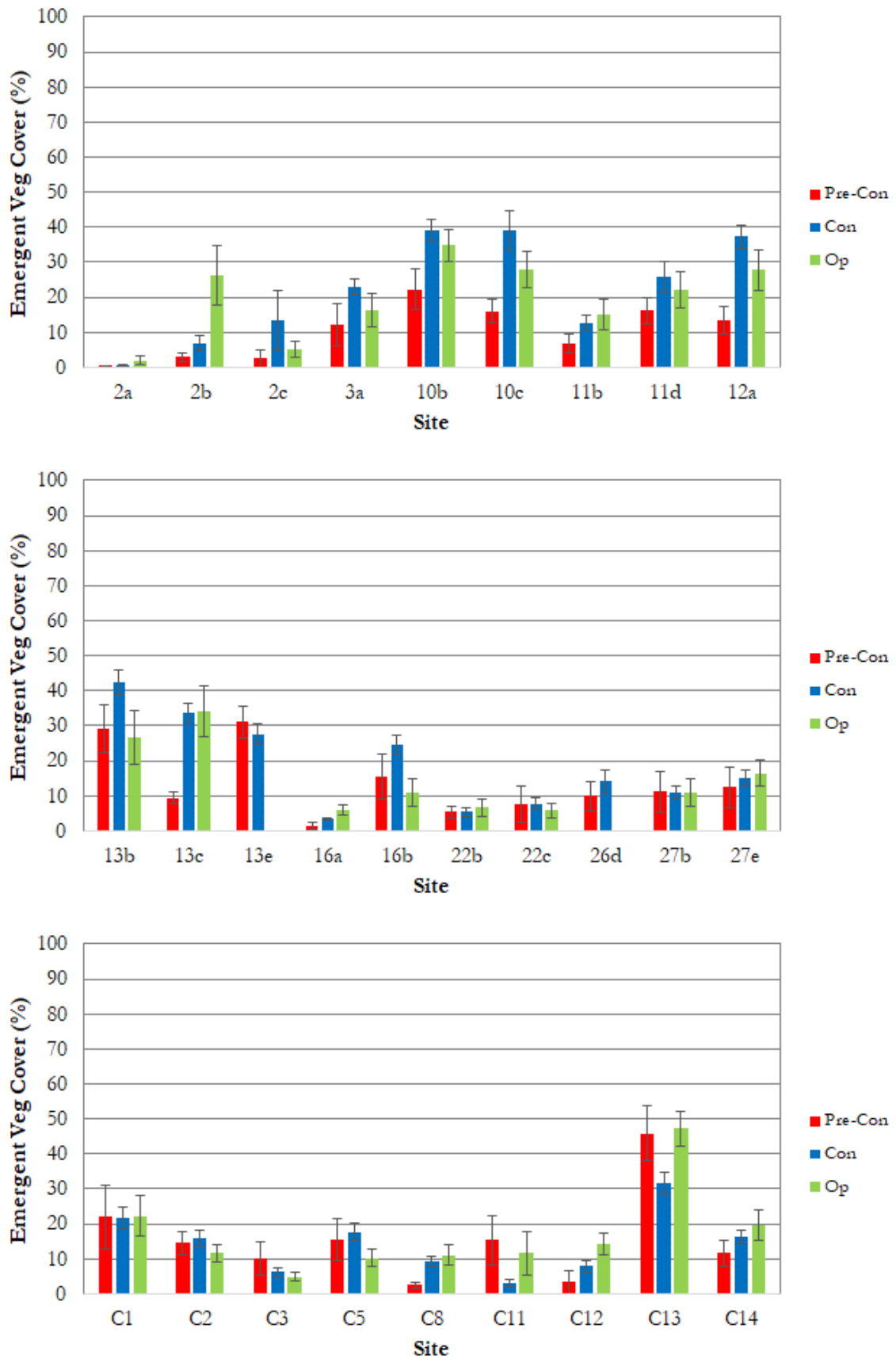


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

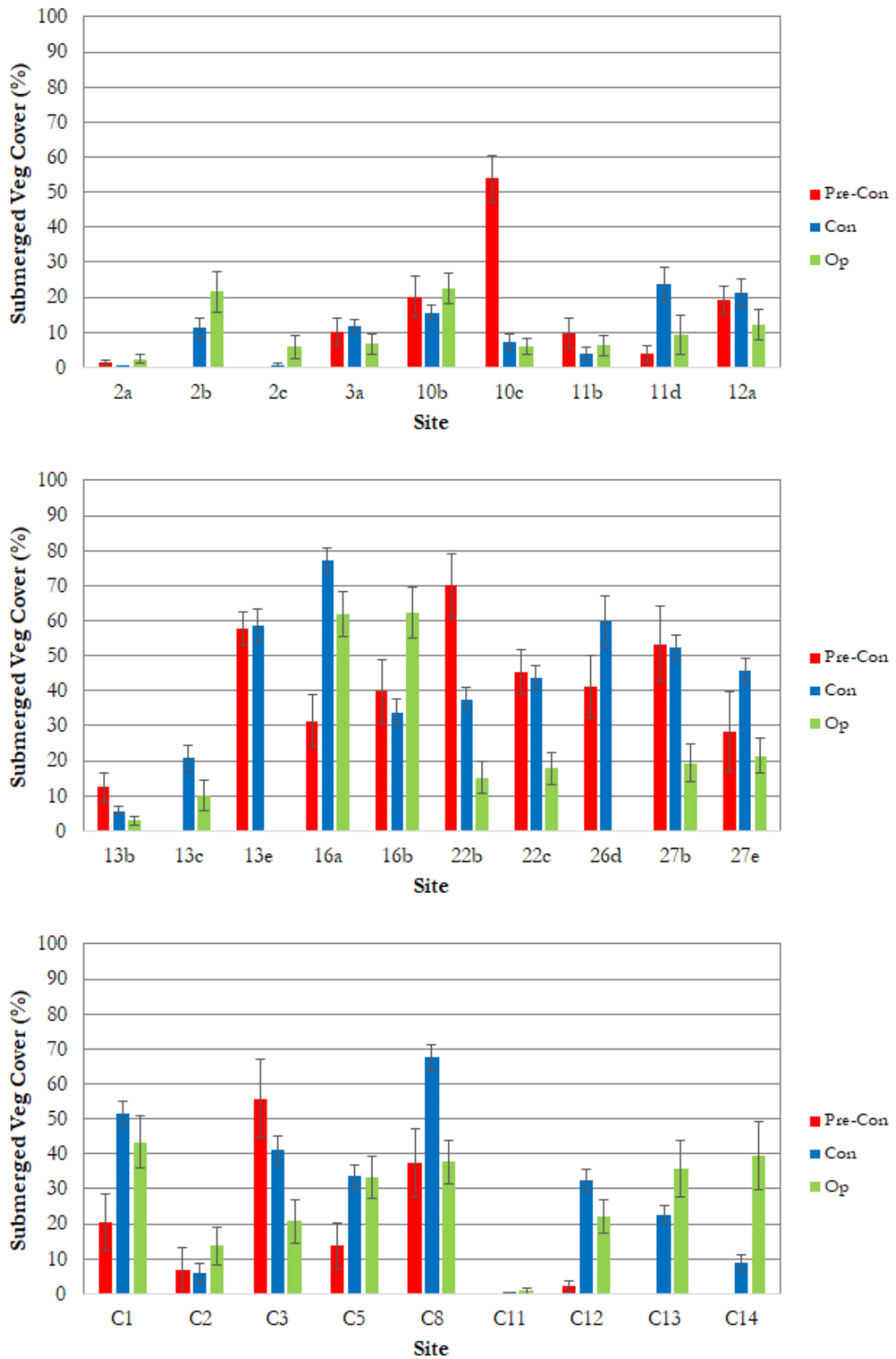


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

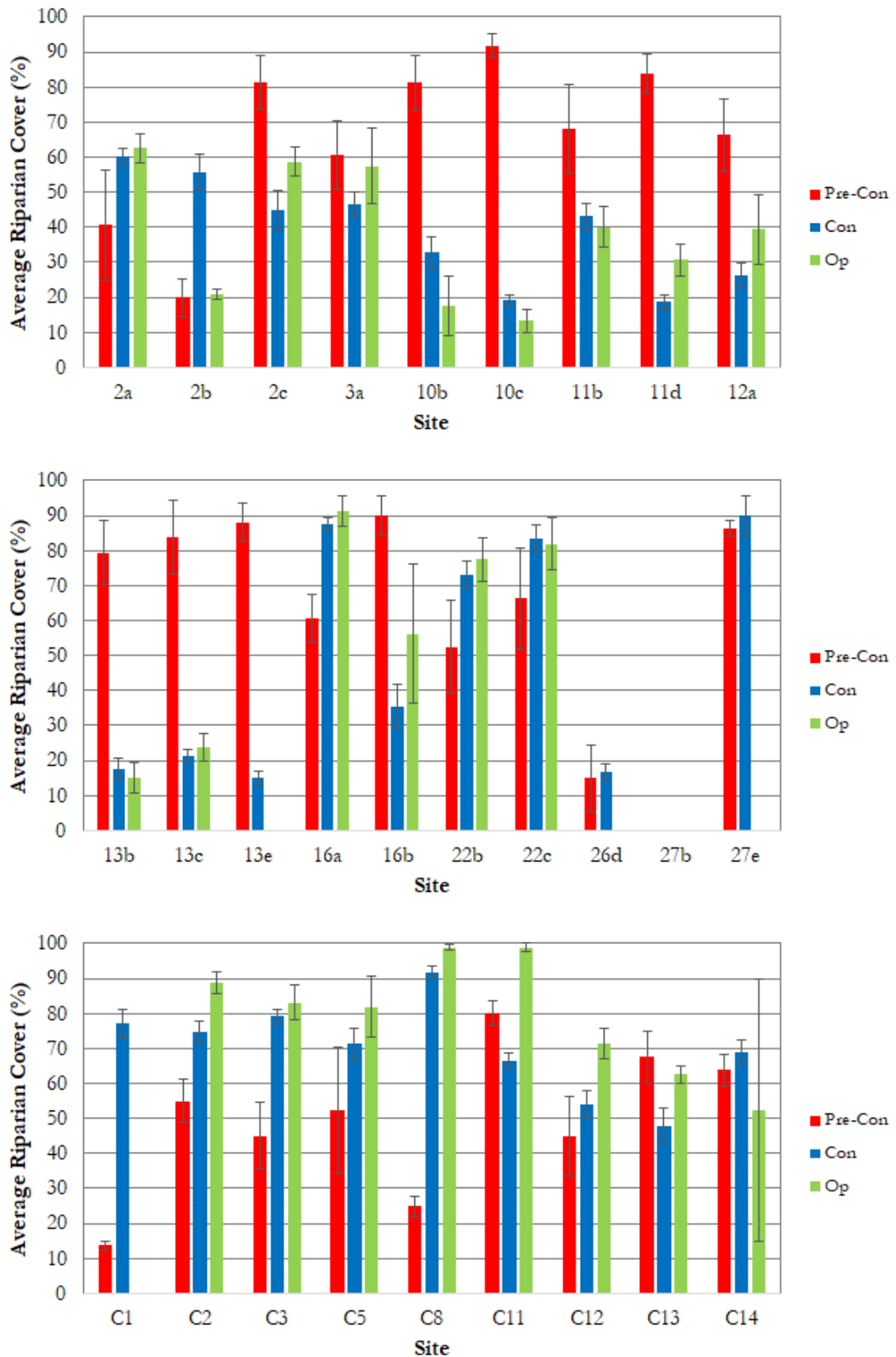


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

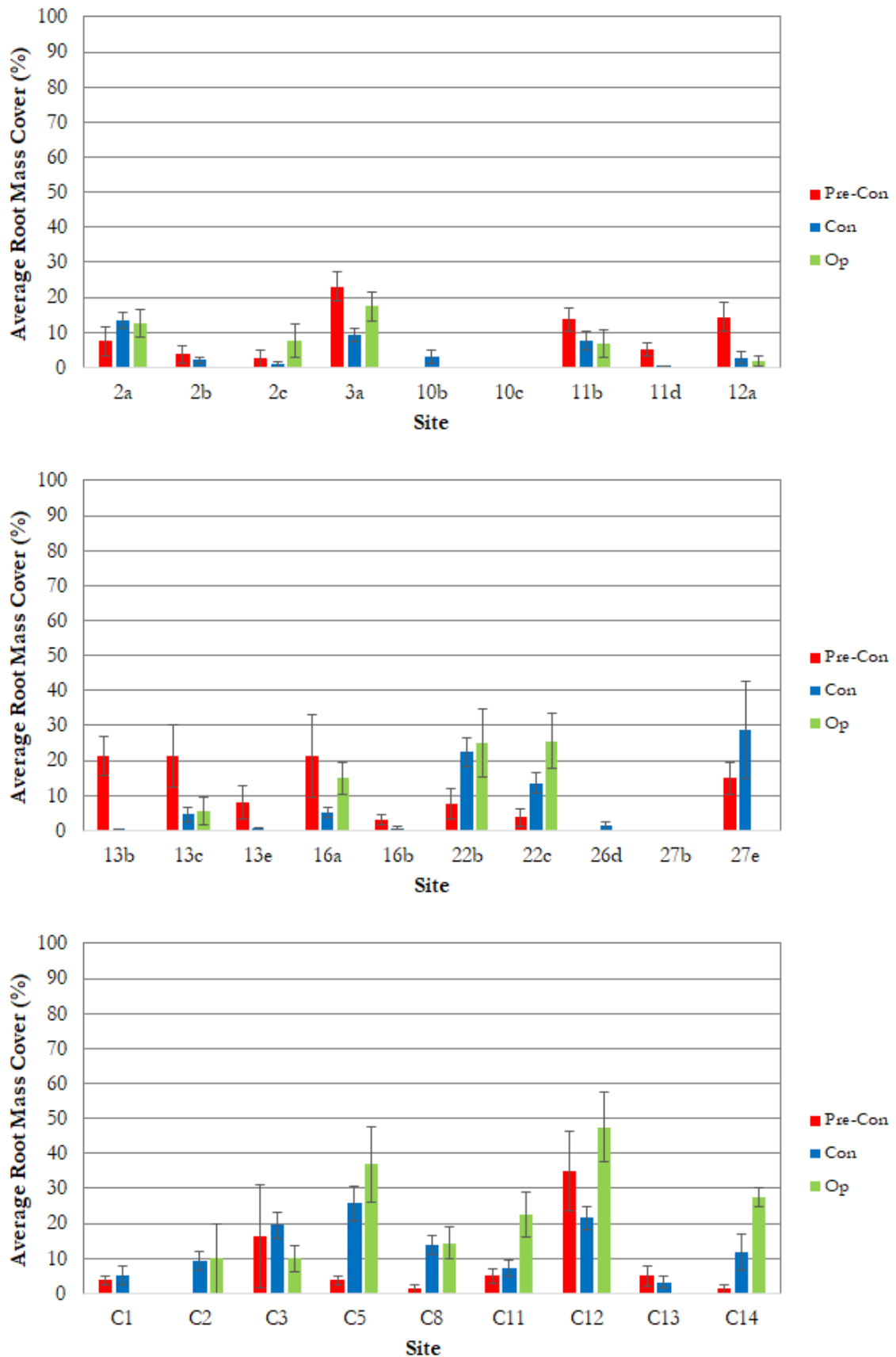


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring

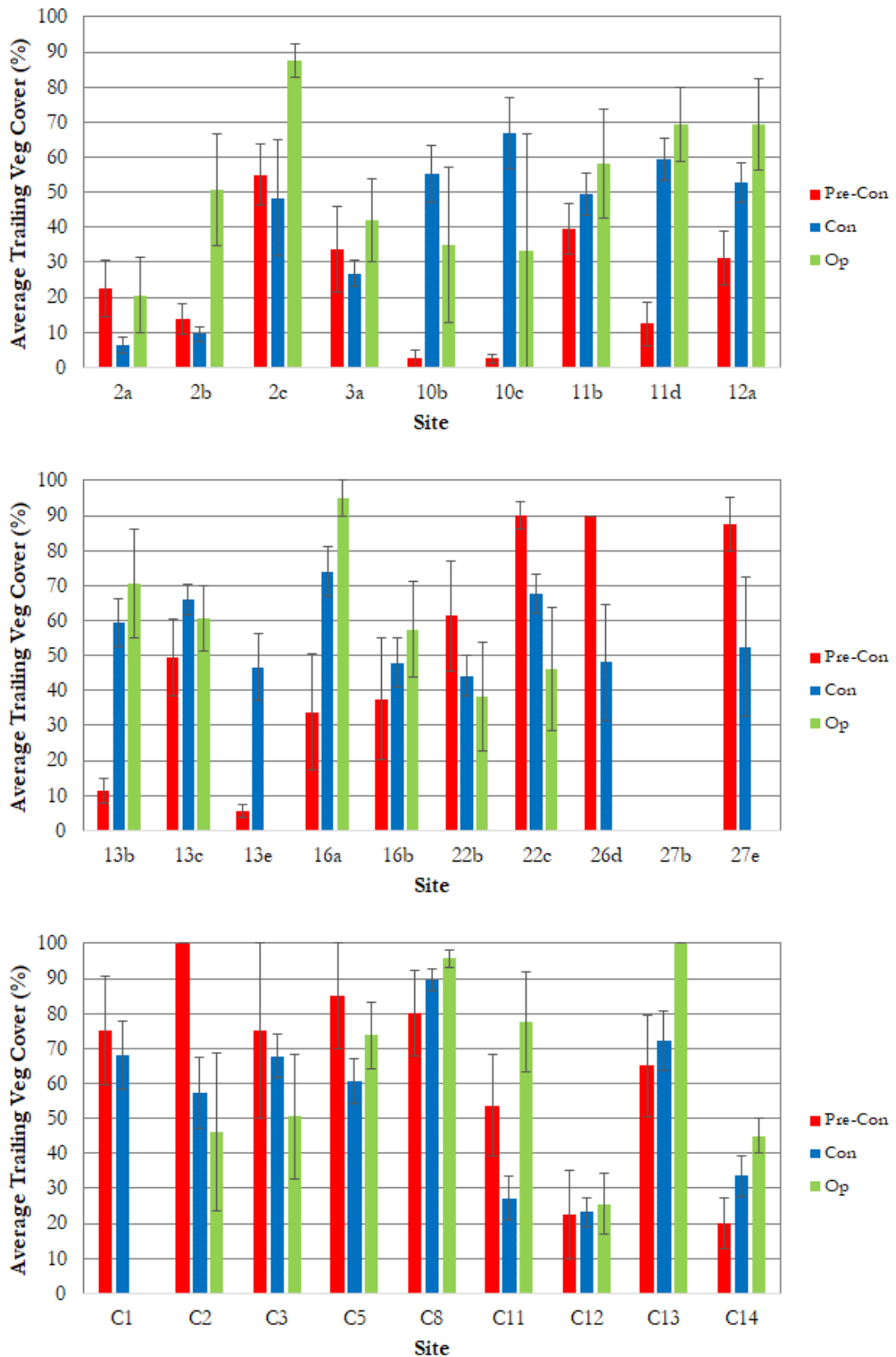
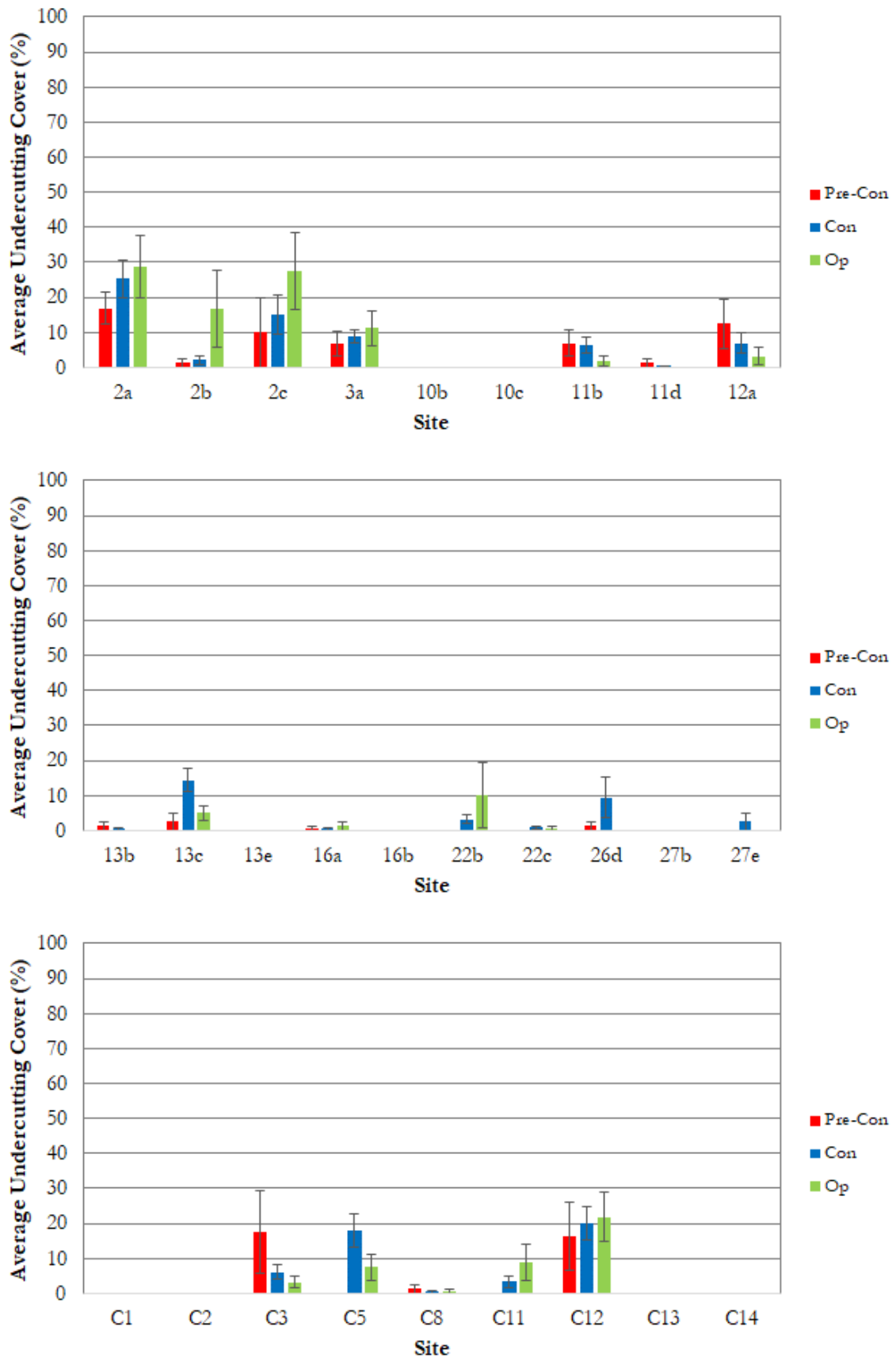


Figure A1 Average (\pm SE) habitat measurements at each site in the pre-construction and construction phases of monitoring



Appendix B

Construction Phase Fish Monitoring Results

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

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

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

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

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

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

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

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

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

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

* No survey - access restrictions.

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

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

* No survey - access restrictions.

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

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

* No survey - access restrictions.

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

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

* No survey - access restrictions.

Table B9. Summary of captures for all fishing methods at all impact sites during the July 2019 survey

<i>Scientific Name</i>	<i>Common Name</i>	<i>Site</i>																		
		2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e*	16a	16b	22b	22c	26d*	27b	27e
<i>Anguilla australis</i>	Shortfin Eel	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	31	0	0	9	2	0	14	9	4	3	0	0	0	0	4	10	0	0	1
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	29	0	14	0	6	0	0	0	0	0	0	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	26	0	0	45	5	0	0	0	0	0	0	0	0	5	11	12	0	0	3
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	0	0	0	4	0	0	0	0	0	0	0	0	0	0	18	31	0	0	1
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	1	
<i>Gambusia</i>	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

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

* No survey - access restrictions.

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

<i>Scientific Name</i>	<i>Common Name</i>	<i>Site</i>																		
		2a	2b	2c	3a	10b	10c	11b*	11d	12a	13b	13c	13e*	16a	16b	22b	22c	26d*	27b	27e
<i>Anguilla australis</i>	Shortfin Eel	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	3	0	0	14	10	0	0	0	5	0	0	0	0	0	9	7	0	0	2
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	75	0	0	0	6	0	0	0	0	0	0	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	8	0	0	86	3	0	0	0	0	0	0	0	0	95	50	65	0	0	6
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	13	3	0	0	1	
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	4	12	0	0	5	
<i>Gambusia</i>	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

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

* No survey - access restrictions.

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
<i>Ambassis agassizii</i>	Olive Perchlet	0	6	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anguilla australis</i>	Shortfin Eel	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	5	0	0	8	12	2	19	36	47	0	0	0	0	0	7	7	0	0	0
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	1	40	1	1	2	154	0	0	0	0	0	1	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	18	17	0	25	6	0	2	1	8	0	0	0	0	0	20	38	0	0	0
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	0	0	0	0	1	0	0	0	13	0	0	0	0	0	3	4	0	0	0
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
<i>Tandanus tandanus</i>	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carassius auratus</i>	Goldfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gambusia holbrooki</i>	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
<i>Ambassis agassizii</i>	Olive Perchlet	0	0	0	0	0	0	0	66	0	0	0	0	0	4	0	0
<i>Anguilla australis</i>	Shortfin Eel	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	1	0	0	4	0	0	4	13	0	4	9	17	0	0	0	0
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	0	0	0	18	0	1	7	1	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	12	1	0	32	23	12	37	170	31	1	3	1	0	42	0	0
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	11	0	0	8	28	0	22	9	4	0	0	0	0	2	0	0
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	10	0	0	6	1	0	6	0	0	0	0	0	0	0	0	0
<i>Tandanus tandanus</i>	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carassius auratus</i>	Goldfish	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
<i>Gambusia holbrooki</i>	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

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

Scientific Name	Common Name	Site															
		C1	C2	C3	C5	C8	C11	C12	C13	C14	OPP1	OPP2	OPP3	OPP4*	OPP5	OPP6	OPP7
<i>Ambassis agassizii</i>	Olive Perchlet	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	0
<i>Anguilla australis</i>	Shortfin Eel	0	0	0	1	1	0	1	0	0	6	2	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	0	0	0	3	0	0	3	75	0	7	12	10	0	0	0	0
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	0	0	0	8	0	1	0	1	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	26	0	0	8	101	18	554	40	3	6	10	15	0	12	0	0
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	21	2	0	20	35	14	164	0	0	0	0	0	0	0	0	0
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	6	0	0	3	2	1	9	0	0	0	0	0	0	0	0	0
<i>Tandanus tandanus</i>	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Carassius auratus</i>	Goldfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gambusia holbrooki</i>	Mosquito Fish	0	0	0	0	0	2	0	910	86	165	41	2	0	109	0	0

* No survey - access restrictions.

Table B17. Summary of captures for all fishing methods at all impact sites during the May 2021 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
<i>Ambassis agassizii</i>	Olive Perchlet	0	9	71	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anguilla australis</i>	Shortfin Eel	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	18	0	1	52	5	6	19	24	24	5	2	0	0	0	26	7	0	2	3
<i>Hypseleotris compressa</i>	Empire Gudgeon	2	0	0	3	34	18	24	0	18	3	9	0	0	0	0	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	24	8	8	84	8	1	10	1	4	2	3	0	0	2	41	25	0	0	0
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	0	0	5	19	0	0	0	4	4	0	0	0	2	0	13	30	0	0	0
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	14	0	0	0
<i>Tandanus tandanus</i>	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carassius auratus</i>	Goldfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gambusia holbrooki</i>	Mosquito Fish	49	47	17	21	116	6	40	2	1	39	0	0	0	0	0	0	0	0	0

* No survey - access restrictions.

Table B18. Summary of captures for all fishing methods at all control and Devils Pulpit sites during the May 2021 survey

Scientific Name	Common Name	Site															
		C1	C2	C3	C5	C8	C11	C12	C13	C14	OPP1	OPP2	OPP3	OPP4*	OPP5*	OPP6	OPP7
<i>Ambassis agassizii</i>	Olive Perchlet	0	0	0	0	0	0	0	14	35	7	2	2	0	0	0	0
<i>Anguilla australis</i>	Shortfin Eel	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	1	0	0	4	0	0	8	12	1	3	3	4	0	0	6	0
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	0	0	0	18	0	21	5	1	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	19	0	2	21	227	16	86	19	68	109	23	35	0	0	3	6
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	20	0	4	0	1	0	0	0	1
<i>Rhadinocentrus ornatus</i>	Ornate Rainbowfish	37	3	2	27	56	14	123	11	2	14	4	75	0	0	3	5
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	41	2	1	6	1	0	8	0	0	0	0	0	0	0	0	0
<i>Tandanus tandanus</i>	Eel-Tailed Catfish	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Carassius auratus</i>	Goldfish	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
<i>Gambusia holbrooki</i>	Mosquito Fish	0	0	0	0	0	6	0	97	18	146	126	18	0	0	2	8

* No survey - access restrictions.

Table B19. Summary of captures for all fishing methods at all impact sites during the September 2021 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
<i>Ambassis agassizii</i>	Olive Perchlet	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Anguilla australis</i>	Shortfin Eel	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
<i>Gobiomorphus australis</i>	Striped Gudgeon	20	8	0	31	53	0	43	25	100	18	0	0	0	0	14	27	0	0	3
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	24	0	0	157	0	16	0	52	12	0	0	0	0	1	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	99	97	0	83	2	0	10	27	0	0	1	0	0	0	23	26	0	0	0
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhadinocestrus ornatus</i>	Ornate Rainbowfish	0	0	0	17	0	0	0	8	2	0	0	0	0	0	0	0	0	2	1
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	0	0	0	0	0	0	0	0	3	0	0	0	3	0	36	14	0	1	0
<i>Tandanus tandanus</i>	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carassius auratus</i>	Goldfish	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gambusia holbrooki</i>	Mosquito Fish	14	80	0	19	32	5	22	0	2	12	0	0	0	0	0	0	0	0	0

* No survey - access restrictions.

Table B20. Summary of captures for all fishing methods at all control and Devils Pulpit sites during the September 2021 survey

Scientific Name	Common Name	Site															
		C1	C2	C3	C5	C8	C11	C12	C13	C14	OPP1	OPP2	OPP3	OPP4*	OPP5	OPP6	OPP7
<i>Ambassis agassizii</i>	Olive Perchlet	0	0	0	0	0	0	0	3	0	3	8	1	0	0	0	0
<i>Anguilla australis</i>	Shortfin Eel	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0
<i>Anguilla reinhardtii</i>	Longfin Eel	0	0	0	0	0	0	0	3	0	1	2	0	0	0	0	0
<i>Gobiomorphus australis</i>	Striped Gudgeon	5	0	0	22	0	0	10	36	0	1	32	13	0	0	0	0
<i>Hypseleotris compressa</i>	Empire Gudgeon	0	0	0	0	0	0	0	149	0	4	1	4	0	0	0	0
<i>Hypseleotris galii</i>	Firetail Gudgeon	28	3	4	37	283	0	623	32	0	60	122	91	0	0	0	0
<i>Melanotaenia duboulayi</i>	Crimson-spotted Rainbowfish	0	0	0	0	0	0	0	17	0	3	1	0	0	0	0	0
<i>Rhadinocestrus ornatus</i>	Ornate Rainbowfish	68	9	0	8	5	0	144	60	0	10	6	1	0	0	0	0
<i>Nannoperca oxleyana</i>	Oxleyan Pygmy Perch	75	34	1	8	9	0	16	0	0	0	0	0	0	0	0	0
<i>Tandanus tandanus</i>	Eel-Tailed Catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carassius auratus</i>	Goldfish	0	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0
<i>Gambusia holbrooki</i>	Mosquito Fish	0	0	0	0	0	0	0	313	0	200	291	0	0	0	0	0

* No survey - access restrictions.

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	Con Range	2021 Range	2022 Range	2023 Range
Unnamed waterway south of Serendipity Rd Ch. 11400	2a, 2b, 2c	Temp	(°C)	10.9 – 28.3	13.3 – 23.6	10.76 – 22.01	17.88 – 22.27		
		DO	(mg/L)	2.15 – 10.02	4.11 - 10	0 – 5.64	3.12 – 10.57		
		pH		3.32 – 6.9	5 – 6.9	4.98 – 7.1	5.44 – 7.51		
		Conductivity	(mS/cm)	0.068 – 2.148	0.009 – 0.368	0.093 - 0.578	0.089 – 0.597		
		Turbidity	(NTU)	0 - 80	0.9 - 118	0 - 446	7.9 – 32.5		
Tabbimoble floodway no. 1 Ch. 115300	3a	Temp	(°C)	10.9 – 28.3	12.8 - 24	10.11 – 19.4	16.93 – 18.38		
		DO	(mg/L)	2.15 – 10.02	1.3 - 8.07	4.4 - 7.71	5.55 – 5.8		
		pH		3.32 – 6.9	4.4 – 7.2	5.43 – 7.62	5.51 – 5.86		
		Conductivity	(mS/cm)	0.068 – 2.148	0.009 – 0.140	0.089 - 0.331	0.112 – 0.163		
		Turbidity	(NTU)	0 - 80	18.9 – 132	0 - 17	11		
Unnamed waterway south of MacDonalDs Ck Ch. 134600	10b, 10c	Temp	(°C)	10.9 – 28.3	16.6 - 29	11.11 – 21.7	17.04 – 23.96		
		DO	(mg/L)	2.15 – 10.02	3.17 - 10	0.58 - 6.32	0.09 – 14.33		
		pH		3.32 – 6.9	4 – 9.3	4.7 - 7.06	4.9 – 6.02		
		Conductivity	(mS/cm)	0.068 – 2.148	0.102 – 0.537	0.249 - 0.581	0.13 – 0.474		
		Turbidity	(NTU)	0 - 80	1.3 - 800	3.8 - 28.8	0 – 3.8		
MacDonalDs Ck Tributary Ch. 135200, 135530 and 136450	11b, 11d, 22b, 22c	Temp	(°C)	10.9 – 28.3	15.4 – 26.7	10.29 - 24.69	15.36 – 22.03		
		DO	(mg/L)	2.15 – 10.02	2.27 – 8.9	0.74 - 9.46	1.31 – 5.45		
		pH		3.32 – 6.9	3.8 – 8.9	3.44 - 6.44	3.82 – 5.63		
		Conductivity	(mS/cm)	0.068 – 2.148	0.092 – 0.606	0.131 - 0.237	0.115 – 0.227		
		Turbidity	(NTU)	0 - 80	2.4 - 138	0 - 212	0 – 6.7		
MacDonalDs Ck Ch. 136600	12a	Temp	(°C)	10.9 – 28.3	14.9 - 26	12.89 - 19.72	16.26 – 17.76		
		DO	(mg/L)	2.15 – 10.02	1.7 – 8.1	0.43 – 2.74	2.03 – 2.48		
		pH		3.32 – 6.9	3.6 – 6.3	2.72 – 6.41	4.48 – 5.58		
		Conductivity	(mS/cm)	0.068 – 2.148	0.164 – 0.406	0.25 – 0.41	0.148 – 0.331		
		Turbidity	(NTU)	0 - 80	0 - 14	0 - 41.6	0		
Broadwater NP Swampland	16a, 16b, 27b, 27c	Temp	(°C)	10.9 – 28.3	18.6 – 21.45	9.92 - 21.38	14.2 – 21.75		
		DO	(mg/L)	2.15 – 10.02	1.83 – 5.39	0.62 - 10.28	0.2 – 10.95		

Location	Sites	Parameter	Units	OPP Range	Pre-Con Range	Con Range	2021 Range	2022 Range	2023 Range
Ch. 139000		pH		3.32 – 6.9	4.15 – 4.63	3.7 - 5.91	3.71 – 6.24		
		Conductivity	(mS/cm)	0.068 – 2.148	0.128 – 0.171	0.116 - 0.571	0.098 – 0.412		
		Turbidity	(NTU)	0 - 80	0 - 703	0 - 64.2	0 – 18.8		
Montis Gully Tributary 1 Ch. 141180 and 141850	13b, 13c, 13e, 26d	Temp	(°C)	10.9 – 28.3	17.23 – 30.9	13.33 - 24.6	13.7 – 24.5		
		DO	(mg/L)	2.15 – 10.02	2.1 – 9.4	0.29 - 4.23	0.04 – 1.1		
		pH		3.32 – 6.9	3.7 - 7	3.44 – 6.8	3.67 – 6.36		
		Conductivity	(mS/cm)	0.068 – 2.148	0.026 – 0.209	0.137 - 0.818	0.138 – 0.293		
		Turbidity	(NTU)	0 - 80	0 - 225	0 - 90	7.6 – 9.1		
W of Bundjalung NP Approximately 4 km east of Ch. 110000	C13, C14	Temp	(°C)	10.9 – 28.3	18.09 – 19.11	11.79 - 17.4	17.65 – 19.5		
		DO	(mg/L)	2.15 – 10.02	2.24 – 4.38	1.34 - 10.97	0.89 – 5.38		
		pH		3.32 – 6.9	4.56 – 5.47	4.84 - 6.92	5.62 – 6.22		
		Conductivity	(mS/cm)	0.068 – 2.148	0.086 – 0.112	0.063 - 0.155	0.065 – 0.134		
		Turbidity	(NTU)	0 - 80	0 – 8.7	0 - 18.9	0 – 0		
Broadwater NP 6.5 km east of Ch.13000	C11, C12	Temp	(°C)	10.9 – 28.3	15.91 – 18.49	9.73 - 29.36	17.08 – 17.83		
		DO	(mg/L)	2.15 – 10.02	2.9 – 5.59	1.76 - 8.35	2.28 – 4.04		
		pH		3.32 – 6.9	3.85 - 4	3.79 - 4.54	4.11 – 4.33		
		Conductivity	(mS/cm)	0.068 – 2.148	0.124 – 0.149	0.106 - 0.278	0.081 – 0.145		
		Turbidity	(NTU)	0 - 80	0 – 2.3	0 - 6.8	0 – 0.8		
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	8.15 - 20. 2	13.36 – 23.71		
		DO	(mg/L)	2.15 – 10.02	4.58 – 4.69	2.08 - 5.42	0.96 – 5.5		
		pH		3.32 – 6.9	3.7 – 4.22	3.31 - 4.47	3.83 – 4.39		
		Conductivity	(mS/cm)	0.068 – 2.148	0.115 – 0.158	0.013 - 0.256	0.089 – 0.254		
		Turbidity	(NTU)	0 - 80	0 - 0	0 - 37.6	0 – 0		
Broadwater NP 1 km east of Ch 138000	C1, C3	Temp	(°C)	10.9 – 28.3	17.2 - 18.91	12.33 - 23.66	17.74 – 20.76		
		DO	(mg/L)	2.15 – 10.02	4.55 - 9.18	1.35 - 9.65	2.82 – 7.88		
		pH		3.32 – 6.9	3.97 – 4.49	3.42 - 4.27	3.46 – 4.15		
		Conductivity	(mS/cm)	0.068 – 2.148	0.089 - 0.176	0.100 - 0.306	0.091 – 0.231		
		Turbidity	(NTU)	0 - 80	0 – 1.4	0 - 28.5	0 - 3		

Location	Sites	Parameter	Units	OPP Range	Pre-Con Range	Con Range	2021 Range	2022 Range	2023 Range
Broadwater NP 2 km east of 136400	C8	Temp	(°C)	10.9 – 28.3	17.98	12.18 - 19.02	17.51 – 22.33		
		DO	(mg/L)	2.15 – 10.02	5.77	2.46 - 9.96	1.36 – 4.56		
		pH		3.32 – 6.9	3.95	3.21 - 4.07	3.57 – 3.93		
		Conductivity	(mS/cm)	0.068 – 2.148	0.236	0.269 - 0.458	0.176 – 0.263		
		Turbidity	(NTU)	0 - 80	12.1	0 - 12.2	0		
Tabbimoble Channel 2	OPP1, OPP2, OPP4, OPP7	Temp	(°C)	10.9 – 28.3	7.86 – 18.66	8.91 – 16.15	16.04 – 17.54		
		DO	(mg/L)	2.15 – 10.02	3.17 – 8.74	1.89 – 5.83	3.72 – 8.2		
		pH		3.32 – 6.9	4.79 – 6.92	5.06 – 6.8	5.35 – 6.93		
		Conductivity	(mS/cm)	0.068 – 2.148	0.081 – 0.194	0.104 – 0.23	0.039 – 0.215		
		Turbidity	(NTU)	0 - 80	1.3 – 44.3	1.8 – 12.1	10.3 – 58.5		
Tabbimoble Channel 3	OPP3, OPP6	Temp	(°C)	10.9 – 28.3	11.66 – 19.14	11.99 – 18.14	16.59 – 18.46		
		DO	(mg/L)	2.15 – 10.02	4.64 – 6.53	0.79 - 5.3	3.89 – 8.61		
		pH		3.32 – 6.9	4.99 – 6.11	5.87 – 6.56	5.4 – 6.28		
		Conductivity	(mS/cm)	0.068 – 2.148	0.128 – 0.215	0.171 – 0.185	0.041 – 0.2		
		Turbidity	(NTU)	0 - 80	0 – 6.5	0 - 0	5.3 – 44.7		

