

Woolgoolga to Ballina Pacific Highway Upgrade

Threatened Fish Monitoring Program Annual Report 2019

Construction Phase Report



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Client Name: TfNSW

Project Manager: Chris Thomson

Author: Mathew Birch

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Woolgoolga to Ballina Pacific
Highway Upgrade
Threatened Fish Monitoring Program Annual
Report 2019

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Introduction

The following report summarises the methods and results from the third year of threatened fish monitoring undertaken during the construction phase of the Woolgoolga to Ballina Pacific Highway upgrade (W2B Upgrade).

1.1 Background

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

1.2 Objectives

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

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

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

1.3 Species Profile

1.3.1 Oxleyan Pygmy Perch (OPP)

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

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

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

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

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

From Knight & Arthington (2008)



Plate 1.1 OPP captured at site 27e during the September 2019 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 threatened fish monitoring 27 and 28 sites were sampled in May 2017 and September 2017 respectively. In the second year of monitoring and a reduced number of sites were sampled due to landholder restrictions upon access to sites 11b, 13e and 26b. In the current monitoring period 7 sites, previously monitored as part of the Devils Pulpit Pacific Highway upgrade threatened fish monitoring (GeoLINK 2015), were added to the survey.

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

The study area and location of sampling sites are displayed in **Illustrations 2.1, 2.2, 2.3** and **2.4**. A list of sampling locations is presented in **Table 2.1**.

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

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

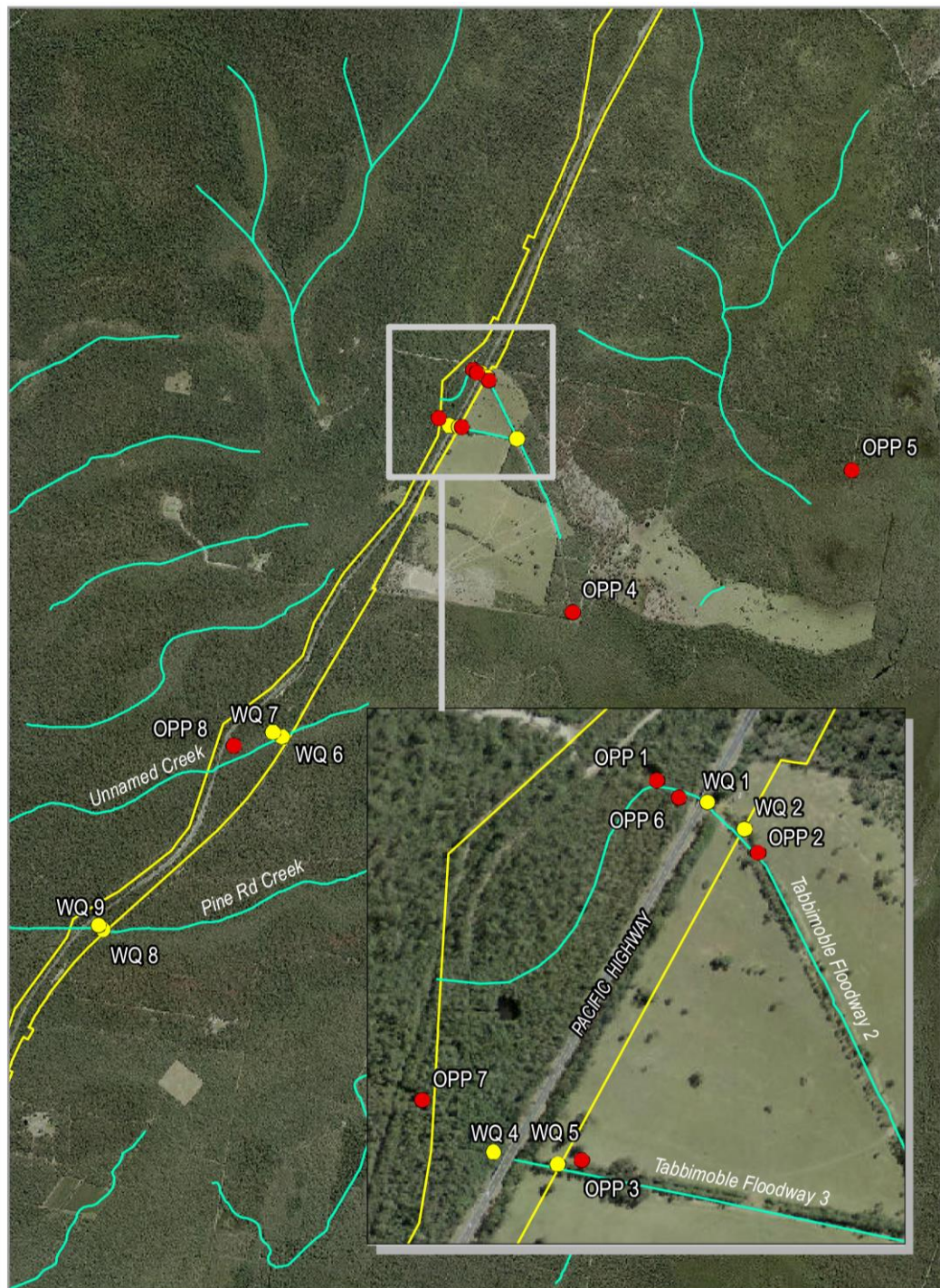
<i>Section</i>	<i>Waterway</i>	<i>Sites</i>	<i>Chainage</i>	<i>Notes</i>
DP	Tabbimoble 3 Channel	OPP3, OPP7	110500	Constructed channel that drains floodwaters from the west of the Pacific Highway. Confluence with Tabbimoble 2 Channel 300m downstream of the highway. Permanent Class 1 stream with intermittent 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.
7	Tabbimoble floodway no. 1	3a	115300	Drains from headwaters approximately 1.5km upstream. Intermittent Class 1 stream. OPP previously identified. 1 site at impact.

Section	Waterway	Sites	Chainage	Notes
8	Unnamed waterway south of MacDonalds Ck	10b, 10c	134600	Class 1 waterway, draining flood prone land connecting with Broadwater NP. OPP previously identified. 2 sites , impact and downstream. The downstream site frequently dries out.
8	MacDonalds Ck tributary	11b, 11d	135200, 135530, 136450	Manmade drains connecting cane fields and flood prone land in Broadwater NP with a small natural Class 1 waterway. OPP previously identified. 2 sites , impact and downstream.
8	MacDonalds Ck	12a	136600	Class 1 waterway draining flood prone land connecting with Broadwater NP. OPP previously identified. 1 site , at impact.
8	Various dams south of Broadwater National Park	22b, 22c	136700 - 137900	Two manmade dams and excavations on private property. OPP previously identified. Each individual waterbody sampled at 1 site only. Both located E (downstream) of impact.
9	Broadwater NP Swampland	16a, 16b	139000	Series of wetland pools throughout protected wallum country. Class 1 stream. OPP previously identified. 2 sites one impact, one to the east.
9	Various potential refuges	27b, 27e	139200 - 140500	Series of wetland pools throughout protected wallum country. Class 1 stream. OPP previously identified. 2 sites all located E of the impact.
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**.

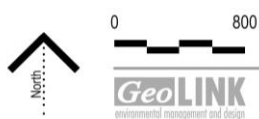
Access to some sites was restricted in the current monitoring period. Sites 13e, 26b and OPP4 could not be accessed for either survey in 2019 due to landholder restrictions. Site 11b could not be accessed in September 2019 because the landholder did not respond.

A number of sites were dry during one or both surveys in 2019. Sites OPP5, OPP6, OPP7, 2c, and C2 were dry during both surveys. Sites 2b, 10c, 16a, C3, C11 and C14 were dry during the September survey only.



LEGEND

- OPP
- WQ
- Drainage line
- Approved project boundary



Study Area and Site Location

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

Illustration 2.1

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

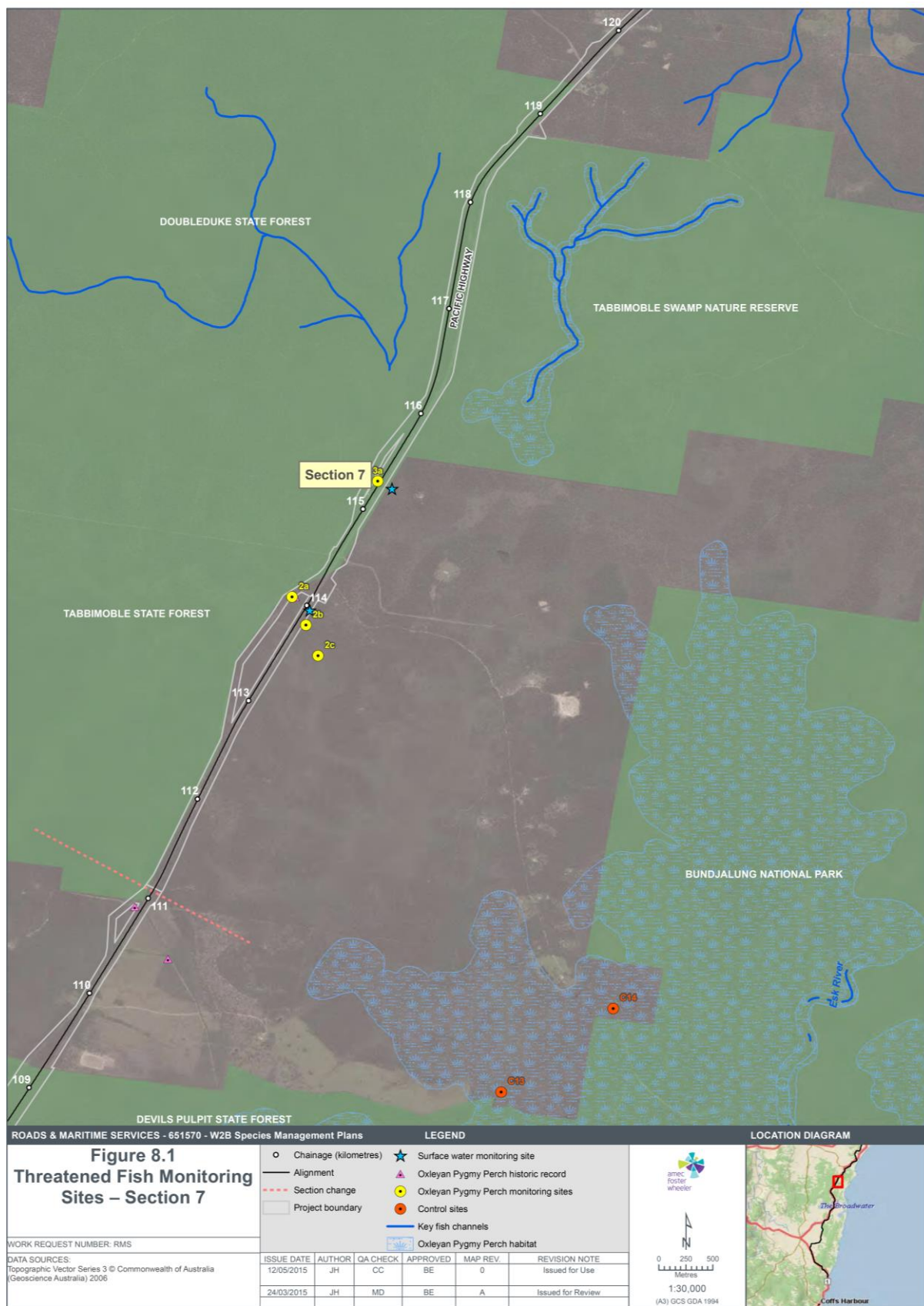


Illustration 2.2 Map of Section 7 sampling sites taken from the TFMP (RMS 2015)

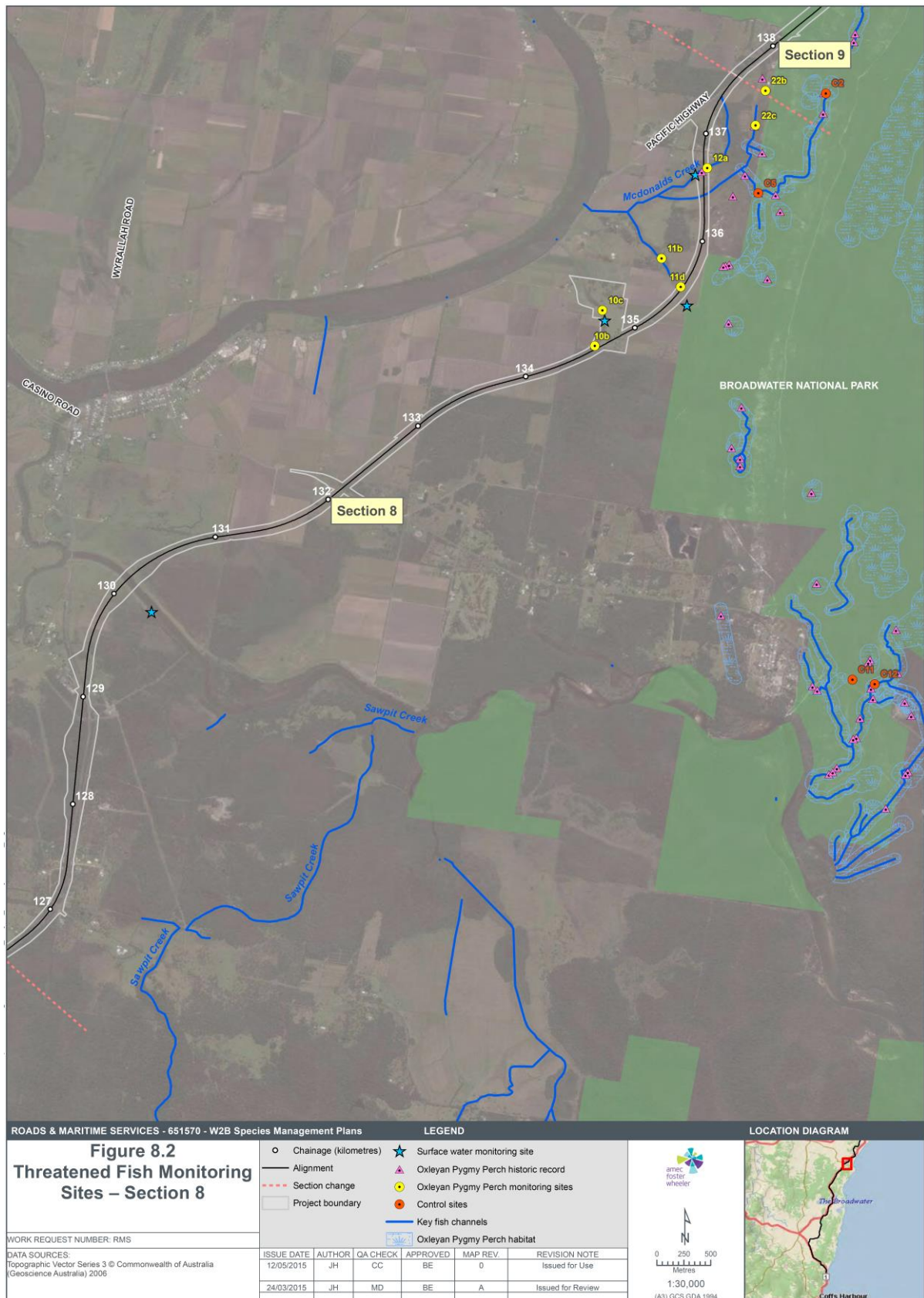


Illustration 2.3 Map of Section 8 sampling sites taken from the TFMP (RMS 2015)



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 July 2019 and September 2019.

The monitoring scheduled for May 2019 was delayed in the hope that rainfall would increase the number of sites that could be surveyed, after a site inspection in March 2019 revealed that a number of sites were dry (Birch 2019). Significant rainfall in June 2019 failed to fill some of the dry sites but monitoring progressed regardless.

Monitoring was scheduled to avoid the OPP breeding season, which peaks between October and April, and timed to ensure optimum conditions with respect to water levels.

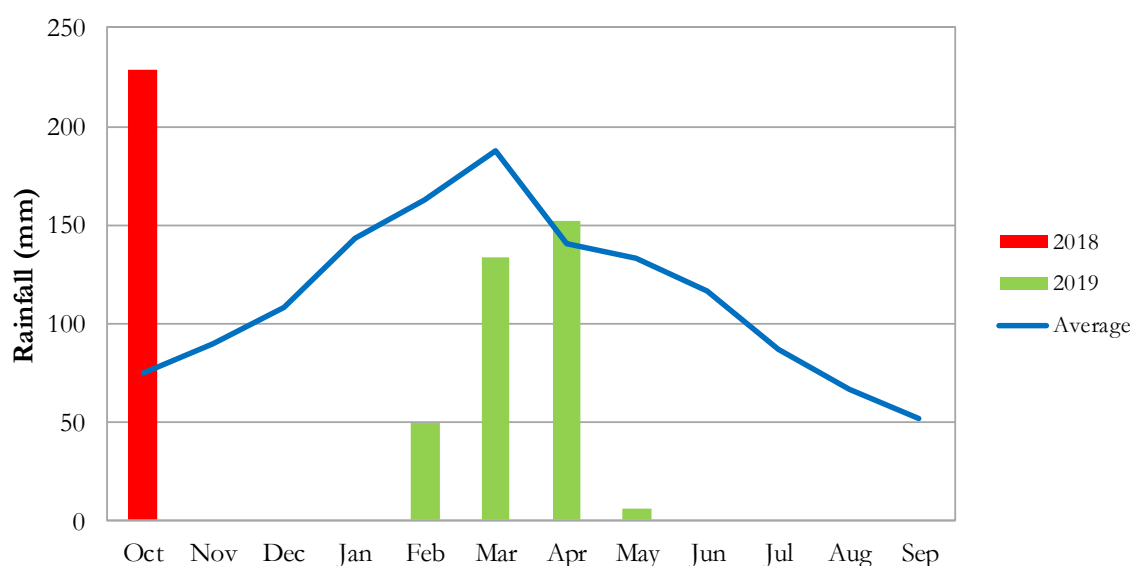


Figure 2.1 Mean monthly rainfall and total monthly rainfall from the Woodburn Bureau of Meteorology station for the current reporting period.

The long-term rainfall was below average for all but 2 months of this reporting period and there was no rain recorded at Woodburn for 7 months of the reporting period (**Figure 2.1**). The total annual rainfall for the reporting period was approximately 40% of the annual average. The months of surveys were characterised by no rain. Most of the sites did not have significant flows (> 0.1 m/s) at the time of the surveys and there was no water for sampling activities at many sites, particularly in the September 2019 survey. Sites that were dry at the time of the surveys are displayed in **Tables 2.2** and **2.3**.

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 July 2019

<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	275	50	12	1	601
6	OPP2	225	50	12	1	617
6	OPP3	225	50	12	1	603
6	OPP4	No Access				
6	OPP5	No Water				
6	OPP6	No Water				
6	OPP7	No Water				
7	2a	150	50	12	2	470
7	2b	100	50	12	2	204
7	2c	No Water				
7	3a	200	50	15	1	603
8	10b	250	50	15	1	601
8	10c	150	50	15	2	594
8	11b	150	50	15	1	601
8	11d	125	50	15	1	619
8	12a	150	50	12	1	607
9	13b	150	50	15	1	604
9	13c	200	50	15	1	601
9	13e	No Access				
9	16a	150	50	15	1	608
9	16b	250	50	15	1	603
8	22b	250	50	12	1	607
8	22c	250	50	12	1	605
9	26d	No Access				
9	27b	300	50	15	1	606
9	27e	250	50	15	1	604
Control	C1	300	50	15	1	606
Control	C2	No Water				
Control	C3	150	50	15	1	607
Control	C5	150	50	12	1	600
Control	C8	250	50	15	1	600
Control	C11	125	50	12	2	408
Control	C12	175	50	15	1	657
Control	C13	175	50	12	1	607
Control	C14	100	50	12	2	240

Table 2.3 Details of electrofisher settings and effort at each site in the September 2019 sampling

<i>Section</i>	<i>Site</i>	<i>Voltage (V)</i>	<i>Pulse Freq (Hz)</i>	<i>Duty Cycle (%)</i>	<i>Passes</i>	<i>Seconds Pulsed</i>
6	OPP1	150	50	15	1	602
6	OPP2	150	50	15	1	600
6	OPP3	150	50	15	1	601
6	OPP4	No Access				
6	OPP5	No Water				
6	OPP6	No Water				
6	OPP7	No Water				
7	2a	Dip net only – almost dry				
7	2b	No Water				
7	2c	No Water				
7	3a	150	50	15	1	631
8	10b	175	50	15	1	607
8	10c	No Water				
8	11b	No Access				
8	11d	100	50	12	1.5	603
8	12a	100	50	12	1.75	607
9	13b	75	50	15	2	509
9	13c	150	50	15	1	610
9	13e	No Access				
9	16a	No Water				
9	16b	150	50	15	2	793
8	22b	175	50	15	1	605
8	22c	175	50	15	1	601
9	26d	No Access				
9	27b	125	50	15	1	602
9	27e	100	50	15	1	624
Control	C1	200	50	15	1	608
Control	C2	No Water				
Control	C3	No Water				
Control	C5	150	50	15	2	251
Control	C8	100	50	15	1.25	607
Control	C11	No Water				
Control	C12	150	50	15	2	601
Control	C13	175	50	15	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 July 2019 survey approximately 183 hours of fish trapping and 15,283 seconds of electrofishing were used. During the September 2019 survey approximately 152 hours of fish trapping and 11,266 seconds of electrofishing were used.

There were some sites where fish capture was not attempted during the two surveys this year due to either a lack of water at the time of the survey or changing access permission to private lands. These sites include:

- Sites OPP5, OPP6, OPP7, 2c and C2, which were dry at the time of the July 2019 survey.
- Sites OPP4, 13e and 26d, which had access restrictions at the time of the July 2019 survey.
- Sites OPP5, OPP6, OPP7, 2b, 2c 10c, 16a, C2, C3, C11 and C14, which were dry at the time of the September 2019 survey.
- Sites OPP4, 11b, 13e and 26d, which had access restrictions at the time of the September 2019 survey.

In the July 2019 survey a total of 808 fish from nine species were captured. Of the total number of fish captured, 712 individuals from nine species were captured using the electrofisher and 96 individuals from six species were captured using fish traps.

In the September 2019 survey a total of 1,347 fish from eight species were captured. Of the fish captured during the September 2019 survey 673 individuals from eight species were captured using the backpack electrofisher and 674 individuals from six species were captured using bait traps.

In the July 2019 survey 8 individual OPP were captured. Of these, 6 were captured using the backpack electrofisher and 2 in fish traps. In the July 2019 survey OPP were captured at 3 of the 24 impact sites and at 1 of the 11 control sites.

In the September 2019 survey 33 individual OPP were captured. Of these 26 were captured using the backpack electrofisher and 7 in fish traps. In the September 2019 survey OPP were captured at 3 of the 24 impact sites and at 2 of the 11 control sites.

The most commonly captured species of fish during the July 2019 survey was the Mosquitofish (*Gambusia holbrooki*). Individuals of this species accounted for approximately 40 per cent of the total number of fish captured in the July 2019 survey. The most commonly captured species of fish during the September 2019 survey was the Firetail Gudgeon (*Hypseleotris galii*), accounting for approximately 54 per cent of the fish captured. Overall, OPP accounted for approximately 1 per cent of the fish captured in the July 2019 survey and approximately 2 per cent of the fish captured during the September 2019 survey.

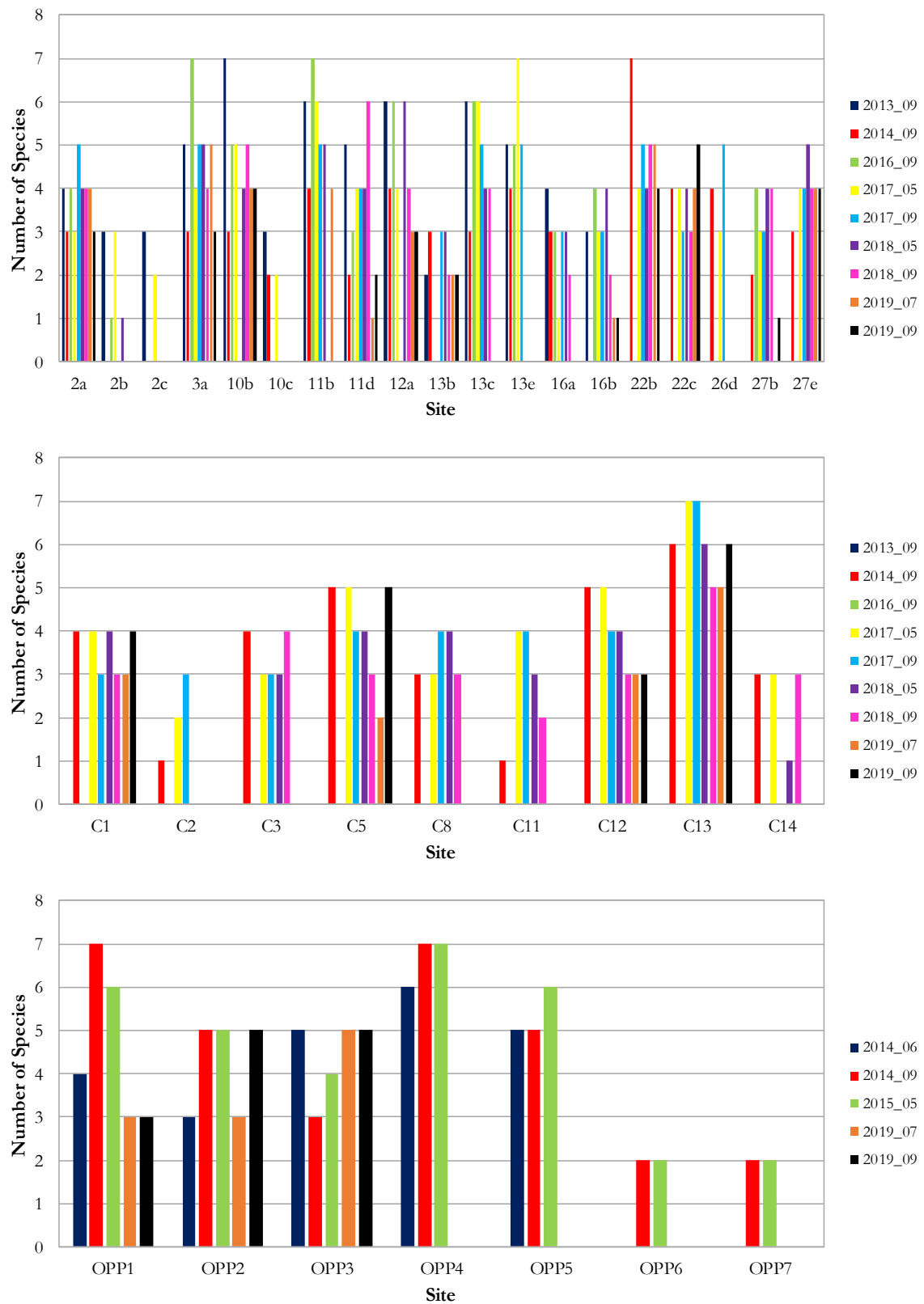


Figure 3.1 Taxonomic richness of captured fish at all sites since 2013 (pre-construction data from GeoLINK 2014, 2015a & 2015b)

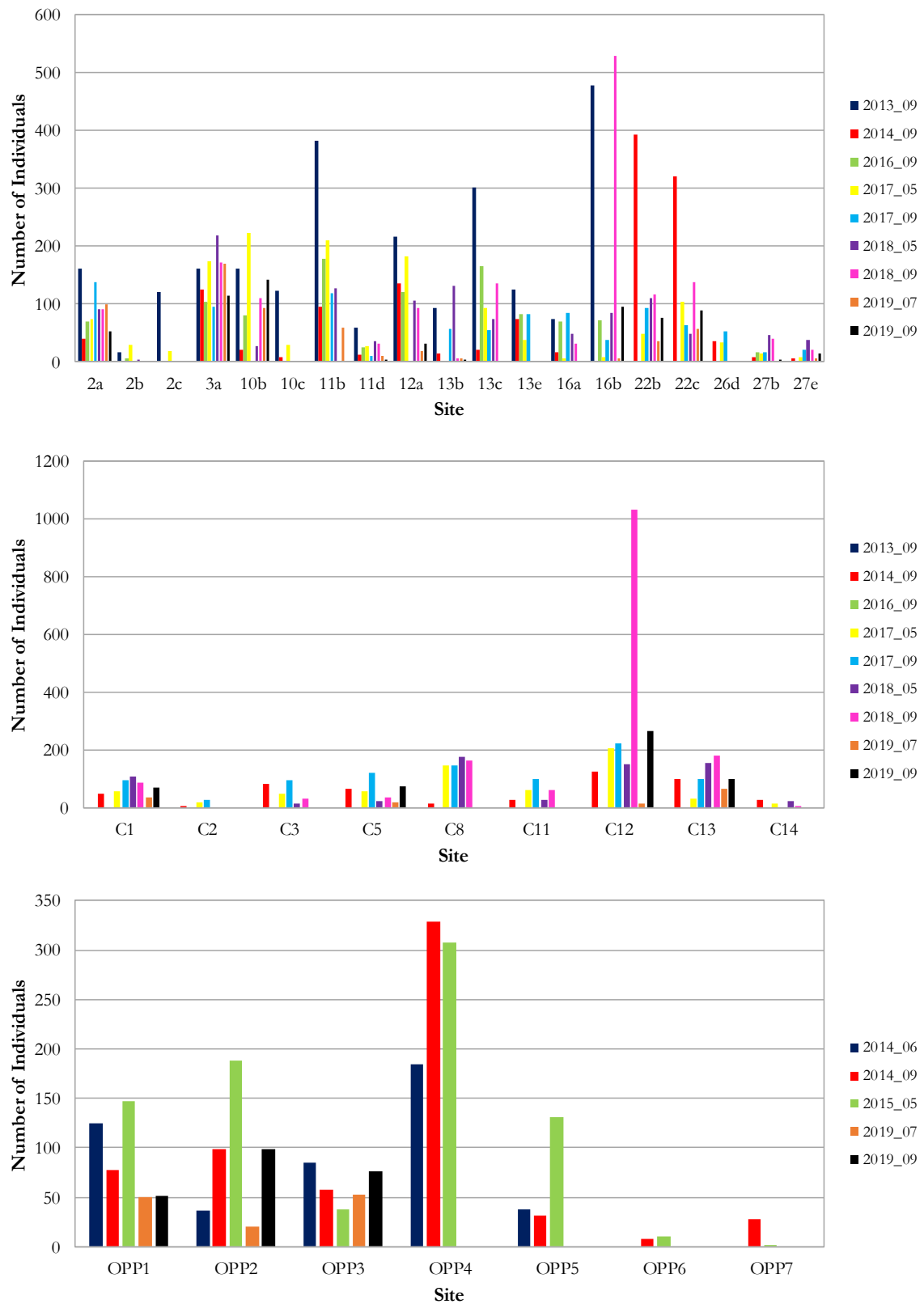


Figure 3.2 Abundance of captured fish at all sites since 2013 (pre-construction data from GeoLINK 2014, 2015a & 2015b)

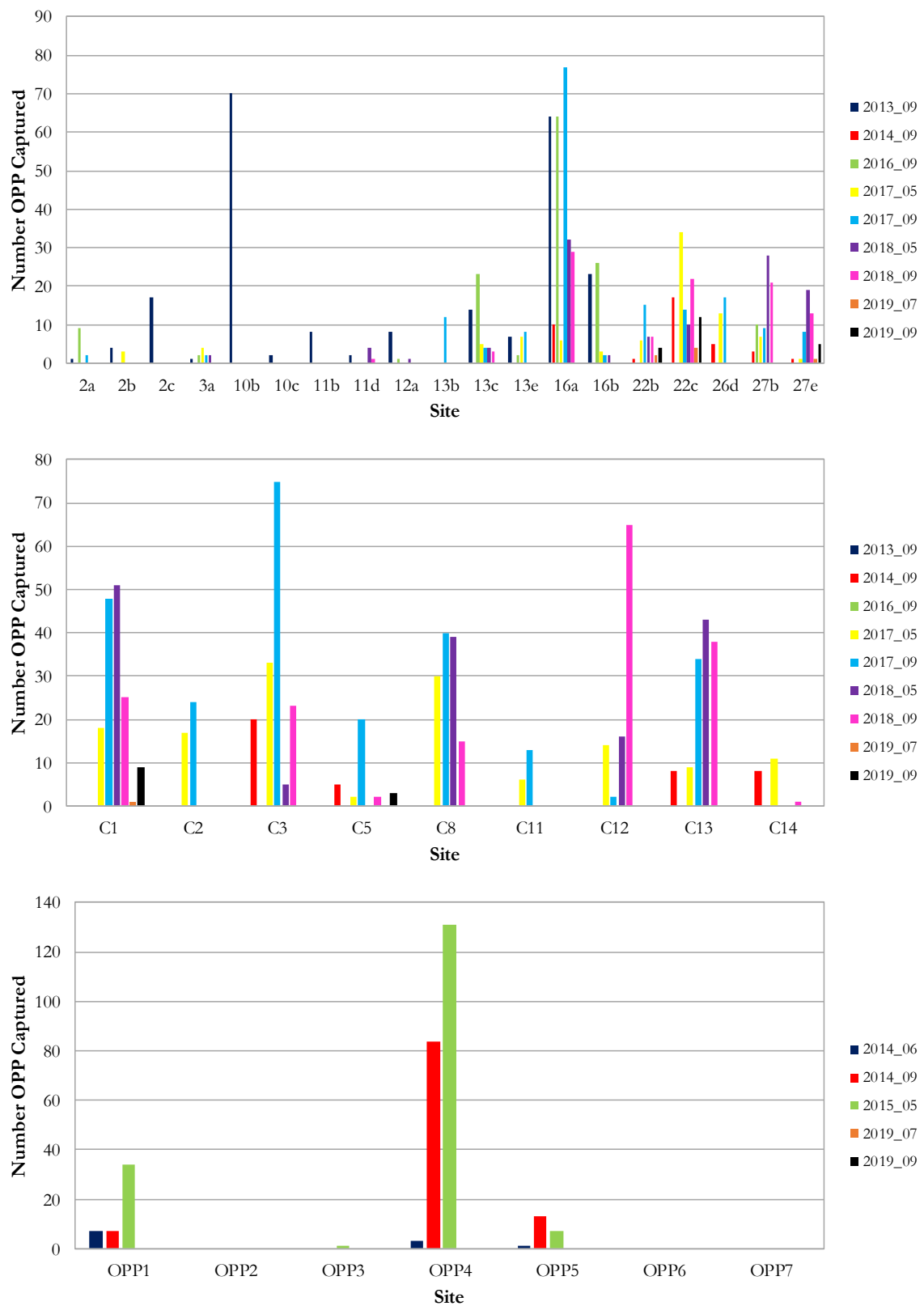


Figure 3.3 Number of OPP captured at all sites since 2013 (pre-construction data from GeoLINK 2014, 2015a & 2015b)

There has been a moderate degree of variation at most impact and control sites throughout the pre-construction and ongoing monitoring in terms of fish diversity and a high degree of variation in terms of abundance (**Figures 3.1, 3.2 and 3.3**). In the 2 surveys this year between one and six species were captured at each site where surveys were possible, with the exception of sites 13c and C8, where no fish were captured in September 2019, and sites 2b, 10c, 13c, 16a 27b, C3, C8, C11 and C14, where no fish were captured in July 2019. All of the sites where no fish were captured except 13c were found to be completely dry prior to the survey season in March 2019 (Birch 2019). In addition, the rainfall between March 2019 and September 2019 would not have been sufficient to provide fish passage between drought refuges and these sites. In the July 2019 survey the sites with the highest diversity of captured fish were 3a, 22b, C13 and OPP3. In the September 2019 survey the impact sites with the highest diversity of captured fish were C13, 22c, C5, OPP2 and OPP3.

Between 0 and 170 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 July 2019 survey were 3a, 2a and 10b. In the September 2019 survey the impact sites where the most individual fish were captured were 10b, 3a and 16b.

The total number of individual fishes captured at the control sites varied between 0 and 266, with the largest numbers of fish captured at C13 and C1 in the July 2019 and C12, C13 and C1 in the September 2018 surveys.

The numbers of OPP captured at each site are presented in **Figure 3.3**. There is a large degree of variation over time evident at both impact and control sites. The numbers of OPP captured during this reporting period were very low and OPP were only captured at 5 sites in the two surveys this year (compared to 22 sites in 2017 and 17 sites in 2018). Many of the sites where OPP weren't captured were either sites that were found to be dry in March 2019 (Birch 2019) or sites that were dry during the surveys. This included sites 2b, 2c, 10c, 11d, 13b, 16a, 27b, C2, C3, C8, C11 and C14). Other sites where OPP weren't captured included sites where the dissolved oxygen concentrations measured in March 2019 weren't sufficient to support fish populations (sites 13c and 16b, Birch 2019). As discussed, the rainfall conditions between March 2019 and September 2019 would not have generated the overland flows required for OPP to re-colonise these sites from the available drought refuges.

The full results of the May 2019 and September 2019 fish surveys are presented in **Appendix B**.

3.2 Water Quality

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

Table 3.1 Results of water quality sampling from all sites for the July 2019 survey

<i>Site</i>	<i>Date</i>	<i>Temperature</i> °C	<i>pH</i>	<i>Conductivity</i> mS/cm	<i>Turbidity</i> NTU	<i>DO</i> mg/L	<i>DO%</i> %
OPP1	18/07/2019	8.91	5.06	0.162	7.8	1.89	16.9
OPP2	18/07/2019	10.14	5.86	0.209	3.3	3.78	34.8
OPP3	18/07/2019	11.99	6.41	0.173	0	0.79	7.6
OPP4							
OPP5	18/07/2019	No Water					
OPP6	18/07/2019	No Water					
OPP7	18/07/2019	No Water					
2a	15/07/2019	10.76	6.44	0.127	36.7	1.26	11.8
2b	15/07/2019	10.88	6.92	0.539	22.5	4.96	46.4
2c	15/07/2019	No Water					
3a	24/07/2019	10.11	6.42	0.331	17	5.44	49.9
10b	17/07/2019	11.11	6.21	0.456	0	3.18	29.9
10c	17/07/2019	13.37	6.08	0.281	18.3	6.07	60
11b	23/07/2019	17.48	5.47	0.209	35.3	4.13	44.5
11d	17/07/2019	16.76	5.53	0.195	0	3.35	35.6
12a	19/07/2019	12.89	5.08	0.41	5.7	2.11	20.6
13b	22/07/2019	16.18	4.38	0.286	27.5	3.51	36.8
13c	22/07/2019	14.39	3.48	0.458	1.9	2.55	25.9
13e	22/07/2019	No Access					
16a	23/07/2019	11.69	3.76	0.306	0	7.89	75.1
16b	22/07/2019	11.57	4.92	0.347	0	4.05	38.5
22b	16/07/2019	14.44	4.67	0.178	0	6.13	62
22c	16/06/2019	10.29	4.1	0.21	104	3.33	30.7
26d	22/07/2019	No Access					
27b	19/07/2019	9.92	4.14	0.277	0	3.14	28.7
27e	23/07/2019	11.09	4.29	0.24	1.1	3.03	28.5
C1	23/07/2019	12.33	4.2	0.147	0	3.52	34
C2	22/07/2019	No Water					
C3	23/07/2019	12.97	3.74	0.306	0	9.65	94.6
C5	16/07/2019	8.15	3.73	0.256	0	3.29	28.9
C8	22/07/2019	13.33	3.76	0.413	0	9.96	98.4
C11	16/07/2019	14.67	4.25	0.278	0	5.94	60.5
C12	17/07/2019	9.73	4.21	0.262	0	5.09	46.3
C13	15/07/2019	11.79	6.92	0.105	3.5	3.72	35.5
C14	15/07/2019						

Red Text Outside of the known range of OPP

Blue Text Within a range thought to provide OPP with a competitive advantage

Table 3.2 Results of water quality sampling from all sites for the September 2019 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	19/09/2019	16.01	6.04	0.148	7.2	3.76	39.3
OPP2	19/09/2019	15.12	6.8	0.23	3.8	5.53	56.8
OPP3	19/09/2019	16.06	6.56	0.185	0	0.98	10.2
OPP4	23/09/2019	No Access					
OPP5	19/09/2019	No Water					
OPP6	19/09/2019	No Water					
OPP7	19/09/2019	No Water					
2a	16/09/2019	20.47	6.48	0.132	446	0	0
2b	16/09/2019	No Water					
2c	16/09/2019	No Water					
3a	20/08/2019	19.4	7.62	0.324	12.9	7.71	86.3
10b	18/09/2019	16.74	7.06	0.581	10.8	3.08	32.7
10c	18/09/2019	No Water					
11b	23/09/2019	No Access					
11d	18/09/2019	17.83	6.44	0.189	25	1.77	19.2
12a	18/09/2019	19.58	6.41	0.374	12.3	2.74	30.8
13b	18/09/2019	19.84	6.8	0.62	31.3	0.29	3.3
13c	23/09/2019	24.6	3.55	0.818	54.4	2.93	36
13e	18/09/2019	No Access					
16a	18/09/2019	No Water					
16b	20/09/2019	16.22	5.91	0.302	57.2	3.9	41
22b	17/09/2019	18.26	4.7	0.227	53.1	5.98	65.4
22c	17/09/2019	15.47	4.35	0.237	32.3	4.21	43.6
26d	18/09/2019	No Access					
27b	18/09/2019	17.69	4.49	0.249	0	6.83	73.9
27e	23/09/2019	21.02	4.88	0.245	0	8.02	92.4
C1	17/09/2019	17.61	4.27	0.154	0.3	6.18	66.8
C2		No Water					
C3		No Water					
C5	17/09/2019	13.99	3.88	0.206	1.8	3.05	30.6
C8	23/09/2019	19.02	3.97	0.458	12.2	7.38	82
C11		No Water					
C12	16/09/2019	18.66	4.53	0.252	0	3.8	42
C13	16/09/2019	14.55	5.43	0.137	4.1	1.34	13.6
C14	16/09/2019	No Water					

Red Text Outside of the known range of OPP

Blue Text Within a range thought to provide OPP with a competitive advantage

The results of the water quality measurements show that, at the time of sampling, the water quality at most sites was within the known physico-chemical tolerances of OPP (refer to **Table 1.1**). 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 pH, dissolved oxygen concentration, temperature and turbidity.

The dissolved oxygen (DO) concentrations at some sites were below the levels thought to be ideal for fish survival and function (> 4-5 mg/L). However, as stated previously, OPP are commonly associated with dystrophic (low DO concentration) waterways and the swamps and streams in the wallum country favoured by OPP are typically low in DO. During the September 2017 survey OPP were captured from water with a measured concentration of 1.12 mg/L, a value lower than the reported ranges for OPP (Pusey *et al.* 2004).

A comparison of baseline water quality ranges with the water quality results collected during the July 2019 and September 2019 surveys is presented in **Appendix C**. The comparison indicates that the lowest temperatures and DO concentrations since threatened fish monitoring began were measured during this reporting period, corresponding with very low water levels and zero flow conditions at many sites.

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

3.3 Habitat Description

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

The flows were negligible (< 0.1m/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. At the time of the September 2019 survey Site 2a was reduced to a very small pool of water less than 0.1m deep.
7	2b	Site 2b is located in a shallow drainage line immediately downstream of a bank of 20 existing culverts under the Pacific Highway. There was very limited structural habitat. The benthic material was mostly mud with a small amount of gravel and sand and some scattered rock. The riparian zone was sparsely vegetated but continuous with adjacent forest. At the time of the July 2019 surveys there was no flow and in September 2019 the site was dry.
7	2c	Site 2c is also located in a shallow drainage line approximately 300m downstream of the existing highway. Site 2c was dry at the time of both surveys.

Section	Site	Habitat Description
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>Triglochin procerum</i>) and Maundia (<i>Maundia triglochinoidea</i>). The margins are mostly steep. The riparian cover has been disturbed in recent times for construction. At the time of sampling there was no flow.
8	10b	Site 10b is an excavation located within the upgrade corridor at the point where a wide ephemeral wetland of variable depth drains out into open agricultural land. The benthic material was mud. Structural habitat availability varied throughout the site, although there was mostly a high proportional cover of leaf litter and some emergent and submerged vegetation. The stream margins were gently sloping and grassy. There was no flow at the time of sampling. This site has been substantially modified during construction, including the construction of an upstream refuge pool, a deepened channel under the bridge crossing and 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. There was no notable vegetative or structural habitat apart from grassed margins. The benthic material was mud. At the time of the July 2019 survey there was no flow and at the time of the September 2019 survey there was no water.
8	11b	Site 11b consists of a narrow channel, possibly modified by excavation, draining agricultural land and cane fields. The benthic material was mud, with a high proportional cover of debris. Other structural habitat included scattered rushes, regular root balls and trailing vegetation. The stream banks were relatively well vegetated with a mixture of trees, rushes and grasses. There was no flow at the time of sampling. Site 11b is located on private property and there was no access arrangement for the September 2019 survey period.
8	11d	Site 11d consists of a narrow, shallow channel, probably modified by excavation, draining sugar cane fields. The benthic material was mud, with a 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. At the time of the July 2019 survey there was a low flow but in September 2019 there was no flow.
8	12a	Site 12a consisted of a narrow channel, possibly modified by excavation, draining agricultural land. The benthic material was mud, with a high proportional cover of leaf litter and dense emergent plants, mostly Grey Rush (<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 2019 surveys. The site has now been significantly modified by a diversion and revegetation.
9	13b	Site 13b is located in a very shallow drain on agricultural land. The benthic material was dominated by mud, with a small proportion of sand. There was a high proportion of leaf litter and a moderate cover of emergent plants. The

<i>Section</i>	<i>Site</i>	<i>Habitat Description</i>
		banks at this site were grassy with rushes and regular trees. There was no flow at the time of sampling and the remaining water was very shallow at the time of the September 2019 survey. The site has now been significantly modified by a diversion and revegetation.
9	13c	Site 13c is located in a narrow, deep drain on agricultural land. The benthic material was dominated by mud, with a small proportion of sand. There was a high proportion of leaf litter and scattered small woody debris. Other structural habitat included 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 sampling.
9	13e	Site 13e consists of a small billabong located along the path of an agricultural drain. It was approximately 15 m wide at its widest point and 1.2m deep. The margins were gently sloping and grassy. At the time of the last survey in September 2017 most of the structural habitat was formed by submerged and emergent vegetation. The benthic material was dominated by mud with low percentage of sand. There was no flow. Site 13e is located on private property with no access arrangement in place for this monitoring period.
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 the July 2019 survey and no water at the time of the September 2019 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. At the time of the September 2019 survey the water level was very low, limiting structural habitat to the features in the lowest part of the pool. 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. Low levels at the time of the September 2019 survey limited the available structural habitat. There was no flow.
8	22c	Site 22c is a deep excavation located in an agricultural drainage line approximately 250m E of the upgrade corridor on a private property. The margins were well vegetated and there was a high proportion of trailing vegetation, mostly Sphagnum moss and Bladderwort (<i>Utricularia</i> sp.). Structural habitat is limited in the middle but around the margins consisted of submerged vegetation and occasional debris. Low levels at the time of the September 2019 survey limited the available structural habitat. The benthic material was mostly sand. There was no flow.
9	26d	Site 26b is a deep pool in a shallow natural drainage line. At the time of the last survey in September 2017 the margins were very well vegetated and trailing vegetation was a major habitat feature. Other structural habitat

Section	Site	Habitat Description
		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 triglochinoides</i> , <i>Triglochin 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.
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 triglochinoides</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 surveys.
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 first surveys.

Table 3.4 Aquatic plants identified at impact sites during the July 2019 survey

<i>Species Name</i>	<i>Common Name</i>	2a	2b	2c	3a	10b	10c	11b	11d	12a	13b	13c	13e	16a	16b	22b	22c	26d	27b	27e
<i>Azolla</i> spp	Azolla															x				
<i>Alisma plantago</i>	Common Water-plantain																		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	
<i>Baumea rubiginosa</i>	Baumea														x					
<i>Blechnum</i> sp.	Fern																x		x	x
<i>Carex appressa</i>	Tall Sedge					x			x		x									
<i>Carex fascicularis</i>	Tassel Sedge	x	x		x			x												
<i>Ceratophyllum demersum</i>	Hornwort				x															
<i>Cyperus difformis</i>	Dirty Dora								x	x	x	x			x					
<i>Eleocharis acuta</i>	Common Spikerush						x													
<i>Eleocharis pusilla</i>	Small Spike-rush									x										
<i>Eleocharis sphacelata</i>	Tall Spike-rush											x								
<i>Gahnia sieberana</i>	Sawsedge				x			x		x					x	x	x			x
<i>Gleichenia dicarpa</i>	Pouched Coral Fern								x							x	x			
<i>Hypolepis muelleri</i>	Harsh Ground Fern							x		x		x								
<i>Isolepis inundata</i>	Swamp Club Rush																			
<i>Juncus usitatus</i>	Common Rush					x				x	x	x			x	x	x		x	
<i>Leersia hexandra</i>	Swamp Ricegrass							x		x										
<i>Lepironia articulata</i>	Grey Rush					x				x				x	x					x
<i>Lomandra longifolia</i>	Creek Mat rush	x	x						x	x										
<i>Maundia triglochbinoides</i>	Maundia				x															
<i>Nymphaea</i> sp	Waterlily					x				x		x				x				x
<i>Ottelia ovalifolia</i>	Swamp Lily				x															
<i>Paspalum distichum</i>	Water Couch					x	x		x	x	x	x								
<i>Persicaria decipiens</i>	Slender Knotweed						x		x											

<i>Persicaria hydropiper</i>	Water Pepper					x													
<i>Persicaria lapathifolia</i>	Pale Knotweed											x							
<i>Persicaria strigosa</i>	Prickly Knotweed							x		x									
<i>Philydrum lanuginosum</i>	Frogsmouth	x	x		x	x		x	x									x	
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush							x											
<i>Sphagnum</i> sp.	Peat Moss												x		x	x		x	x
<i>Triglochin procerum</i>	Water Ribbons				x														x
<i>Triglochin striata</i>	Streaked Arrow Grass		x																
<i>Utricularia</i> sp.	Bladderwort					x									x				x

Table 3.5 Aquatic plants identified at control and Devils Pulpit sites during the July 2019 survey

Species Name	Common Name	C1	C2	C3	C5	C8	C11	C12	C13	C14	OPP1	OPP2	OPP3	OPP4	OPP5	OPP6	OPP7
<i>Azolla</i> spp	Azolla								x								
<i>Alisma plantago</i>	Common Water-plantain									x							
<i>Baloskion (Restio) pallens</i>	Zigzag Rush	x		x	x		x										
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush				x	x		x									
<i>Baumea articulata</i>	Jointed Rush								x								
<i>Baumea rubiginosa</i>	Baumea	x		x		x	x										
<i>Blechnum</i> sp.	Fern				x				x								
<i>Carex fascicularis</i>	Tassel Sedge										x		x				
<i>Cyperus exaltatus</i>	Giant Sedge								x								
<i>Cyperus papyrus</i>	Papyrus								x								
<i>Eleocharis acuta</i>	Common Spikerush										x						
<i>Eleocharis sphacelata</i>	Tall Spike-rush											x					
<i>Emydra fluctuans</i>	Buffalo Spinach								x								
<i>Gabnia sieberana</i>	Sawsedge	x		x	x	x			x								
<i>Gleichenia dicarpa</i>	Pouched Coral Fern				x			x									
<i>Juncus usitatus</i>	Common Rush				x			x			x						
<i>Leersia hexandra</i>	Swamp Ricegrass								x		x						

<i>Species Name</i>	<i>Common Name</i>	<i>C1</i>	<i>C2</i>	<i>C3</i>	<i>C5</i>	<i>C8</i>	<i>C11</i>	<i>C12</i>	<i>C13</i>	<i>C14</i>	<i>OPP1</i>	<i>OPP2</i>	<i>OPP3</i>	<i>OPP4</i>	<i>OPP5</i>	<i>OPP6</i>	<i>OPP7</i>
<i>Lepironia articulata</i>	Grey Rush	x															
<i>Lomandra longifolia</i>	Creek Mat rush								x		x	x					
<i>Lycopodiella cernua</i>	Scrambling Clubmoss	x															
<i>Maundia triglochmoides</i>	Maundia										x	x					
<i>Nymphaea sp.</i>	Waterlily	x															
<i>Nymphoides indica</i>	Water Snowflake								x								
<i>Ottelia ovalifolia</i>	Swamp Lily								x								
<i>Persicaria decipiens</i>	Slender Knotweed								x								
<i>Persicaria strigosa</i>	Prickly Knotweed								x			x					
<i>Philydrum lanuginosum</i>	Frogsmouth								x	x	x	x					
<i>Potamogeton octandrus</i>	Pondweed								x								
<i>Schoenoplectus mucronatus</i>	Marsh Clubrush								x			x					
<i>Schoenoplectus validus</i>	River Clubrush									x							
<i>Sphagnum sp.</i>	Peat Moss	x		x	x	x					x						
<i>Triglochin procerum</i>	Water Ribbons								x	x							
<i>Utricularia sp.</i>	Bladderwort	x							x								

Table 3.6 Aquatic plants identified at impact sites during the September 2019 survey

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

<i>Ceratophyllum demersum</i>	Hornwort				x															
<i>Cyperus sp.</i>	Sedge									x	x					x				
<i>Cyperus difformis</i>	Dirty Dora									x	x	x			x	x				
<i>Cyperus exaltatus</i>	Giant Sedge					x														
<i>Eleocharis acuta</i>	Common Spikerush										x									
<i>Eleocharis sphacelata</i>	Tall Spike-rush											x								
<i>Gahnia sieberana</i>	Sawsedge									x					x	x	x			x
<i>Gleichenia dicarpa</i>	Pouched Coral Fern								x								x			
<i>Hypolepis muelleri</i>	Harsh Ground Fern									x		x								
<i>Juncus usitatus</i>	Common Rush					x			x	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					x				
<i>Lycopodiella cernua</i>	Scrambling Clubmoss																			
<i>Maundia triglochinoidea</i>	Maundia					x														
<i>Nymphaea sp</i>	Waterlily					x				x		x			x	x				x
<i>Ottelia ovalifolia</i>	Swamp Lily					x	x													
<i>Paspalum distichum</i>	Water Couch					x			x	x	x	x								
<i>Persicaria decipiens</i>	Slender Knotweed									x										
<i>Persicaria lapathifolia</i>	Pale Knotweed											x								
<i>Persicaria strigosa</i>	Prickly Knotweed					x				x					x					
<i>Phragmites australis</i>	Common Reed										x									
<i>Philydrum lanuginosum</i>	Frogsmouth	x			x				x		x									
<i>Sphagnum sp.</i>	Peat Moss										x					x	x		x	x
<i>Triglochin procerum</i>	Water Ribbons					x														x
<i>Utricularia sp.</i>	Bladderwort					x										x				

Table 3.7 Aquatic plants identified at control and Devils Pulpit sites during the September 2019 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									
<i>Baloskion (Restio) tetraphyllum</i>	Feathery Rush	x			x	x											
<i>Baumea articulata</i>	Jointed Rush								x								
<i>Baumea rubiginosa</i>	Baumea							x									
<i>Blechnum</i> sp.	Fern								x								
<i>Carex fascicularis</i>	Tassel Sedge								x		x	x	x				
<i>Drosera spatulata</i>	Spoon-leaved Sundew							x									
<i>Eleocharis sphacelata</i>	Tall Spike-rush										x	x					
<i>Enhydra fluctuans</i>	Buffalo Spinach								x								
<i>Gahnia sieberana</i>	Sawsedge	x			x	x											
<i>Gleichenia dicarpa</i>	Pouched Coral Fern							x									
<i>Juncus usitatus</i>	Common Rush	x				x					x						
<i>Leersia hexandra</i>	Swamp Ricegrass								x								
<i>Lepironia articulata</i>	Grey Rush	x															
<i>Lomandra longifolia</i>	Creek Mat rush										x	x	x				
<i>Maundia triglochinosides</i>	Maundia										x	x					
<i>Nymphaea</i> sp	Waterlily	x							x								
<i>Ottelia ovalifolia</i>	Swamp Lily								x								
<i>Persicaria strigosa</i>	Prickly Knotweed								x			x					
<i>Phragmites australis</i>	Common Reed								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									
<i>Utricularia</i> sp.	Bladderwort	x			x			x			x						

Discussion and Conclusion

The two fish surveys completed during the third year of the construction phase for the W2B Threatened Fish monitoring were completed in July and September 2019. The July survey, scheduled for May 2019, was undertaken late in the hope that suitable rainfall conditions would eventuate allowing fish passage into sites that were found to be dry in March 2019. No such rainfall event occurred and dry to very dry conditions characterised the current reporting period and the results described herein. There were OPP captured at 3 of the 24 impact sites and 2 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 6 of the impact sites and 5 of the control sites for at least one of the surveys this year. At most of the other impact and control sites there was reduced structural habitat availability due to lower than usual water levels. At both impact and control sites the combination of habitat and water quality were less favourable for occupation by OPP than has been recorded in previous surveys, particularly in relation to structural habitat and dissolved oxygen availability. In comparison with the results from the pre-construction monitoring and the first year of construction phase threatened fish monitoring (GeoLINK 2014 & 2015, Jacobs 2018), the results collected in 2019 are even poorer than the results collected in September 2014, another year that was characterised by severe drought and dry sites. Continued monitoring, which is required to meet the aims of the Threatened Fish Management Plan, will improve the understanding of population dynamics in the post-drought environment.

After a significant effort to identify and quantify threatened fish populations along the W2B upgrade corridor 18 impact and 9 control sites were identified for ongoing threatened fish monitoring. Another site (site 13b) was added prior to the September 2017 survey after OPP were observed there in August 2017 and changes to threatened fish management were proposed for the Montis Gully area (Chainage 140600 – 141200). For this reporting period a further 5 impact and 2 control sites (sites OPP1 to OPP7), previously monitored for the Devils Pulpit Pacific Highway upgrade, were added to the survey. Since the 2018 annual report (Jacobs 2019), there have been changes to access arrangements on some of the private properties bordering the W2B upgrade corridor. These have resulted in restricted access to some of the threatened fish monitoring sites including site 11b (September 2019 only) and sites OPP4, 13e and 26d (May and September 2019).

The fishing effort for the two surveys this year consisted of 336 individual fish trapping hours and 26,549 seconds of electrofishing. A total of 808 fish were captured in July 2019 and 1347 fish were captured in September 2019. These totals included 8 (1%) OPP and 33 (2%) OPP respectively. The OPP capture rates (as a percentage of total fish captured) in previous surveys have varied between 4% and 25%. The sites where OPP were captured in 2019 included:

- Two of the eleven control sites. OPP were captured at site C1 during both surveys and at site C5 in September 2019 only (There was no access to OPP4, OPP5 and C2 were dry for both surveys and C2, C3, C11 and C14 were dry in September 2019).
- Three of the impact sites, 22b, 22c and 27e, during both surveys. Each of these 3 sites maintained aquatic habitat throughout the drought period.

The sites where OPP were not captured during either survey in 2019 included 21 of the 24 impact sites and 9 of the 11 control sites. Of the impact sites, 11 were found to be dry during

either a site inspection in March 2019, one of the two surveys this year or both of the surveys this year and 3 had restricted access. Of the remaining sites, no OPP have been captured at site 10b since September 2013 and no OPP have been captured at Site 16b since construction activities necessitated a translocation activity in July 2017.

There has been significant variability in the numbers of OPP captured at each site during different surveys, at both the impact and control sites. Due to the opportunistic life cycle strategies and quick responses to stochastic environmental factors displayed by OPP (Knight *et al.* 2012) it is expected that surveys conducted at different times would yield different results depending upon favourable or unfavourable breeding and dispersal conditions. The breeding and dispersal conditions in the lead up to the 2019 surveys were highly unfavourable. In addition to the very low numbers of OPP captured, there were no juvenile OPP captured in either survey during this year (Table 4.1, Figures 4.1 and 4.2).

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

Survey	Number of OPP Captured			Percentage of Juvenile OPP captured		
	Total	Impact	Control	Total	Impact	Control
May 2017	229	89	140	69.9	52.8	80.7
September 2017	425	170	255	73.4	56.5	84.7
May 2018	263	109	154	22.1	23.9	20.8
September 2018	265	96	169	27.9	18.8	33.1
July 2019	8	7	1	0	0	0
September 2019	33	21	12	0	0	0

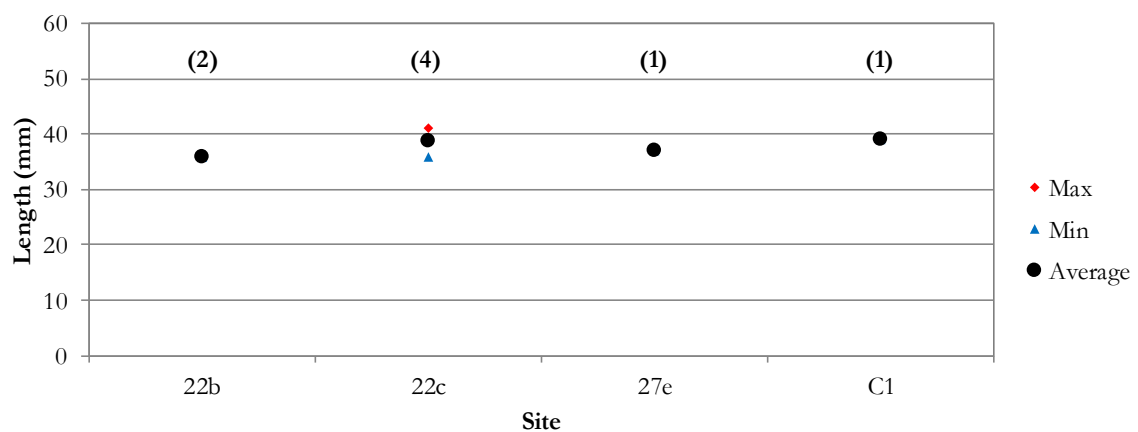


Figure 4.1 Length distribution data of OPP captured in the July 2019 survey (counts in brackets)

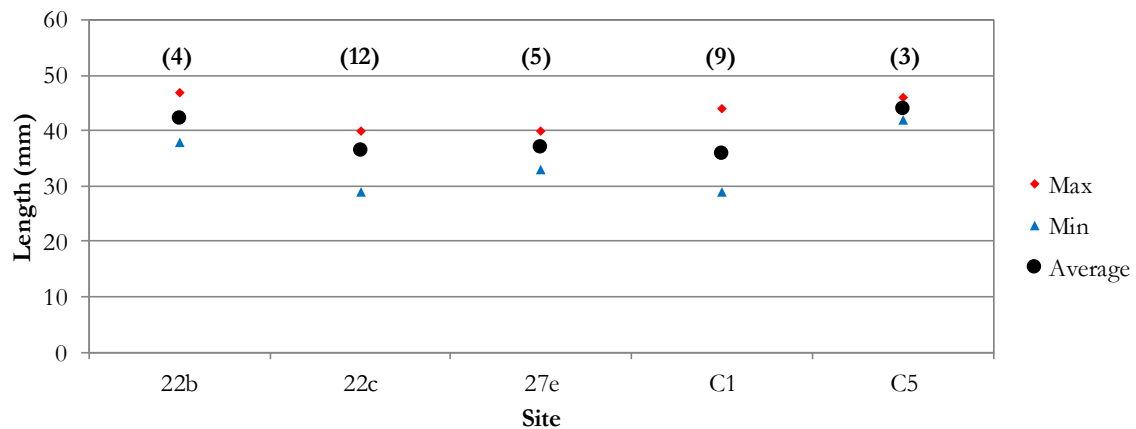


Figure 4.2 Length distribution data of OPP captured in the September 2019 survey (counts in brackets)

Total rainfall was very low for most months of the 2018 – 2019 OPP breeding season and much lower than average between the months of March 2019 and September 2019. There have been no significant flood events to aid dispersal since March 2017. This in large part explains the very low numbers of OPP captured at both impact and control sites. The very low numbers of OPP captured during this survey at the impact sites were closely reflected by very low numbers of OPP captured at the control sites. It is clear that the key factors impacting OPP populations at both impact and control sites are drought and poor breeding and dispersal conditions.

The lack of rainfall meant that the conditions during both surveys this year were generally poor for capturing fish. As previously described, there were many sites that were dry during the survey periods and at many sites there was insufficient water to set traps (sites 2a, 10c, 11d, 13b, 16a, C11 and C14) or insufficient area to set the full complement of 10 traps (sites 11b, 12a, C3 and C5 in July 2019 and sites 16b and 27e in September 2019). At one site (2a) there was not enough water to electrofish during the September 2019 survey. The lack of rainfall did mean that water was confined to channel margins and the degree of confidence that the results accurately reflect the fish populations present during the surveys is thereby increased.

In addition to the OPP, a lower than usual number of other fish were encountered during threatened fish surveys on the W2B upgrade this year. Although the numbers were lower, in general the fish communities at most sites resembled those observed during pre-construction surveys. One species not previously identified during threatened fish surveys, Crimson-spotted Rainbowfish (*Melanotaenia duboulayi*) was captured at Site 3a during the May 2019 survey. This species is known from freshwater creeks and rivers north of the Hastings River and is increasingly common heading north from the Richmond River (Pusey *et al.* 2004). The numbers of Mosquitofish (*Gambusia holbrooki*) encountered at each site are of specific interest as they have been identified as a Key Threatening Process under the *Threatened Species Conservation Act 1995* and are antagonistic towards OPP. There has been variation in the numbers of Mosquitofish encountered during construction phase surveys but there is no apparent trend. There is no evidence at present that Mosquitofish numbers are increasing as a result of disturbances associated with construction.

This study measured vegetative and physical habitat features including, flow, width, depth, in-stream vegetation, debris and stream bank forms. Over the course of the two surveys we

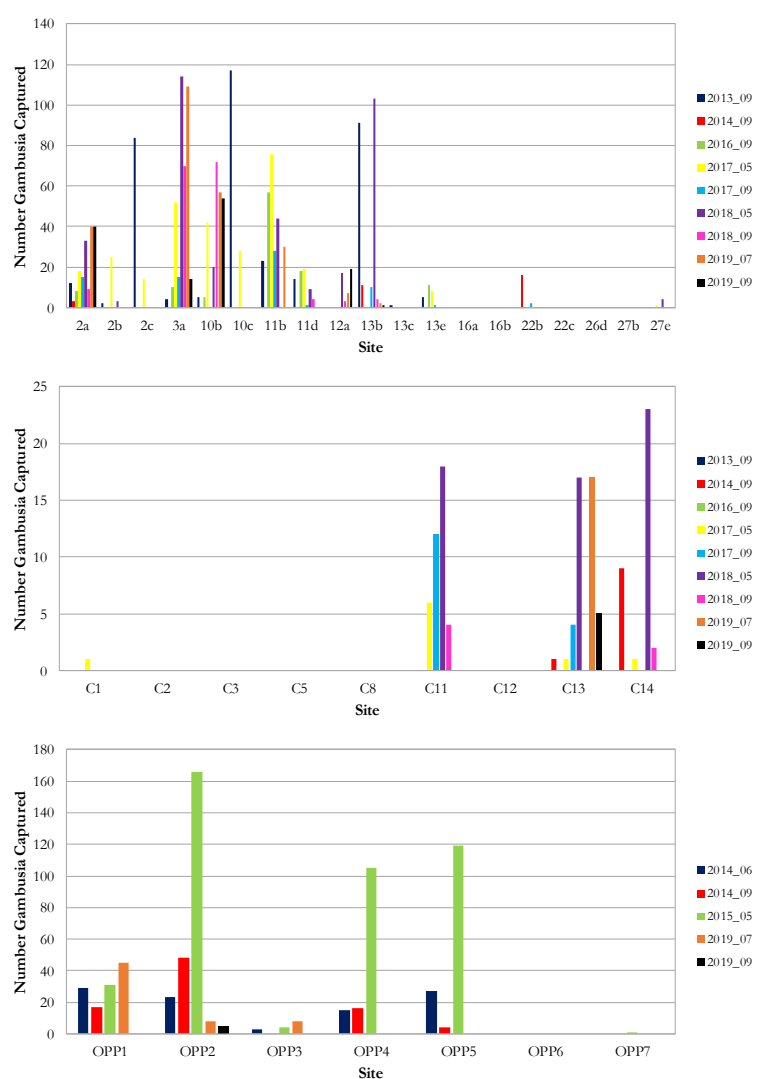
have collected a large volume of information describing habitat conditions at all sites qualitatively and quantitatively. All of the sites surveyed (that weren't dry) had at least some habitat features commonly associated with OPP (Knight & Arthington 2008). There is variation in the habitat features measured at each site between surveys (**Appendix A**). The variation in habitat condition measured at the impact sites during the surveys this year is generally within the ranges observed in pre-construction surveys and mirrored by the variation in habitat condition measured at the control sites.

This study also measured physicochemical water quality variables. During this reporting period several sites had the lowest DO concentrations measured during threatened fish surveys since 2013. There were also some sites where the pH was the highest measured during threatened fish surveys since 2013. Both of these categories included impact and control sites, indicating that these results also resulted, at least in part from ongoing drought. Crossings and modifications made at some of the impact sites may have also contributed, but more information is required to determine whether this is part of a trend at these sites. Increased pH is of concern in OPP waterways because low pH waters are thought to provide OPP with a competitive advantage. Water quality information collected as part of ongoing, regular W2B upgrade water quality monitoring may provide more details and will be assessed as part of the next annual report. There were two turbidity measurements collected during this monitoring period that were outside the known range of OPP (**Tables 3.1** and **3.2**). It is worth noting that one of these measurements was collected from a site upstream of the new highway alignment (site 2a) and the other was collected from a site that would not have received runoff from the highway for over 3 months at the time of monitoring (site 22c). Neither of these elevated turbidity measurements would have been associated with W2B upgrade construction activities.

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.

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

<i>Performance Indicator</i>	<i>Notes</i>	<i>Conclusion</i>
Relative abundance of OPP in impact sites has reduced significantly when compared to control sites over three consecutive monitoring periods	There was a reduced number of OPP captured during this survey in comparison to previous surveys. The reduced numbers of OPP captured at impact sites are accurately reflected in reduced numbers of OPP captured at control sites. A conclusion of this report is that drought conditions are responsible for the reduced numbers of OPP captured, not construction impacts. There was also high degree of variation in the pre-construction monitoring results for OPP due to drought conditions. Although OPP abundance has varied at several impact sites during construction phase monitoring and reduced numbers have been noted at some sites, a similar degree of variability leading to reduced numbers has also been evident at some of the control sites, particularly the sites prone to drying out, such as C14.	Continued monitoring at normal frequency.

Performance Indicator	Notes	Conclusion
Survey of Class 1 and 2 waterways with known or potential OPP habitat identifies additional populations of OPP.	A population of OPP were found in the Montis Gully area during the construction period. As a result, an impact site (13b) was added to the list of sites monitored prior to the September 2017 survey.	Continue monitoring at site 13b
Occurrence of Eastern Gambusia in waterways where they have not previously been recorded	During monitoring this year Gambusia were captured at several control and impact sites, all of which had Gambusia present during pre-construction monitoring. The variation in Gambusia capture at the impact sites is reflected by variation in the Gambusia capture at control sites.  The top chart displays the number of Gambusia captured at various sites (2a to 27e) from 2013 to 2019. The y-axis represents the number of Gambusia captured, ranging from 0 to 140. The x-axis lists the sites. The legend indicates the following years: 2013_09 (dark blue), 2014_09 (red), 2016_09 (green), 2017_05 (yellow), 2017_09 (cyan), 2018_05 (purple), 2018_09 (pink), 2019_07 (orange), and 2019_09 (black). Notable captures are seen at sites 2a, 2b, 2c, 3a, 10b, 10c, 11b, 11d, 12a, 13b, 13c, 16a, 16b, 22b, 22c, 26d, 27b, and 27e. The middle chart displays the number of Gambusia captured at control sites (C1 to C14) from 2013 to 2019. The y-axis represents the number of Gambusia captured, ranging from 0 to 25. The x-axis lists the sites. The legend is the same as the top chart. Notable captures are seen at sites C1, C2, C3, C5, C8, C11, C12, C13, and C14. The bottom chart displays the number of Gambusia captured at impact sites (OPP1 to OPP7) from 2014 to 2019. The y-axis represents the number of Gambusia captured, ranging from 0 to 180. The x-axis lists the sites. The legend indicates the following years: 2014_06 (dark blue), 2014_09 (red), 2015_05 (green), 2019_07 (orange), and 2019_09 (black). Notable captures are seen at sites OPP1, OPP2, OPP3, OPP4, OPP5, OPP6, and OPP7.	No corrective action required

Performance Indicator	Notes	Conclusion
Any change in habitat structure downstream of construction area, i.e. macrophyte and woody snag cover.	No significant changes to habitat structure have been noted to date.	No corrective action required
Any change in natural stream flow and velocity resulting in threatened fish being trapped in isolated pools	No significant changes to stream flow and velocity have been noted to date.	No corrective action required
Any weed incursion into OPP waterways	There were no new introduced species of aquatic plants observed at any of the control or impact sites during the surveys this year.	No corrective action required
No threatened fish species observed in ponds where fish have been translocated to.	OPP were translocated from construction sites at Montis Gully (Ch 141100 - 141900) and the Woodburn to Broadwater Service Rd (Ch 139000) on several occasions in 2017 into sites 27b and C1 during the course of dewatering and stream diversion activities. OPP, in relatively large numbers, were captured at C1 during both surveys conducted this year and both surveys in both of the previous annual reporting periods. OPP were not captured at Site 27b during surveys this year.	Future translocations to site C1 only.
Any change in water quality from baseline conditions in the vicinity of, or downstream of the construction works	The water quality results collected as part of the threatened fish monitoring gives some indication that there has been a reduction in the DO concentrations in the vicinity of construction works in comparison with baseline results. However, there was also a reduction in the DO concentrations at some of the control sites in comparison with baseline results. Some of the pH measurements have indicated a potential increase in the pH around construction areas. Measurements from sites 2a, 3a, 10b, 12a 13b and 16b, while generally within background variation for those waterways (Appendix C), warrant further investigation as monitoring proceeds. Changes in temperature measurements were recorded at many sites during this reporting period but these are likely to reflect only the timing of the survey in July and the climatic conditions of winter.	Conduct an assessment of DO concentrations and pH using data collected under the W2B Water Quality Monitoring Program in the next Threatened Fish Monitoring report
Any evidence of sediment or erosion being caused by the project	No erosion or sedimentation being caused by the project were noted during the threatened fish surveys during the construction phase monitoring to date.	No corrective action required
Disparity in water quality between downstream and upstream monitoring sites observed during operation of the project	Information collected under the Water Quality Monitoring Program for the W2B upgrade will be used to assess whether the W2B upgrade is meeting requirements for this performance indicator.	This performance indicator should be assessed in the W2B upgrade water quality monitoring reports

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

Results from previous reporting periods have indicated that the threatened fish management actions adopted along the W2B upgrade have been successfully protecting OPP populations and habitat. Consideration of the results presented against performance indicators from the TFMP indicate that it may be necessary to assess pH and dissolved oxygen at some sites using data from water quality monitoring undertaken as part of the W2B upgrade.



Plate 4.2 Site 16a was dry at the time of the September 2019 survey.

Project Team

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

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Appendix A

Aquatic Habitat Summaries

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

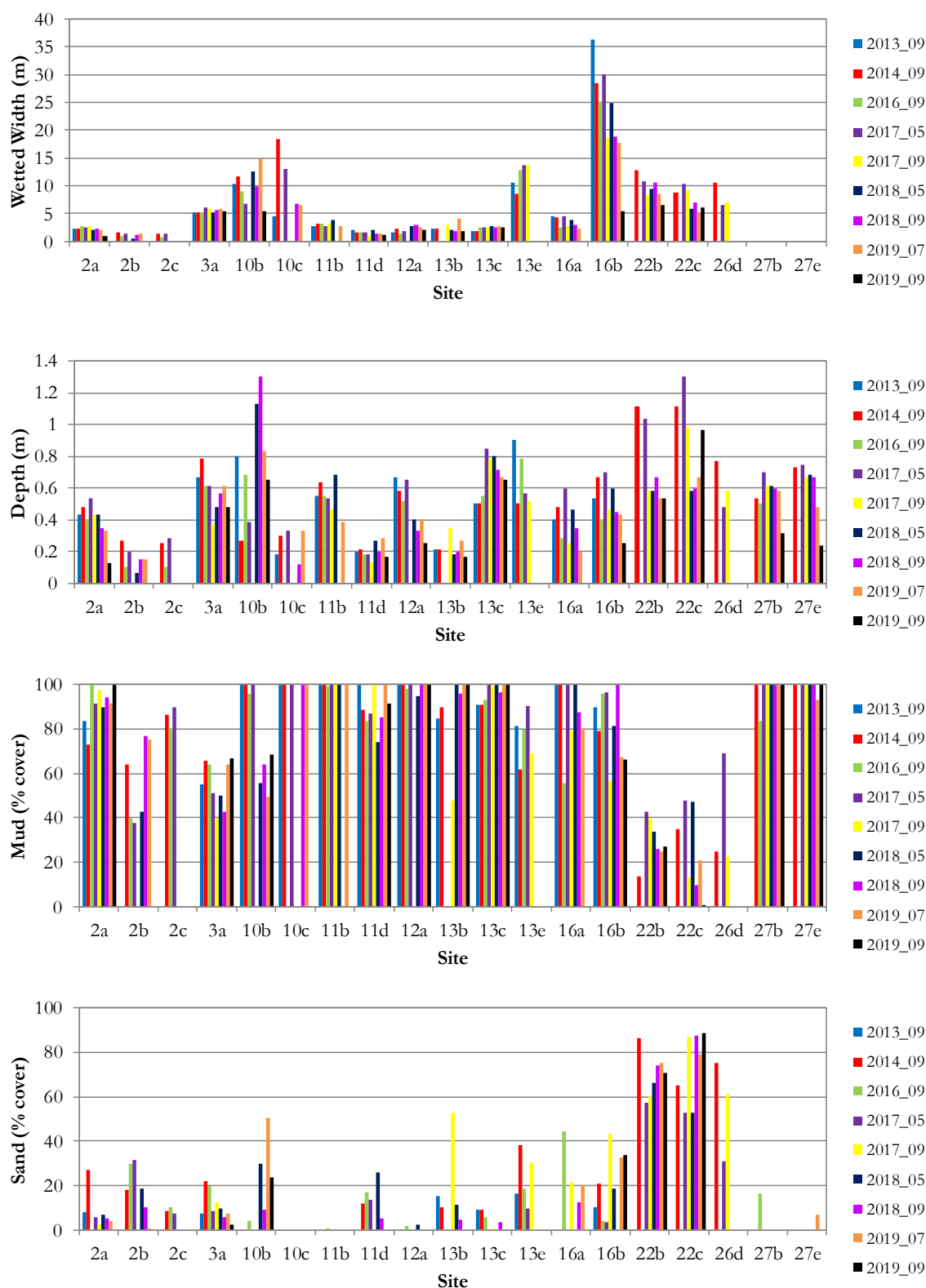


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

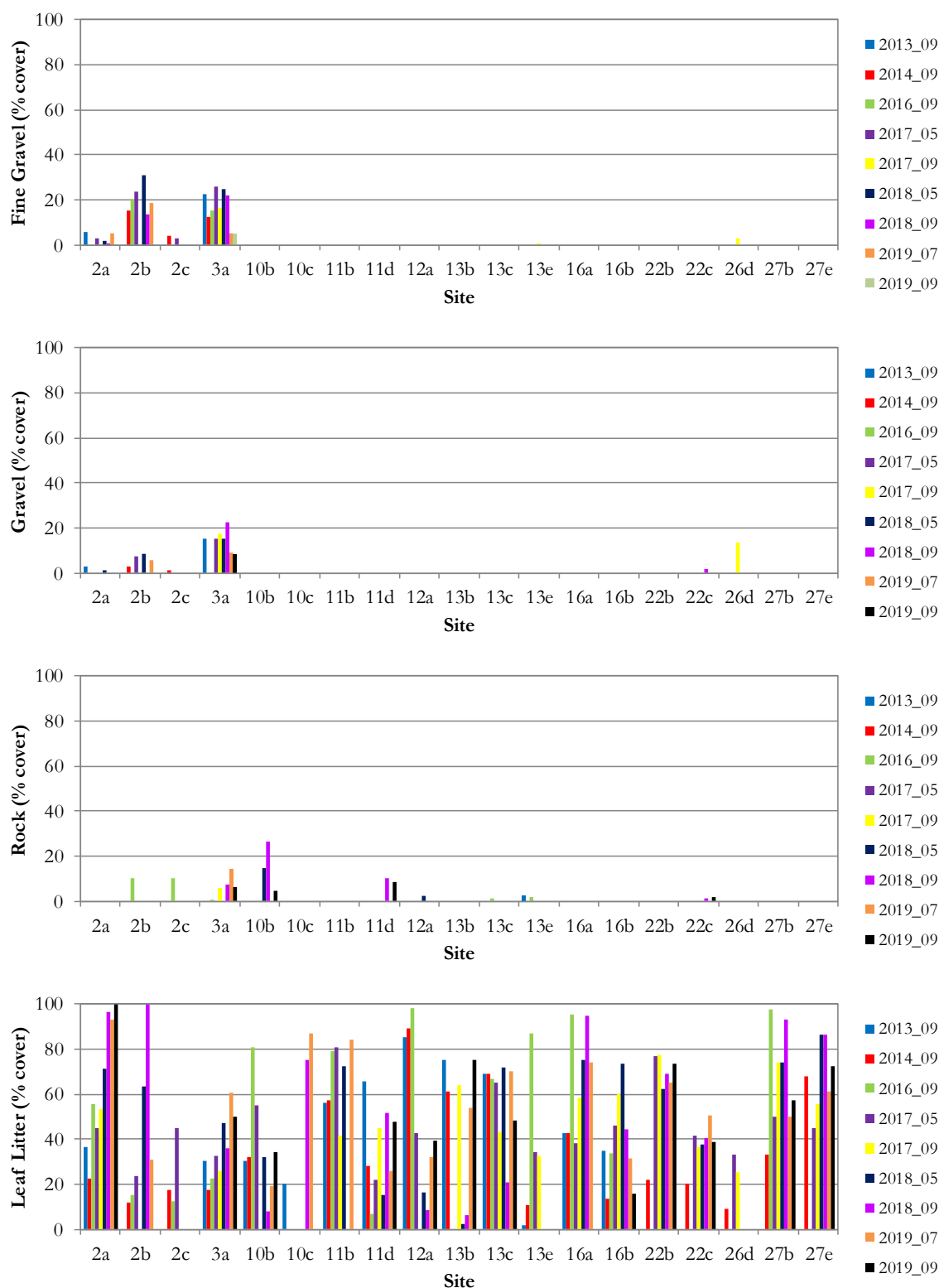


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

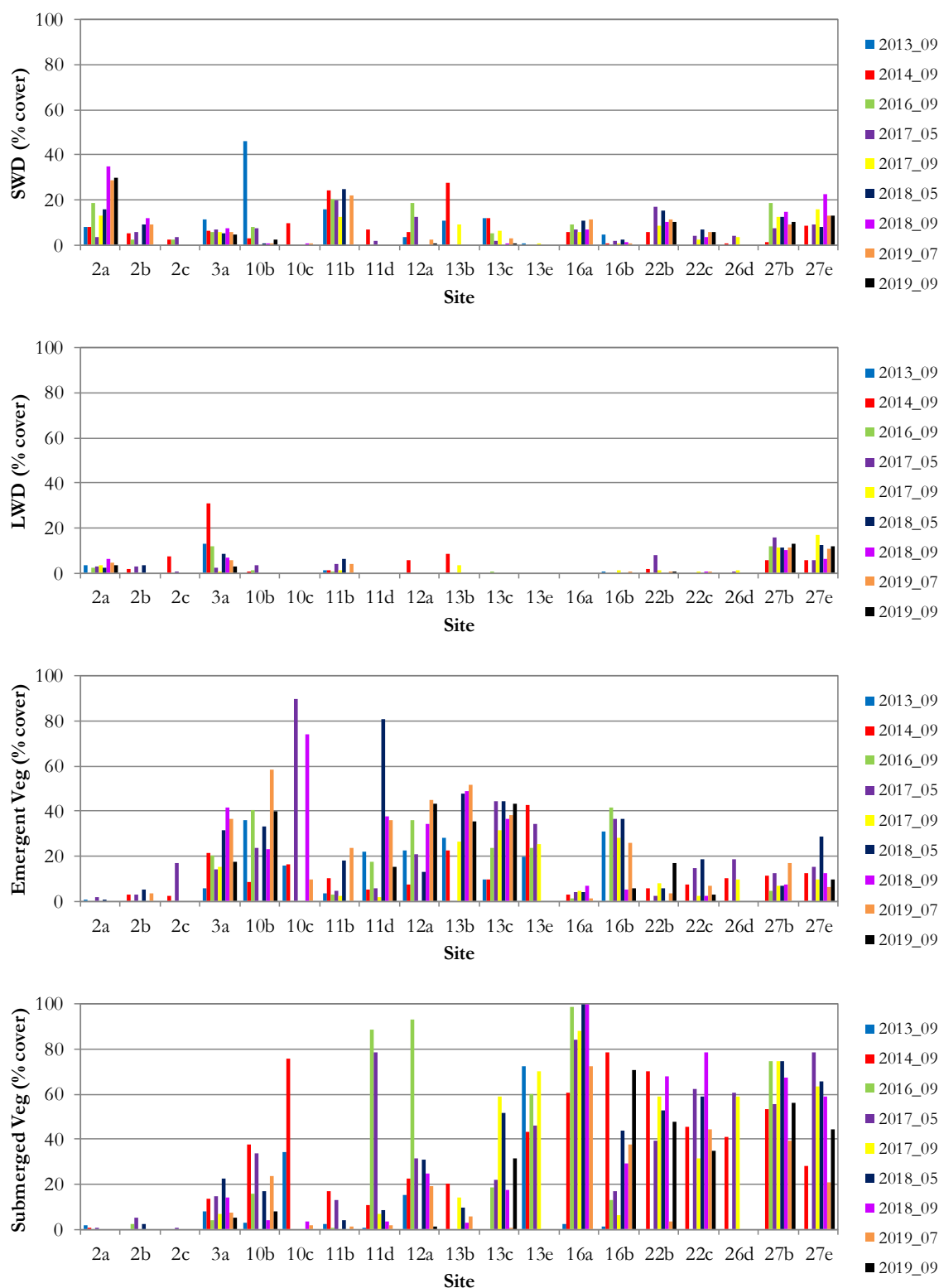


Figure A1 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at impact sites.

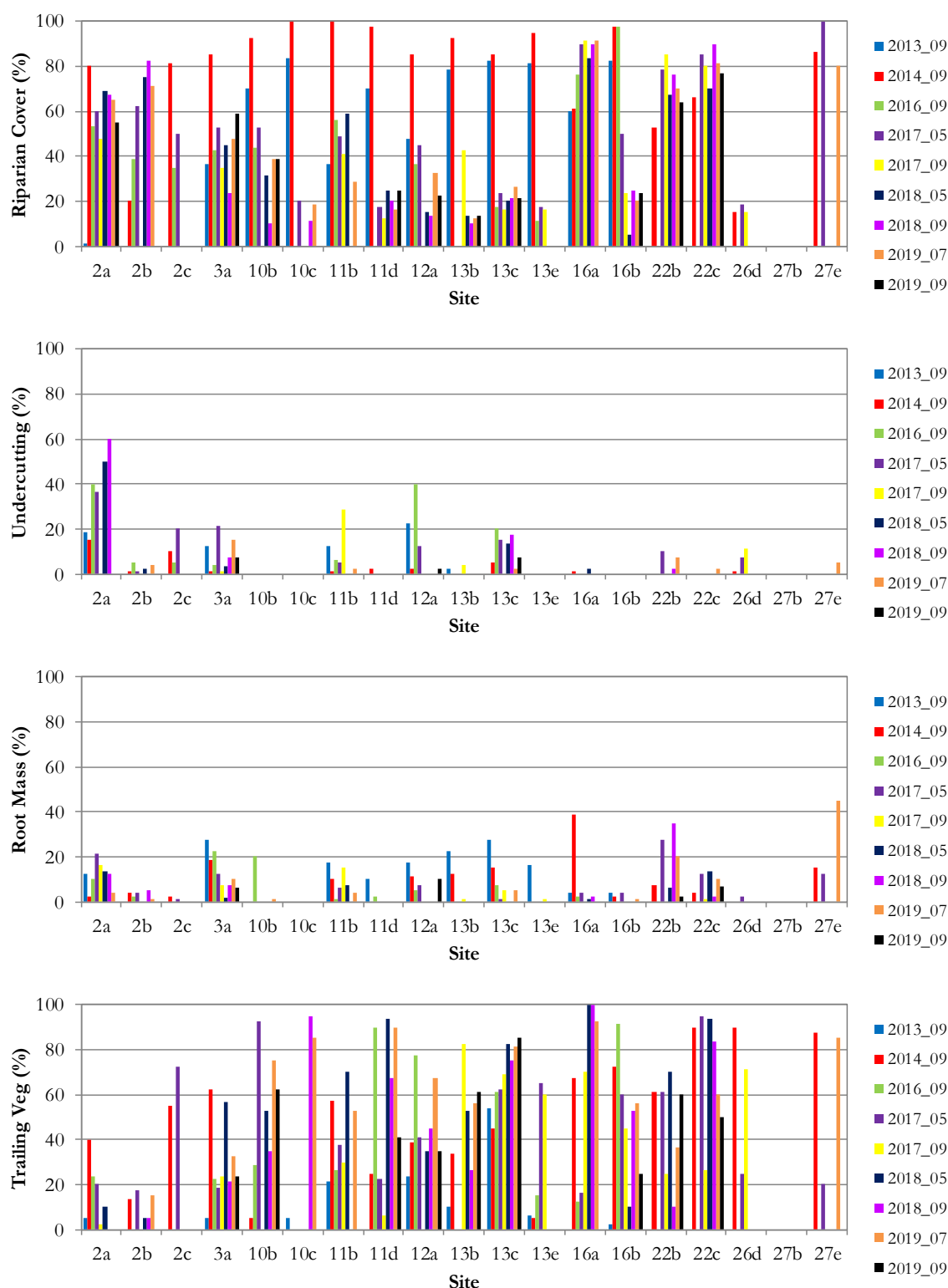


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

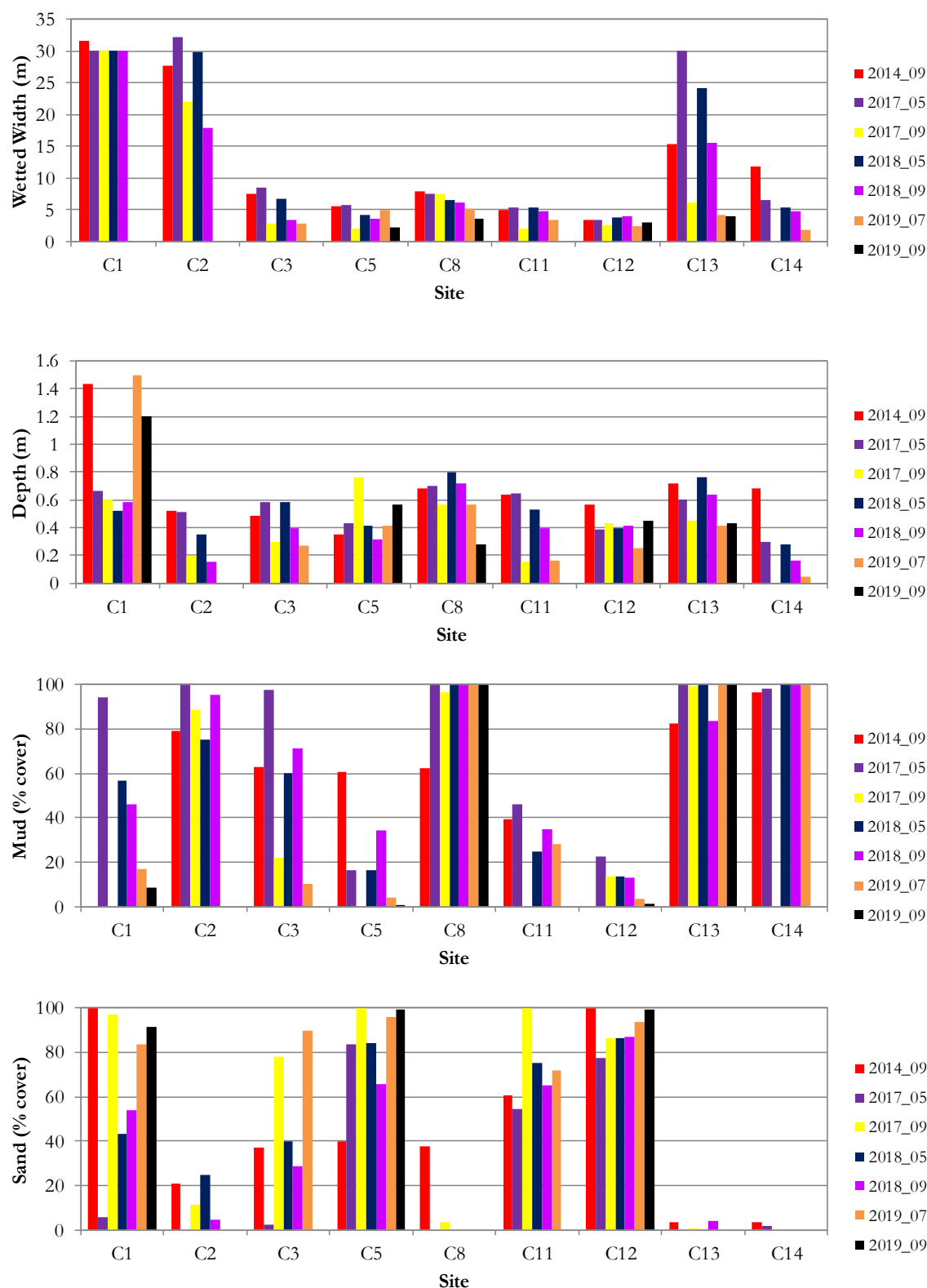


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

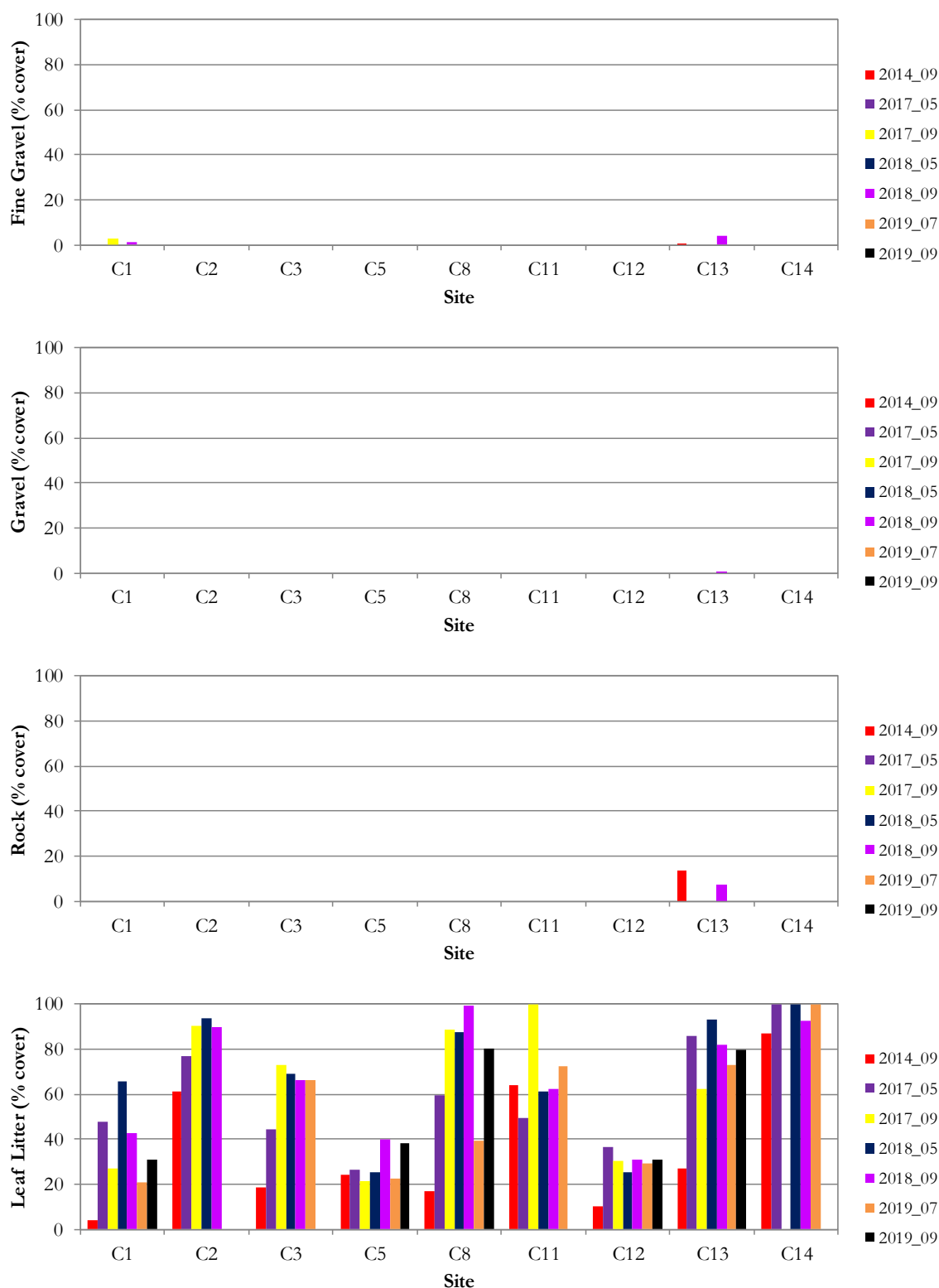


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

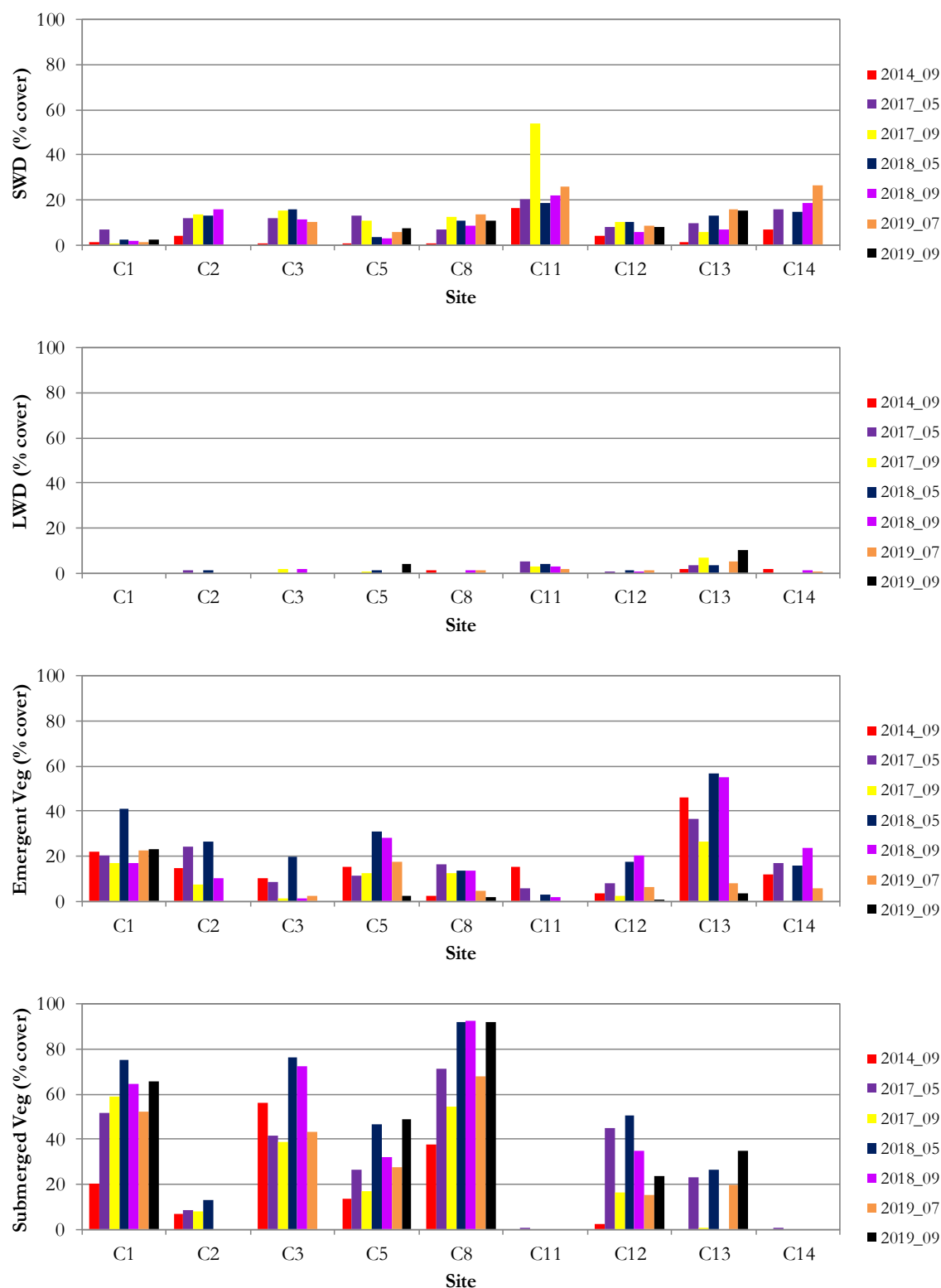


Figure A2 A summary of aquatic habitat data collected in pre-construction and construction phase monitoring at control sites.

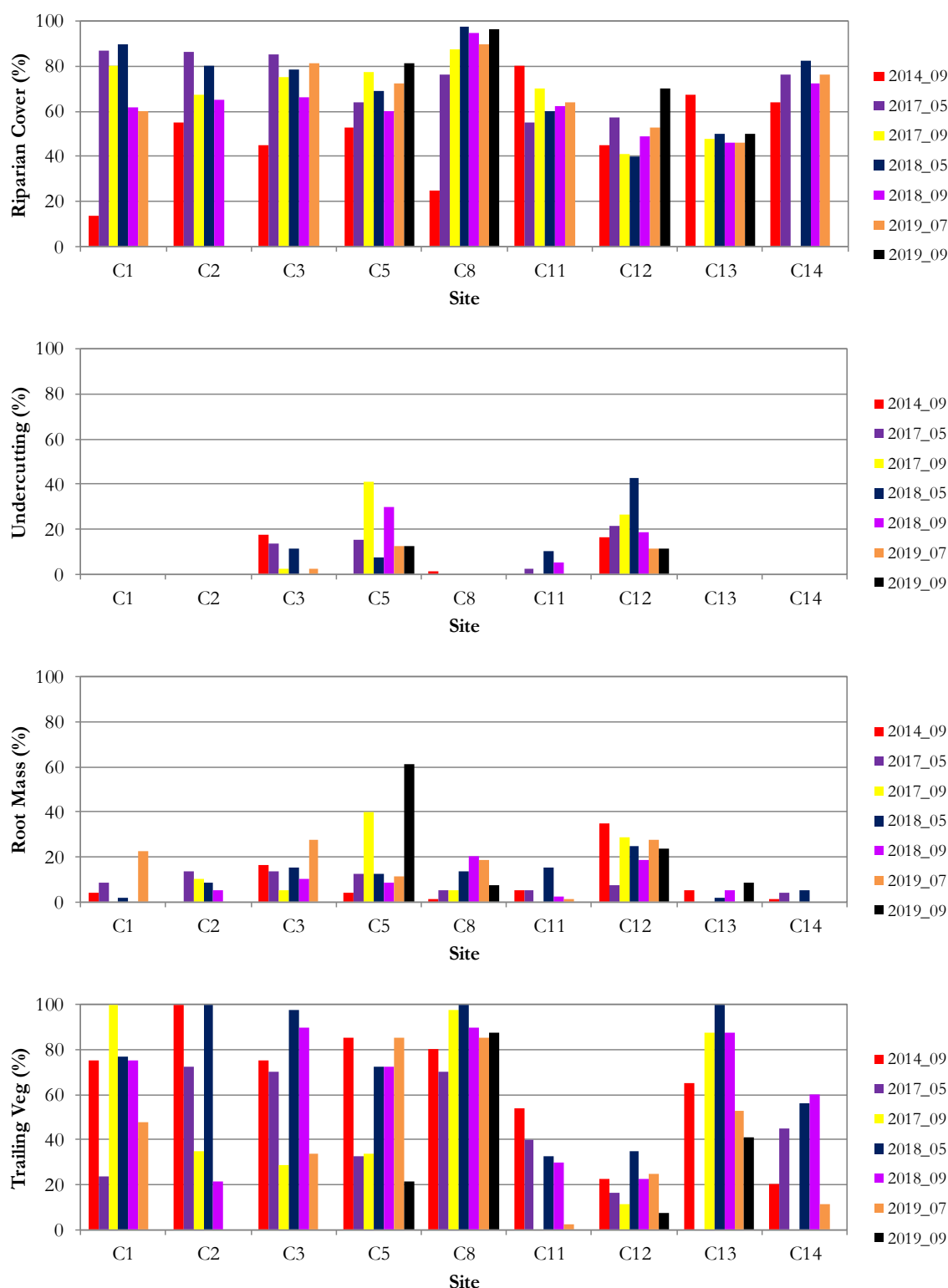


Figure A3 A summary of aquatic habitat data collected in post-construction phase monitoring at Devils Pulpit sites.

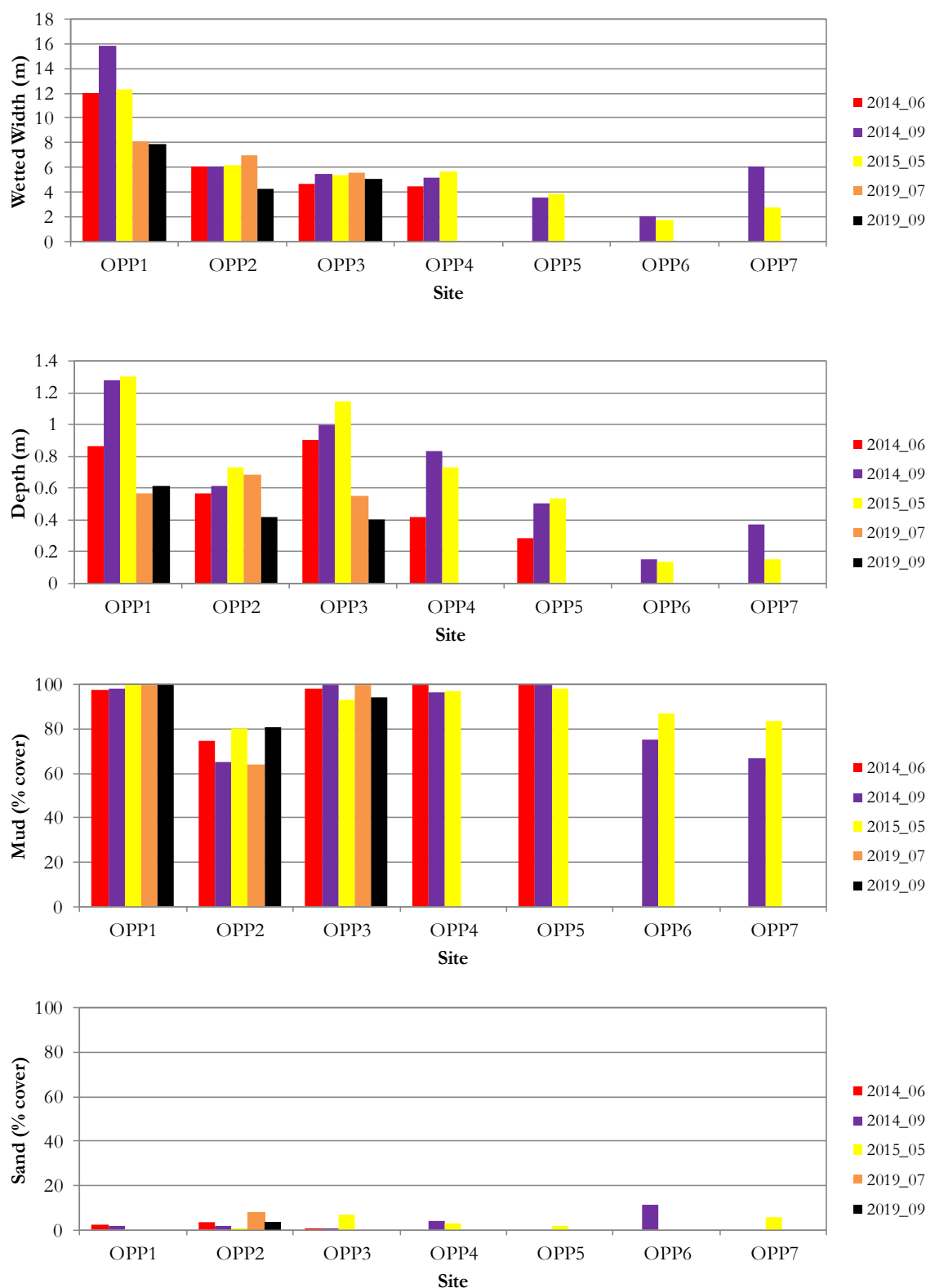


Figure A3 A summary of aquatic habitat data collected in post-construction phase monitoring at Devils Pulpit sites.

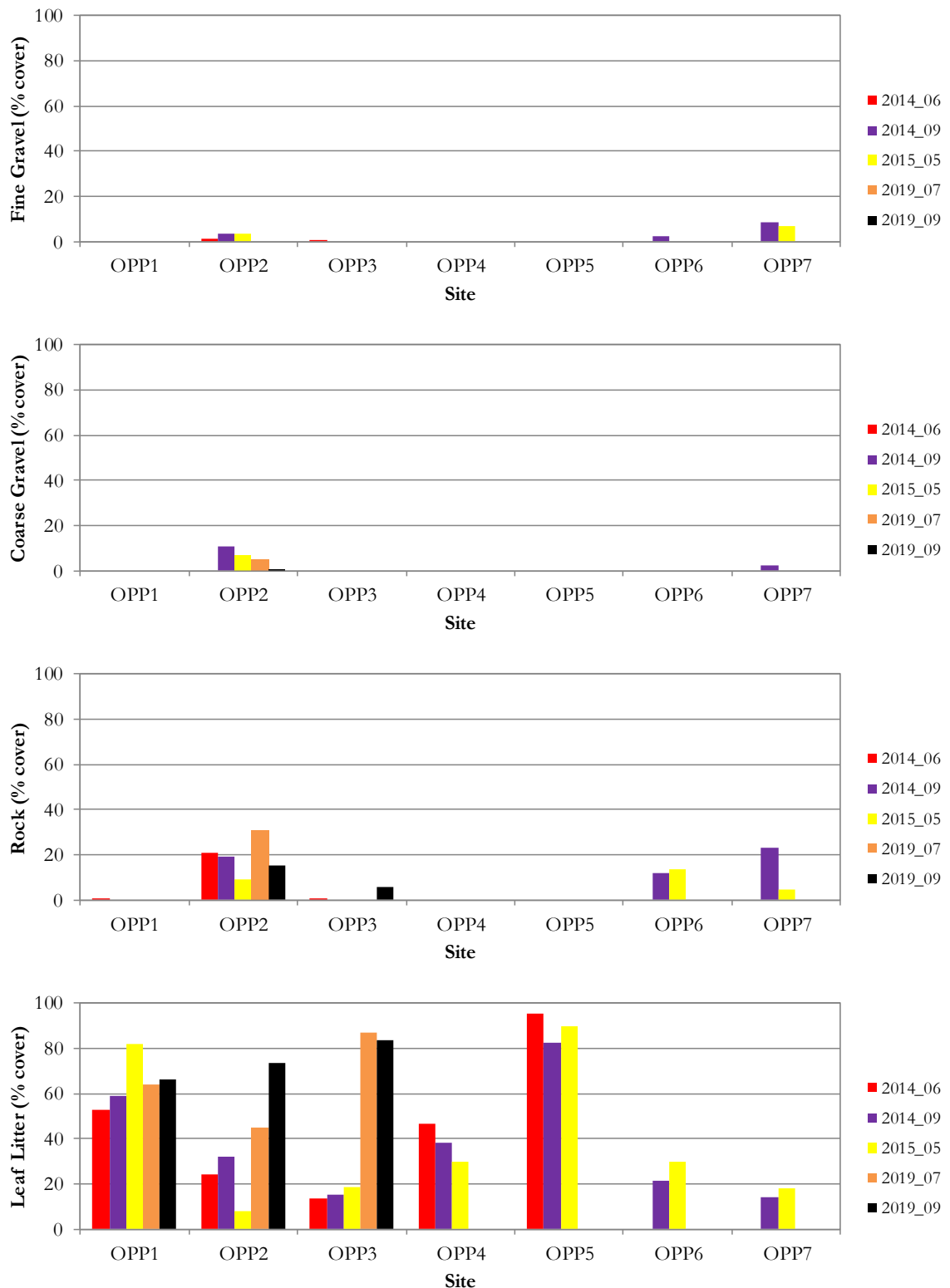


Figure A3 A summary of aquatic habitat data collected in post-construction phase monitoring at Devils Pulpit sites.

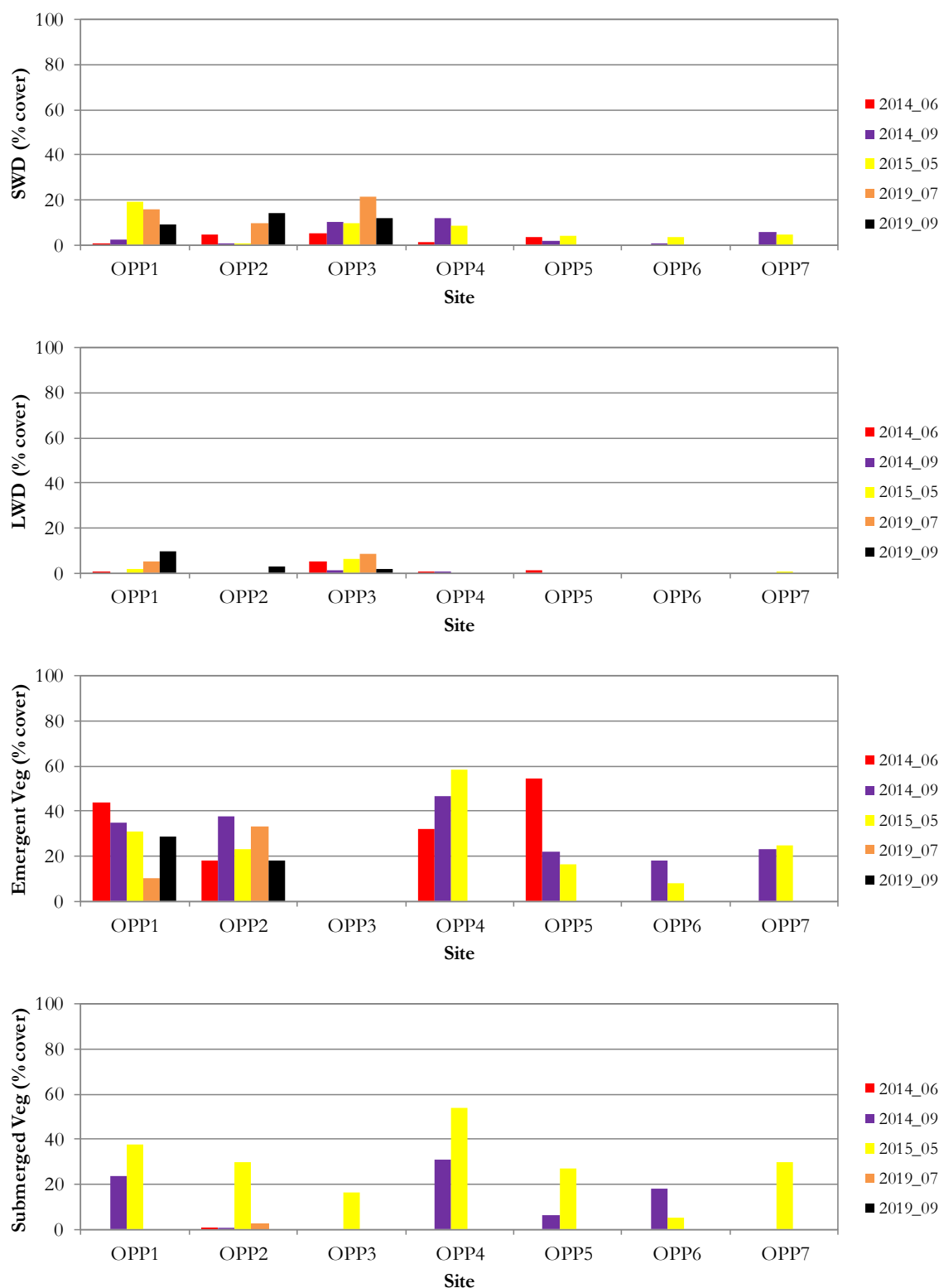
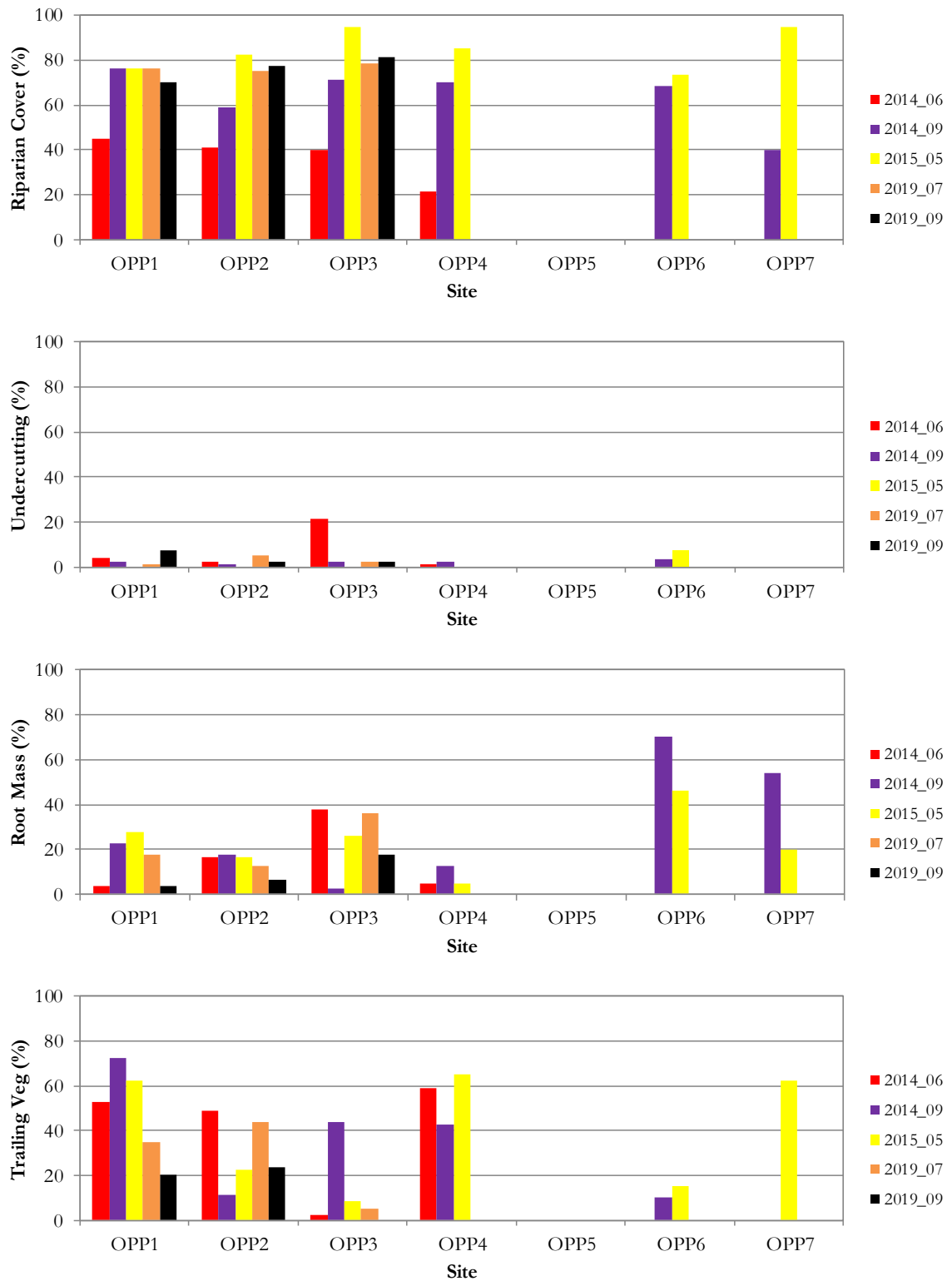


Figure A3 A summary of aquatic habitat data collected in post-construction phase monitoring at Devils Pulpit sites.



Appendix B

Construction Phase Fish Monitoring Results

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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	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 due to access restrictions or dry conditions at sites 2c, 11b, 13e and 26d.

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>															
		<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>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

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	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	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 due to access restrictions or dry conditions at sites 2c, 11b, 13e and 26d.

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

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

Appendix C

Water Quality Comparisons

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

Location	Sites	Parameter	Units	Pre-construction range	2017 Range	2018 Range	2019 Range
Unnamed waterway south of Serendipity Rd Ch. 11400	2a, 2b, 2c	Temp	(°C)	13.3 – 23.6	12.42 - 16.00	13.31 - 17.02	10.76 – 20.47
		DO	(mg/L)	4.11 - 10	1.42 - 4.58	1.09 - 4.10	0 – 4.96
		pH		5 – 6.9	4.98 - 5.83	6.13 – 7.1	6.44 – 6.92
		Conductivity	(mS/cm)	0.009 – 0.368	0.105 - 0.275	0.093 - 0.472	0.127 – 0.539
		Turbidity	(NTU)	0.9 - 118	7.6 - 20.8	13.1 - 109	22.5 - 446
Tabbimoble floodway no. 1 Ch. 115300	3a	Temp	(°C)	12.8 - 24	13.73 - 16.79	16.56 - 18.86	10.11 – 19.4
		DO	(mg/L)	1.3 - 8.07	4.61 - 5.59	4.4 – 4.41	5.44 – 7.71
		pH		4.4 – 7.2	5.43 - 5.62	6.36 - 6.52	6.42 – 7.62
		Conductivity	(mS/cm)	0.009 – 0.140	0.089 - 0.093	0.171 - 0.262	0.324 – 0.331
		Turbidity	(NTU)	18.9 – 132	12.5 - 13.5	10.3 - 11.0	12.9 - 17
Unnamed waterway south of MacDonalds Ck Ch. 134600	10b, 10c	Temp	(°C)	16.6 - 29	12.5 - 15.5	18.0 - 21.7	11.11 – 16.74
		DO	(mg/L)	3.17 - 10	0.61 - 0.89	0.58 - 6.32	3.08 – 6.07
		pH		4 – 9.3	4.7 - 4.75	6.19 - 6.56	6.08 – 7.06
		Conductivity	(mS/cm)	0.102 – 0.537	0.249 - 0.333	0.294 - 0.508	0.281 – 0.581
		Turbidity	(NTU)	1.3 - 800	3.8 - 5.7	4.0 - 80	0 – 18.3
MacDonalds Ck Tributary Ch. 135200, 135530 and 136450	11b, 11d, 22b, 22c	Temp	(°C)	15.4 – 26.7	14.16 - 24.69	16.68 - 22.64	10.29 – 18.26
		DO	(mg/L)	2.27 – 8.9	0.74 - 8.65	2.67 - 9.46	1.77 – 6.13
		pH		3.8 – 8.9	3.44 - 5.97	3.82 - 5.49	4.10 – 6.44
		Conductivity	(mS/cm)	0.092 – 0.606	0.131 - 0.178	0.14 - 0.193	0.178 – 0.237
		Turbidity	(NTU)	2.4 - 138	0 - 212	0.7 - 34.8	0 – 104
MacDonalds Ck Ch. 136600	12a	Temp	(°C)	14.9 - 26	13.36	19.08 - 19.72	12.89 – 19.58
		DO	(mg/L)	1.7 – 8.1	1.36	0.43 - 2.08	2.11 – 2.74
		pH		3.6 – 6.3	2.72	5.71 - 5.82	5.08 – 6.41
		Conductivity	(mS/cm)	0.164 – 0.406	0.25	0.28 - 0.295	0.374 – 0.41
		Turbidity	(NTU)	0 - 14	0	2.4 - 41.6	5.7 – 12.3
Broadwater NP Swampland Ch. 139000	16a, 16b, 27b, 27e	Temp	(°C)	18.6 – 21.45	13.33 - 21.38	14.29 - 20.3	9.92 – 21.02
		DO	(mg/L)	1.83 – 5.39	0.62 - 8.3	0.85 - 9.02	3.03 – 8.02

Location	Sites	Parameter	Units	Pre-construction range	2017 Range	2018 Range	2019 Range
		pH		4.15 – 4.63	3.7 - 4.6	3.9 - 5.83	3.76 – 5.91
		Conductivity	(mS/cm)	0.128 – 0.171	0.116 - 0.23	0.129 - 0.200	0.24 – 0.347
		Turbidity	(NTU)	0 - 703	0 - 64.2	0 - 61.5	0 – 57.2
Montis Gully Tributary 1 Ch. 141180 and 141850	13b, 13c, 13e, 26d	Temp	(°C)	17.23 – 30.9	13.33 - 19.27	14.29 - 17.88	14.39 – 24.6
		DO	(mg/L)	2.1 – 9.4	0.95 - 4.23	0.47 – 4.2	0.29 – 3.51
		pH		3.7 - 7	3.39 - 3.8	3.44 - 6.43	3.48 – 6.8
		Conductivity	(mS/cm)	0.026 – 0.209	0.137 - 0.206	0.163 - 0.200	0.286 – 0.818
		Turbidity	(NTU)	0 - 225	0 - 4.1	3.2 - 14.4	1.9 – 54.4
W of Bundjalung NP Approximately 4 km east of Ch. 110000	C13, C14	Temp	(°C)	18.09 – 19.11	12.59 - 16.47	13.92 - 16.51	11.79 – 14.55
		DO	(mg/L)	2.24 – 4.38	3.4 - 3.79	2.86 - 10.97	1.34 – 5.09
		pH		4.56 – 5.47	4.84 - 5.51	5.20 - 5.68	5.43 – 6.92
		Conductivity	(mS/cm)	0.086 – 0.112	0.102 - 0.112	0.063 - 0.155	0.105 – 0.137
		Turbidity	(NTU)	0 – 8.7	0 - 15	2.8 - 18.9	3.5 – 4.1
Broadwater NP 6.5 km east of Ch.13000	C11, C12	Temp	(°C)	15.91 – 18.49	17.08 - 29.36	20.09 - 24.65	9.73 – 18.66
		DO	(mg/L)	2.9 – 5.59	1.76 - 8.35	2.91 – 5.69	3.8 – 5.09
		pH		3.85 - 4	3.79 - 4.54	3.94 - 4.40	4.21 – 4.53
		Conductivity	(mS/cm)	0.124 – 0.149	0.106 - 0.155	0.143 - 0.208	0.252 – 0.278
		Turbidity	(NTU)	0 – 2.3	0 - 6.8	3.4 - 4.8	0 – 0
MacDonalds Ck Tributary 0.5 km east of 136600 and 1 km east of 137800	C2, C5	Temp	(°C)	16.87 – 17.78	12.36 - 19.3	15.34 - 20.2	8.15 – 13.99
		DO	(mg/L)	4.58 – 4.69	2.74 - 4.70	2.08 - 4.26	3.05 – 3.29
		pH		3.7 – 4.22	3.31 - 3.99	3.76 - 4.29	3.73 – 3.88
		Conductivity	(mS/cm)	0.115 – 0.158	0.113 - 0.183	0.115 - 0.185	0.206 – 0.256
		Turbidity	(NTU)	0 - 0	0 - 37.6	0 - 29.2	0 – 1.8
Broadwater NP 1 km east of Ch 138000	C1, C3	Temp	(°C)	17.2 - 18.91	14.33 - 23.66	16.05 - 21.91	12.33 – 17.61
		DO	(mg/L)	4.55 - 9.18	2.45 - 3.77	1.35 - 9.43	3.52 – 9.65
		pH		3.97 – 4.49	3.42 - 3.96	3.45 - 4.17	3.74 – 4.27
		Conductivity	(mS/cm)	0.089 - 0.176	0.100 - 0.201	0.113 - 0.209	0.147 – 0.306
		Turbidity	(NTU)	0 – 1.4	0 - 26.4	1.8 - 28.5	0 – 0.3

Location	Sites	Parameter	Units	Pre-construction range	2017 Range	2018 Range	2019 Range
Broadwater NP 2 km east of 136400	C8	Temp	(°C)	17.98	12.18 - 18.49	13.52 - 14.71	13.33 – 19.02
		DO	(mg/L)	5.77	2.87 - 3.29	2.46 - 3.8	7.38 – 9.96
		pH		3.95	3.21 - 3.46	3.73 - 3.92	3.76 – 3.97
		Conductivity	(mS/cm)	0.236	0.315 - 0.363	0.291 - 0.321	0.413 – 0.458
		Turbidity	(NTU)	12.1	0 - 5	5 - 12.2	0 – 12.2
Tabbimoble Channel 2	OPP1, OPP2, OPP4, OPP7	Temp	(°C)	7.86 – 18.66	-	-	8.91 – 16.01
		DO	(mg/L)	3.17 – 8.74	-	-	1.89 – 5.83
		pH		4.79 – 6.92	-	-	5.06 – 6.8
		Conductivity	(mS/cm)	0.081 – 0.194	-	-	0.148 – 0.23
		Turbidity	(NTU)	1.3 – 44.3	-	-	3.3 – 7.8
Tabbimoble Channel 3	OPP3, OPP6	Temp	(°C)	11.66 – 19.14	-	-	11.99 – 16.06
		DO	(mg/L)	4.64 – 6.53	-	-	0.79 – 0.98
		pH		4.99 – 6.11	-	-	6.41 – 6.56
		Conductivity	(mS/cm)	0.128 – 0.215	-	-	0.173 – 0.185
		Turbidity	(NTU)	0 – 6.5	-	-	0 - 0