UPGRADING THE PACIFIC HIGHWAY

Woolgoolga to Ballina Planning Alliance

UPGRADING THE PACIFIC HIGHWAY

Woolgoolga to Ballina Upgrade

Supplementary Biodiversity Assessment

FINAL

November 2013

NSW GOVERNMENT Transport Roads & Maritime Services

aurecon

SINCLAIR KNIGHT MERZ SKM

Contents

Table of figures

Appendix F. Supplementary fish survey reports for Section 1 and 2

Aquatic Monitoring

RMS Woolgoolga to Glenugie – Stage 1

Prepared for: NSW Roads and Maritime Service

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

info@geolink.net.au

UPR	*Description*	*Date Issued*	*Issued By*
2083-1006	Draft	24/10/2012	Simon Williams
2083-1010	Final Draft	11/12/2012	Simon Williams

Table of Contents

Illustrations

Tables

Plates

Figures

Appendices

1

Introduction

The following report is a summary of aquatic ecological monitoring undertaken as part of the planning and assessment of the Woolgoolga to Glenugie section of the Pacific Highway upgrade. GeoLINK has engaged Aquatic Science and Management to undertake this monitoring and prepare this report.

1.1 Background

As part of the broader Woolgoolga to Ballina section of the Pacific Highway upgrade, construction work on the Woolgoolga to Glenugie section is proposed to commence shortly. A variety of environmental variables will require monitoring prior to, during and after construction, including threatened species. Formal environmental assessments undertaken during the planning phase of the Woolgoolga to Glenugie upgrade revealed the actual and potential occurrence of a variety of threatened species listed under NSW state government and federal government legislation at various locations along the highway upgrade alignment or potential construction footprint. Under direction of the environmental advisory group, a need for monitoring of threatened species of fish with potential to occur within, or near to, the construction footprint has been identified. The two threatened fish species of concern are the Oxleyan pygmy perch (*Nannoperca oxleyana*) and the Purple-spotted gudgeon (*Mogurnda adspersa*).

1.2 Objectives

The key objective of pre-construction aquatic monitoring was to identify Oxleyan pygmy perch (OPP) and Purple spotted gudgeon (PSG) populations occurring within the construction footprint. Secondary objectives included:

- assessing available aquatic habitats within the construction footprint for potential to house OPP and PSG populations;
- providing a baseline dataset describing the condition of aquatic habitats and structure of aquatic fauna communities upstream of, downstream of, and along the road alignment to assess future potential construction impacts; and
- providing recommendations regarding any future monitoring activities and strategies to mitigate any potential impacts upon known or potential populations of OPP or PSG.

1.3 Species Profile - Oxleyan Pygmy Perch (OPP)

Plate 1.1 Oxleyan Pygmy Perch (*Nannoperca oxleyana*) Pic: NSW DPI

1.3.2 Identification

OPP grow to a total length (TL) of around 70mm but are most commonly found at around 35 – 45mm. A survey conducted near Evans Head found OPP from 15 – 55mm but the majority were 17 -37mm (Knight 2000). OPP are light brown to olive colour and are darker on the back and paler on the sides. They have 2 – 4 dark brown bars between their head and tail, a black spot with orange margin at caudal peduncle and eyes with faint blue margin. Their fins are clear, except during breeding when their dorsal and anal fins go black and their caudal fin and stripes go scarlet. They have ctenoid scales with dark margins and their body is moderately compressed and has no lateral line.

1.3.3 Distribution

In NSW OPP are known to occur in Banksia dominated heath (wallum) ecosystems and coastal lakes as far south as Tick Gate Swamp (just south of Wooli) (Knight & Arthrington 2008). The predicted natural range of OPP in NSW is from the Queensland border south as far as the Manning River. OPP had been collected from Cassons Creek in 1976 (Knight & Arthrington 2008).

1.3.4 Habitat

In NSW OPP are confined to dystrophic, acidic freshwater systems draining through coastal lowlands (Knight & Arthrington 2008). They are mostly collected from shallow, slow and narrow streams and lakes and mostly found over sandy and sometimes muddy benthos with high proportions of riparian cover, leaf litter and emergent aquatic plants. Typically, depths are around 50 cm but have been collected from depths of 130 cm. Water velocities are almost always below 0.4 m/sec, limiting occurrence to backwaters and small tributaries (Pusey, Kennard & Arthrington 2004).

1.3.5 Water Quality

OPP tend towards well oxygenated, acidic freshwater sites. A summary of water quality information from sites where OPP have been found is presented in **Table 1.1.**

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

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

From Knight & Arthrington (2008)

1.3.6 Survey Methods

OPP are known to be particularly sensitive to capture by nets. In particular, surveys using seine nets have resulted in significant mortality in the past. The methods suggested for OPP surveys are electrofishing and setting unbaited standard fish traps. In order to minimise disturbances to breeding, surveys should be avoided between October and April.

1.4 Species Profile - Purple Spotted Gudgeon (PSG)

1.4.1 Identification

Purple-spotted gudgeon (PSG) are thought to reach a TL of 140 mm. They are most often found at 70 – 80 mm. They are an elongate fish with a slightly compressed body posteriorly. The caudal fin is rounded. They have diagonal brown stripes on their cheeks; males have 3 and females have 2. Their fins are yellowish, becoming

darker towards the margins and with red spots. They have brownish spots on their sides, overlaid with white, purple and red spots. Mature males have a distinct bump on the head. The mouth reaches to below the eye.

Plate 1.2 Purple Spotted Gudgeon (*Mogurnda adspersa*). Pic: NSW DPI

1.4.2 Distribution

PSG are geographically widespread, occurring in coastal and inland drainages in QLD and northern NSW. They are predicted to occur in coastal drainages as far south as the Clarence River and are common in coastal drainages of Queensland but endangered in the western flowing streams.

1.4.3 Habitat

PSG are collected from a wide variety of habitats, including coastal streams, large rivers and dune lakes and streams. They have been found in riffles and pools and over a wide variety of benthic habitats but on average they appear to prefer streams that are less than 10 m wide, 40 cm deep and with a moderate to low current. They are most often encountered over finer substrates. They also appear to prefer streams with abundant submerged marginal vegetation and those with abundant root masses and undercut banks. In coastal drainages, they are most common at around 200 km upstream of the river mouth and are most frequently collected within 1 m of the bank.

1.4.4 Water Quality

A summary of water quality information from coastal sites where PSG have been collected appears in **Table 1.2**. PSG tend towards well oxygenated freshwater sites and, unlike OPP, show no selectivity towards wallum, or coastal swamps.

Table 1.2 A summary of water quality data from coastal sites where PSG have been captured

Measure	*Range*	*Mean*
Temp (°C)	11.9 – 31.7	19.8
DO (mg/L)	0.6 – 12.8	7.3
pH	5.6 – 8.8	7.5
Cond (µS/cm)	72 - 2495	654.5
Turbidity (NTU)	0.2 - 200	5.8

From Pusey, Kennard & Arthrington (2004)

1.4.5 Survey Methods

PSG have been collected using a variety of methods including electrofishing, bait traps and seine and fyke nets. In order to avoid disturbances to breeding, surveys should be avoided from November to February.

2

Methodology

2.1 Study Area

The area being studied is the Pacific Highway upgrade corridor between Woolgoolga and Glenugie. The Pacific Highway upgrade between Woolgoolga and Glenugie is being planned in two sections, Section 1 and Section 2. These sections will be referred to throughout the following report, and all data collected throughout the study will be displayed by section. There are 16 significant waterway crossings along the upgrade corridor. Section 1 covers the waterways between Arrawarra Gully and Boneys Creek inclusive. Section 2 covers the waterways between Halfway Creek and Glenugie Creek. All of the waterways in Section 1 flow east into the Corindi River or Arrawarra Creek, with the exception of Dundoo Creek and Boneys Creek, which flow west into the Orara River. All of the waterways in Section 2 flow west into the Orara River. The Orara River is a major tributary of the Clarence River. The study area is displayed in **Illustration 2.1**.

Due to the potential for construction impacts to be transported along waterways, some sites were located outside of the immediate highway upgrade corridor. In most cases, the maximum distance from the highway corridor covered by the survey was 100 m.

2.2 Sites

A preliminary survey was undertaken to select sites within the study area. The best sites in each significant waterway were identified using known habitat preferences of the target species (Pusey, Kennard & Arthrington 2004) and/or were considered generally representative of the range of aquatic habitat types found within the study area. Sixteen significant waterways (locations) were identified within the study area. Between 1 and 3 monitoring sites were chosen within each of the 16 significant locations. The number of monitoring sites per location directly relates to the habitat potential of the waterways. In order to assess waterways for their habitat potential the classes of Fairfull and Witheridge (2003) were applied (see **1Table 2.1**). Class 3 and Class 4 intermittent streams were only sampled at one site located downstream of any potential impact. Class 2 streams were sampled at the site of potential disturbance and downstream. Class 1 waterways were sampled at 3 sites, located at the site of, upstream of, and downstream of potential construction impacts.

Table 2.1 Classification method used to assess waterways for fish habitat potential.

Classification	*Characteristics of waterway type*	*Minimum recommended crossing type*
Class 1- Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species	Bridge, arch structure or tunnel
Class 2 - Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks and with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.	Bridge, arch structure, culvert or ford
Class 3- Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert or ford

Classification	*Characteristics of waterway type*	*Minimum recommended crossing type*
Class 4 – Unlikely fish habitat	Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event (e.g. dry gullies or shallow floodplain depression with no permanent wetland aquatic flora).	Culvert, causeway or ford

(Source: Fairfull & Witheridge, 2003)

A total of 27 sites were chosen from the 16 significant waterways identified. 16 sites were located downstream of the road corridor, 8 within the road corridor and 3 upstream of the road corridor. Fifteen sites from 9 locations were located in Section 2 of the upgrade and 12 sites from 7 locations were located in Section 1 of the upgrade. Two sites, one is Section 1 and one in Section 2 of the upgrade, were dry at the time of sampling and therefore habitat descriptions and fish sampling were not undertaken. A brief description of the physical location and habitat potential of each of the locations is presented in **Table 2.2**. The position of the sites is presented in **Illustration 2.1**. Locations were numbered in order of sampling as opposed to a positional basis. Sites within locations were lettered from upstream to downstream.

Table 2.2 A brief description of the significant waterways crossing the upgrade alignment.

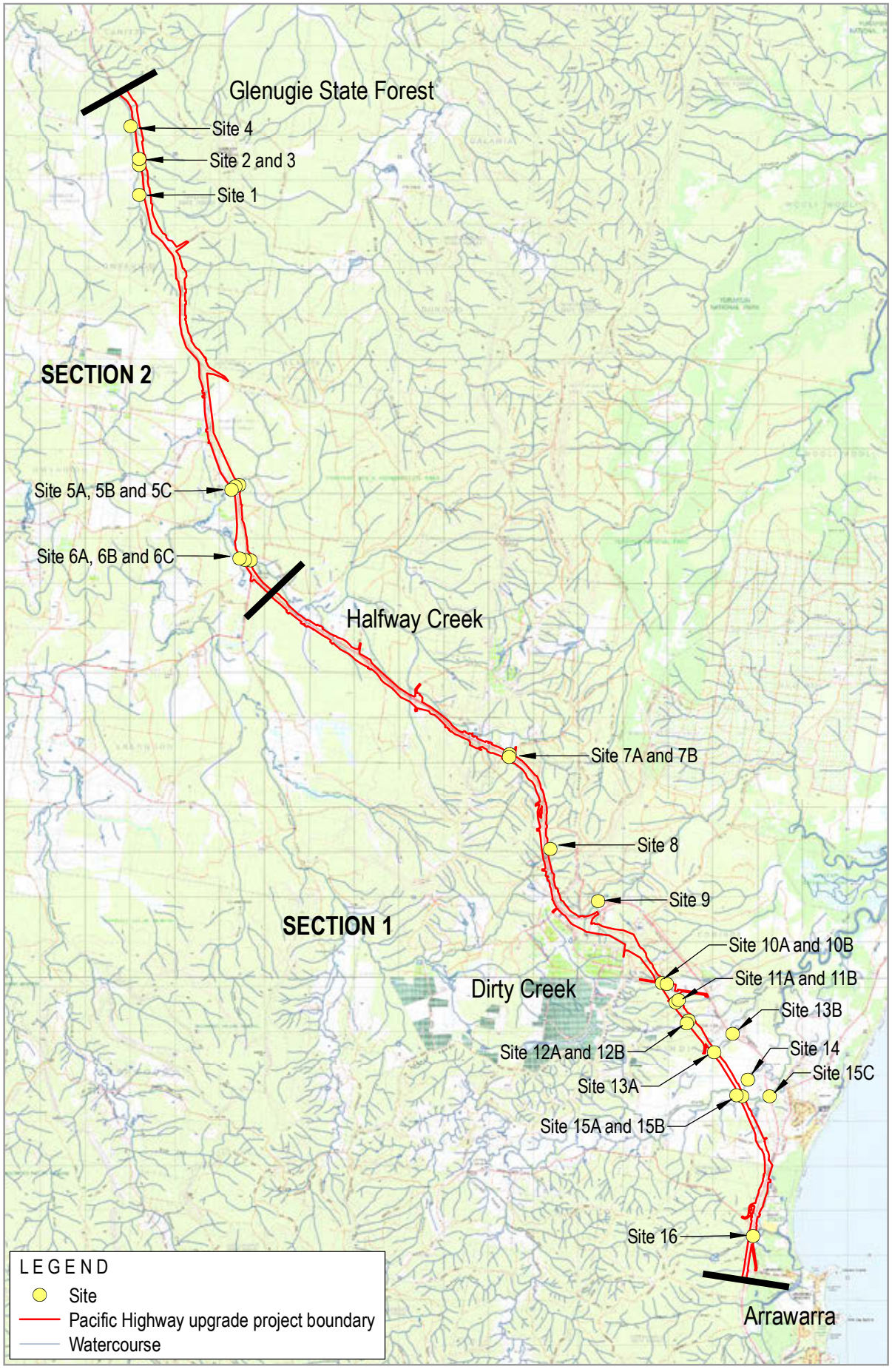
Waterway	*Location*	*Section*	*Chainage*	*Notes*
Glenugie Creek	1	2	29300	Drains from headwaters approximately 2 km upstream. Intermittent **Class 4** Stream. Marginal fish habitat. **1 site** D/S of impact.
Unnamed (Glenugie Ck Trib)	2	2	29850	Drains from headwaters approximately 1 km upstream. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** at confluence with Glenugie Ck.
Unnamed (Glenugie Ck Trib)[1]	3	2	30200	Drains from headwaters approximately 1.5 km upstream. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** D/S of impact. Dry at time of sampling.
Unnamed (Glenugie Ck Trib)	4	2	30800	Drains from headwaters approximately 1 km upstream. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** at confluence with Glenugie Ck.
Wells Crossing	5	2	22400	Drains from headwaters approximately 3 km upstream. Damned downstream. Series of connected pools and wetlands forming a **Class 1/2** waterway. Significant fish habitat. **3 sites**, U/S, impact and D/S.
Halfway Creek	6	2	20700	Drains from a subcatchment to the Orara River. **Class 1/2** waterway. Significant fish habitat. **3 sites** U/S, impact and D/S.
Boneys Creek (Halfway Creek Trib)	7	1	13350	Drains headwaters approximately 3 km upstream and flows into Halfway Creek via a makeshift dam immediately downstream of impact. **Class 2** stream. **2 sites**, impact and D/S.
Dundoo Creek[1]	8	1	10700	Drains headwaters approximately 1 km upstream into the Orara River. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** immediately D/S of impact. Dry at time of sampling.
Dirty Creek[2]	9	1	8500	Drains headwaters approximately 1 km upstream of impact into Saltwater Creek. Very steep bedrock **Class 3** waterway. **1 site** D/S of impact

Waterway	*Location*	*Section*	*Chainage*	*Notes*
Corindi Local Access Road (Redbank Ck Trib)	10	1	6200	Drains headwaters approximately 2 km upstream into Redbank Ck. Series of connected pools and wetlands forming a **Class 2/3** wetland. **2 sites**, impact and D/S.
Unnamed (Redbank Ck Trib)	11	1	6650	Drains headwaters approximately 2 km upstream into Redbank Ck. Series of connected pools and wetlands forming a **Class 2/3** wetland**. 2 sites**, impact and D/S.
Redbank Creek	12	1	5650	Drains headwaters approximately 2.5 km upstream into Corindi River. Series of connected pools and wetlands forming a **Class 2/3** wetland. **2 sites**, impact and D/S.
Cassons Creek	13	1	4750	Drains a floodplain swamp into Redbank Creek. Discontinuous series of large pools forming a **Class 2** waterway. **2 sites**, impact and D/S.
Blackadder Gully (floodplain)	14	1		Swamp drainage channel forming a **Class 3/4** waterway. Marginal fish habitat potential. **1 site** D/S of impact
Corindi River	15	1	3600	Permanent **Class 1** waterway with an entrance to the ocean. Significant fish habitat. **3 sites** U/S, impact and D/S.
Arrawarra Gully	16	1	300	Drains headwaters approximately 2 km upstream into Arrawarra Ck. Series of pools forming a **Class 3** stream. Marginal fish habitat. **1 site** D/S of impact.

[1] Dry at the time of preliminary survey.
[2] Crosses alignment on escarpment but better to monitor downstream near old highway.

Information shown is for illustrative purposes only

Drawn by: RE Checked by: MB Reviewed by: SDW Date: December 2012
Source of base data: NSW Topographic Map



0 2.5 km

North

Site Locations

GeoLINK environmental management and design

Woolgoolga to Glenugie Aquatic Monitoring - Stage 1
2083-1007

Illustration 2.1

2.3 Timing

The aquatic survey work was undertaken on 11, 12, 17, 18 and 19 September 2012. The work was scheduled to avoid the OPP breeding season which is thought to stretch between October and May. The survey was undertaken following an extended dry period, with no rain in the two weeks prior to the beginning of the survey and unusually low rainfall in the preceding two months. A summary of mean and monthly rainfall prior to the survey is presented in **Figure 2.1**. Heavy rainfall was recorded on the night of 18 September but this did not appear to influence conditions with no significant flows (> 0.1m/s) noted at any of the sites visited throughout the survey.

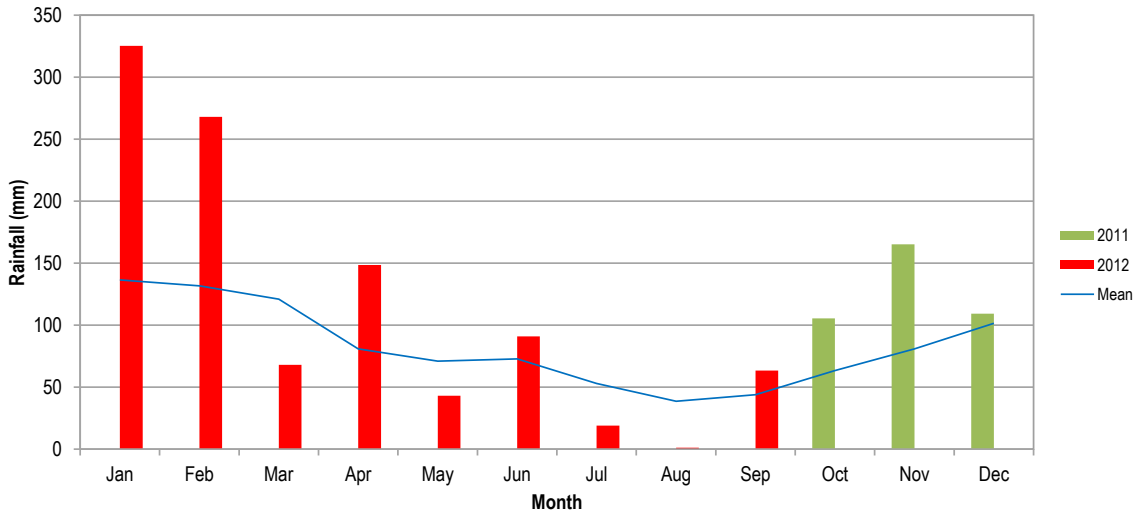


Figure 2.1 Mean monthly rainfall and total monthly rainfall for 12 month period prior to sampling from the Grafton BoM weather station.

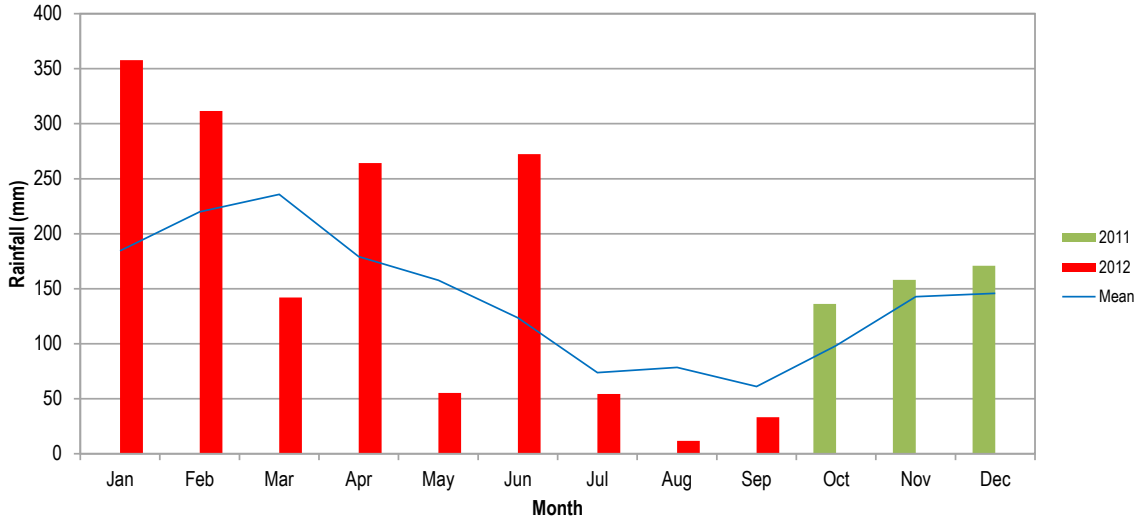


Figure 2.2 Mean monthly rainfall and total monthly rainfall for 12 month period prior to sampling from the Coffs Harbour (MO) BoM weather station.

2.4 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 and Purple-spotted gudgeon were recorded at the sampling station in the first 30 minute period;
- undertaking back-pack electro-fishing at each site, where safe to do so. Backpack electrofishing was restricted to shallow areas (e.g. <1m 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 2.3**. 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 5 mm dip net (knotless mesh).

Table 2.3 Details of electrofisher settings and effort at each site

Section	*Site*	*Voltage (V)*	*Pulse Freq (Hz)*	*Duty Cycle (%)*	*Passes*	*Seconds Pulsed*
2	1	300	25	50	2	570
2	2	200	25	20	2	247
2	4	200	25	20	2	273
2	5a	400	50	25	1.5	470
2	5b	400	50	25	2	184
2	5c	300	40	25	2	580
2	6a	250	45	30	2	604
2	6b	300	45	30	1.5	538
2	6c	300	45	30	2	504
1	7a	200	25	20	2	420
1	9	250	45	30	1	604
1	10a	150	45	20	2	600
1	10b	250	45	20	2	606
1	11a	250	45	20	2	513
1	11b	300	45	30	2	480
1	12a	300	45	30	2	427
1	12b	200	40	25	2	215
1	13a	250	45	25	2	588
1	13b	200	40	25	1.5	602
1	14	300	40	25	2	271
1	15a	200	45	30	2	606
1	15b	200	40	25	2	600
1	15c	200	45	30	2	600
1	16	250	40	30	2	508

All captured fish were retained in 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 on captured fish were recorded at the time of capture. Exotic species captured were euthanised in accordance with approved animal ethics procedures (Barker *et al*. 2009).

2.5 Water Quality

At each site physico-chemical water quality parameters were measured in surface water with an HORIBA U52 multimeter to determine the suitability of the site for the target species in terms of water quality. The measures collected were:

- temperature (˚C) - a measure of the degree of hotness or coldness of water. It is a form of pollution and can impact on riverine biota and associated biological and chemical processes;
- conductivity (mS/cm) - a measure of the amount of dissolved salts in the water and its ability to conduct an electrical current. It is important as some plant and animal species are salt sensitive whilst others require higher salt concentrations. It is also particularly important for electrofishing as it determines the suitable settings to be utilised at each site;
- dissolved Oxygen (mg/L & % saturation) - a measure of the amount of oxygen dissolved in water. Dissolved oxygen is vital for many forms of riverine and estuarine biota including native fish and is also vital for the functioning of healthy aquatic ecosystems;
- pH - a measure of hydrogen ion concentration that describes the acidity or alkalinity of water. Many organisms have a specific pH range within which they are able to function; and
- turbidity (NTU) – a measure of the capacity of the water to transmit light, which is an important aspect of healthy aquatic systems. Turbid waters often contain high concentrations of suspended sediment. Some fish are intolerant of high suspended sediment concentrations.

In addition to the above methods observations of surface films and debris were made at each site.

2.6 Habitat Description

A general description of the habitat characteristics of each monitoring site was undertaken, 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 & Arthrington (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 water 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 % cover of mud, sand, fine gravel (2-16 mm), coarse gravel (16-64 mm), cobble (64-128 mm), rock and bedrock;
- per cent of bank classified as undercut (30 cm overhang within 10 cm of surface), 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 do this three transects were positioned perpendicular to stream flow and the substrate composition, debris cover and vegetative cover were estimated in four 0.5 m^2 quadrats randomly positioned along each transect. Wetted width and depth were also measured at each of these transects. Additionally, 4 transects, representing a total of 20% 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 location of the photographic monitoring point as well as upstream and downstream site boundaries were recorded with a GARMIN 12 handheld GPS to facilitate repeat sampling. All spatial data were collected and are reported in WGD84.

3.1 Fish Survey

Approximately 186 hours of fish trapping and 11624 seconds of electrofishing were undertaken. A total of 1172 fish from 11 species were captured during the fish survey. Of the 11 species captured, 10 were found in Section 2 and 7 in Section 1. A total of 919 individual fish were captured in Section 1 and 253 in Section 2. Of the total number of fish captured, 944 individuals from 11 species were captured utilising the electrofisher and 228 individuals from 7 species were captured using fish traps.

No Oxleyan pygmy perch or Purple spotted gudgeon were collected during the survey. The most common fish captured during both electrofishing and fish trapping were *Hypseleotris spp* (the majority of these were confirmed to be Firetail gudgeon, *Hypseleotris galii,* but some smaller specimens may have been Western carp gudgeon, *Hypseleotris klunzingeri*). They accounted for approximately 43% of the total number of individual fish captured. The next most common species were Mosquito fish (*Gambusia holbrooki*), which accounted for approximately 24%, Striped gudgeon (*Gobiomorphus australis*), which accounted for approximately 15%, and Empire gudgeon (*Hypseleotris compressa*), which accounted for approximately 13%.

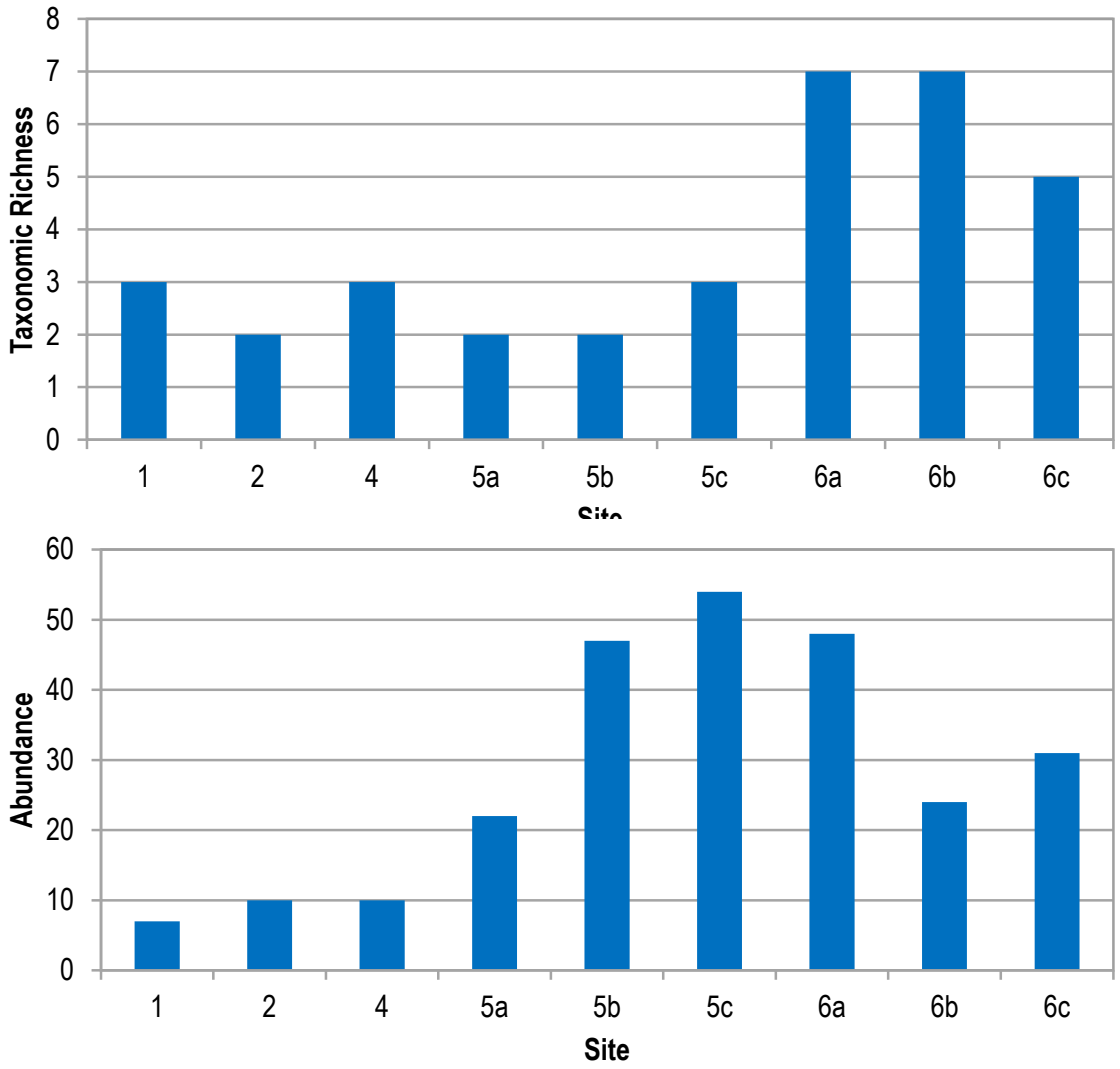


Figure 3.1 Taxonomic richness and abundance of fish at all sites within Section 2.

Taxonomic richness at the sites in Section 2 ranged from 2 species to 7 species. The most taxonomically diverse sites within Section 2 were 6a and 6b, both located in Halfway Creek (**Figure 3.1**). Halfway Creek is also the largest waterway within Section 2. Abundance at sites in Section 2 also varied strongly with captures of between 7 and 54 fish. Overall abundance in Section 2 was greatest at sites 5b, 5c and 6a.

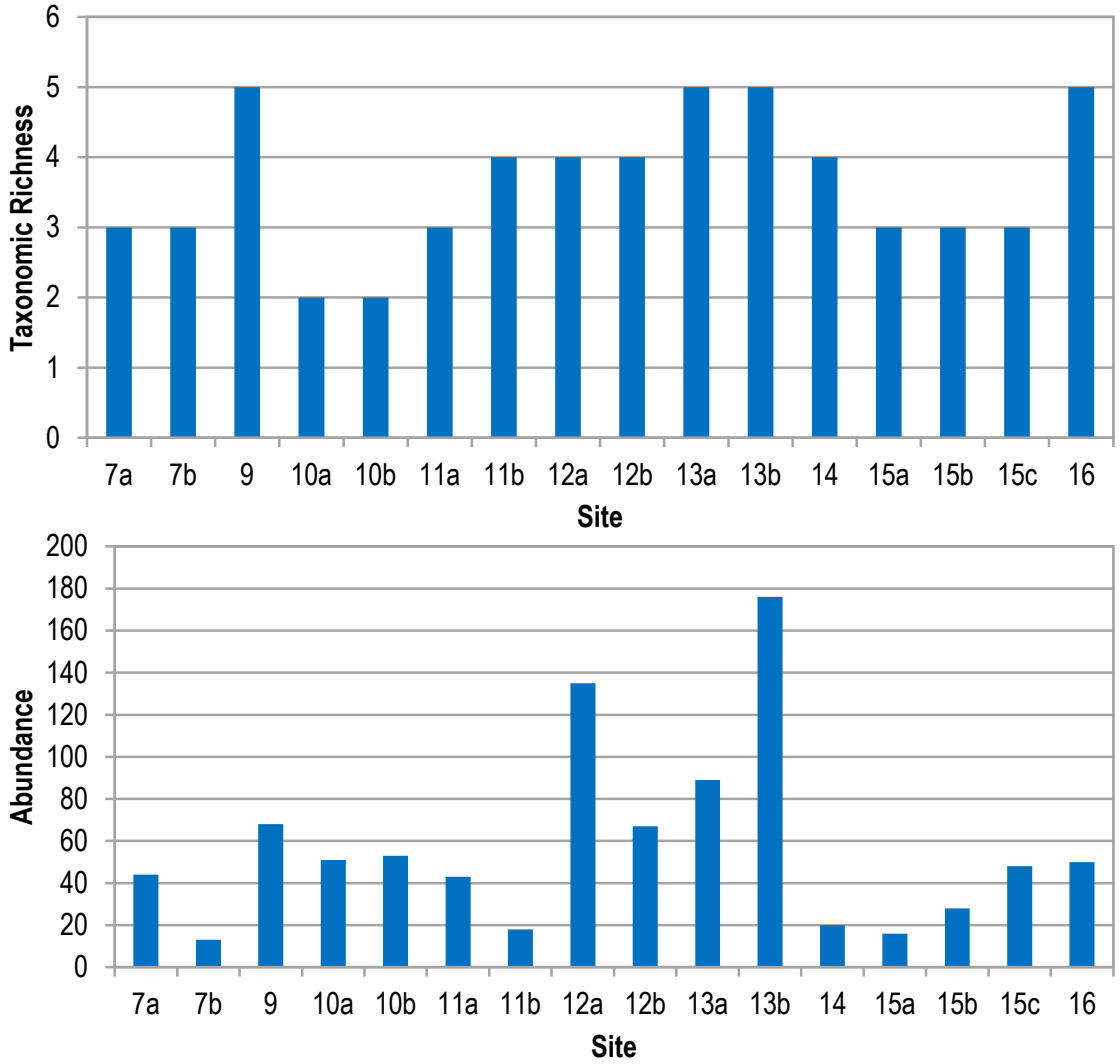


Figure 3.2 Taxonomic richness and abundance of fish at all sites within Section 1.

In Section 1 taxonomic richness ranged from 2 to 5 taxa. The most taxonomically rich sites were 9, 13a, 13b and 16. Abundance varied widely among sites in Section 1, with between 16 and 176 fish collected at each site. The greatest numbers of fish were captured at sites 12a and 13b.

Four crustacean taxa were captured. Of these, only the conspicuous species of long-armed shrimp and yabbies were counted. Numbers of caridean shrimp and penaeid prawns were estimated to within an order of magnitude at each site.

Summaries of the fish survey results for each of the two highway upgrade sections are presented in **Error! Reference source not found.** and Error! Reference source not found.. Pie charts representing the fish community structure are displayed in **Appendix B**.

Table 3.1 Summary of captures for all fishing methods at all sites in Section 2

Scientific Name	Common Name	Site								
		1	*2*	*4*	*5a*	*5b*	*5c*	*6a*	*6b*	*6c*
Family: Anguillidae										
Anguilla reinhardtii	Longfin Eel	0	0	0	0	0	0	1	0	0
Family: Atherinidae										
Craterocephalus marjoriae	Majories Hardyhead	0	0	3	0	0	0	0	1	1
Family: Eleotriidae										
Gobiomorphus australis	Striped Gudgeon	0	0	0	0	0	1	11	10	16
Hypseleotris spp	Firetail Gudgeon	2	9	6	16	31	39	20	9	12
Hypseleotris compressa	Empire Gudgeon	0	0	0	0	0	0	1	1	0
Philypnodon sp.	Dwarf Flathead Gudgeon	1	1	1	0	0	0	1	1	0
Family: Melanotaeniidae										
Rhadinocentrus ornatus	Ornate Rainbowfish	4	0	0	0	0	0	13	0	1
Family: Plotosidae										
Tandanus tandanus	Freshwater Catfish	0	0	0	0	0	0	1	0	1
Family: Poeciliidae										
Gambusia holbrooki	Mosquito Fish	0	0	0	6	16	14	0	1	0
Family: Retropinnidae										
Retropinna semoni	Australian Smelt	0	0	0	0	0	0	0	1	0
Family: Parastacidae										
Cherax sp.	Yabby	1	2	0	0	0	6	3	0	1
Family: Paleomonidae										
Macrobrachium spp.	Long-armed Shrimp	0	0	0	0	0	0	0	0	0
Unknown sp.	Freshwater Prawn	0	0	1	0	0	0	0	>10	>10
Family: Atyidae										
Caridina spp.	Freshwater Shrimp	>10	>100	>100	>1000	>1000	>10000	>100	>100	>1000

Table 3.2 Summary of captures for all fishing methods at all sites in Section 1

		Site															
Scientific Name	***Common Name***	***7a***	***7b***	***9***	***10a***	***10b***	***11a***	***11b***	***12a***	***12b***	***13a***	***13b***	***14***	***15a***	***15b***	***15c***	***16***
Family: Anguillidae																	
Anguilla australis	Shortfin Eel	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Anguilla reinhardtii	Longfin Eel	1	0	0	0	0	0	0	4	1	3	2	0	0	0	1	2
Family: Eleotriidae																	
Gobiomorphus australis	Striped Gudgeon	2	2	14	0	0	2	1	3	2	25	22	3	12	9	23	15
Hypseleotris spp	Firetail Gudgeon	41	10	16	7	5	5	6	72	26	49	69	14	2	12	0	26
Hypseleotris compressa	Empire Gudgeon	0	1	27	0	0	0	0	0	0	5	77	0	2	7	24	6
Family: Melanotaeniidae																	
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	10	0	0	0	1	0	0	0	0	0	0	0	0	0
Family: Poeciliidae																	
Gambusia holbrooki	Mosquito Fish	0	0	0	44	48	36	10	56	38	7	6	2	0	0	0	1
Family: Parastacidae																	
Cherax sp.	Yabby	2	0	7	40	63	26	8	15	21	3	1	0	0	0	0	0
Family: Paleomonidae																	
Macrobrachium spp.	Long-armed Shrimp	0	0	0	0	0	0	7	0	0	0	0	0	1	0	11	6
	Freshwater Prawn	0	0	0	>100	0	0	2	0	0	0	0	0	>1000	>10	>100	0
Family: Atyidae																	
Caridina spp.	Freshwater Shrimp	>1000	0	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>100	>1000	>1000	>100	>100	>1000	>100

3.2 Water Quality

The results of water quality samples are presented in **Table 3.3**. 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. The pH values that are low enough to confer a competitive advantage upon OPP, and hence indicative of greater habitat potential are shown in blue text. The pH values that fall outside of the known range occupied by OPP are shown in red text.

Table 3.3 Results of water quality sampling from all sites

Section	*Location*	*Site*	*Temperature*	*pH*	*Conductivity*	*Turbidity*	*Dissolved Oxygen*	*DO%*
			°C		*mS/cm*	*NTU*	*mg/L*	*%*
2	1	-	12.36	7	0.456	34.5	5.47	53
2	2	-	15.22	7.06	0.326	28.5	4.72	48.6
2	4	-	15.45	7.16	0.409	23	7.03	72.8
2	5	a	13.5	6.1	0.166	3	6.6	65.5
2	5	b	16.97	5.84	0.151	5.7	6.2	66.1
2	5	c	16.85	5.82	0.155	11.1	6.2	66.1
2	6	a	16.33	6.38	0.18	16.8	6.97	73.4
2	6	b	15.8	6.52	0.149	9.8	9	93.7
2	6	c	15.03	6.65	0.153	46.4	9.02	92.5
1	7	b	15.06	6.92	0.351	11.5	10.49	107.7
1	7	c	13.59	6.61	0.331	17.2	7.21	71.7
1	9	-	15.32	5.94	0.434	14.9	6.46	66.7
1	10	a	13.25	4.95	1.31	8.6	4.82	47.7
1	10	b	15.16	5.32	0.528	29.9	7.34	75.5
1	11	a	15.16	5.76	0.461	7.2	4.45	45.8
1	11	b	18.36	5.75	0.325	0	5.77	63.3
1	12	a	20.46	6.03	0.256	11.7	7.55	86.1
1	12	b	18.09	5.87	0.23	16.9	4.99	54.4
1	13	a	14.31	5.94	0.302	7.8	6.43	64.9
1	13	b	16.74	6.2	0.285	10.4	4.74	50.3
1	14	-	23.91	6.81	0.141	62	7.79	94.3
1	15	a	15.96	6.34	0.17	19.8	6.91	72.2
1	15	b	16.89	6.52	0.173	0.3	8.18	87.1
1	15	c	15.93	6.7	0.178	5.7	8.93	93.3
1	16	-	14.31	5.76	0.222	15.7	6.43	64.9

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

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 both OPP and PSG (refer to **Error! Reference source not found.** and **Table 1.2**). However, in most cases the waters were only slightly acidic as opposed to the more acidic waters pH < 5 – 5.5 that are ideal for, or confer a competitive advantage upon, OPP. Despite the fact that the majority of sites were not experiencing significant flow at the time of sampling the dissolved oxygen concentrations were mostly at levels adequate for fish survival and function (i.e. > 5mg/L). It could be reasonably expected that water quality at most sites would differ following significant rainfall. Planned future monitoring will confirm this.

3.3 Habitat Description

A brief description of the general habitat conditions at each location is presented in **Table 3.4**. Summary results from habitat surveys are displayed in graphical form in **Appendix Error! Reference source not found.**. An inventory of aquatic plants found at each site is presented in **Table 3.5** and **Table 3.6**.

A wide variety of habitats were identified throughout the study area. The site descriptions in **Table 3.4** and the habitat data presented in **Appendix A** indicate that there was a high degree of similarity among sites within locations but also a high degree of variation among locations.

No significant flows (> 0.1 m/s) were measured at any of the sites visited. However, small riffles with gentle flows (approximately 0.5 m/s) were noted downstream of sites 6b and 15c. As a result of the dry conditions prior to sampling many of the sites were comprised of a series of disconnected pools along the channel.

Table 3.4 Brief descriptions of habitat features at all sites

Section	*Site*	*Habitat Description*
2	1	Site 1 is an intermittent headwater stream located downstream (west) of the upgrade corridor that was comprised of one long and one short pool separated by a log jam in the centre. There was little structural habitat available in stream. The benthic material was dominated by sand, with a variety of scattered leaf, twig and woody debris. The stream margin was well vegetated, primarily with *Lomandra longifolia*, some of which was overhanging and trailing, but instream vegetation was very sparse. There was no flow at the time of sampling.
2	2	Site 2 is located at the confluence of two intermittent creeks, downstream (west) of the upgrade corridor. The site was comprised of a series of disconnected pools up to 8 m wide and to a depth of over 1 m in areas. Benthic material at this site was dominated by mud and benthic structural habitat comprised of scattered leaf and twig matter with more common large woody debris derived from the well forested riparian zone. At the downstream end of the site there were some scattered emergent rushes including *Baumea articulata* and *Triglochin procerum*. The stream margin was densely vegetated, primarily with *Lomandra longifolia*. Much of the lomandra and overstorey vegetation (*Leptospermum sp*. and *Melaleuca sp*.) was trailing. There was no flow at the time of sampling.
2	3*	Site 3 is a series of small pools in an intermittent headwater stream located immediately to downstream (west) of the highway corridor. At the time of sampling the site was reduced to two small puddles less than 20 cm deep and 5 m^2 surface area. The site was not sampled due to lack of water.
2	4	Site 4 is located at the confluence of two intermittent creeks, downstream (west) of the upgrade corridor. The site was comprised of a series of semi-connected pools up to 5 m wide and around 0.5 m deep. Benthic material at this site was dominated by gravel and sand and benthic structural habitat comprised of scattered leaf, twig and large woody matter. The stream margin was densely vegetated, primarily with *Lomandra longifolia*, much of which trailed in the channel. At the time of sampling there was a very slight flow (< 0.1 m/s)
2	5a	Site 5a is located in a broad, shallow swampy channel upstream of the upgrade corridor. It is likely that channel morphology of all location 5 sites is impacted by a large dam located approximately 1 km downstream. Structural habitat at the site was comprised mostly of emergent and submerged vegetation and some small woody debris. The substrate was mostly mud, overlain with a thick layer of coarse organic material. The stream margin was gently sloping and well vegetated with grasses and low rushes. At the time of sampling there was no perceptible flow.

Section	Site	Habitat Description
2	5b	Site 5b is located in a broad, deep swampy channel in the upgrade corridor. The depth and breadth of the site probably result in part from the dam located downstream. A large part of the site consisted of open water but no further details were collected due to the depth, which was greater than 2.5 m in area. The gently sloping margins and broad shallow flanks of the site were mostly covered with grasses and emergent rushes dominated by *Eleocharis sphacelata*. Structural habitat at the site was comprised mostly of emergent and submerged vegetation. The substrate was mostly mud, overlain with a thick layer of coarse organic material. At the time of sampling there was no perceptible flow.
2	5c	Site 5c is located amongst a series of swampy channels downstream of the upgrade corridor. At the most downstream point the channel was greater than 1.5 m deep though mostly it was broad, shallow and well vegetated. The substrate was mostly mud, covered with organic material and a thick mat of the aquatic weed species *Myriophyllum aquaticum*. The margins were generally low and intermittently vegetated, with pugging from livestock access evident. The broad shallow channel was dominated by emergent rushes such as *Lepironia articulata* and *Triglochin procerum.* Structural habitat at the site was comprised mostly of the emergent and submerged vegetation. At the time of sampling there was no perceptible flow.
2	6a	Site 6a is a narrow, deep channel located upstream (east) of the corridor. The benthic material was dominated by sand but also included mud and some bedrock. Overhangs, large woody debris, trailing vegetation, root balls and twig and leaf litter provided abundant structural habitat. The stream margins were nearly vertical in many places, and covered with mosses and a variety of vegetation. At the time of sampling there was very little flow (< 0.1m/s) although there was noticeable flow across a narrow, short riffle located downstream of the site.
2	6b	Site 6b consists of a meandering channel with steep sandy banks located in the highway alignment. The substrate was sand. Regular overhangs, and rootballs, in addition to scattered large woody debris, and twig and leaf litter provided structural habitat. The stream margins were mostly steep sloping sand with little riparian cover interacting with the stream, although a tall overstorey shaded most of the open water. At the time of sampling there was very little flow (< 0.1 m/s).
2	6c	Site 6c is very similar to site 6b and consisted of a meandering channel with steep sandy banks located downstream (west) of the highway alignment. The benthic material was dominated by sand. Regular overhangs, and rootballs, in addition to scattered large woody debris, and twig and leaf litter provided abundant structural habitat. The margins were mostly steep sloping sand with little riparian cover interacting with the stream, although a tall overstorey shaded most of the open water. At the time of sampling there was very little flow (< 0.1 m/s).
1	7a	Site 7a is a straight, narrow, permanent channel located within the upgrade alignment. The benthic material was variable at the site with interspersed sandy and muddy patches as well as areas where gravel has congregated. Structural habitat at the site was dominated by regular cover of leaf litter and scattered small and large woody debris. The stream margins were well vegetated and trailing vegetation provided some habitat. Only a very slight (< 0.1 m/s) flow was noted at the time of sampling.
1	7b	Site 7b is a broad deep area of creek located downstream (east) of the upgrade alignment and immediately upstream of a makeshift dam. The water was relatively deep (>1.5 m) in some areas as a result of the dam and the substrate was mostly deep soft mud that has settled out of the water column. Structural habitat at the site consisted of large and small woody debris and a dense bed of *Utricularia sp*., but the proportional cover of each feature was low. The stream margins were mostly vegetated, as was a small island that occurred mid-stream. No flow was detected at the time of sampling.
1	8*	Site 8 is an intermittent headwater stream that was dry at the time of sampling.

Section	Site	Habitat Description
1	9	Site 9 is a moderately narrow permanent pool in an intermittently flowing stream located well downstream (east) of the upgrade alignment. Overall, habitat availability at the site was good. Structural habitat varied widely across the site, with small proportional covers of most available microhabitat classes. The benthic materials were dominated by coarse gravel and mud, though sand and fine gravel were also present. Emergent vegetation was mostly *Triglochin procerum*, *Philydrum lanuginosum* and *Baumea articulata*. The stream margin was well vegetated, with grasses and rushes. Iron oxide stains were apparent on the stream margins and there was no flow at the time of sampling.
1	10a	Site 10a is a series of shallow, small pools in an intermittent headwater stream located within the highway corridor. Benthic material at this site was dominated by mud, mostly covered with a layer of coarse organic material with high proportional cover of leaf litter. Although the stream margins were well covered with grasses and rushes, structural habitat at the site was dominated by emergent rushes, mostly *Baumea articulata*. There was no perceptible flow at the time of sampling. The surrounding vegetation was dominated by *Melaleuca spp*.
1	10b	Site 10b is very similar to 10a, a series of wider, shallow, small pools in an intermittent headwater stream located downstream of the highway corridor. Benthic material at this site was dominated by mud, mostly covered with a layer of coarse organic material with high proportional cover of leaf litter. The stream margins were well covered with grasses and rushes. The key difference with site 10a was the lower proportional cover of emergent vegetation and a higher proportional cover of submerged aquatic vegetation, mostly the aquatic weed species *Myriophyllum aquaticum*. There was no perceptible flow at the time of sampling. The surrounding vegetation was dominated by *Melaleuca spp*.
1	11a	Site 11a is a series of wider, shallow, small pools in an intermittent headwater stream located within the highway corridor. Benthic material at this site was dominated by mud, mostly covered with a layer of coarse organic material with a very high proportional cover of leaf litter. The stream margins were well covered with grasses and rushes and the cover of emergent vegetation, dominated by *Baumea articulata*, was very high. There was also a relatively high proportional cover of submerged aquatic vegetation, mostly the aquatic weed species *Myriophyllum aquaticum*. There was no perceptible flow at the time of sampling. The surrounding vegetation was dominated by *Melaleuca spp*.
1	11b	Site 11b is very similar to 11a, though the pools were wider and deeper, with a higher proportion of open water and corresponding lower proportion of emergent vegetation. Site 11b is located downstream of the highway corridor.
1	12a	Site 12a is also a series of moderately wide, shallow, small pools in an intermittent headwater stream located within the highway corridor. Benthic material at this site was dominated by mud, although there were significant proportions of sand and fine gravel. The substrate was covered with a high proportion of leaf litter and scattered small woody debris. The stream margins were well sparsely vegetated and erosion and headcut activity was evident within the channel. The primary forms of structural habitat were emergent and submerged vegetation. There was no perceptible flow at the time of sampling. The surrounding vegetation was dominated by *Melaleuca spp*.
1	12b	Site 12b is very similar to site 12a. It is also a series of moderately wide, shallow, small pools in an intermittent headwater stream but is located downstream of the highway corridor. A higher proportional cover of emergent vegetation, dominated by *Baumea articulata*, was present at this site than at 12a. There was no perceptible flow at the time of sampling.
1	13a	Site 13a is a large, permanent but disconnected pool in the upgrade alignment. The site was up to 25 m wide, and greater than 2 m deep in parts. Along the margins there was very little structural habitat. Riparian vegetation was mostly restricted to large *Melaleuca sp*. that provides shade but, apart from irregularly spaced root balls, did not provide physical habitat. The benthic material was an even mixture of sand and mud with a high proportion of leaf litter cover. Structural habitat was dominated by large woody debris

Section	Site	Habitat Description
		which was prevalent but did not represent a high proportion of cover due to the large surface area of the site. Emergent vegetation, mostly *Baumea articulata* was scattered across the site. There was no flow at the time of sampling.
1	13b	Site 13b is a permanent pool located downstream of the upgrade alignment. The site was mostly around 10 m wide and around 1.4 m deep at the deepest point. The habitat features varied throughout the site. The benthic material was mostly mud but also includes significant proportions of sand and fine gravel. The margins of the stream were well vegetated with *Juncus usitatus*, *Persicaria spp*., and *Lomandra sp*. A variety of structural habitats were present in-stream including scattered leaf litter, large woody debris and beds of emergent and submerged vegetation. Emergent vegetation included *Baumea articulata* and *Triglochin procerum*. Benthic vegetation was mostly *Myriophyllum aquaticum*. There was evidence of cattle access to the creek with some pug marks along the margins. At the time of sampling there was very little flow (< 0.1 m/s).
1	14	Site 14 is located in a narrow, shallow sinuous channel draining a floodplain and is immediately downstream of the upgrade alignment. The site is surrounded by pasture and cattle access to the waterway was evident. The site was relatively homogenous with respect to habitat. The margins were covered with grasses, the benthic material was mostly mud covered with a thick layer of organic material and leaf litter, and emergent macrophytes dominated by *Persicaria sp*. are prevalent. There was no flow at the time of sampling
1	15a	Site 15a is located in a river channel and is located upstream of the upgrade corridor. The stream margins were steep and sparsely vegetated with *Lomandra longifolia*. Tall vegetation provided shade and a source of leaf litter and large and small woody debris. There was also a small percentage of root mass and trailing vegetation. The channel was deep and wide and the benthic material was dominated by sand. In-stream structural habitat included a high percentage of leaf litter and small percentages of large and small woody debris. There were a number of large fallen trees crossing the channel. At the time of sampling there was very little (< 1 m/s) flow.
1	15b	Site 15b is very similar to site 15a and is located within the upgrade corridor.
1	15c	Site 15c is also similar to sites 15a and 15b. It differed in that it was wider and shallower and the margin on one side was sand with no marginal vegetation. The benthic material also had a higher proportion of gravel. At the time of sampling there was very little flow, though some flow was evident in a riffle located further downstream.
1	16	Site 16 is a narrow, shallow, intermittent lowland stream located downstream of the upgrade corridor. The stream margins were well covered with grasses and rushes with a reasonably high proportion of trailing vegetation. The benthic material varied throughout the site but is dominated by mud and rock that was covered in most areas with organic matter and a high proportion of leaf litter. There was a variety of emergent vegetation, mostly *Baumea articulata* and *Shoenoplectus mucronatus*, forming a moderate proportion of structural in-stream habitat. There was no detectable flow at the time of sampling.

* Dry at the time of sampling

Table 3.5 Aquatic plants identified at sites in Section 2

Species Name	*Common Name*	*1*	*2*	*4*	*5a*	*5b*	*5c*	*6a*	*6b*	*6c*
Baumea articulata	Jointed rush		x					x	x	x
Baumea rubiginosa	Baumea						x			
Elatine gratioloides	Waterwort	x	x	x						
Eleocharis sphacelata	Tall spikerush		x		x	x				
Juncus usitatus	Common rush	x	x	x	x	x				
Lepironia articulata							x			
Lomandra longifolia	Creek mat rush	x	x	x				x	x	x
*Myriophyllum aquaticum**	Parrots feather	x	x		x		x			
Philydrum lanuginosum	Frogsmouth				x	x	x			
Schoenoplectus mucronatus										
Schoenoplectus validus	River clubrush				x	x				
Triglochin procerum	Water ribbons		x		x	x	x			
Utricularia gibba	Yellow bladderwort					x				

* Introduced species

Table 3.6 Aquatic plants identified at sites in Section 1

Species Name	*Common Name*	*7a*	*7b*	*9*	*10a*	*10b*	*11a*	*11b*	*12a*	*12b*	*13a*	*13b*	*14*	*15a*	*15b*	*15c*	*16*
Baumea articulata	Jointed rush			x	x	x	x	x	x	x	x	x					x
Eleocharis sphacelata	Tall spikerush											x					
Juncus usitatus	Common rush			x	x	x	x	x				x					x
Lomandra longifolia	Creek mat rush	x	x		x	x	x	x	x	x	x	x		x	x	x	x
*Myriophyllum aquaticum**	Parrots feather		x	x	x	x	x	x					x				x
Ottelia ovalifolia	Swamp lily					x	x	x									x
Persicaria sp.	Knotweed											x	x				
Philydrum lanuginosum	Frogsmouth			x	x	x	x	x	x	x	x	x					x
Schoenoplectus mucronatus			x														x
Triglochin procerum	Water ribbons			x	x	x	x	x	x	x		x	x				x
Utricularia gibba	Yellow bladderwort		x														

* Introduced species

4

Discussion and Conclusion

This study did not find any OPP or PSG in the 16 significant waterways crossed by the Pacific Highway upgrade alignment between Woolgoolga and Glenugie. Habitat quality and availability varied across the sites sampled, as did water quality. At some sites the combination of available habitat and water quality were indicative of sites that are potentially suitable for OPP and PSG. During this study a significant quantity of data has been collected and interpreted. The available dataset will provide a useful baseline for any future aquatic monitoring that is planned for the Woolgoolga to Glenugie Pacific Highway upgrade.

An intensive fishing effort has been engaged in the search for OPP and PSG in and outside of the Woolgoolga to Glenugie Pacific Highway upgrade corridor. However, at a total of 27 sites, 186 hours of fish trapping and 11624 seconds of electrofishing failed to find any OPP or PSG. It is considered possible that under different seasonal or environmental conditions that OPP could occur at some of the sites visited. Such an occurrence would be most likely in the Section 1 sites, between Arrawarra Gully and Boneys Creek, because OPP are thought to be restricted to coastal lowlands (Knight and Arthrington 2008). In addition, whilst the study area is outside of the current known range of OPP, they were collected from Cassons Creek in 1972 (Knight & Arthrington 2008). It is also considered possible that PSG could occur within the study area under different conditions. However, in contrast to OPP, any PSG encountered would be most likely to occur in Section 2 sites, between Halfway Creek and Glenugie Creek. The rationale for such a statement is that the southern distribution of PSG is thought to be restricted to the Clarence River catchment and PSG are most often encountered at a distance of around 200km upstream of river mouths. The sites in Section 2 of the upgrade are in some of the most southern sections of the Clarence River catchment and are also a great distance from the Clarence River mouth.

Despite the lack of OPP and PSG, a large number and variety of fish were encountered during this study. In general, as would be expected, the abundance and variety of fish fauna increased with the upstream catchment area and permanency of the waterway being sampled, particularly amongst the sites located in Section 2 of the upgrade corridor. It was not the case for the Corindi River, which was the largest waterway sampled, but this is thought to be related to the depth of the water and steepness of the banks at this site, and the subsequent difficulty accessing all available habitats with the electrofisher. There were also some small streams in Section 1 with diverse fish communities, specifically Arrawarra Gully and Dirty Creek. In the case of these waterways, the proximity to tidal waters and/or increased frequency of connection with downstream reaches may explain the greater diversity encountered. In any case, the fish community data collected and presented in this report will provide a useful baseline for assessing any potential future construction impacts upon aquatic fauna.

This study measured vegetative and physical habitat features including, flow, width, depth, instream vegetation, debris and stream bank forms. Habitat quality and availability varied substantially among sites. OPP are known to prefer sandy substrates with high proportions of emergent and submerged vegetation and structural formations such as leaf litter, woody debris and steep or undercut banks with trailing vegetation and root balls. In Section 1, where it is most likely that OPP would be encountered, the sites conforming best to those preferred by OPP included sites 9 (Dirty Creek), 16 (Arrawarra Gully) and 13b (Cassons Creek). Whilst PSG have been encountered under a greater variety of conditions they are known to prefer sites with good structural habitat along the stream banks, such as overhangs, root balls, trailing vegetation and submerged and emergent vegetation. The sites within Section 2 of the upgrade corridor that best fit this description were 6a, 6b and 6c (Halfway Creek). The information about aquatic habitats and aquatic flora collected throughout this study may also be a useful baseline for the assessment of potential future construction impacts.

This study also measured physicochemical water quality variables. Whilst water quality varied throughout the study area, at all but one of the sites within Section 1 (and most of those in Section 2) of the upgrade corridor the water quality data fell within the ranges known to be inhabited by OPP. In addition, all of the sites within Section 2 of the upgrade corridor (and most of those within Section 1) were within the ranges known to be

inhabited by PSG. As this study was undertaken following an unusually dry period, it is likely that water quality would change significantly at most sites following rainfall. For this reason, the water quality data collected and reported here is not an adequate baseline for future comparisons.

The following recommendations arise from this report:

- in order to further confirm the presence or absence of OPP and PSG from the study area another survey should be undertaken after the conclusion of the OPP breeding season (approximately May). This is the highest priority in terms of aquatic monitoring;
- in order to assess the impacts of planned construction activities upon water quality a baseline water quality dataset needs to be developed via a regular monitoring program during the pre-construction period. This information will also assist in the preparation of water quality targets for release of water into downstream environments during construction. It is understood that a program is being planned at the time of writing;
- that all possible measures identified during the planning and assessment phases, to maintain or improve the condition of aquatic habitats during and after construction of the Pacific Highway upgrade between Woolgoolga and Glenugie, be implemented; and
- an aquatic monitoring program assessing water quality, fish populations and aquatic habitats should be considered during and after construction in order to assess the impacts of construction upon the aquatic environment and inform adaptive management and mitigative measures.

Plate 4.1 Electrofishing in Halfway Creek.

Project Team

GeoLINK: Project Manager
Simon Williams – Principal: Environment & Planning

Aquatic Science and Management

- Mathew Birch – Aquatic Ecologist: Technical leader and author
- Robert Veal – Field Team
- Damon Telfer – Field Team
- Joanne Cunningham – Field Team

References

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

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

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

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

Knight, J. & Arthrington, 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 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., & Arthrington, A. (2004) Freshwater Fishes of North-Eastern Australia. CSIRO Publishing, Collingwood.

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

Copyright and Usage

Appendix A

Aquatic Habitat Summaries

Figure A1 **A summary of aquatic habitat data collected in Section 2 of the Woolgoolga to Glenugie Pacific Highway upgrade.**

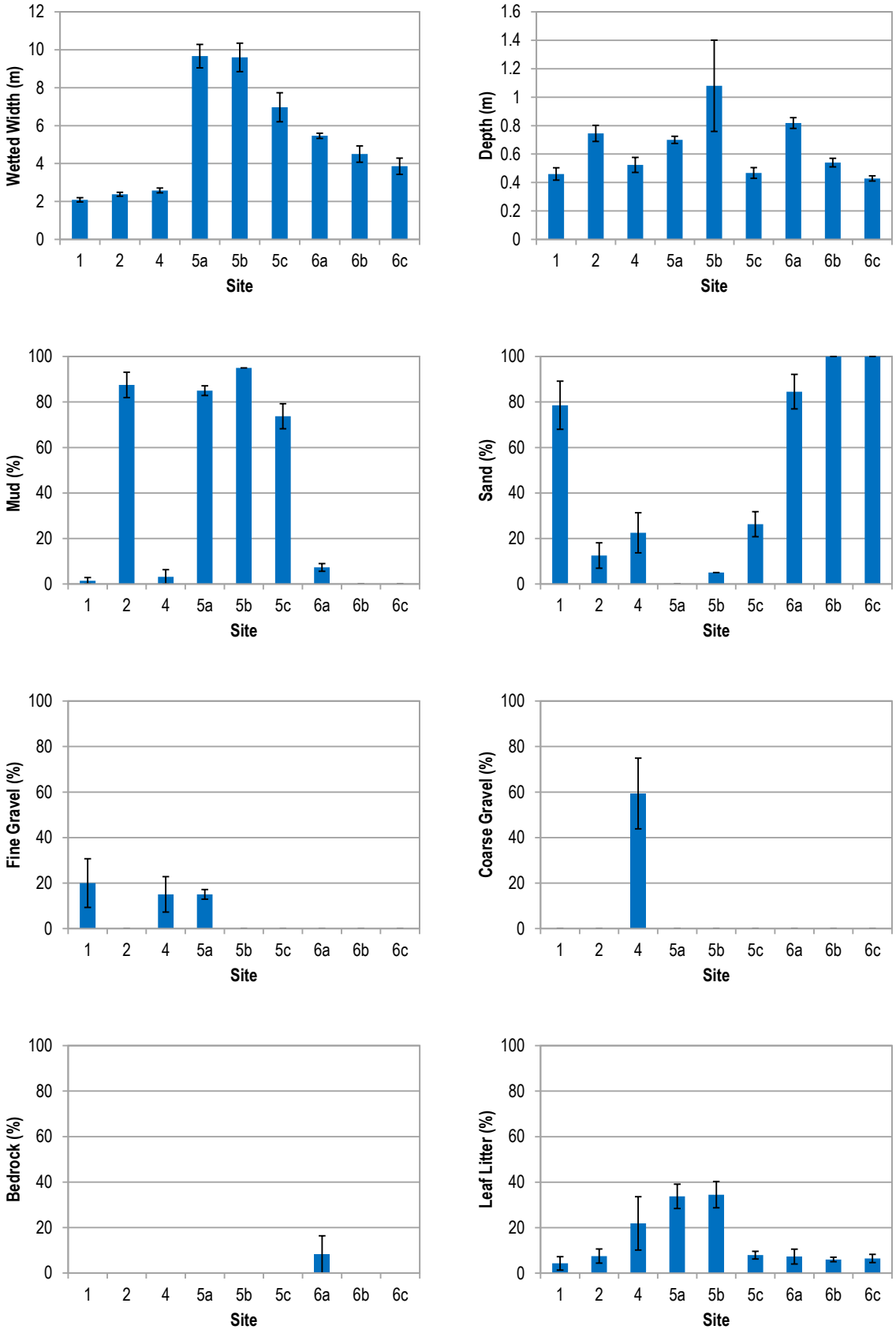


Figure A1 **A summary of aquatic habitat data collected in Section 2 of the Woolgoolga to Glenugie Pacific Highway upgrade.**

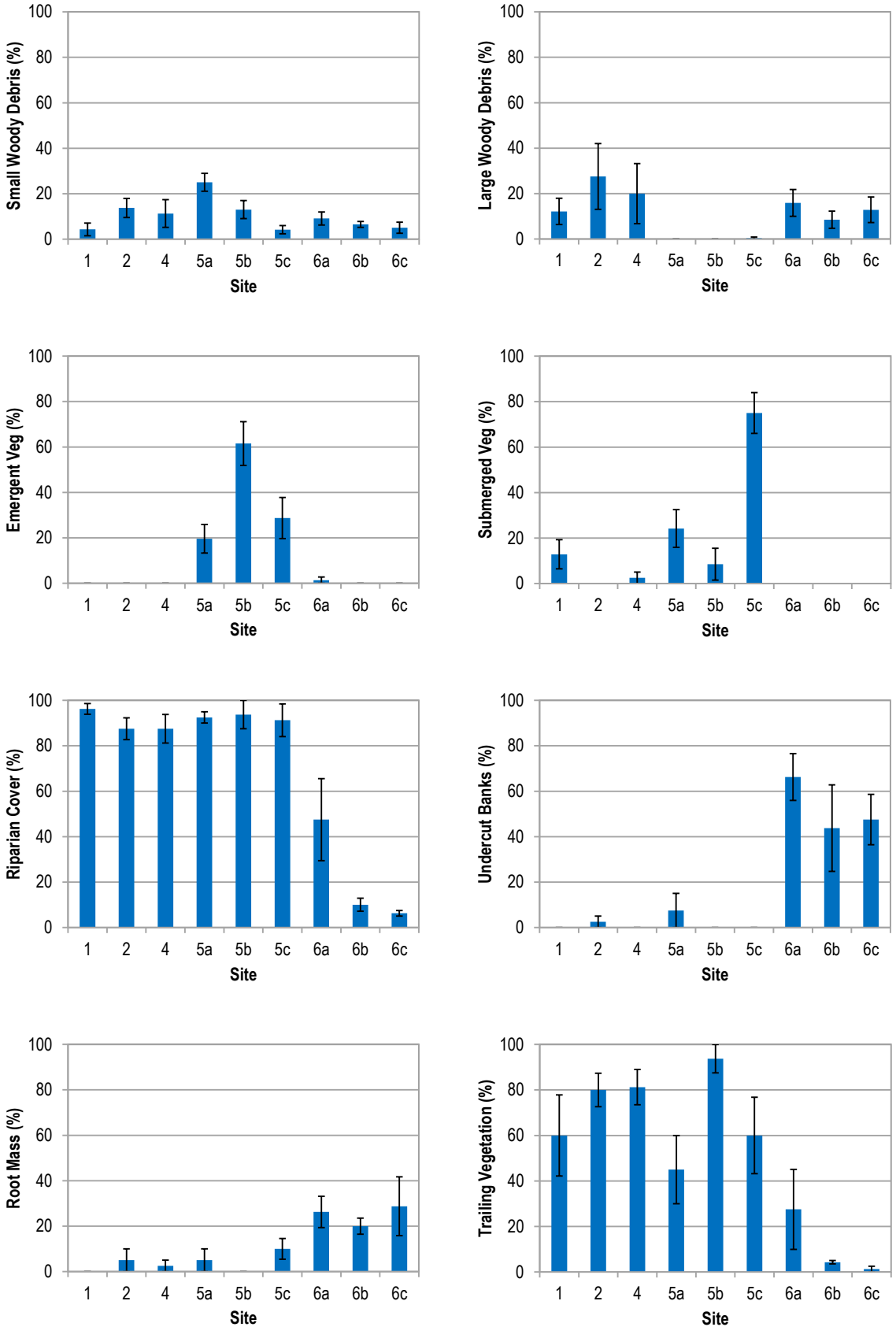


Figure A2 **A summary of aquatic habitat data collected in Section 1 of the Woolgoolga to Glenugie Pacific Highway upgrade.**

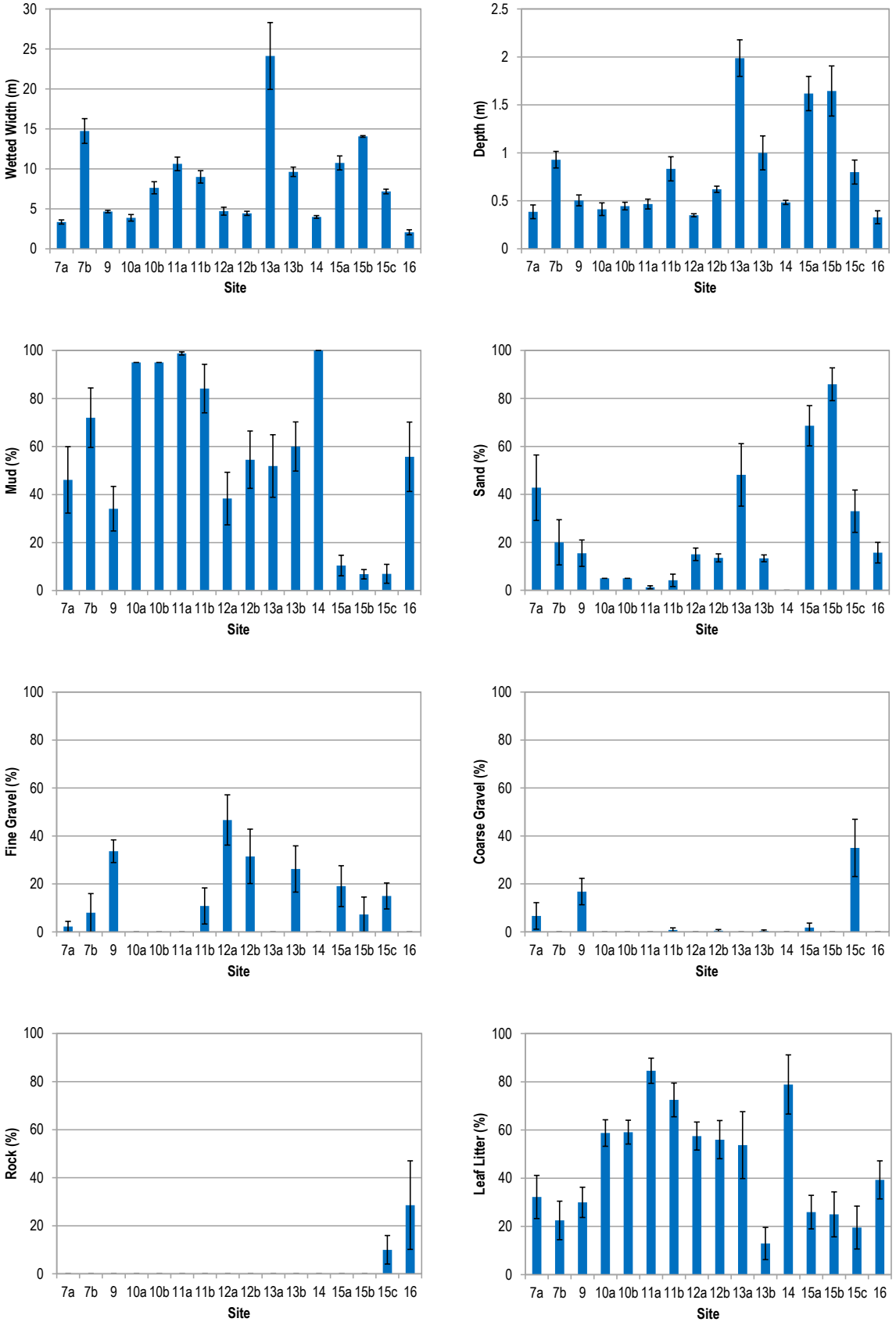
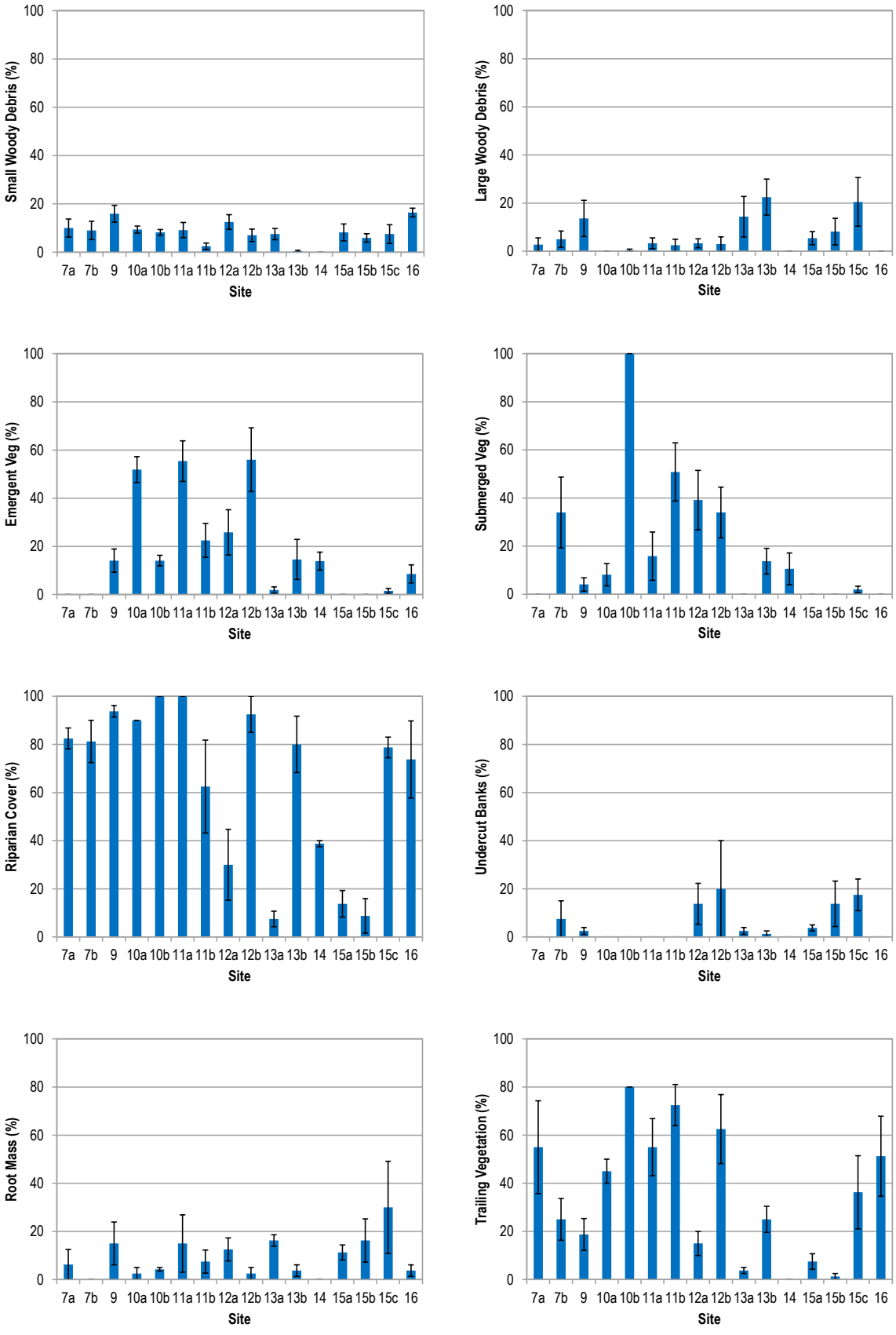


Figure A2 **A summary of aquatic habitat data collected in Section 1 of the Woolgoolga to Glenugie Pacific Highway upgrade.**



Appendix B

Fish Community Structure

Figure B1 Fish community structure at all sites

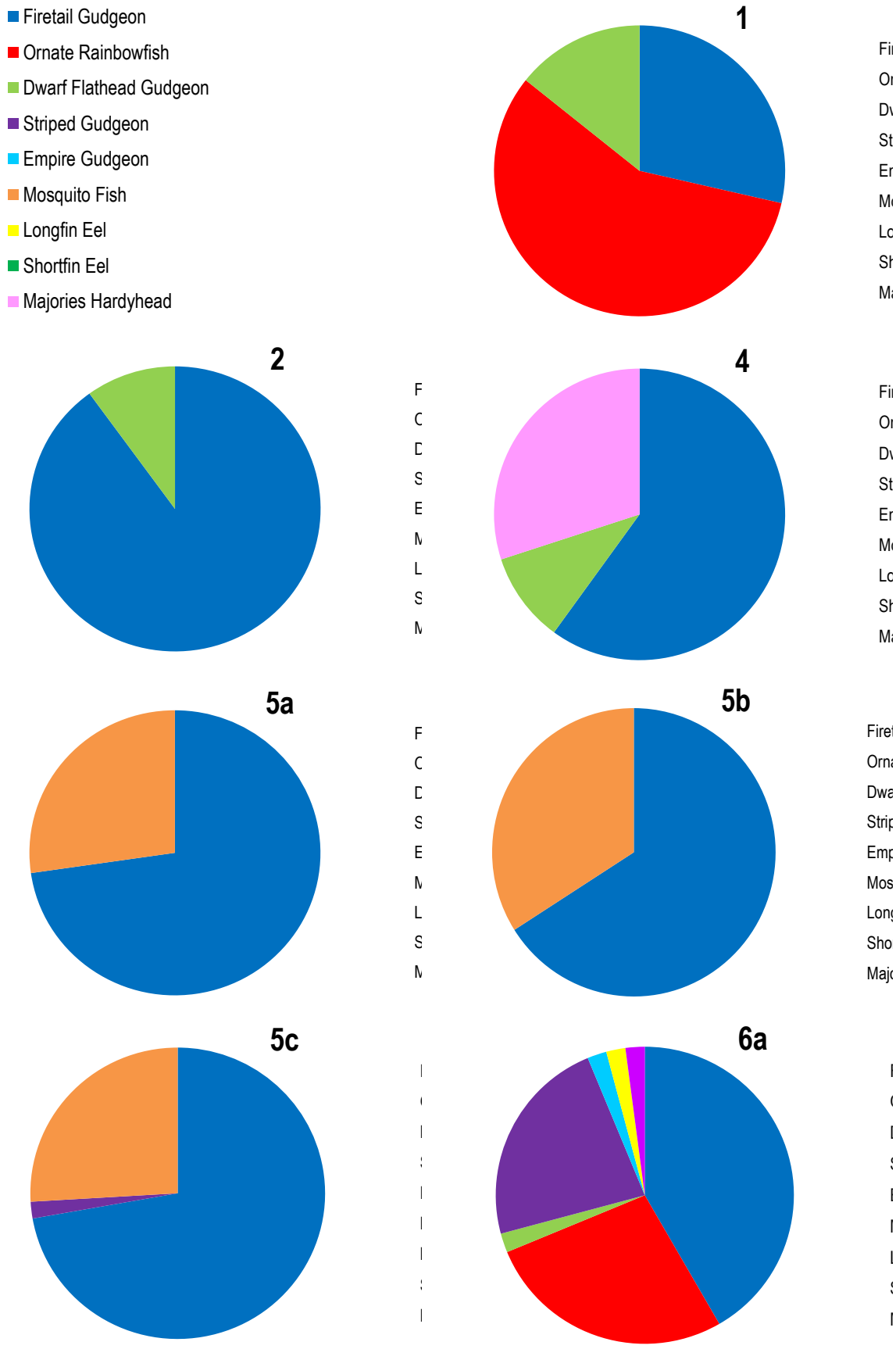


Figure B1 Fish community structure at all sites

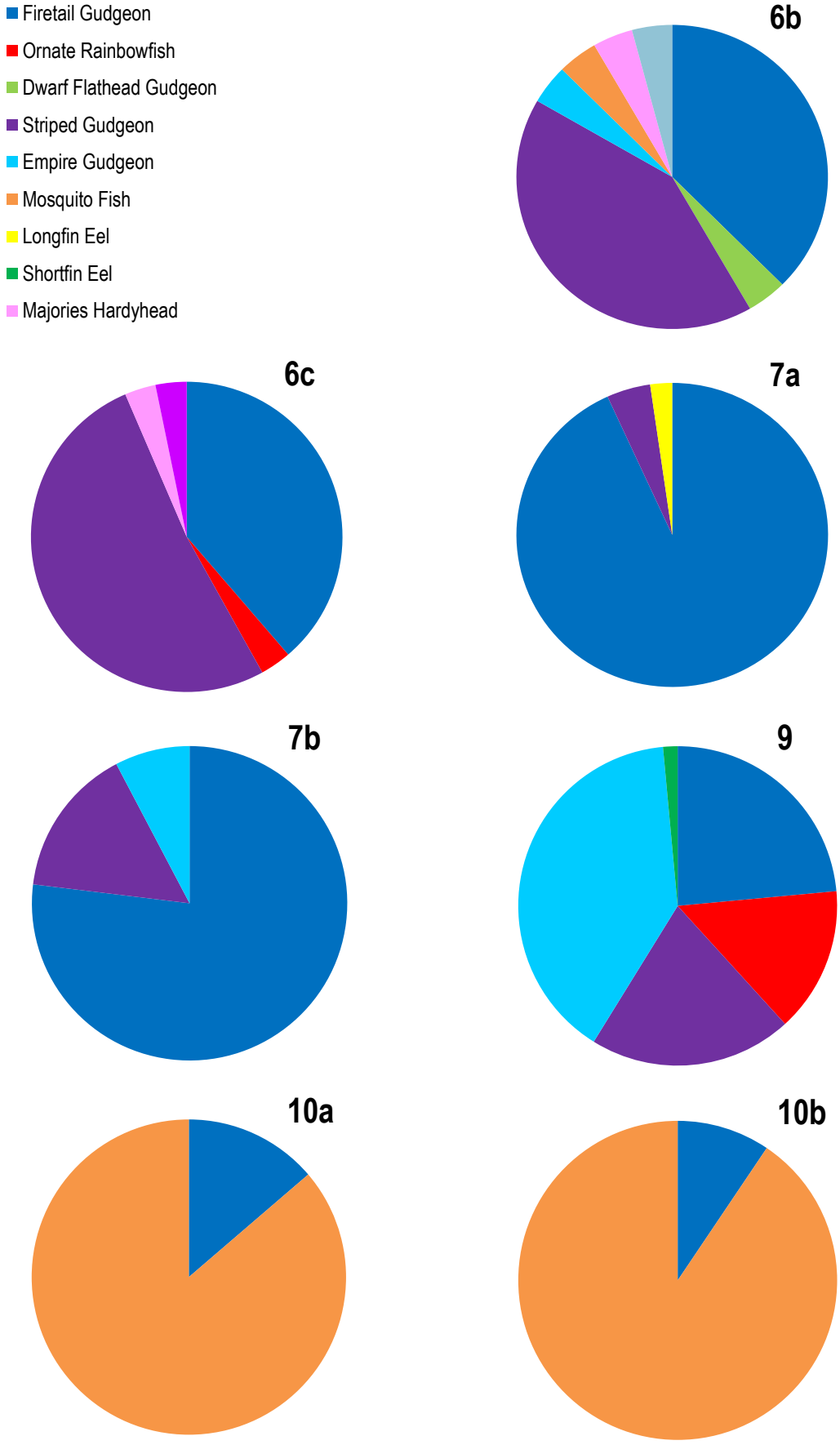


Figure B1 Fish community structure at all sites

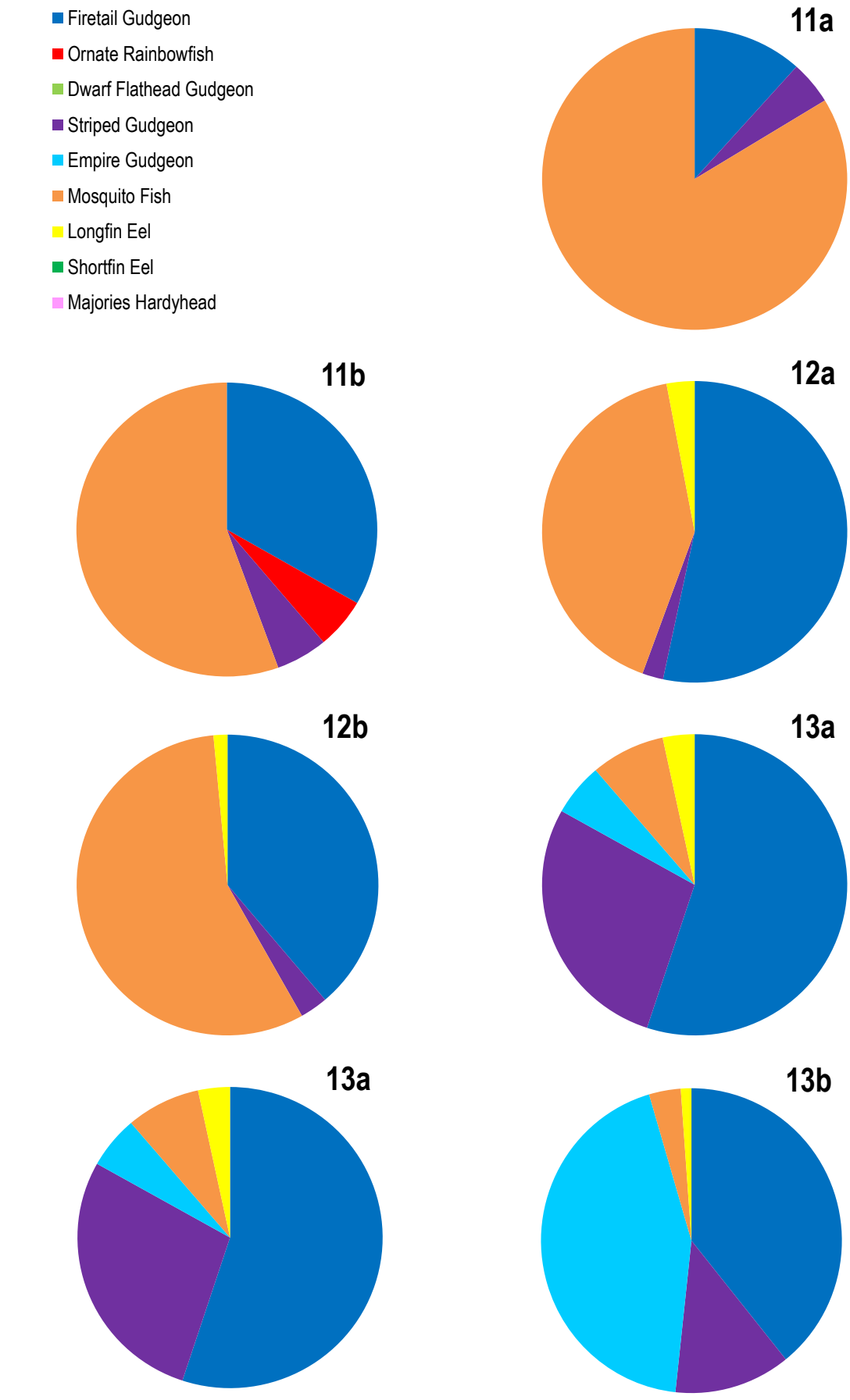
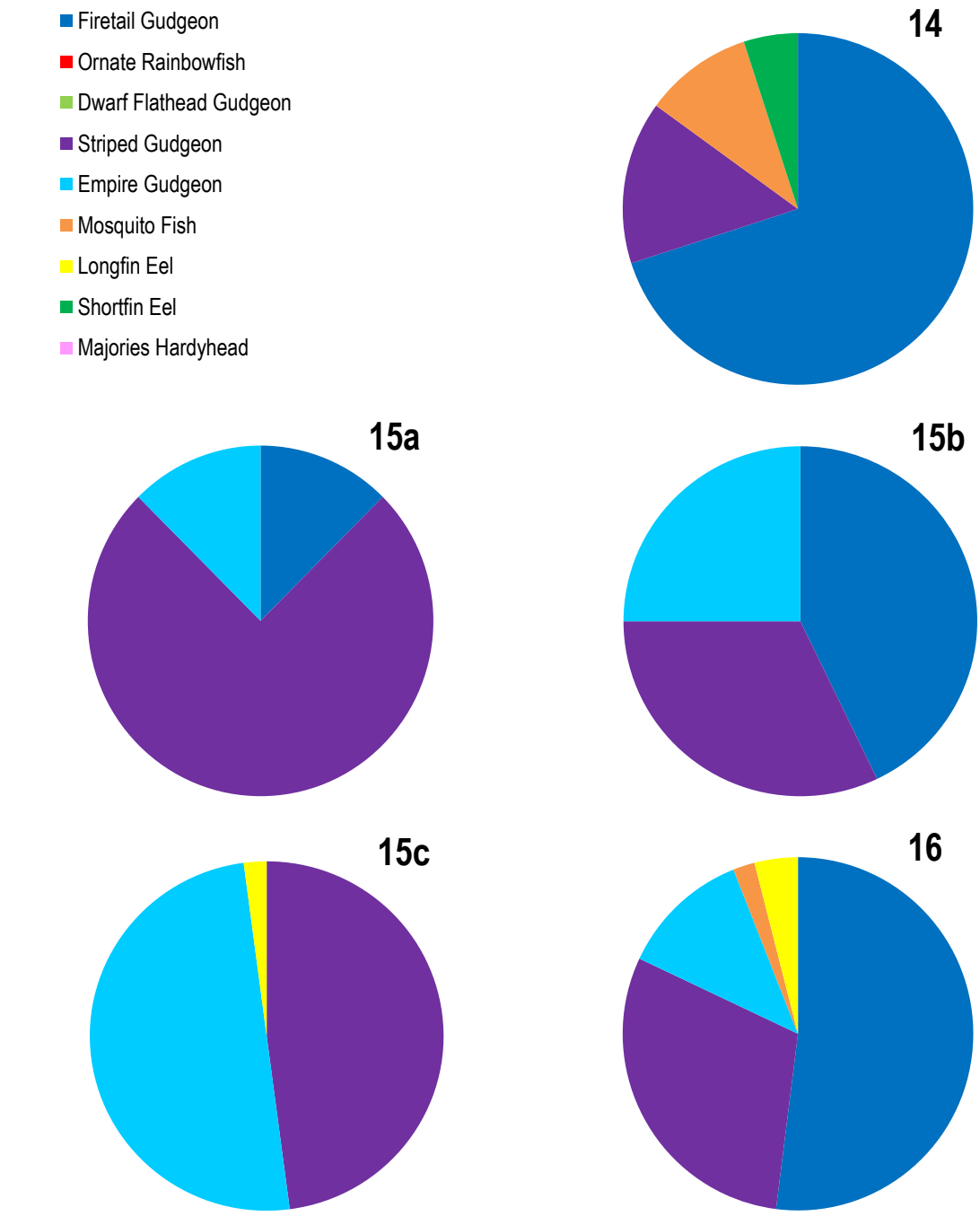


Figure B1 Fish community structure at all sites



PO Box 214
Bellingen NSW 2454

02 6655 2140
0410 470 204

matbirch@iinet.net.au
ABN: 47576386408

AQUATIC SCIENCE AND MANAGEMENT

Woolgoolga to Glenugie Pacific Highway Upgrade

Aquatic Monitoring – Stage 2

Final

Report Prepared for:
NSW Roads and Maritime Services

July 2013

Prepared By:
Aquatic Science and Management

Woolgoolga to Glenugie Pacific Highway Upgrade

Aquatic Monitoring – Stage 2

Report Prepared for:
NSW Roads and Maritime Services

July 2013

Prepared By:
Aquatic Science and Management

Document History

Version	*Issued To*	*Format*	*Date*
DRAFT_V1	Sarah Wain - RMS	*.doc	19/07/13
FINAL	Sarah Wain - RMS	*.pdf	30/07/13
FINAL_V2	Sarah Wain - RMS	*.pdf	31/07/13
FINAL_V3	Sarah Wain - RMS	*.pdf	31/07/13

Table of Contents

Illustrations

Tables

Plates

Figures

Appendices

1

Introduction

The following report is a summary of the second stage of aquatic ecological monitoring undertaken as part of the planning and assessment of the Woolgoolga to Glenugie section of the Pacific Highway upgrade. Aquatic Science and Management have been engaged by RMS to undertake this monitoring and prepare this report.

1.1 Background

As part of the broader Woolgoolga to Ballina section of the Pacific Highway upgrade, construction work on the Woolgoolga to Glenugie section is proposed to commence shortly. A variety of environmental variables require monitoring prior to, during and after construction, including threatened species. Formal environmental assessments undertaken during the planning phase of the Woolgoolga to Ballina upgrade revealed the actual and potential occurrence of a variety of threatened species listed under NSW state government and federal government legislation at various locations along the highway upgrade alignment or potential construction footprint. Under direction of the environmental advisory group, a need for monitoring of threatened species of fish with potential to occur within, or near to, the construction footprint has been identified. The two threatened fish species of concern are the Oxleyan Pygmy Perch (*Nannoperca oxleyana*) and the Purple-spotted Gudgeon (*Mogurnda adspersa*).

The first stage of monitoring of these two species was undertaken in September 2012 (GeoLINK 2012). No Oxleyan Pygmy Perch or Purple-spotted Gudgeon were encountered. A recommendation of that report was that another round of monitoring should be undertaken following the known breeding season of both species and following the wetter summer season when fish would have opportunities for dispersal.

1.2 Objectives

The key objective of pre-construction aquatic monitoring is to identify Oxleyan Pygmy Perch (OPP) and Purple-spotted Gudgeon (PSG) populations occurring within the construction footprint. Secondary objectives included:

- assessing available aquatic habitats within the construction footprint for potential to house OPP and PSG populations;
- providing a baseline dataset describing the condition of aquatic habitats and structure of aquatic fauna communities upstream of, downstream of, and along the road alignment; and
- providing recommendations regarding any future monitoring activities and strategies to mitigate any potential impacts upon known or potential populations of OPP or PSG.

1.3 Target Species

A more detailed description of the target species can be found in the stage 1 report (GeoLINK 2012).

1.3.1 Oxleyan Pygmy Perch

In NSW OPP are known to occur in Banksia dominated heath (wallum) ecosystems and coastal lakes as far south as Tick Gate Swamp (just south of Wooli) (Knight & Arthrington 2008). The predicted natural range of OPP in NSW is from the Queensland border south as far as the Manning River. OPP had been collected from Cassons Creek, located within the study area, in 1976 (Knight & Arthrington 2008).

OPP prefer dystrophic, acidic freshwater systems draining through coastal lowlands (Knight & Arthrington 2008). They are mostly collected from shallow, slow and narrow streams and lakes and mostly found over sandy and sometimes muddy benthos with high proportions of riparian cover, leaf litter and emergent aquatic plants. Typically, depths are around 50cm but have been collected from depths of 130cm. Water velocities are almost always below 0.4m/sec, limiting occurrence to backwaters and small tributaries (Pusey, Kennard & Arthrington 2004).

A summary of water quality information from sites where OPP have been found is presented in **Table 1.1**.

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

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

From Knight & Arthrington (2008)

1.3.2 Purple Spotted Gudgeon

PSG are geographically widespread, occurring in coastal and inland drainages in QLD and northern NSW. They are predicted to occur in coastal drainages as far south as the Clarence River and are common in coastal drainages of Queensland but endangered in the western flowing streams. In NSW they are endangered state-wide.

PSG are collected from a wide variety of habitats, including coastal streams, large rivers and dune lakes and streams. They have been found in riffles and pools and over a wide variety of benthic habitats but on average they appear to prefer streams that are less than 10m wide, 40cm deep and with a moderate to low current. They are most often encountered over finer substrates. They also appear to prefer streams with abundant submerged marginal vegetation and those with abundant root masses and undercut banks. In coastal drainages, they are most common at around 200km upstream of the river mouth and are most frequently collected within 1m of the bank.

A summary of water quality information from coastal sites where PSG have been collected appears in **Table 1.2**.

Table 1.2 A summary of water quality data from coastal sites where PSG have been captured

Measure	Range	Mean ± SE
Temp (°C)	11.9 – 31.7	19.8
DO (mg/L)	0.6 – 12.8	7.3
pH	5.6 – 8.8	7.5
Cond (µS/cm)	72 - 2495	654.5
Turbidity (NTU)	0.2 - 200	5.8

From Pusey, Kennard & Arthrington (2004)

2

Methods

2.1 Study Area

The area being studied is the Pacific Highway upgrade corridor between Woolgoolga and Glenugie. The Pacific Highway upgrade between Woolgoolga and Glenugie is being planned in two sections, Section 1 and Section 2. These sections will be referred to throughout the following report, and all data collected throughout the study will be displayed by section. There are 16 significant waterway crossings along the upgrade corridor. Section 1 covers the waterways between Arrawarra Gully and Boneys Creek inclusive. Section 2 covers the waterways between Halfway Creek and Glenugie Creek. All of the waterways in Section 1 flow east into the Corindi River or Arrawarra Creek, with the exception of Dundoo Creek and Boneys Creek, which flow west into the Orara River. All of the waterways in Section 2 flow west into the Orara River. The Orara River is a major tributary of the Clarence River. The study area is displayed in **Illustration 2.1**.

Due to the potential for construction impacts to be transported along waterways, some sites were located outside of the immediate highway upgrade corridor. In most cases, the maximum distance from the highway corridor covered by the survey was 100m. In the case of two sites, located on Cassons Creek and Dirty creek sites located over a kilometre from the highway corridor were surveyed due to the greater potential for OPP to be found.

2.2 Sites

Sites were located on every significant waterway crossing located along the Woolgoolga to Glenugie Pacific Highway upgrade corridor. Prior to the first stage of aquatic monitoring a survey was undertaken to select sites within the study area. The best sites in each significant waterway were identified using known habitat preferences of the target species (Pusey, Kennard & Arthrington 2004) and/or were considered generally representative of the range of aquatic habitat types found within the study area. Sixteen significant waterways (locations) were identified within the study area. Between 1 and 3 monitoring sites were chosen within each of the 16 significant locations. The number of monitoring sites per location directly related to the habitat potential of the waterways using the classes of Fairfull and Witheridge (2003) (see **Table 2.1**). Class 3 and Class 4 intermittent streams were only sampled at one site located downstream of any potential impact. Class 2 streams were sampled at the site of potential disturbance and downstream. Class 1 waterways were sampled at 3 sites, located at the site of, upstream of, and downstream of potential construction impacts. In addition to the sites identified in this way, two new sites were sampled during the second stage of monitoring. These sites are located in downstream locations on Cassons Creek and on Dirty Creek.

Table 2.1 Classification method used to assess waterways for fish habitat potential

Classification	Characteristics of waterway type	Minimum recommended crossing type
Class 1- Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species	Bridge, arch structure or tunnel
Class 2 - Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks and with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.	Bridge, arch structure, culvert or ford

Classification	Characteristics of waterway type	Minimum recommended crossing type
Class 3- Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert or ford
Class 4 – Unlikely fish habitat	Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event (e.g. dry gullies or shallow floodplain depression with no permanent wetland aquatic flora).	Culvert, causeway or ford

(Source: Fairfull & Witheridge, 2003)

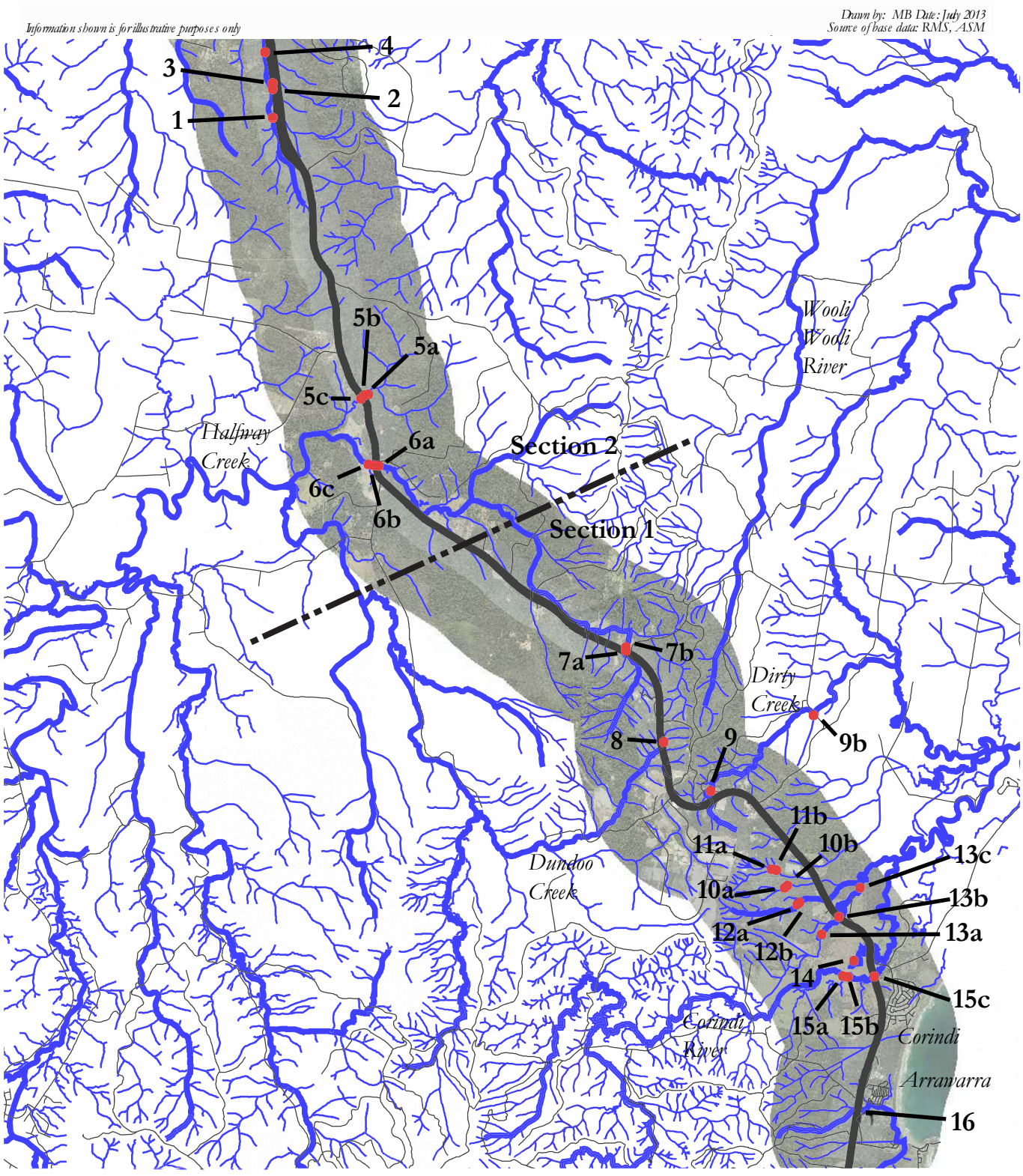
A total of 29 sites were chosen from the 16 significant waterways identified. Of these 29, 18 sites were located downstream of the road corridor, 8 within the road corridor and 3 upstream of the road corridor. Fifteen sites from 9 locations were located in Section 2 of the upgrade and 14 sites from 7 locations were located in Section 1 of the upgrade. Two sites, one is Section 1 and one in Section 2 of the upgrade, were dry at the time of sampling and therefore habitat descriptions and fish sampling were not undertaken. A brief description of the physical location and habitat potential of each of the locations is presented in **Table 2.2**. The position of the sites is presented in **Illustration 2.1**. Locations were numbered in order of sampling as opposed to a positional basis. Sites within locations were lettered from upstream to downstream.

Table 2.2 A brief description of the significant waterways crossing the upgrade alignment

Waterway	Location	Section	Chainage	Notes
Glenugie Creek	1	2	29300	Drains from headwaters approximately 2km upstream. Intermittent **Class 3** Stream. Marginal fish habitat. **1 site** D/S of impact.
Unnamed (Glenugie Ck Trib)	2	2	29850	Drains from headwaters approximately 1km upstream. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** at confluence with Glenugie Ck.
Unnamed (Glenugie Ck Trib)	3	2	30200	Drains from headwaters approximately 1.5km upstream. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** D/S of impact. Dry at time of sampling.
Unnamed (Glenugie Ck Trib)	4	2	30800	Drains from headwaters approximately 1km upstream. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** at confluence with Glenugie Ck.
Wells Crossing	5	2	22400	Drains from headwaters approximately 3km upstream. Damned downstream. Series of connected pools and wetlands forming a **Class 1** waterway. Significant fish habitat. **3 sites**, U/S, impact and D/S.
Halfway Creek	6	2	20700	Drains from a subcatchment to the Orara River. **Class 1** waterway. Significant fish habitat. **3 sites** U/S, impact and D/S.

Waterway	Location	Section	Chainage	Notes
Boneys Creek (Halfway Creek Trib)	7	1	13350	Drains headwaters approximately 3km upstream and flows into Halfway Creek via a makeshift dam immediately downstream of impact. **Class 2** stream. **2 sites**, impact and D/S.
Dundoo Creek	8	1	10700	Drains headwaters approximately 1km upstream into the Orara River. Intermittent **Class 4** stream. Marginal fish habitat. **1 site** immediately D/S of impact. Dry at time of sampling.
Dirty Creek[1]	9	1	8500	Drains headwaters approximately 1km upstream of impact into Saltwater Creek. Very steep bedrock **Class 3** waterway. **2 sites**, both D/S of impact
Corindi Local Access Road (Redbank Ck Trib)	10	1	6200	Drains headwaters approximately 2km upstream into Redbank Ck. Series of connected pools and wetlands forming a **Class 2** wetland. **2 sites**, impact and D/S.
Unnamed (Redbank Ck Trib)	11	1	6650	Drains headwaters approximately 2km upstream into Redbank Ck. Series of connected pools and wetlands forming a **Class 2** wetland**. 2 sites**, impact and D/S.
Redbank Creek	12	1	5650	Drains headwaters approximately 2.5km upstream into Corindi River. Series of connected pools and wetlands forming a **Class 2** wetland. **2 sites**, impact and D/S.
Cassons Creek	13	1	4750	Drains a floodplain swamp into Redbank Creek. Discontinuous series of large pools forming a **Class 2** waterway. **3 sites**, one impact and two D/S.
Blackadder Gully (floodplain)	14	1		Swamp drainage channel forming a **Class 3** waterway. Marginal fish habitat potential. **1 site** D/S of impact
Corindi River	15	1	3600	Permanent **Class 1** waterway with an entrance to the ocean. Significant fish habitat. **3 sites** U/S, impact and D/S.
Arrawarra Gully	16	1	300	Drains headwaters approximately 2km upstream into Arrawarra Ck. Series of pools forming a **Class 3** stream. Marginal fish habitat. **1 site** D/S of impact.

[1]Crosses alignment on escarpment but better to monitor downstream near old highway.



Site Locations

2.3 Timing

The second stage aquatic survey work was undertaken on the 31st May and the 3rd, 4th, 5th, 6th and 7th of June 2013. The work was scheduled to avoid the OPP breeding season which is thought to stretch between October and May. Above average rainfall occurred in 3 of the 5 months leading up to the survey. Summaries of mean and monthly rainfall at Coffs Harbour and Grafton prior to the survey are presented in **Figure 2.1** and **Figure 2.2**.

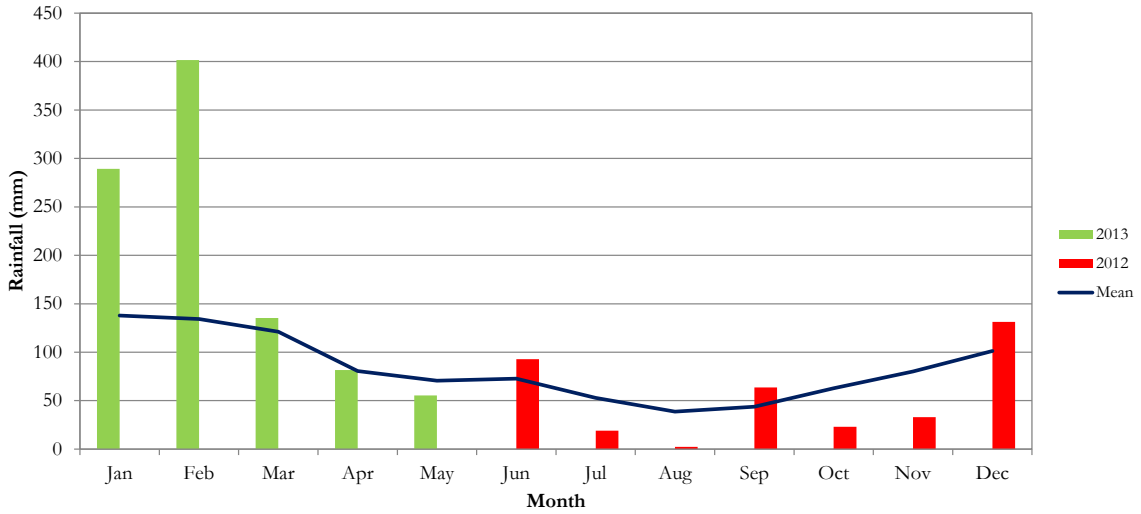


Figure 2.1 Mean monthly rainfall and total monthly rainfall for 12 month period prior to sampling from the Grafton BoM weather station

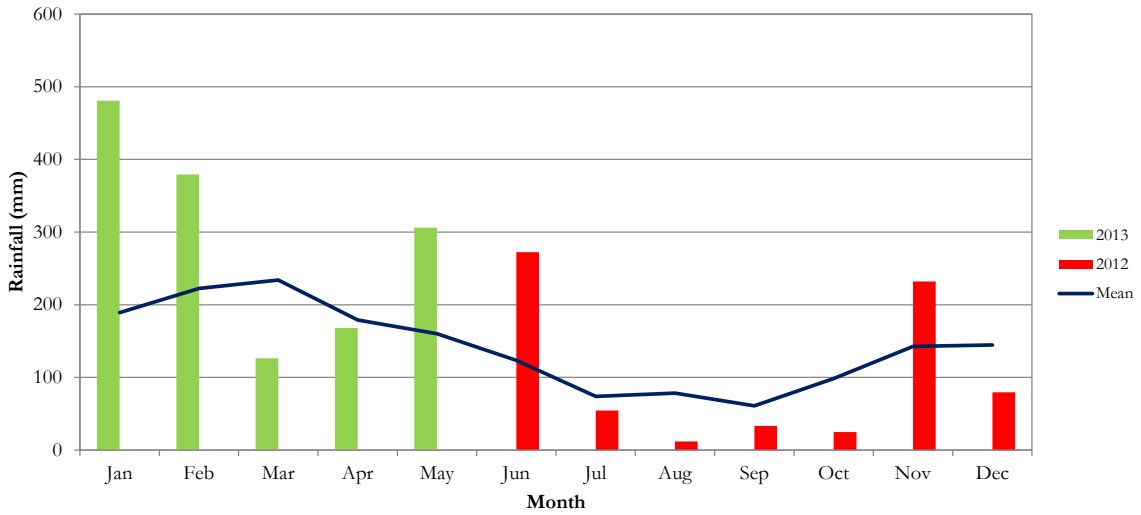


Figure 2.2 Mean monthly rainfall and total monthly rainfall for 12 month period prior to sampling from the Coffs Harbour (MO) BoM weather station

The weeks prior to the survey were relatively dry with the exception of a heavy rainfall event around the 24th of May where approximately 40mm of rain was measured at Grafton and over 250mm was measured at Coffs Harbour. During the survey very little rain was recorded. There was little to no flow observed at the majority of sites. However, at the sites where flow was observed, it was generally stronger than the flow that had been observed in the first stage of aquatic monitoring. Daily rainfall at the Grafton and Coffs Harbour weather stations in the month leading up to the survey and during the survey is reproduced in **Figure 2.3** and **Figure 2.4**.

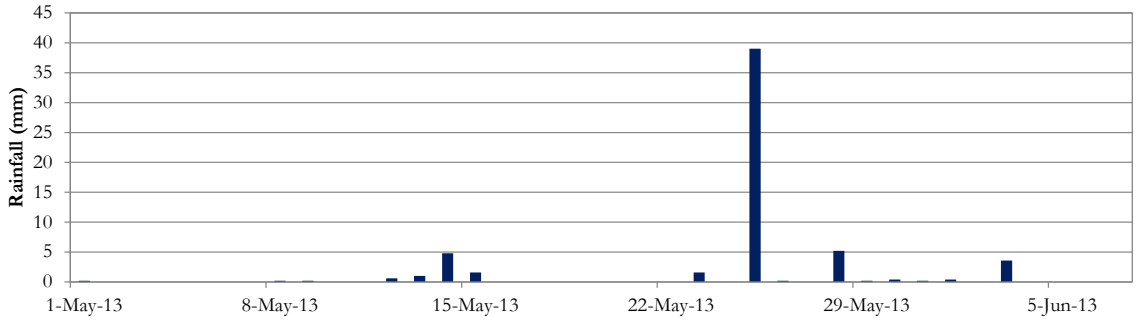


Figure 2.3 Daily rainfall for the month prior to sampling from the Grafton weather station

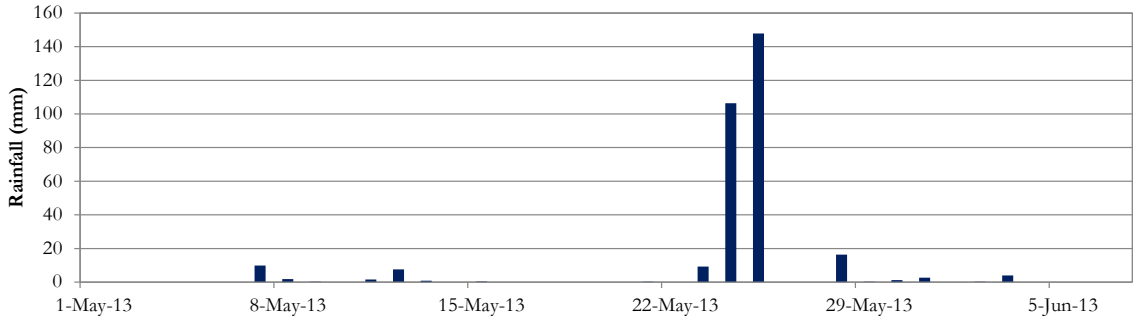


Figure 2.4 Daily rainfall for the month prior to sampling from the Coffs Harbour weather station

2.4 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 and Purple-spotted Gudgeon were recorded at the sampling station in the first 30 minute period;
- undertaking back-pack electro-fishing at each site, where safe to do so. Backpack electrofishing was restricted to shallow areas (e.g. <1m 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 2.3**. 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 5 mm dip net (knotless mesh);

Table 2.3 Details of electrofisher settings and effort at each site

Section	Site	Voltage (V)	Pulse Freq (Hz)	Duty Cycle (%)	Passes	Seconds Pulsed
2	1	300	35	50	1	602
2	2	300	35	50	2	572
2	4	300	35	50	1.5	600
2	5a	400	40	40	1	605
2	5b	400	40	40	1	612
2	5c	350	40	40	1	600
2	6a	350	40	30	1	607

Section	Site	Voltage (V)	Pulse Freq (Hz)	Duty Cycle (%)	Passes	Seconds Pulsed
2	6b	350	40	35	1	621
2	6c	350	40	30	1.5	617
1	7a	250	40	30	1	614
1	8	150	40	30	2	311
1	9	300	35	30	1.5	614
1	9b	300	35	30	1	598
1	10a	200	40	30	1	604
1	10b	200	40	30	1	613
1	11a	250	40	30	2	601
1	11b	250	40	30	1	604
1	12a	300	40	30	1.5	607
1	12b	300	40	30	2	606
1	13a	300	35	30	1	604
1	13b	300	35	30	1	603
1	13c	300	35	30	1	604
1	14	400	40	30	2	420
1	15a	350	40	30	2	606
1	15b	350	40	30	1	602
1	15c	350	35	30	1.5	560
1	16	300	35	30	2	524

All captured fish were retained in 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 on captured fish were recorded at the time of capture. Exotic species captured were euthanased in accordance with approved animal ethics procedures (Barker *et al.* 2009).

2.5 Water Quality

At each site physico-chemical water quality parameters were measured in surface water with an HORIBA U52 multimeter to determine the suitability of the site for the target species in terms of water quality. The measures collected were:

- temperature (˚C) - a measure of the degree of hotness or coldness of water. It is a form of pollution and can impact on riverine biota and associated biological and chemical processes;
- conductivity (mS/cm) - a measure of the amount of dissolved salts in the water and its ability to conduct an electrical current. It is important as some plant and animal species are salt sensitive whilst others require higher salt concentrations. It is also particularly important for electrofishing as it determines the suitable settings to be utilised at each site;
- dissolved Oxygen (mg/L & % saturation) - a measure of the amount of oxygen dissolved in water. Dissolved oxygen is vital for many forms of riverine and estuarine biota including native fish and is also vital for the functioning of healthy aquatic ecosystems;
- pH - a measure of hydrogen ion concentration that describes the acidity or alkalinity of water. Many organisms have a specific pH range within which they are able to function; and

- turbidity (NTU) – a measure of the capacity of the water to transmit light, which is an important aspect of healthy aquatic systems. Turbid waters often contain high concentrations of suspended sediment. Some fish are intolerant of high suspended sediment concentrations.

In addition to the above methods observations of surface films and debris were made at each site.

2.6 Habitat Description

A general description of the habitat characteristics of each monitoring site was undertaken, 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 & Arthrington (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:

- maximum channel depth from 3 points in each site;
- stream wetted width from 3 points in each site;
- per cent cover of large woody debris (>150mm 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 % cover of mud, sand, fine gravel (2-16mm), coarse gravel (16-64mm), cobble (64-128mm), rock and bedrock);
- per cent of bank classified as undercut (30cm overhang within 10cm of surface) from 4 transects at each site;
- per cent of bank with root masses from 4 transects at each site;
- per cent cover of riparian vegetation from 4 transects at each site; and
- flow rates.

In order to do this three transects were positioned perpendicular to stream flow and the substrate composition, debris cover and vegetative cover were estimated in four 0.5m^2 quadrats randomly positioned along each transect. Wetted width and depth were also measured at each of these transects. Additionally, 4 transects, representing a total of 20% 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 location of the photographic monitoring point as well as upstream and downstream site boundaries were recorded with a GARMIN 12 handheld GPS to facilitate repeat sampling. All spatial data were collected and are reported in WGD84.

3

Results

3.1 Fish Survey

Approximately 247 hours of fish trapping and 15731 seconds of electrofishing were undertaken. A total of 1341 fish from 10 species were captured using the electrofisher and 237 from 6 species using bait traps. Of the 10 total species captured, 8 were found in Section 2 and 7 in Section 1. A total of 1142 individual fish were captured in Section 1 and 436 in Section 2. Large numbers of crustaceans and a few tadpoles were also captured.

No Oxleyan pygmy perch or Purple-spotted Gudgeon were collected during the survey. The most common fish captured during both electrofishing and fish trapping were *Hypseleotris spp.* (the majority of these were confirmed to be Firetail Gudgeon, *Hypseleotris galii,* but some smaller specimens may have been Western Carp Gudgeon, *Hypseleotris klunzingeri*). They accounted for approximately 52% of the total number of fish captured. This is an increase upon the 43% represented in the first survey. The next most common species were Mosquito Fish (*Gambusia holbrooki*), which accounted for approximately 19%, Striped Gudgeon (*Gobiomorphus australis*), which accounted for approximately 10%, and Empire Gudgeon (*Hypseleotris compressa*), which accounted for approximately 10%.

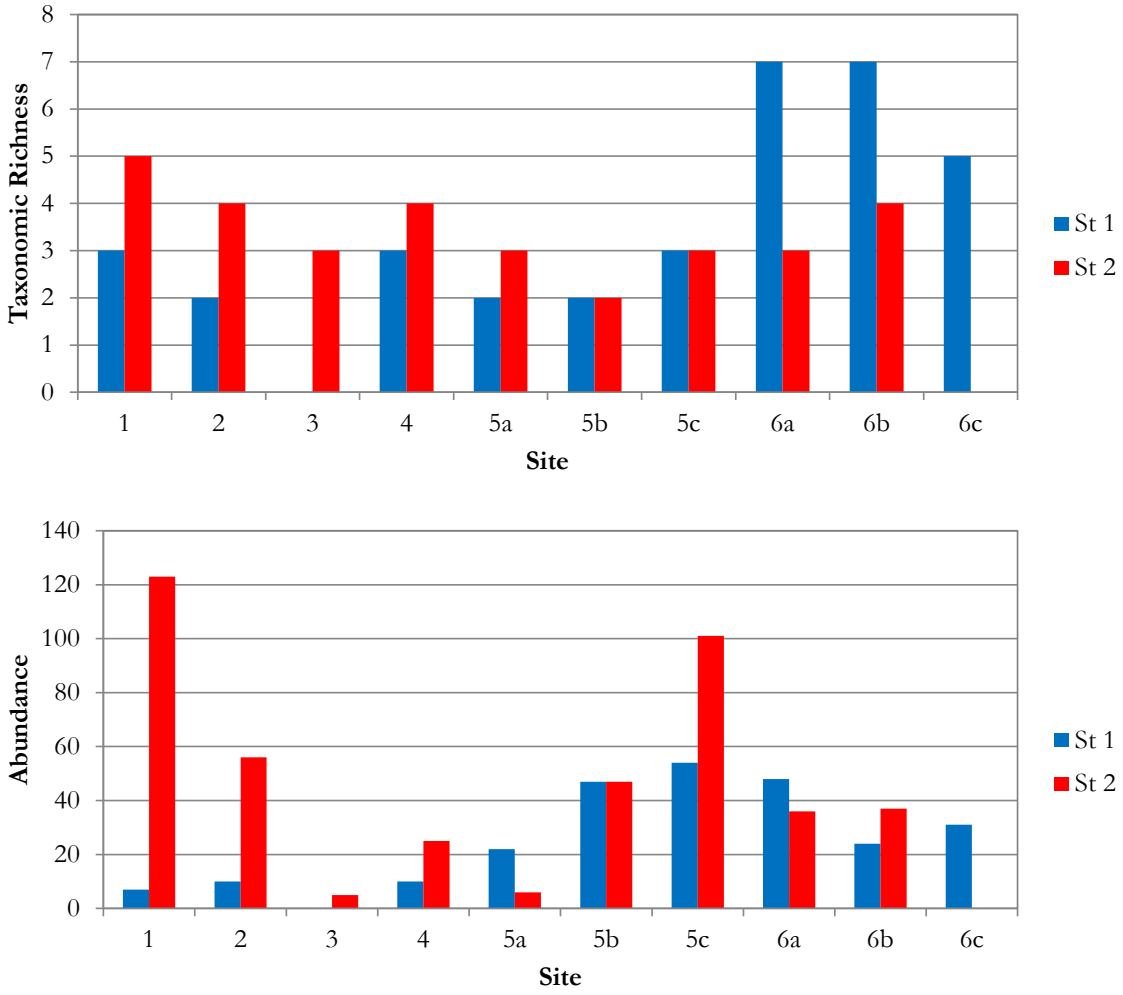


Figure 3.1 Taxonomic richness and abundance of fish at all sites within Section 2

Taxonomic richness at the sites in Section 2 ranged from 0 species to 5 species. The most taxonomically diverse sites within Section 2 were 1, 2, 4 and 6b (**Figure 3.1**). Abundance at sites in Section 2 also varied, with captures of between 0 and 123 fish. Overall abundance in Section 2 was greatest at sites 1 and 5c.

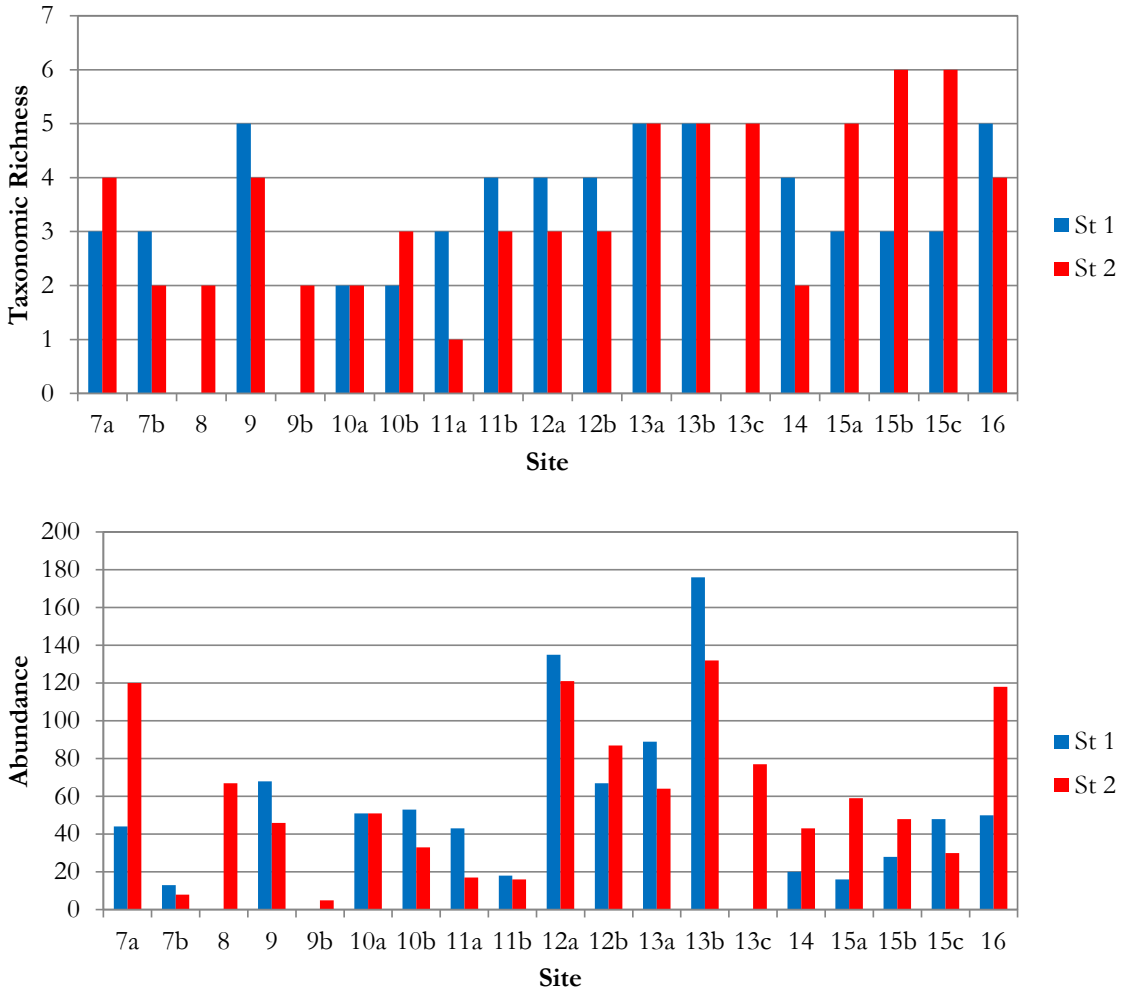


Figure 3.2 Taxonomic richness and abundance of fish at all sites within Section 1

In Section 1of the upgrade alignment taxonomic richness ranged from 1 to 6 taxa. The most taxonomically rich sites were 13a, b and c and 15a, b and c. Abundance varied among sites in Section 1, with between 5 and 132 fish collected at each site. The greatest numbers of fish were captured at sites 7a, 12a, 13b and 16 (**Figure 3.2**).

Four crustacean taxa were captured. Of these, only the conspicuous species of long-armed shrimp and yabbies were counted. Numbers of caridean shrimp and penaeid prawns were estimated to within an order of magnitude at each site.

Summaries of the fish survey results for each of the two highway upgrade sections are presented in **Table 3.1** and **Table 3.2**. Pie charts representing the fish community structure are displayed in **Appendix** B.

In comparison with the stage 1 survey, there were changes in abundance and variation at most sites, indicating that fish had had significant opportunities for dispersal into and out of the waterways sampled in the period between the two surveys.

Table 3.1 Summary of captures for all fishing methods at all sites in Section 2

Scientific Name	Common Name	Site									
		1	2	3	4	5a	5b	5c	6a	6b	6c
Family: Atherinidae											
Craterocephalus marjoriae	Marjories Hardyhead	0	0	0	0	0	0	0	0	1	0
Family: Eleotriidae											
Gobiomorphus australis	Striped Gudgeon	4	5	3	0	1	0	4	9	18	0
Hypseleotris compressa	Empire Gudgeon	0	0	1	0	0	0	0	0	0	0
Hypseleotris galii	Firetail Gudgeon	43	35	1	5	1	28	83	17	16	0
Phylipnodon grandiceps	Flathead Gudgeon	4	3	0	0	0	0	0	0	2	0
Phylipnodon macrostomus	Dwarf Flathead Gudgeon	5	0	0	3	0	0	0	0	0	0
Family: Melanotaeniidae											
Rhadinocentrus ornatus	Ornate Rainbowfish	67	13	0	16	0	0	0	10	0	0
Family: Poeciliidae											
Gambusia holbrooki	Mosquito Fish	0	0	0	1	4	19	14	0	0	0
Family: Paleomonidae											
Unknown sp.	Freshwater Prawn										
Family: Parastacidae											
Cherax sp.	Yabby	0	5	0	0	0	3	10	3	1	0
Family: Atyidae											
Caridinia sp.	Freshwater Shrimp	100	100	0	100	1000	1000	1000	100	100	10

Table 3.2 Summary of captures for all fishing methods at all sites in Section 1

Scientific Name	Common Name	Site																	
		7a	7b	8	9	9b	10a	10b	11a	11b	12a	12b	13a	13b	13c	14	15a	15b	15c	16
Family: Anguillidae																				
Anguilla anguilla	Shortfin Eel	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
Anguilla reinhardtii	Longfin Eel	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1
Family: Eleotriidae																				
Gobiomorphus australis	Striped Gudgeon	6	1	0	7	2	0	1	0	4	4	2	5	4	7	0	9	12	16	33
Hypseleotris compressa	Empire Gudgeon	0	0	0	18	0	0	0	0	0	0	0	3	56	46	0	6	12	9	0
Hypseleotris galii	Firetail Gudgeon	100	7	64	19	3	20	10	0	5	105	37	37	68	22	6	40	21	2	33
Family: Melanotaeniidae																				
Rhadinocentrus ornatus	Ornate Rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Family: Poeciliidae																				
Gambusia holbrookii	Mosquito Fish	13	0	3	0	0	31	22	17	7	12	48	18	3	1	37	3	1	1	51
Family: Parastacidae																				
Cherax sp.	Yabby	3	29	0	0	1	21	3	21	23	9	2	0	0	0	0	0	0	0	2
Family: Paleomonidae																				
Macrobrachium sp.	Macrobrachium	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	6	0
Unknown sp.	Freshwater Prawn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family: Atyidae																				
Caridinia sp.	Freshwater Shrimp	1000	1000	0	1000	1000	10000	1000	1000	1000	10000	1000	1000	1000	100	10	100	100	1000	100

3.2 Water Quality

The results of water quality samples are presented in **Table 3.3**. 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. The pH values that are low enough to confer a competitive advantage upon OPP, and hence indicative of greater habitat potential are shown in blue text. The pH values that fall outside of the known range occupied by OPP are shown in red text.

Table 3.3 Results of water quality sampling from all sites

Section	Location	Site	Temperature (°C)	pH	Conductivity (mS/cm)	Turbidity (NTU)	DO (mg/L)	DO (%)
2	1	-	13.78	6.78	0.188	117	6.71	66.9
2	2	-	14.34	6.89	0.185	211	5.23	52.9
2	3	-	14.52	**7.03**	0.246	32.3	3.29	33.3
2	4	-	15.44	**7.19**	0.323	37.9	5.94	61.5
2	5	a	13.89	5.84	0.097	4.6	5.63	56.3
2	5	b	13.67	**5.53**	0.096	3.4	6.44	64.1
2	5	c	16.37	5.92	0.109	6.4	6.96	73.3
2	6	a	12.5	6.68	0.162	8.7	6.96	67.5
2	6	b	14.61	6.34	0.147	7.8	9.06	92.1
2	6	c	14.74	6.48	0.146	7.9	13.51	137.7
1	7	a	13.49	6.49	0.312	24.2	6.92	68.6
1	7	b	14.84	6.47	0.314	18.2	6.81	70.1
1	8	-	15.1	**5.05**	0.76	0.8	5.32	54.7
1	9	-	15.72	6.34	0.321	2	6.11	63.6
1	9	b	15.84	6.08	0.202	1.4	4.92	51.3
1	10	a	12.55	5.67	0.588	12.4	5.06	49.2
1	10	b	13.48	5.76	0.374	2.4	5.87	58.2
1	11	a	14.76	5.81	0.288	17.7	5.98	60.9
1	11	b	16.13	5.61	0.334	1.8	6.19	65
1	12	a	15.84	6.06	0.2	6	5.3	55.2
1	12	b	16.63	5.95	0.195	4.6	5.09	54
1	13	a	15.76	5.83	0.29	41.1	5.09	53
1	13	b	14.06	6.03	0.208	4.2	5.87	58.9
1	13	c	14.88	6.07	0.215	3.3	6.02	61.5
1	14	-	18.39	6.1	0.083	73.7	7.81	85.6
1	15	a	15.63	6.62	0.172	4.6	7.78	80.1
1	15	b	15.36	6.69	0.168	4.3	8.17	84.3
1	15	c	15.21	6.78	0.166	3.4	9.49	97.7
1	16	-	15.42	6.04	0.21	9.6	5.09	52.6

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

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 both OPP and PSG (refer to **Table 1.1** and **Table 1.2**). However, in most cases the waters were only slightly acidic as opposed to the more acidic waters pH < 5 – 5.5 that are ideal for, or confer a competitive advantage upon, OPP. Despite the fact that the majority of sites were not experiencing significant flow at the time of sampling the dissolved oxygen concentrations were mostly at levels adequate for fish survival and function (ie. > 5mg/L).

When compared with the results from the stage 1 aquatic survey the results in **Table 3.3** indicate that water quality is relatively stable at most of the sites visited. In general there was very little difference in water quality values between the two sampling periods and the second survey revealed many of the same general patterns of water quality in individual waterways that were revealed during the first.

3.3 Habitat Description

A brief description of the general habitat conditions at each location is presented in **Table 3.4**. Summary results from habitat surveys are displayed in graphical form in **Appendix A**. An inventory of the aquatic plants found at each site is presented in **Table 3.5** and **Table 3.6**.

A wide variety of habitats were identified throughout the study area. The site descriptions in **Table 3.4** and the habitat data presented in **Appendix A** indicate that there was a high degree of similarity among sites within locations but also a high degree of variation among locations.

At the majority of sites there were no significant flows (< 0.1m/s) at the time of sampling. However, in some of the larger waterways, specifically at sites 5c, 6a, 6b, 6c and 15c, moderate flows of < 1m/s were noted. The majority of sites would have experienced significant flows during heavy rainfall in the two weeks prior to sampling.

Table 3.4 Qualitative descriptions of habitat features at all sites

Section	Site	Habitat Description
2	1	Site 1 is an intermittent headwater stream located downstream (west) of the upgrade corridor that was comprised of one long and one short pool separated by a log jam in the centre. There was little structural habitat available in stream. The benthic material was dominated by sand, with a variety of scattered leaf, twig and woody debris. The stream margin was well vegetated, primarily with *Lomandra longifolia* and *Carex fascicularis*, some of which was overhanging and trailing, but instream vegetation was very sparse. There was no flow at the time of sampling.
2	2	Site 2 is located at the confluence of two intermittent creeks, downstream (west) of the upgrade corridor. The site was comprised of a series of disconnected pools up to 8m wide and to a depth of over 1m in areas. Benthic material at this site was dominated by mud. Debris was less commonly in this survey although there was some submerged vegetation in the shallower areas. There were also some scattered emergent rushes including *Baumea articulata* and *Triglochin procerum*. The stream margin was densely vegetated, primarily with *Lomandra longifolia*. Much of the Lomandra and overstorey vegetation (*Leptospermum sp*. and *Melaleuca sp*.) was trailing. There was no flow at the time of sampling.
2	3*	Site 3 is a series of small pools in an intermittent headwater stream located immediately to downstream (west) of the highway corridor. Benthic material at this site was dominated by mud but sand and gravel were also present. The stream margins were well vegetated and a high proportion of vegetation was trailing, mostly *Lomandra longifolia* and *Carex fascicularis*. Debris was scattered. There was no flow at the time of sampling.
2	4	Site 4 is located at the confluence of two intermittent creeks, downstream (west) of the upgrade corridor. The site was comprised of a series of semi-connected pools up to 5m wide and around 0.5m deep. Benthic material at this site was dominated by gravel and sand and benthic structural habitat comprised of scattered leaf, twig and large woody matter. There was little instream vegetation. The stream margin was densely vegetated, primarily with *Lomandra longifolia*, some of which trailed in the channel. Some sections of the bank were undercut. There was no flow at the time of sampling.
2	5a	Site 5a is located in a broad, shallow swampy channel upstream of the upgrade corridor. The substrate was dominated by mud. Leaf litter and small woody debris were abundant and there was dense emergent vegetation over the majority

Section	Site	Habitat Description
		of the site. At the time of sampling the site was well connected to adjacent wetlands a there was no clear stream bank or perceptible flow.
2	5b	Site 5b is located in a broad, deep swampy channel in the upgrade corridor. The depth and breadth of the site probably result in part from the dam located downstream. A large part of the site consisted of open water but no further details were collected due to the depth, which was greater than 2.5m in area. The gently sloping margins and broad shallow flanks of the site were mostly covered with grasses and emergent rushes dominated by *Baumea articulata*. Structural habitat at the site was comprised mostly of emergent and submerged vegetation. The substrate was mostly mud, overlain with a thick layer of coarse organic material. At the time of sampling there was no perceptible flow.
2	5c	Site 5c is located amongst a series of swampy channels downstream of the upgrade corridor. At the most downstream point the channel was greater than 1.5m deep though mostly it was broad, shallow and well vegetated. The substrate was mostly mud, covered with organic material and a thick mat of the aquatic weed species *Myriophyllum aquaticum*. The margins were generally low and intermittently vegetated, with pugging from livestock access evident. The broad shallow channel was dominated by emergent rushes such as *Lepironia articulata* and *Triglochin procerum*. Structural habitat at the site was comprised mostly of the emergent and submerged vegetation. At the time of sampling there was little flow (0.3m/s).
2	6a	Site 6a is a narrow, deep channel located upstream (east) of the corridor. The benthic material was dominated by sand. There is an abundance of structural habitat at this site including undercut banks, large woody debris, trailing vegetation, root balls and twig and leaf litter. The stream margins were nearly vertical in many places, and covered with mosses and a variety of vegetation. At the time of sampling there was moderate flow (0.5m/s) in the shallow parts of the site.
2	6b	Site 6b consists of a meandering channel with steep sandy banks located in the highway alignment. The substrate was sand. Regular overhangs, and rootballs, in addition to scattered large woody debris, and twig and leaf litter provided structural habitat. There was some riparian vegetation and trailing vegetation recorded, despite the sandy banks. At the time of sampling there was moderate flow (0.4m/s) in the shallow parts of the site.
2	6c	Site 6c was very similar to site 6b and consisted of a meandering channel with steep sandy banks located downstream (west) of the highway alignment. The benthic material was dominated by sand and fine gravel. Regular overhangs, and rootballs, in addition to scattered large woody debris, and twig and leaf litter provided abundant structural habitat. There was a higher degree of riparian vegetative cover noted during this survey than during the previous one. At the time of sampling there was moderate flow (0.6m/s) through the majority of the site.
1	7a	Site 7a is a straight, narrow, permanent channel located within the upgrade alignment. The benthic material was variable at the site with interspersed sandy and muddy patches as well as areas where gravel has congregated. Structural habitat at the site was dominated by regular cover of leaf litter and scattered small and large woody debris. The stream margins were well vegetated and trailing vegetation also provided some habitat. There was no flow at the time of sampling.
1	7b	Site 7b is a broad deep area of creek located downstream (east) of the upgrade alignment and immediately upstream of a makeshift dam. The water was relatively deep (>1.5m) in some areas as a result of the dam and the substrate was mostly deep soft mud that has settled out of the water column. Structural habitat at the site consisted of large and small woody debris and a dense bed of *Utricularia sp*., but the proportional cover of each feature was low. The stream margins were mostly vegetated, as was a small island that occurred mid-stream and was covered with *Shoenoplectus mucronatus* and *Cyperus eragrostis*. No flow was detected at the time of

Section	Site	Habitat Description
		sampling.
1	8*	Site 8 is in an intermittent headwater stream. The benthic material was mud and there were high proportions of leaf litter, small woody debris and in stream vegetation, including *Triglochin procerum* and *Philydrum lanuginosum*. There was a high proportion of the bank vegetated and much of the vegetation was trailing. There was no flow at the time of sampling.
1	9	Site 9 is a moderately narrow permanent pool in an intermittently flowing stream located well downstream (east) of the upgrade alignment. Overall, habitat availability at the site was good. Structural habitat varied widely across the site, with small proportional covers of most available microhabitat classes. The benthic materials were dominated by coarse gravel and mud, though sand and fine gravel were also present. Emergent vegetation was mostly *Triglochin procerum*, *Philydrum lanuginosum* and *Baumea articulata*. The stream margin was well vegetated, with grasses and rushes. Iron oxide stains were apparent on the stream margins and there was no flow at the time of sampling.
1	9b*	Site 9b is located approximately 2km downstream of the upgrade alignment. This site is a broad shallow part of the stream that was well connected with adjacent wetland habitats. As a consequence the bank was poorly defined and difficult to describe adequately. The benthic material was mud and the entire site was densely vegetated, mostly with *B. articulata*. There were a number of large logs scattered around the site and no flow at the time of sampling.
1	10a	Site 10a is a series of shallow, small pools in an intermittent headwater stream located within the highway corridor. Benthic material at this site was dominated by mud. The proportional cover of leaf litter had reduced since the previous survey but was still high. Structural habitat was provided by lots of in-stream vegetation, mostly *Baumea articulata*. The stream margins were well covered with grasses and rushes, with lots of trailing vegetation. There was no perceptible flow at the time of sampling.
1	10b	Site 10b was very similar to 10a, a series of wider, shallow, small pools in an intermittent headwater stream located downstream of the highway corridor. Benthic material at this site was dominated by mud, mostly covered with a layer of coarse organic material with high proportional cover of leaf litter. The stream margins were well covered with grasses and rushes with lots of trailing vegetation and some root balls. There was no perceptible flow at the time of sampling.
1	11a	Site 11a is a series of wider, shallow, small pools in an intermittent headwater stream located within the highway corridor. Benthic material at this site was dominated by mud. The stream margins were well covered with grasses and rushes and there was a high proportional cover of instream vegetation, dominated by *B. articulata* and the aquatic weed species *Myriophyllum aquaticum*. There was no perceptible flow at the time of sampling.
1	11b	Site 11b was very similar to 11a, though the pools were wider and deeper, with a higher proportion of open water and corresponding lower proportion of emergent vegetation. There were also a number of root balls and undercut banks.
1	12a	Site 12a is also a series of moderately wide, shallow, small pools in an intermittent headwater stream located within the highway corridor. Benthic material at this site was dominated by mud, although there were significant proportions of sand and fine gravel. The substrate was covered with a high proportion of leaf litter and scattered small woody debris. The stream margins were well vegetated and erosion and headcut activity was evident within the channel. The primary forms of structural habitat were emergent and submerged vegetation although there were also root balls and undercut banks. There was no perceptible flow at the time of sampling.
1	12b	Site 12b was very similar to site 12a. It was also a series of moderately wide, shallow, small pools in an intermittent headwater stream but is located downstream

Section	Site	Habitat Description
		of the highway corridor. A higher proportional cover of emergent vegetation, dominated by *Baumea articulata*, was present at this site than at 12a. There was no perceptible flow at the time of sampling.
1	13a	Site 13a is a large, permanent but disconnected pool in the upgrade alignment. The site was up to 25m wide, and greater than 2m deep in parts. The channel margins were ill-defined due to high lateral connectivity with adjacent wetlands. Riparian vegetation was mostly restricted to large *Melaleuca sp.* that provide shade but, apart from irregularly spaced root balls, did not provide physical habitat. The benthic material was dominated by mud with a high proportion of leaf litter cover and woody debris. There was also a high proportional cover of submerged vegetation and scattered emergent vegetation, mostly *B. articulata*. There was no flow at the time of sampling.
1	13b	Site 13b is a permanent pool located downstream of the upgrade alignment. The site was mostly around 10m wide and around 1.4 m deep at the deepest point. The habitat features varied throughout the site. The benthic material was mostly mud but also includes significant proportions of sand and fine gravel. The margins of the stream were well vegetated with *Juncus usitatus*, *Persicaria spp.*, and *L. longifolia*. A variety of structural habitats were present in-stream including a high proportional cover of leaf litter and scattered large woody debris and beds of emergent and submerged vegetation. Emergent vegetation included *B. articulata* and *T. procerum.* Benthic vegetation was mostly *M. aquaticum*. There was evidence of cattle access to the creek with some pug marks along the margins. At the time of sampling there was very little flow (< 0.1m/s).
1	13c*	Site 13c is located approximately 1km downstream of the upgrade alignment. The site consisted of a long wide pool with some deeper (1.5m) sections. The benthic material was a mixture of sand and gravel with a high proportional cover of debris. Structural habitat was mostly located near the banks, which had relatively high proportions of trailing vegetation, undercuts and root balls.
1	14	Site 14 is located in a narrow, shallow sinuous channel draining a floodplain and is immediately downstream of the upgrade alignment. The site was surrounded by pasture and cattle access to the waterway was evident. The site was relatively homogenous with respect to habitat. The margins were covered with grasses, the benthic material was mostly mud covered with a thick layer of organic material, submerged vegetation and leaf litter, and emergent macrophytes dominated by *Persicaria sp.* were prevalent. There was no flow at the time of sampling
1	15a	Site 15a is located in a river channel and is located upstream of the upgrade corridor. The stream margins were steep and sparsely vegetated with *L. longifolia*. Tall vegetation provided shade and a source of leaf litter and large and small woody debris. There was also a small percentage of root mass and trailing vegetation. The channel was deep and wide and the benthic material was dominated by sand. In-stream structural habitat included a high percentage of leaf litter and small percentages of large and small woody debris. There were a number of large fallen trees crossing the channel. At the time of sampling there was very little (< 0.1m/s) flow.
1	15b	Site 15b was very similar to site 15a and is located within the upgrade corridor.
1	15c	Site 15c was also similar to sites 15a and 15b. It differed in that it was narrower and shallower and the margin on one side was sand with low proportional vegetation cover. The benthic material also had a higher proportion of gravel. At the time of sampling there was a moderate flow approx. (0.3 – 0.7m/s).
1	16	Site 16 is a narrow, shallow, intermittent lowland stream located downstream of the upgrade corridor. The stream margins were well covered with grasses and rushes with a reasonably high proportion of trailing vegetation. The benthic material varied throughout the site but is dominated by mud and rock that was covered in most areas with organic matter and a high proportion of leaf litter.

Section	Site	Habitat Description
		There was a variety of emergent vegetation, mostly *B. articulata* and *S. mucronatus*, forming a moderate proportion of structural in-stream habitat. There was no detectable flow at the time of sampling.

* Not sampled during 1st stage of monitoring

Plate 3.1 Electrofishing in Corindi Creek

Plate 3.2 Striped Gudgeon (*Gobiomorphus australis*)

Table 3.5 Aquatic plants identified at sites in Section 2

Species Name	Common Name	1	2	3	4	5a	5b	5c	6a	6b	6c
Baumea articulata	Jointed Rush	x	x						x	x	x
Baumea rubiginosa	Baumea						x				
Carex fascicularis	Tassel Sedge										
Elatine gratioloides	Waterwort	x	x	x	x						
Eleocharis sphacelata	Tall Spikerush					x		x			
Juncus usitatus	Common Rush	x	x	x	x	x	x				
Lepironia articulata								x			
Lomandra longifolia	Creek-mat Rush	x	x	x	x				x	x	x
*Maundia triglochinoides***							x				
*Myriophyllum aquaticum**	Parrots Feather	x	x	x		x	x	x			
Ottelia ovalifolia	Swamp Lily					x					
Philydrum lanuginosum	Frogsmouth					x	x	x			
Schoenoplectus mucronatus											
Schoenoplectus validus	River Clubrush							x			
Triglochin procerum	Water Ribbons		x			x	x	x			
Utricularia gibba	Yellow Bladderwort										

* Introduced species

** Species listed under *Threatened Species Conservation Act 1995*

Table 3.6 Aquatic plants identified at sites in Section 1

Species Name	Common Name	7a	7b	8	9	9b	10a	10b	11a	11b	12a	12b	13a	13b	13c	14	15a	15b	15c	16
Baumea articulata	Jointed Rush				x		x	x	x	x	x	x	x	x						x
Carex fascicularis	Tassel Sedge				x	x														
Cyperus difformis	Dirty Dora		x																	x
Elatine gratioloides	Waterwort															x				
Eleocharis sphacelata	Tall spikerush					x								x						
Ghania sp.	Sawsedge			x		x														x
Juncus usitatus	Common rush			x	x		x	x	x	x				x	x	x				x
Lepironia articulata						x														
Lomandra longifolia	Creek mat rush	x	x				x	x	x	x	x	x	x	x	x		x	x	x	x
*Myriophyllum aquaticum**	Parrots feather		x		x	x	x	x	x	x						x				x
Ottelia ovalifolia	Swamp lily							x	x	x						x				x
Persicaria sp.	Knotweed													x		x		x		x
Philydrum lanuginosum	Frogsmouth			x	x		x	x	x	x	x	x	x	x						x
Schoenoplectus mucronatus			x																	x
Triglochin procerum	Water ribbons			x	x	x	x	x	x	x	x	x		x		x				x
Utricularia gibba	Yellow bladderwort		x																	

* Introduced species

5

Discussion and Conclusion

This survey did not find any OPP or PSG in the 16 significant waterways crossed by the Pacific Highway upgrade alignment between Woolgoolga and Glenugie. Habitat quality and availability varied across the sites sampled, as did water quality. Although the combination of available habitat and water quality at some sites was potentially suitable for OPP and PSG there is unlikely to be any populations of OPP or PSG in the construction corridor. In surveying PSG and OPP a large quantity of data has been collected. This dataset may prove useful as a baseline for any future aquatic monitoring that is planned for the Woolgoolga to Ballina Pacific Highway upgrade.

Despite an intensive survey of 16 waterways at 29 sites there were no OPP or PSG captured along the Woolgoolga to Glenugie section of the Pacific Highway upgrade. A total of 247 hours of fish trapping and 15731 seconds of electrofishing were utilised over 6 days during the survey. No OPP or PSG were captured in a similar survey effort in September 2012 and, although there are some sites that are suitable for PSG or OPP in terms of water quality and habitat availability, it is considered unlikely that there are any populations of these species along the upgrade corridor. The sites that are most suitable for recruitment of OPP are within Section 1, between Arrawarra Gully and Dirty Creek, because OPP are thought to be restricted to coastal lowlands (Knight and Arthrington 2008). Whilst the study area is outside of the current known range of OPP, they were collected from Cassons Creek in 1972 (Knight & Arthrington 2008). The sites that would be most likely to harbour a population of PSG are mostly in Section 2, between Halfway Creek and Glenugie Creek, with the addition of Boneys Creek and Dundoo Creek from Section 1. The distribution of PSG is thought to have its southern limit in the Clarence River catchment and PSG in coastal catchments are most often encountered at a distance of around 200km upstream of river mouths.

Though no OPP and PSG were captured, a large number and variety of fish were encountered during this study. The taxonomic richness and fish abundance encountered at most sites did not appear to be related to the upstream catchment area and permanency of the waterway being sampled, as it was in the previous survey. This result may be related to the significant rainfall experienced in the weeks and months prior to the survey and the associated increased opportunities for dispersal. There were also difficulties sampling some of the larger waterways, such as the Corindi River, with the methods utilised due to their depth and steep banks. In general, the survey indicates that there is naturally occurring temporal variation in the fish communities located along the upgrade corridor. The key implications of this are that any consideration of potential future construction impacts upon aquatic fauna needs to allow for natural variation and that all of the waterways along the upgrade corridor are potentially important fish habitats.

The study measured vegetative and physical habitat features including flow, width, depth, instream vegetation, debris cover and stream bank forms. Habitat quality and availability varied substantially among sites. OPP are known to prefer sandy substrates with high proportions of emergent and submerged vegetation and structural formations such as leaf litter, woody debris and steep or undercut banks with trailing vegetation and root balls. In Section 1, where it is most likely that OPP would be encountered, the waterways with habitats conforming best to those preferred by OPP included Dirty Creek, Redbank Creek and its tributaries, Cassons Creek and Arrawarra Gully. Whilst PSG have been encountered under a greater variety of conditions they are known to prefer sites with good structural habitat along the stream banks, such as overhangs, root balls, trailing vegetation and submerged and emergent vegetation. The sites that best fit this description were 6a, 6b and 6c (Halfway Creek). The information about aquatic habitats and aquatic flora collected throughout this study may also be a useful baseline for the assessment of potential future construction impacts.

This study also measured physicochemical water quality variables. Whilst water quality varied throughout the study area, at all of the sites within Section 1 (and all but two of those in Section 2) of the upgrade corridor the water quality data fell within the ranges known to be inhabited by OPP. In

addition, all of the sites within Section 2 of the upgrade corridor (and all but two of those within Section 1) were within the ranges known to be inhabited by PSG. Although the antecedent rainfall conditions were very different prior to this survey, when compared with the results from the stage 1 monitoring there was not a great deal of change at individual sites.

In comparison with the stage 1 survey, there were changes in abundance and species richness at most sites, indicating that fish had had significant opportunities for dispersal into and out of the waterways sampled in the period between the two surveys. Across the study area there were no clear patterns to these changes although at different sites within the same waterway the detected species richness tended to change in the same direction (or stay the same). For example, there was increased species richness at all sites in Glenugie Ck (1, 2 and 4), increased species richness at all sites in the Corindi River, decreased species richness at all sites in Halfway Creek (6a, b and c) and no change in species richness at the sites in Cassons Creek. This indicates that the fish communities in individual waterways differ in their responses to the changes in flow conditions. Although fish species richness and abundance varied between the first and second stage surveys the community structure at most sites remained fairly similar. In effect the most abundant species at most sites did not differ much between the two surveys.

The results of the habitat measurements also differed in some areas between the first stage and second stage monitoring. The following general trends were apparent:

- The composition of benthic materials did not change much between surveys. Outside of heavy flooding conditions this is likely to be a relatively stable feature of these sites.
- The percentage covers of leaf litter and woody debris were among the more variable features, indicating the ephemeral nature of these habitat features.
- The largest changes in habitat features tended to be from the deeper and wider sites. This indicates the difficulty of adequately covering these sites with the methods used and suggests that they may not have adequately captured the inherent variation in habitat at a within site level at those sites.

In conclusion, the following recommendations arise from this report:

- Following two surveys targeting OPP and PSG it is considered unlikely that any populations of these species are currently located along the Pacific Highway upgrade corridor between Woolgoolga and Glenugie.
- Although there is a low likelihood of directly disturbing OPP or PSG populations during construction, all efforts should be made to maintain the integrity of the waterways along the construction corridor during and after construction. As the upgrade is located near the southern limits of distribution for both species and there are sites with suitable water quality and habitat features there remains a possibility of future recruitment to the area.
- An aquatic monitoring program assessing water quality, fish populations and aquatic habitats should be considered during and after construction in order to assess the impacts of construction upon the aquatic environment and inform adaptive management and mitigative measures.
- Any future monitoring of water quality, fish populations and aquatic habitats at the sites used for these surveys should consider the background variation detected in these surveys when interpreting results,

Acknowledgements

The following personnel contributed to this report:

- Mathew Birch – Technical leader and author
- Damon Telfer – Field Team
- Joanne Cunningham – Field Team
- Rebecca Oliver King – Field Team

Permission to utilise the data from the first stage of aquatic monitoring was provided by GeoLINK.

GIS data and orthorectified aerial imagery used in the preparation of maps was provided by NSW RMS.

References

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

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

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

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

GeoLINK (2012) Aquatic Monitoring – RMS Woolgoolga to Glenugie – Stage 1. Report Prepared for NSW Roads and Maritime Service.

Knight, J. & Arthrington, 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 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., & Arthrington, A. (2004) Freshwater Fishes of North-Eastern Australia. CSIRO Publishing, Collingwood.

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

Appendix A

Aquatic Habitat Summaries

Figure A1 A summary of aquatic habitat data collected in Section 2 of the Woolgoolga to Glenugie Pacific Highway upgrade

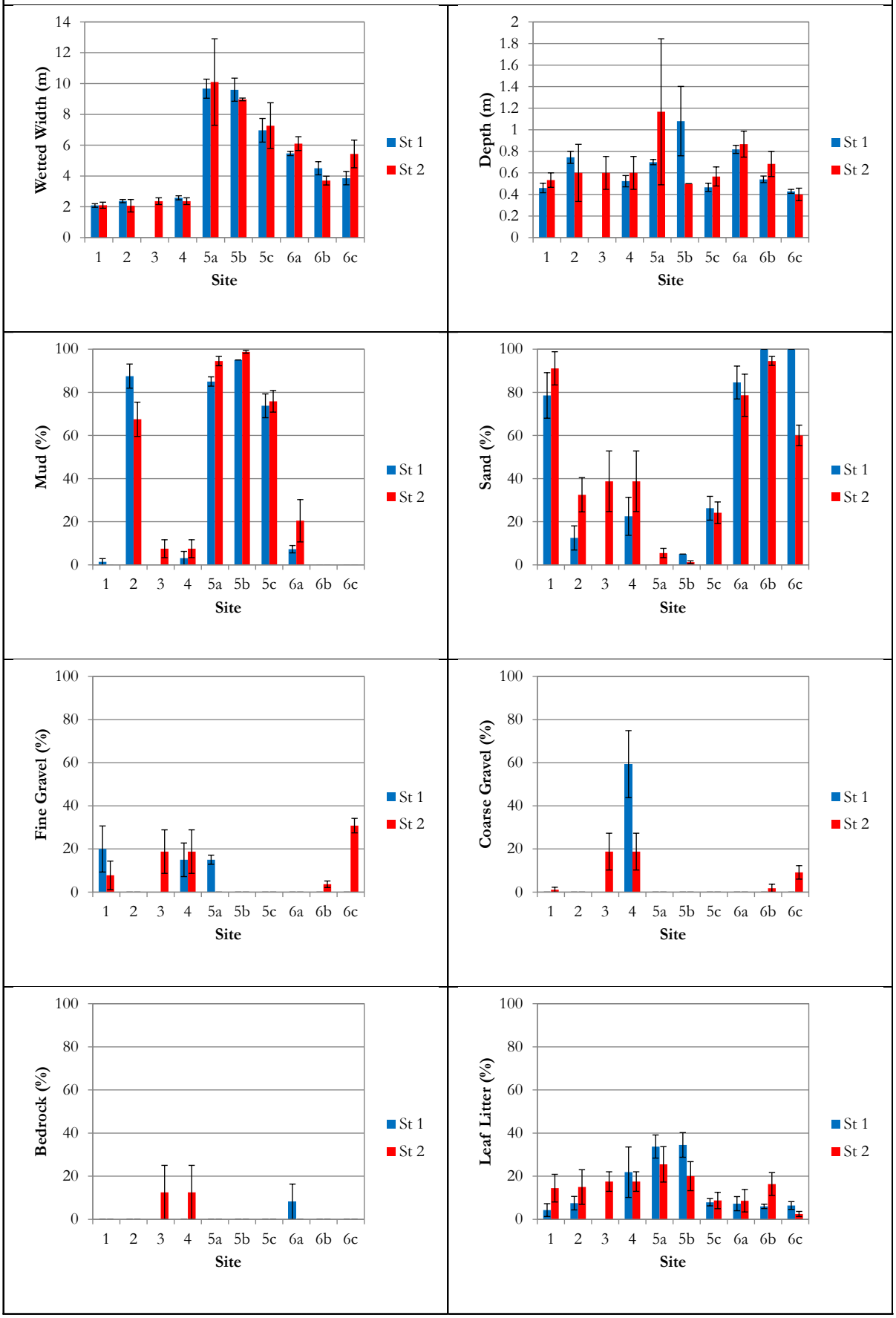


Figure A1 A summary of aquatic habitat data collected in Section 2 of the Woolgoolga to Glenugie Pacific Highway upgrade

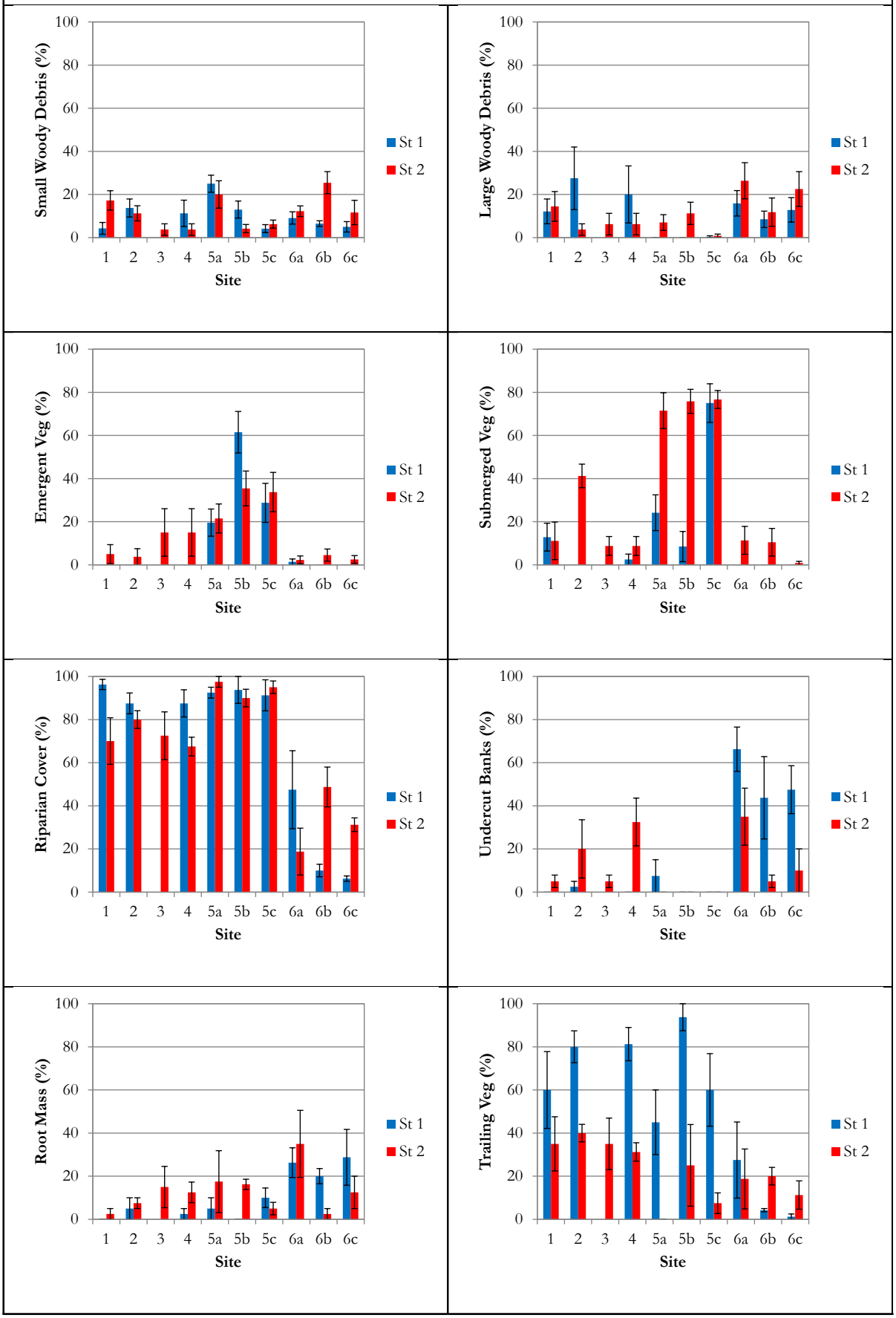
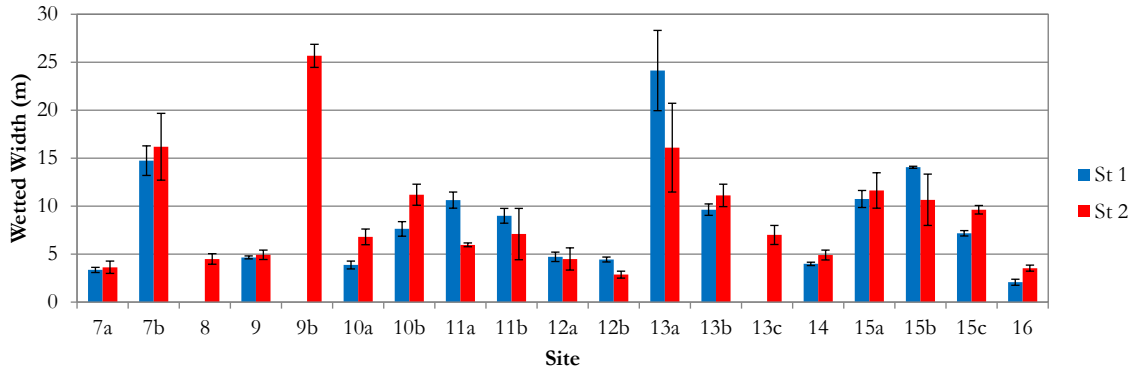
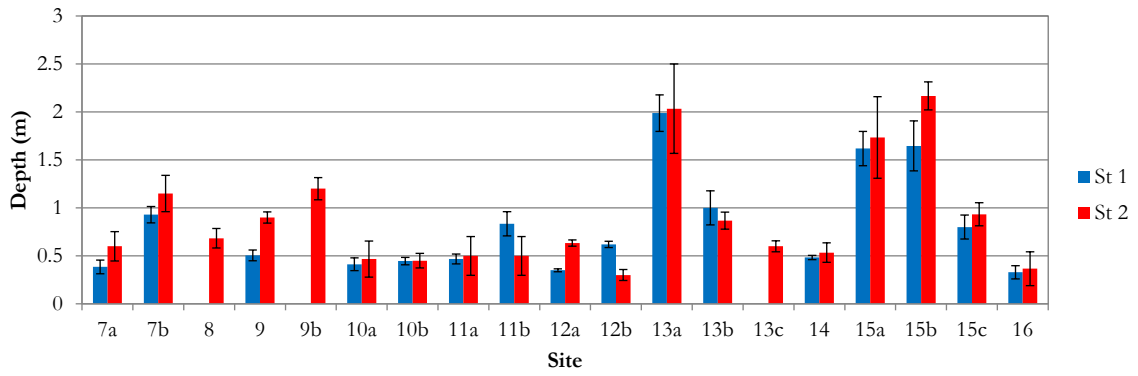
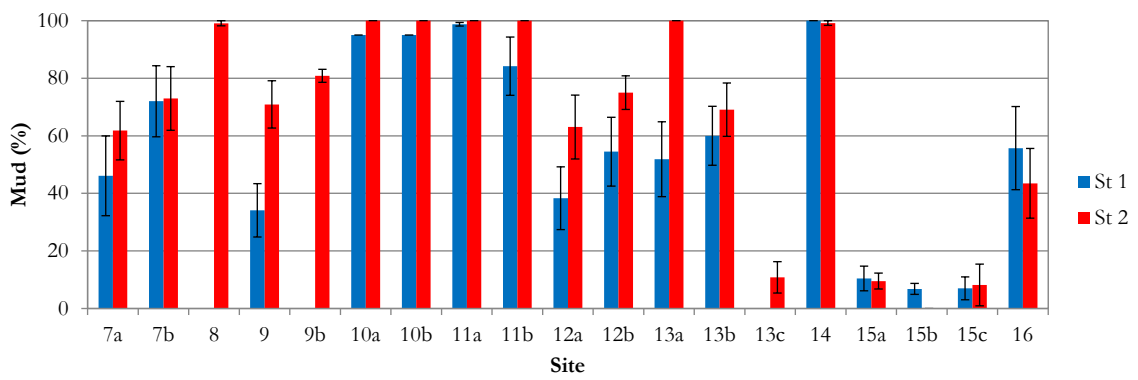


Figure A2 A summary of aquatic habitat data collected in Section 1 of the Woolgoolga to Glenugie Pacific Highway upgrade







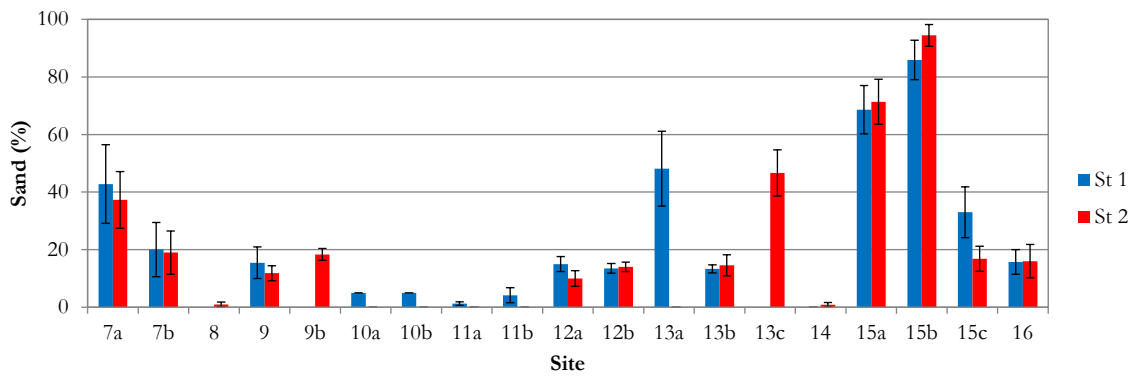
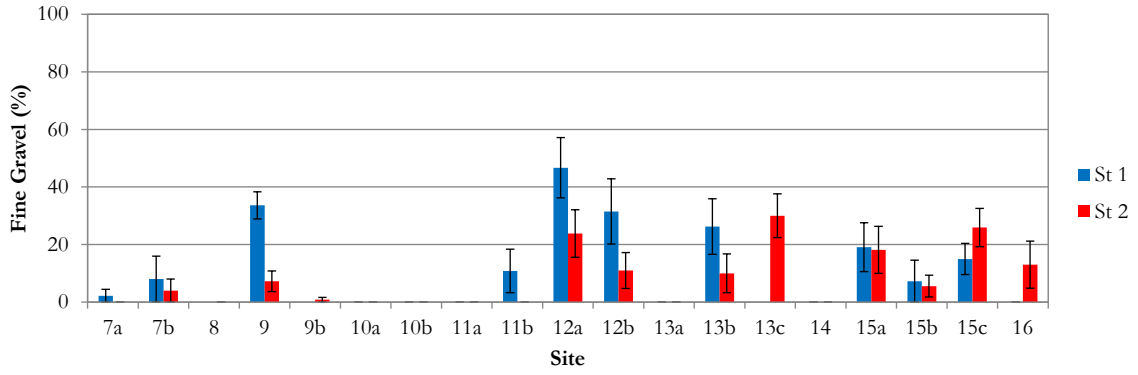
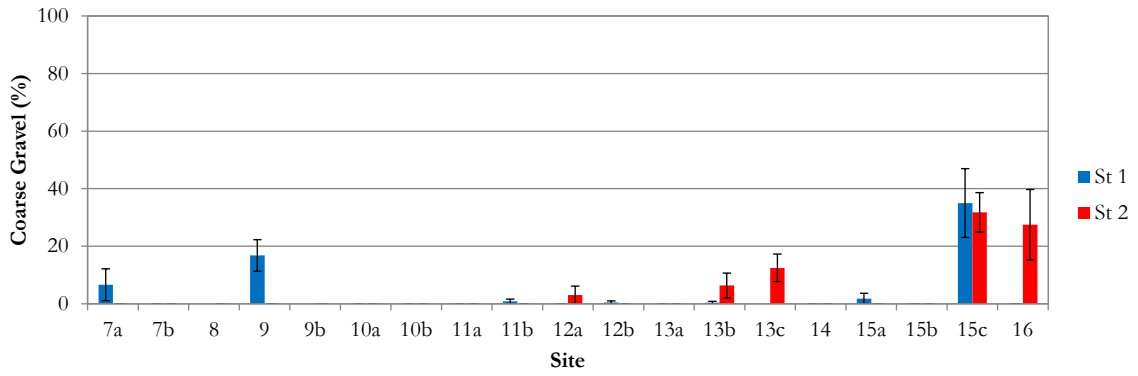
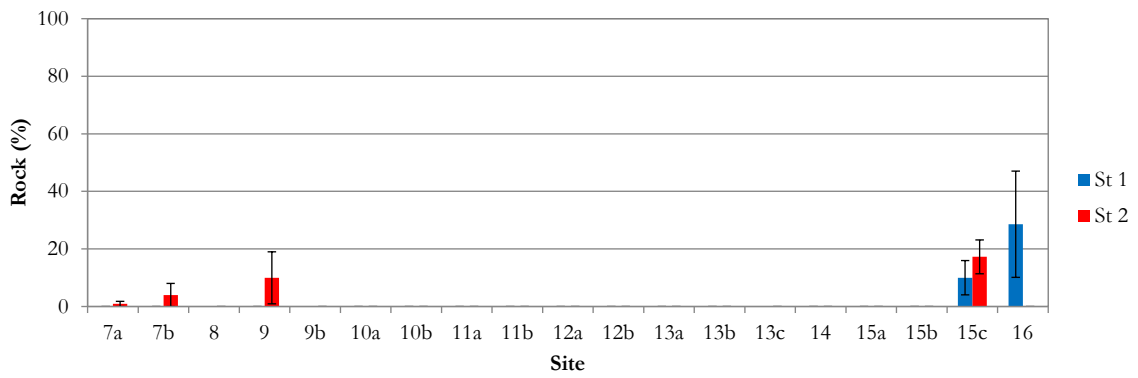


Figure A2 A summary of aquatic habitat data collected in Section 1 of the Woolgoolga to Glenugie Pacific Highway upgrade







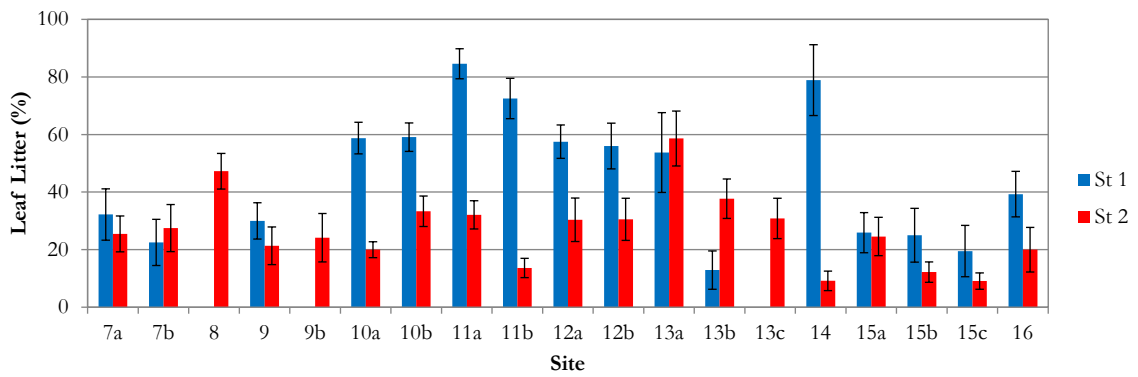
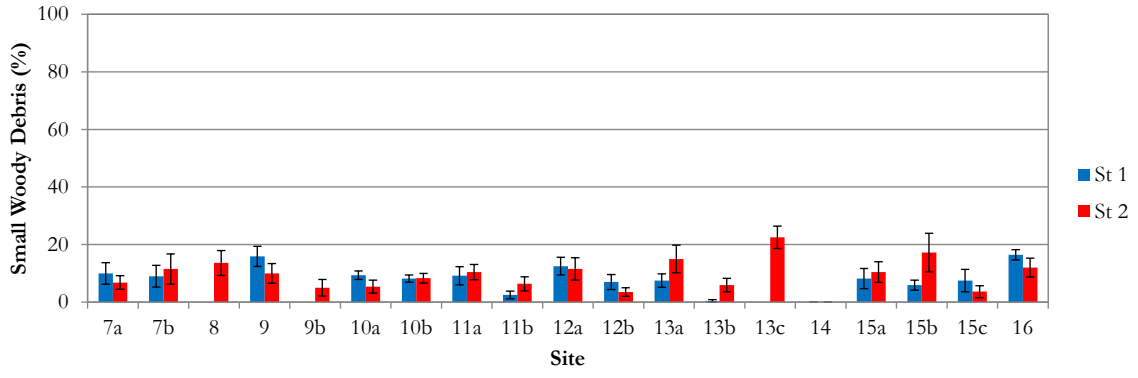
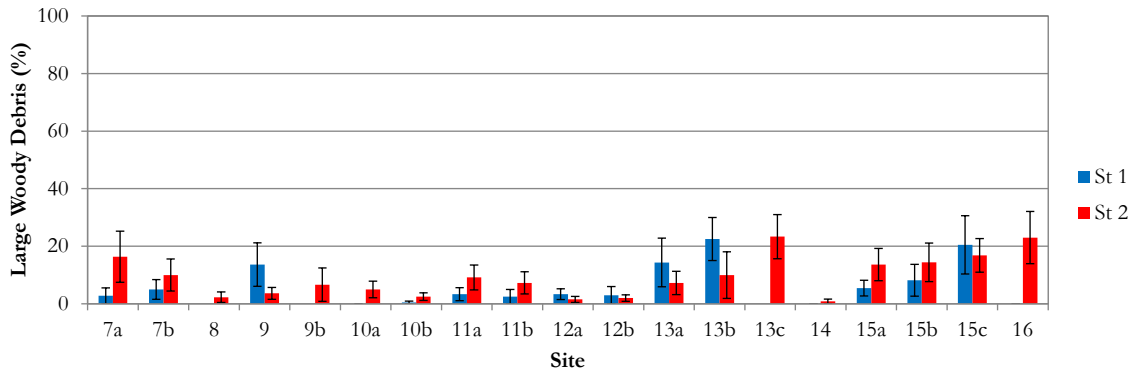
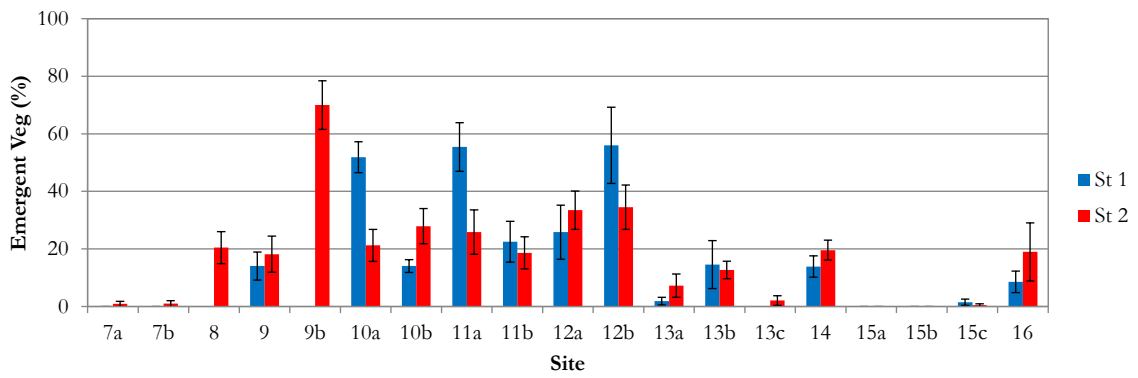


Figure A2 A summary of aquatic habitat data collected in Section 1 of the Woolgoolga to Glenugie Pacific Highway upgrade







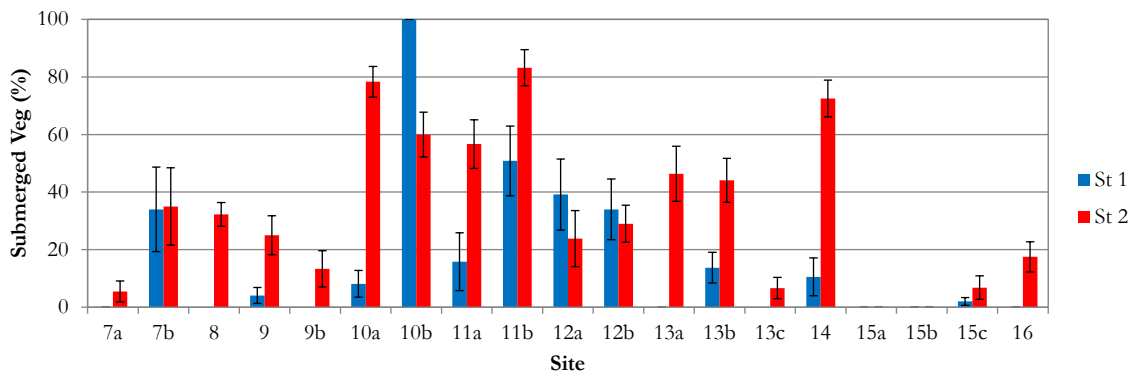
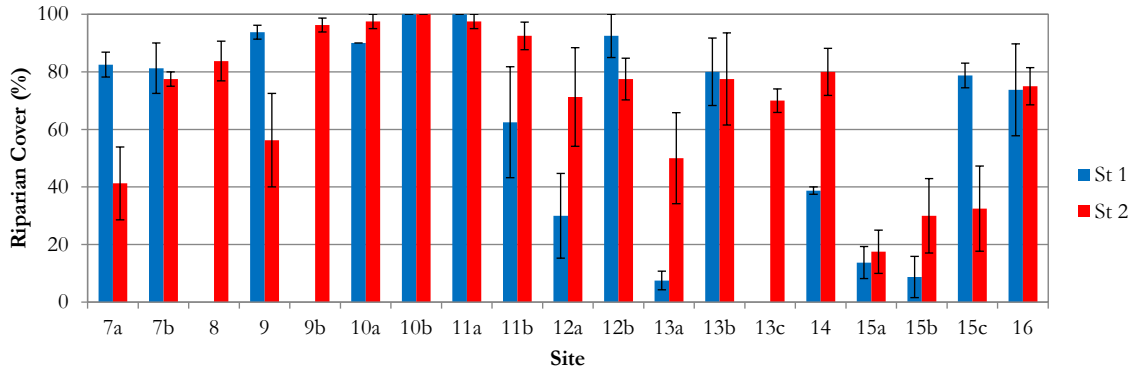
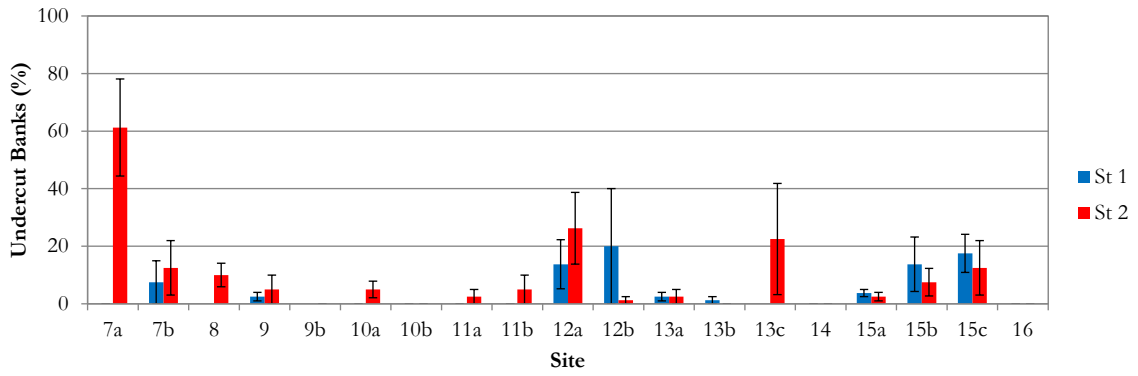
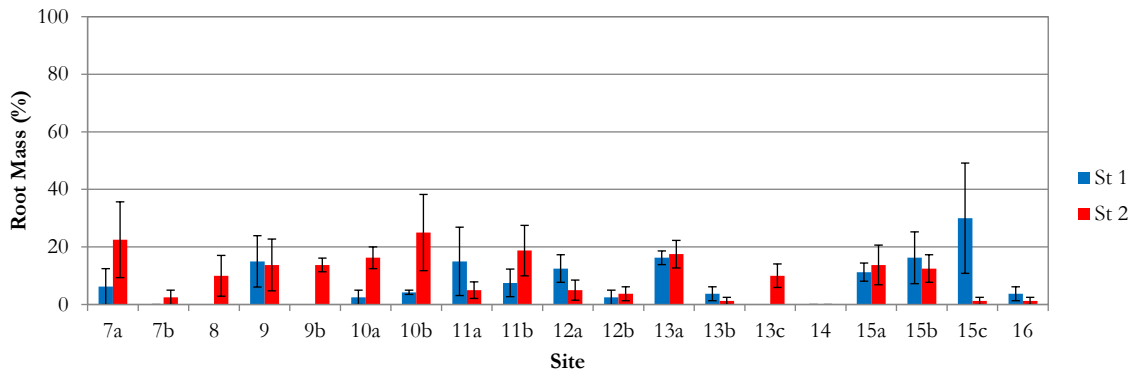
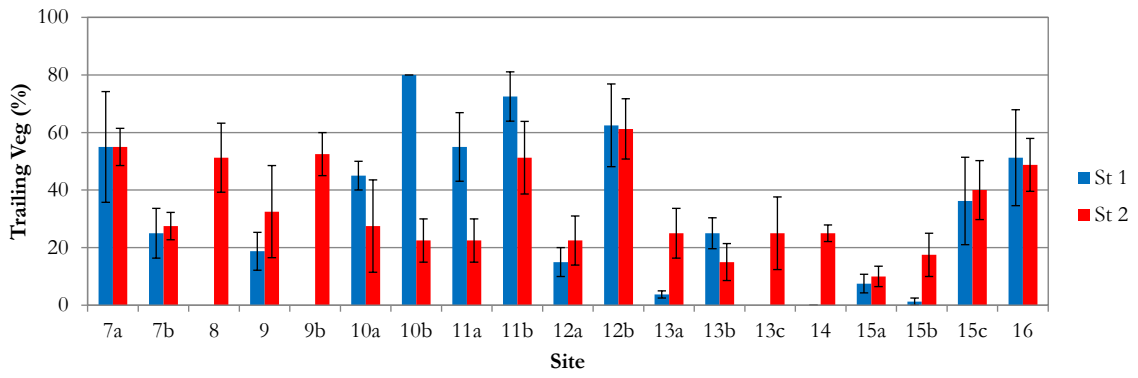


Figure A2 A summary of aquatic habitat data collected in Section 1 of the Woolgoolga to Glenugie Pacific Highway upgrade





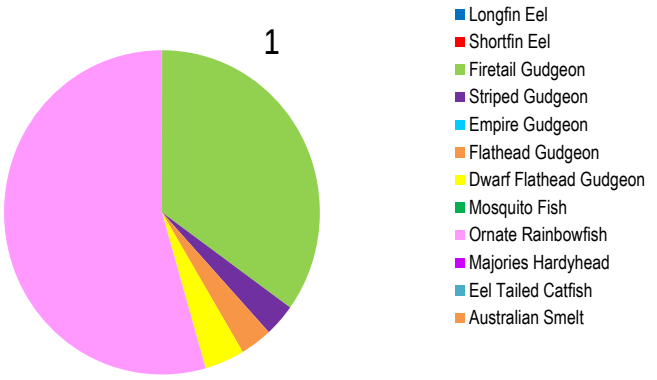


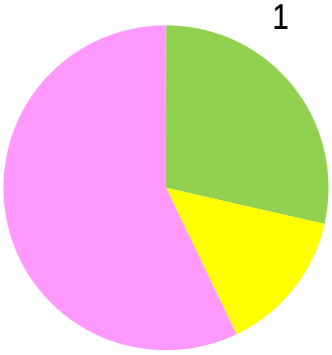


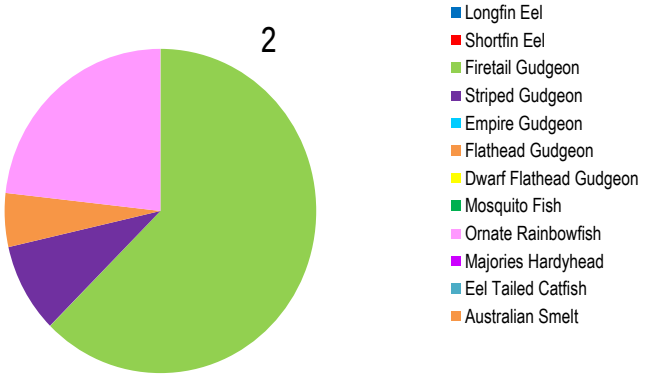
Appendix B

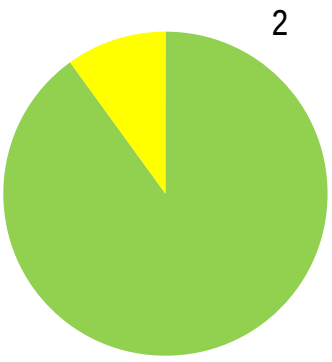
Fish Community Structure

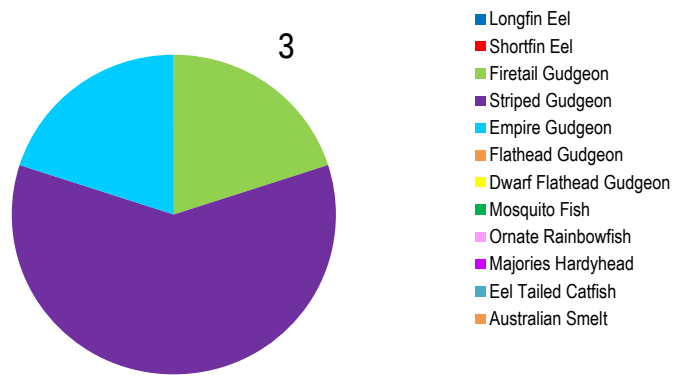
Figure B1 Fish community structure at all sites (Stage 1 results on the right)



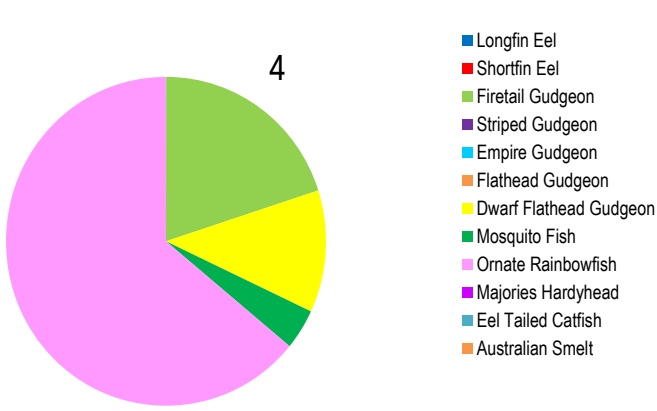








No Data – Dry During Stage 1



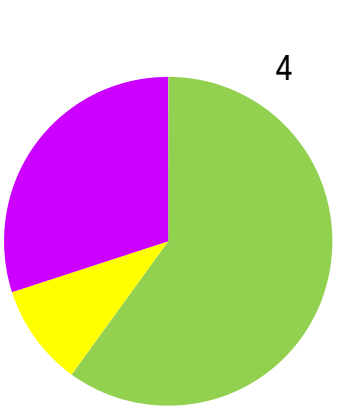
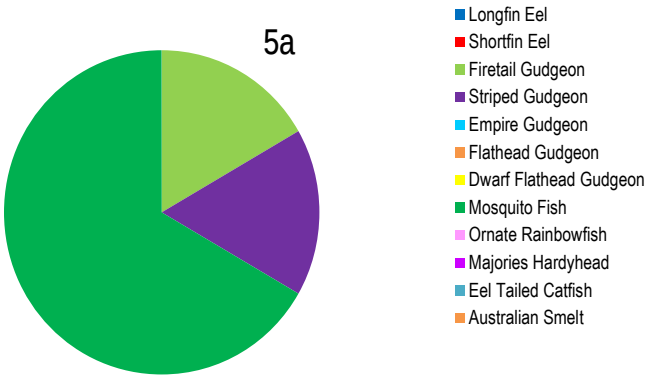
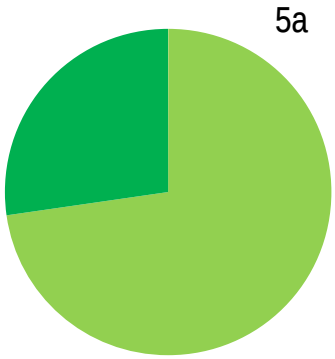
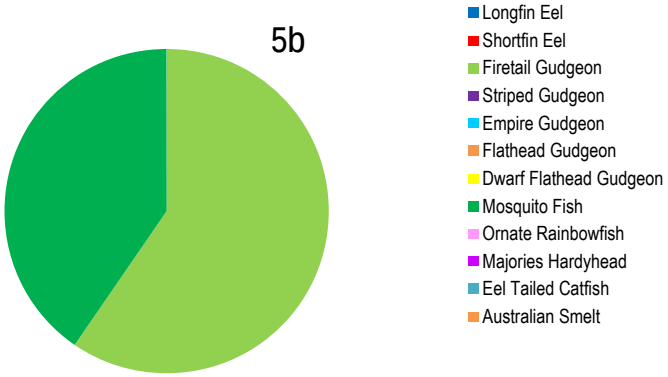
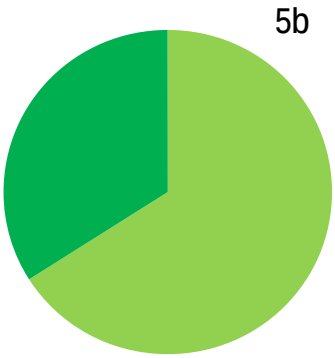


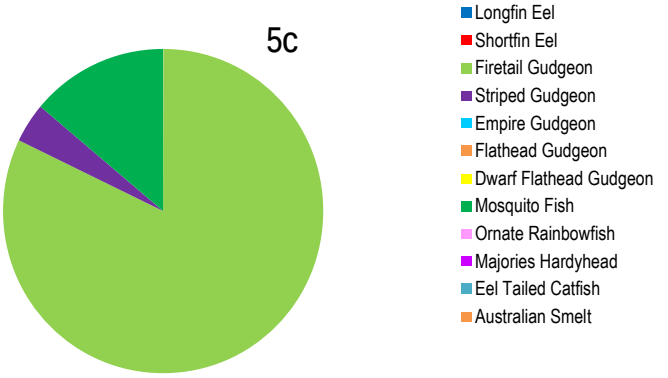
Figure B1 Fish community structure at all sites (Stage 1 results on the right)

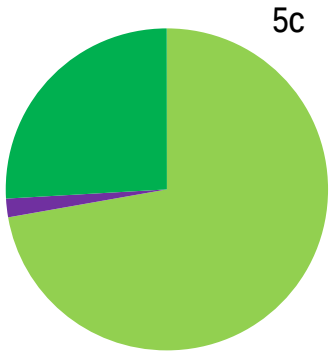


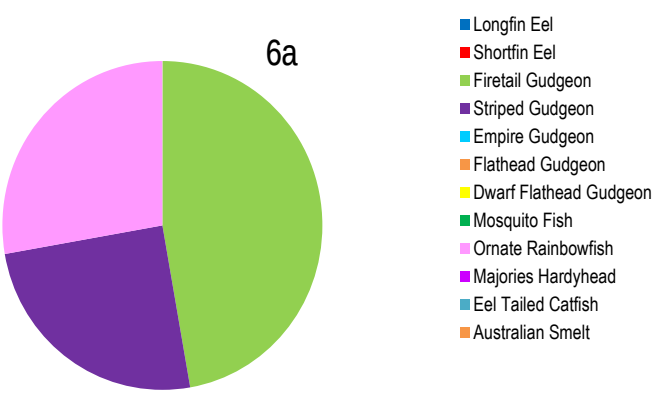












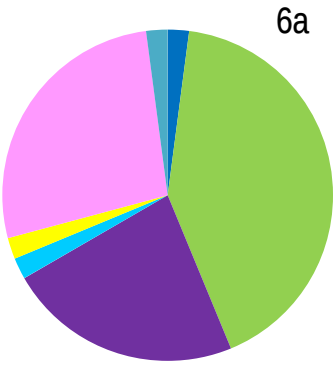


Figure B1 Fish community structure at all sites (Stage 1 results on the right)

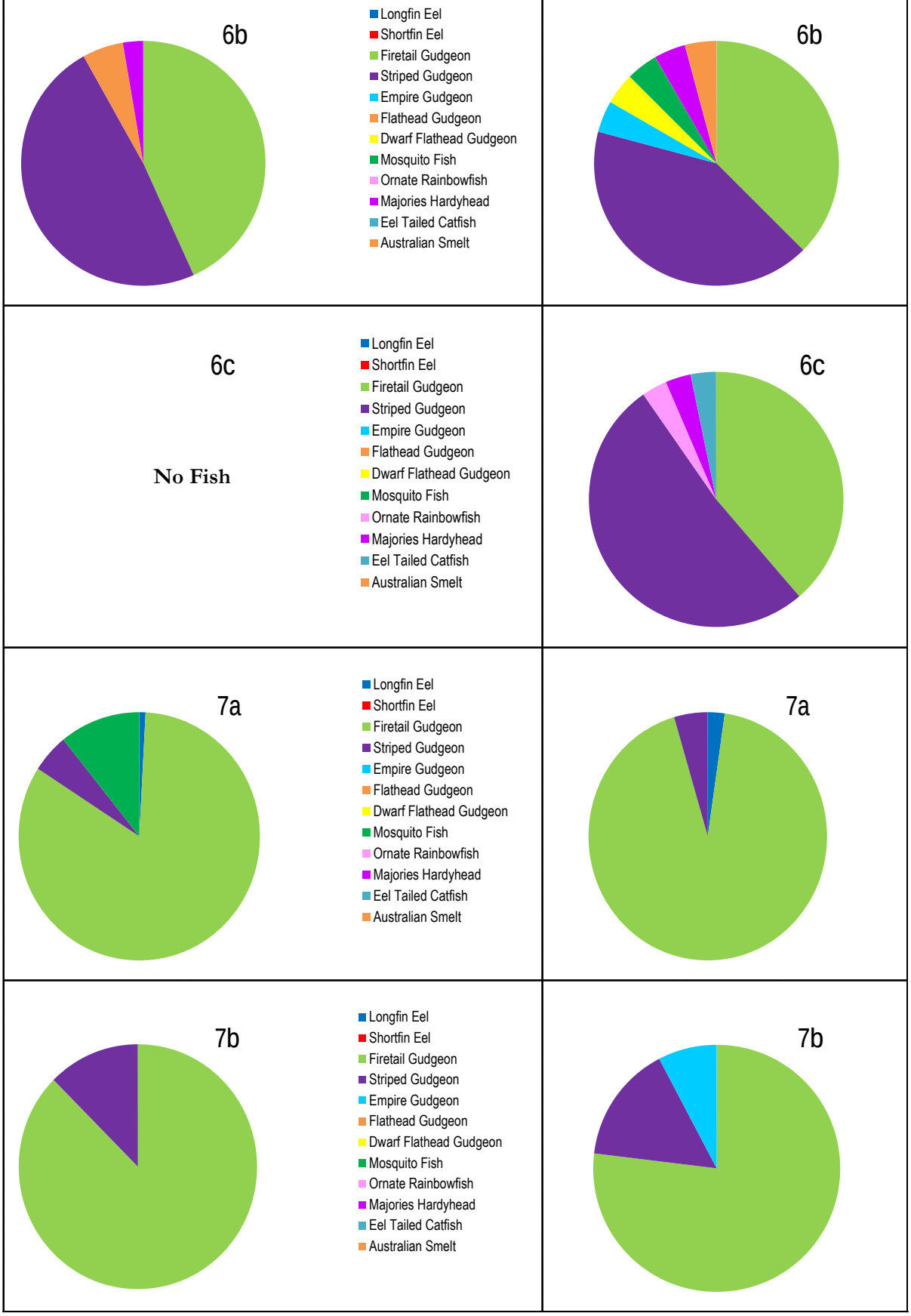
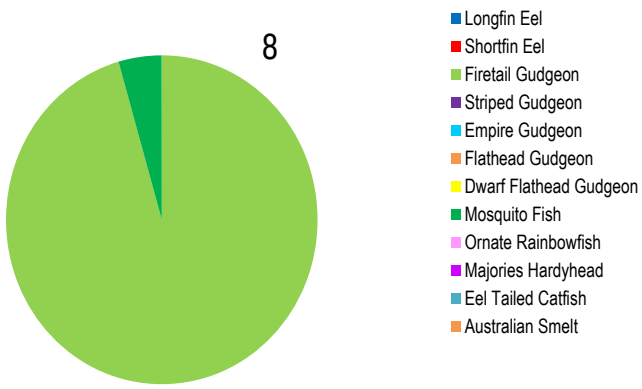
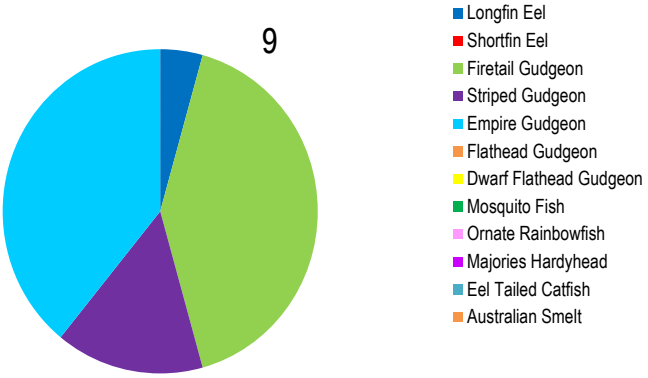
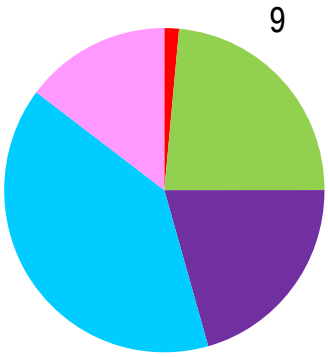


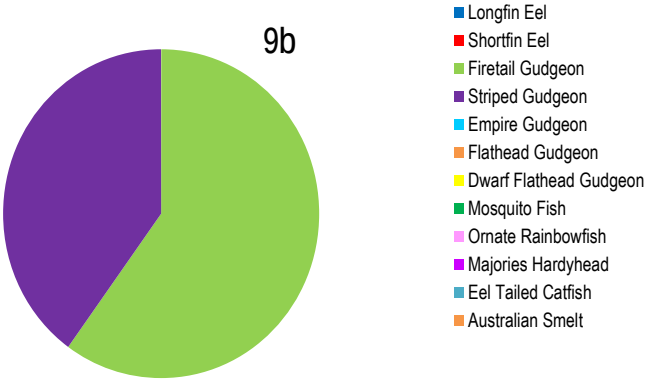
Figure B1 **Fish community structure at all sites (Stage 1 results on the right)**



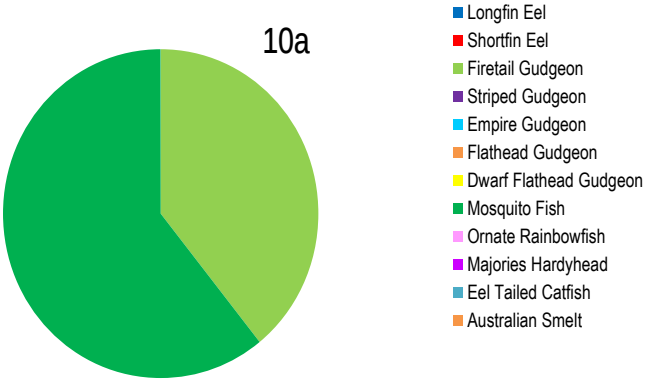
No Data – Dry During Stage 1







No Data – New Site



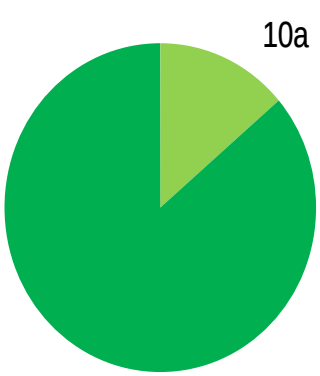
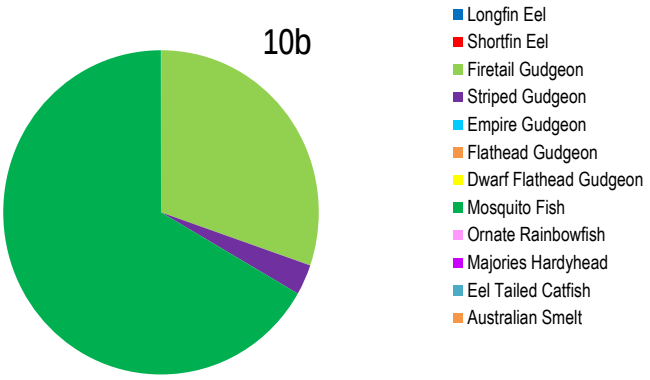
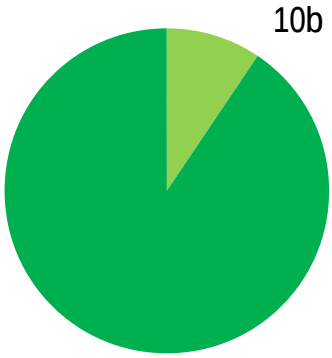
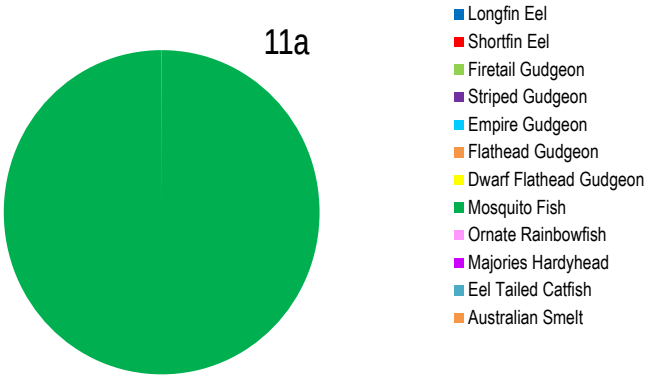
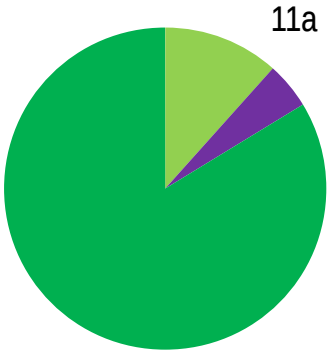


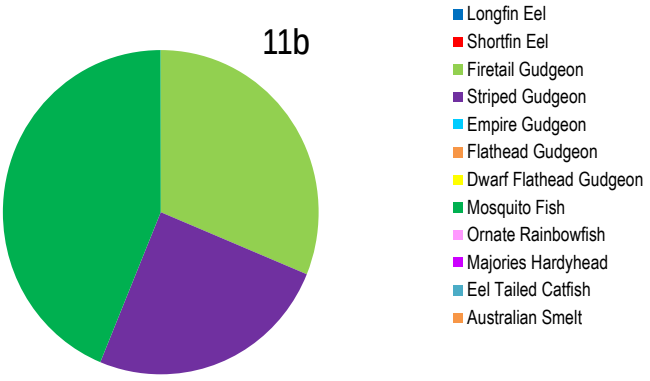
Figure B1 Fish community structure at all sites (Stage 1 results on the right)

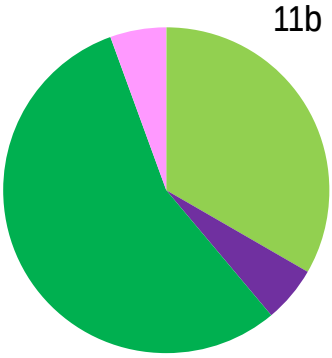


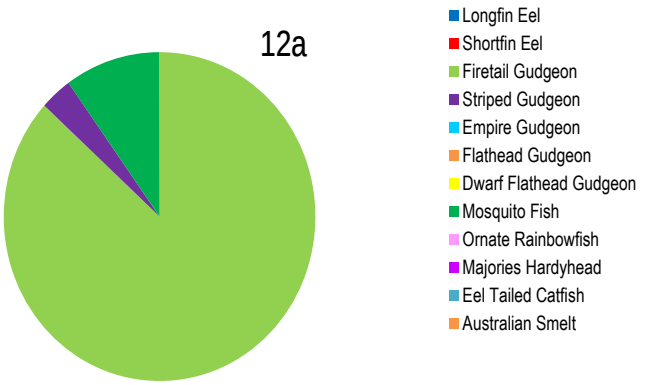












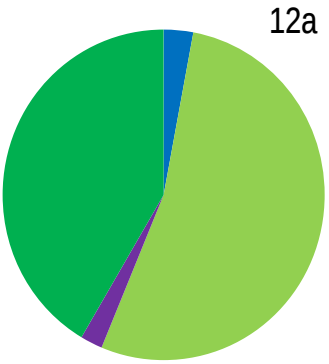
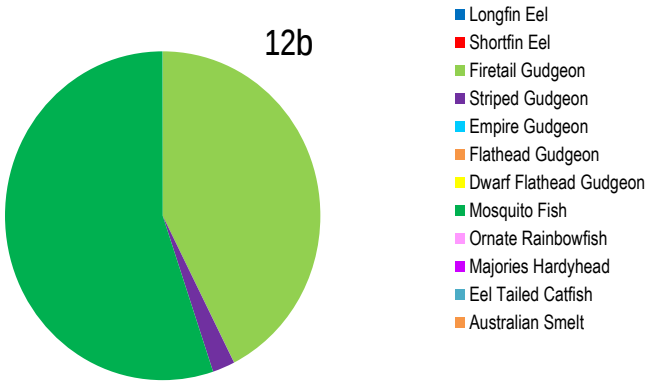
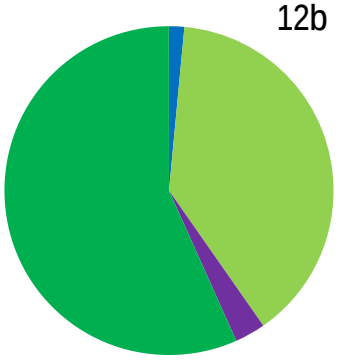
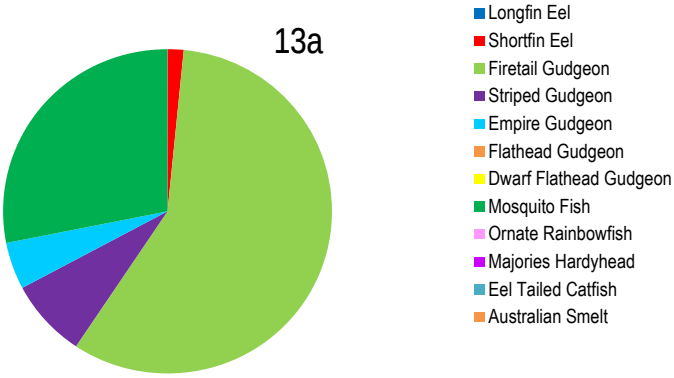
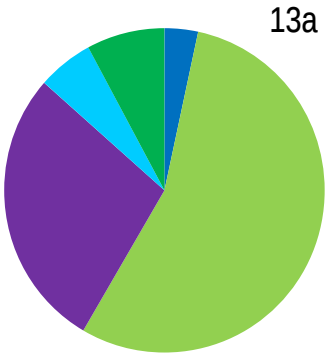


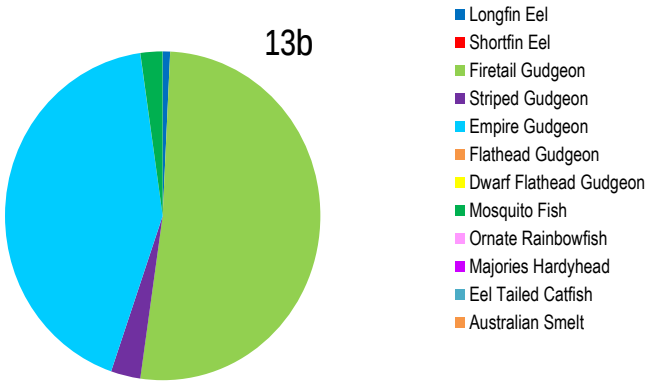
Figure B1 Fish community structure at all sites (Stage 1 results on the right)

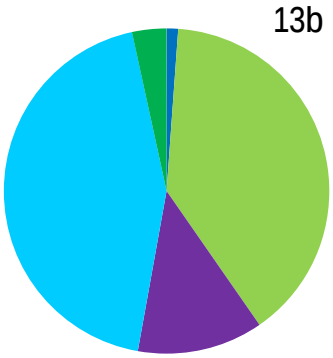


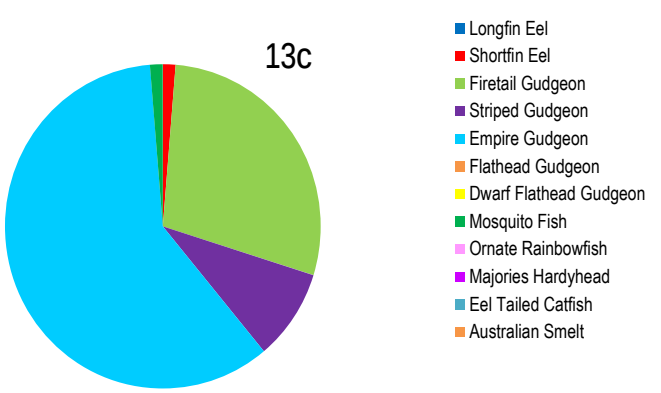












No Data – New Site

Figure B1 Fish community structure at all sites (Stage 1 results on the right)

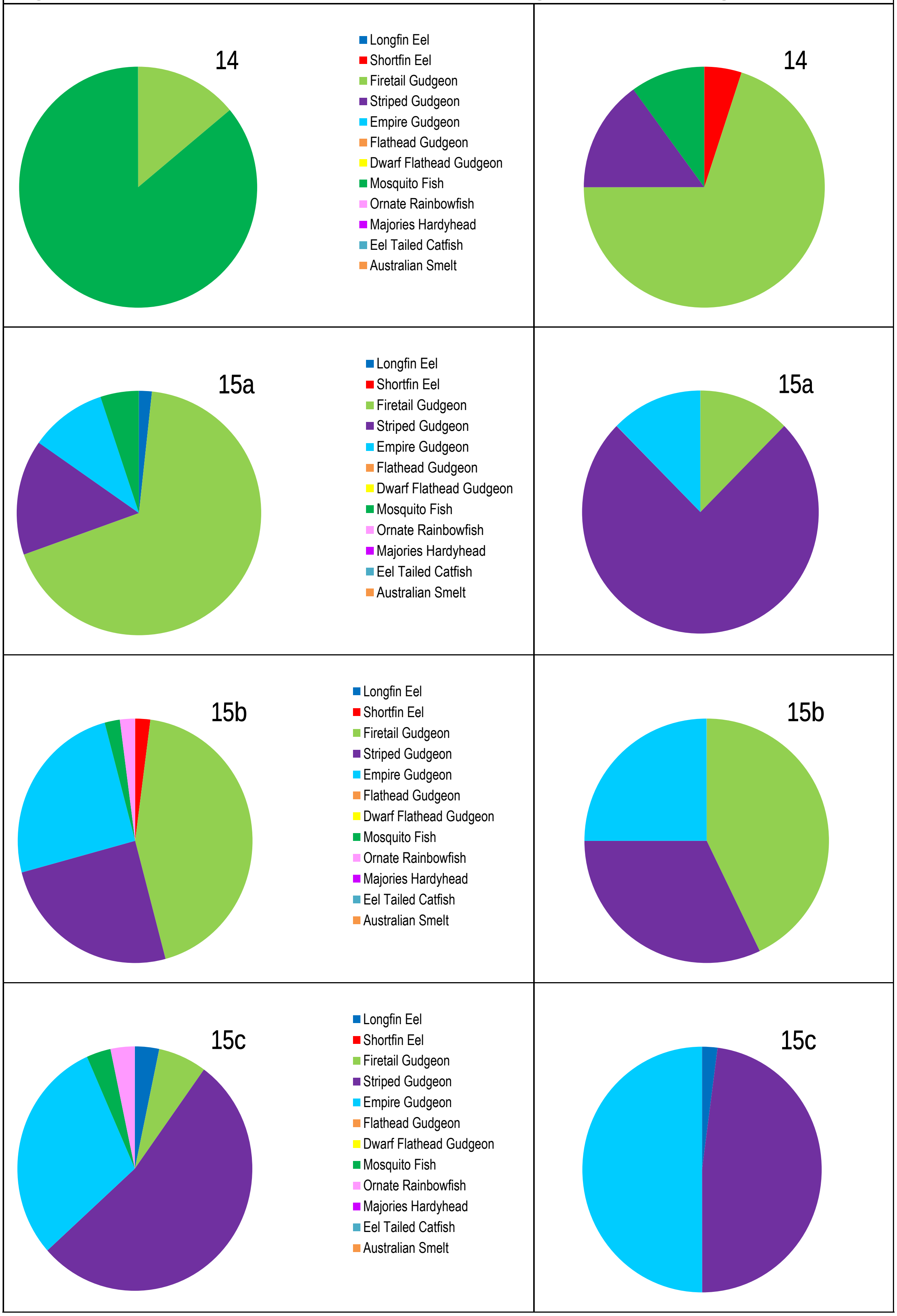
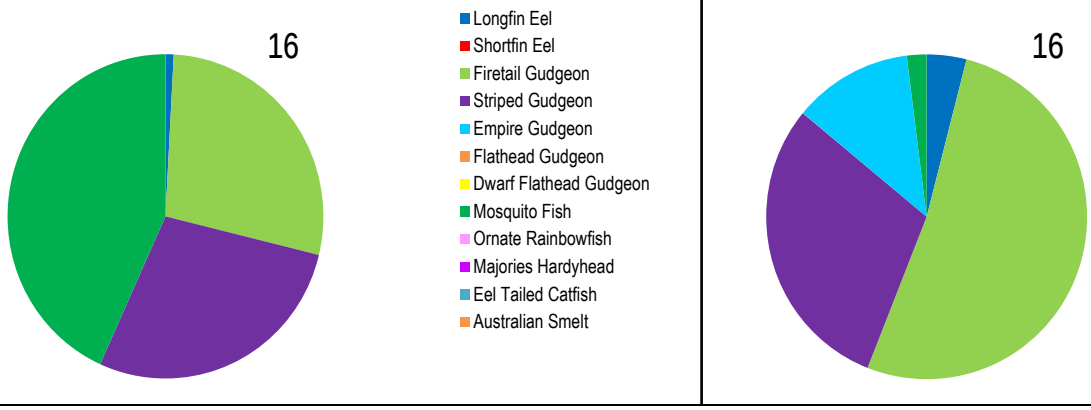


Figure B1 Fish community structure at all sites (Stage 1 results on the right)



Appendix G. Supplementary survey for Pink Underwing Moth for Section 10 and 11

BAAM
ECOLOGICAL CONSULTANTS

1 March 2013

Christopher Thomson
Team Leader Ecology NSW
Sinclair Knight Merz
Level 2, 710 Hunter St
Newcastle NSW 2302

Attention: Chris Thomson
Re: **Supplementary survey for Pink Underwing Moth**

Dear Chris,

BAAM was commissioned by SKM to conduct a supplementary survey for Pink Underwing Moth *Phyllodes imperialis smithersi* along Sections 10-11 of the proposed Woolgoolga to Ballina upgrade of the Pacific Highway. As you would already be aware, the survey was conducted from 11-15 February 2013.

A brief report summarising the methodology and results of the survey is included below, as requested in the Project brief. GIS data (in the form of ESRI shapefiles) containing all records relevant to this survey, as well as habitat mapping for Pink Underwing Moth, will be provided in addition to this report.

We trust this information is suitable for your purposes. Please do not hesitate to contact me on 07 3286 7788 if you have any questions.

Yours sincerely

Lindsay Popple
Senior Ecologist
Biodiversity Assessment and Management Pty Ltd

ABN 59 097 464 992 ACN 097 464 992
233 Middle St, Cleveland Qld 4163
PO Box 1376, Cleveland Qld 4163
Ph+61 7 3286 7788 Fax+61 7 3286 7188
baam@biodiversity.tv www.biodiversity.tv

METHODOLOGY

SITE LOCATION

The field survey was undertaken along the Ballina to Woodburn section of the proposed Pacific Highway upgrade, focusing on Sections 10 and 11, including the following blocks:

- Lot 1 on Plan DP595001;
- Lot 20 on Plan DP878558;
- Lot 2 on Plan DP724878;
- Lot 2 on Plan DP543525;
- Lot 2 on Plan DP870515;
- Lot 1 on Plan DP501685;
- Lot 23 on Plan DP847450; and
- Lot 308 on Plan DP755745.

Some blocks that were identified to include habitat relevant to the survey were not able to be investigated due to access constraints. These included:

- Lot 3 on Plan DP814504;
- Lot 110 on Plan DP755731; and
- Lot 9 on Plan DP1126162.

FIELD SURVEY AND MAPPING

The supplementary field survey targeted areas not previously surveyed within and adjacent to the proposed development footprint to allow for more extensive mapping of known and potential habitat for Pink Underwing Moth. Within each of the additional sites, the following data were collected:

- Presence and abundance of *Phyllodes imperialis smithersi* and estimates of area coverage of its host plant *Carronia multisepalea*, where applicable; and
- Vegetation condition and structure, rainforest indicator species richness and fleshy fruited plant richness (based on commonwealth listing advice on the Lowland Rainforest of Subtropical Australia threatened ecological community), Braun-Blanquet cover abundance and canopy cover.

The combination of these data allowed polygons of potential and known habitat to be identified into three categories. These were:

1. Known habitat for *P. i. smithersi* where host plant and larval records occur and where the moth is considered likely to occur throughout the polygon;
2. Potential habitat for *P. i. smithersi* where the host vine, *Carronia multisepalea*, has been detected, but where moth larvae have not been recorded; and
3. Potential habitat for *P. i. smithersi* where the moth and host vine have not yet been detected.

Areas of potential and known habitat that were examined during the current and/or previous surveys were then scored by 'habitat condition' relative to the ecological requirements of *P. i. smithersi* as far as they are understood. Polygons were given a score of between 0 and 5, with a point being awarded for each one of the following criteria:

- Host plant (*Carronia multisepalea*) was detected during the surveys;
- Number of native fleshy-fruited tree species detected during the survey was >20;
- Patch exhibited natural canopy gaps (allowing for potential recruitment of the host plant);

- Canopy cover comprised >50% native species; and
- Number of rainforest indicator species (from TSSC 2011) was >30.

RESULTS

OUTCOMES OF THE TARGETED FIELD SURVEY

A total of 61 additional point records of *Carronia multisepalea*, the host vine for *Phyllodes imperialis smithersi*, were obtained during the survey and these were found over a wider area than in previous surveys. Records of the moth itself were restricted to a single block (Lot 23 on Plan DP847450), where it was recorded previously; however, the survey of this block was far more extensive than previous surveys. As a consequence, the occurrence of the moth and vine was mapped over a wider area on this occasion. The records of *P. i. imperialis* comprised 45 larvae and nine eggs (**Photo 1**) found in association with the host vine. The larvae comprised three first instar larvae, 38 second instar larvae and four fourth instar larvae (**Photo 2**).

The host vine also displayed evidence of old damage due to herbivory at all other locations where it was located. Some of this damage was potentially due to past feeding of either *P. i. imperialis* or the distantly related and more common fruit-piercing moth *Eudocima fullonia* (encountered feeding on *C multisepalea* on the previous survey; BAAM 2012). However, katydids and leaf beetles were also considered to be responsible for at least some of the leaf damage.

Photo 1. Eggs (left) and a 2nd instar larva of *Phyllodes imperialis smithersi*

Photo 2. The threat display of *Phyllodes imperialis smithersi* (4th instar larva)

HABITAT MAPPING

In sections 10 and 11 of the study area, two large polygons (covering 33.2 hectares) were identified as known habitat for *Phyllodes imperialis smithersi* where moth larvae were detected on the host plant (*Carronia multisepalea*). An area of 57.3 hectares of vegetation was mapped as potential habitat for *Phyllodes imperialis smithersi*, including 18.1 hectares of habitat that comprised polygons where the host plant was detected. **Table 1** summarises the extent of potential habitat that were scored and ranked based on Habitat Condition relative to the ecological requirements of the moth (with a score of "5" being the highest ranking of Habitat Condition).

Table 1. Extent of known or potential habitat for *Phyllodes imperialis smithersi* ranked according to condition.

Habitat Condition ranking (see Methodology)	Area (hectares)		
	Known habitat	Potential habitat (where host is present)	Potential habitat (where host was not detected)
1	0	0	2.9
2	0	0	0.7
3	0	5.0	3.5
4	7.6	2.5	5.1
5	25.5	10.6	0
No ranking[1]	0	0	27.1
TOTAL AREA	33.2	18.1	39.2

[1] Rankings were allocated only to polygons that were visited during either the 2012 or 2013 surveys.

ADDITIONAL SURVEY OBSERVATIONS AND RECORDS

Further observations outside of the scope of the survey were made concerning other conservation significant invertebrates and/or host plants. For instance, 16 additional point records were obtained for *Pararistolochia praevenosa*, host plant for the Richmond Birdwing *Ornithoptera richmondia*. A single male individual of the butterfly was also observed in a clearing where the vine was found to be particularly prolific. Richmond Birding is listed as Regionally Significant under the Byron Biodiversity Conservation Strategy. As noted by Sands (2012), its host plant was generally found to occur in the same habitat and situations as *Carronia multisepalea*.

The previous survey (BAAM 2012) included targeted searches for Atlas Rainforest Ground Beetle *Nurus atlas,* listed as Endangered under the TSC Act. During that survey, a single beetle was collected from a burrow under the root of a White Cedar on Lot 23 on Plan DP847450. On an adjoining property (Lot 2 on Plan DP543525), during the present survey, a freshly dead specimen of *Nurus atlas* was located incidentally on the rainforest floor. This new record was located approximately 750 metres from the previous record, and within the same large patch of vegetation. The specimen was collected and submitted to the Queensland Museum as a voucher. Notably, the soil beneath the root of the White Cedar where the beetle was first encountered on the previous survey was not replaced with the burrow of another *Nurus atlas* beetle. Instead, a new burrow with distinctly funnel-shaped webbing occupied this space.

REFERENCES

Biodiversity Assessment and Management (BAAM) (2012). Ballina to Woodburn Pacific Highway Upgrade Targeted Threatened Invertebrate Study. Report prepared from Sinclair Knight Merz.

Sands, DPA (2012). Review of Australian *Phyllodes imperialis* Druce (Lepidoptera: Erebidae) with description of a new subspecies from subtropical Australia. *Australian Entomologist* **39:** 281-292.

Threatened Species Scientific Committee (TSSC). (2011). Commonwealth Listing Advice on Lowland Rainforest of Subtropical Australia. Department of Sustainability, Environment, Water, Population and Communities.

Appendix H. Woolgoolga to Ballina Biodiversity Offset Strategy (Draft)

PACIFIC HIGHWAY UPGRADE

Woolgoolga to Ballina Biodiversity Offset Strategy

NOVEMBER 2013

DRAFT

(blank page)

Executive Summary

The Australian and NSW governments have been jointly upgrading the Pacific Highway since 1996. There is a shared commitment from both governments to finish its upgrading to a four-lane divided highway as soon as possible.

The Woolgoolga to Ballina upgrade project would upgrade to a four lane divided road, around 155 kilometres of highway between Arrawarra and Ballina. The project therefore forms a major part of the overall upgrade program and when constructed, would complete the four-lane divided road program.

The Woolgoolga to Ballina upgrade project has direct impacts to around 932 hectares of native vegetation. Roads and Maritime has investigated suitable biodiversity offsets for the Woolgoolga to Ballina upgrade project in order to meet the objectives of:

- An outcome that maintains or improves biodiversity values.
- Successfully securing the long-term (in perpetuity) protection and management of lands containing threatened species and ecological communities and habitat for threatened species (key habitat).
- Meeting the minimum requirements for offsets as specified in the conditions of approval.
- The process for setting the scope and quantum of the biodiversity offsets is transparent and justifiable on environmental, social and economic grounds ie Value for Money.

Roads and Maritime has undertaken preliminary EPBC offset calculations for the species impacted by the Woolgoolga to Ballina upgrade. Desktop and field investigations are currently underway on potential offset properties that have been identified from three different scenarios:

1. Properties Roads and Maritime currently owns or has commenced acquisition discussions with the landowners.
2. Private properties where landowners have previously contacted Roads and Maritime about suitability of their properties for offsets.
3. Review of the NSW BioBanking Register to identify any potential registered sites.

Contents

1 Introduction

The Pacific Highway corridor is a major contributor to Australia's economic activity. The road is a vital piece of the nation's infrastructure and is included in the National Land Transport Network. The eastern seaboard of NSW is also one of the fastest growing areas in the country.

The Australian and NSW governments have been jointly upgrading the Pacific Highway since 1996. There is a shared commitment from both governments to finish its upgrading to a four-lane divided highway as soon as possible.

The Woolgoolga to Ballina upgrade project would upgrade to a four lane divided road, around 155 kilometres of highway between Arrawarra and Ballina. The project therefore forms a major part of the overall upgrade program and when constructed, would complete the four-lane divided road program.

Planning for all projects within the Pacific Highway Upgrade program has generally followed the following hierarchy of principles in regard to biodiversity values along the road corridor:

1. Avoid impact.
2. Minimise impact.
3. Mitigate impacts.

Where impacts are unavoidable, mitigation and management measures are incorporated into the project to reduce impacts. In some instances there are residual impacts that cannot be adequately mitigated. Residual impacts identified for the Woolgoolga to Ballina upgrade project include:

- A loss of native vegetation.
- A loss and modification of habitat for a variety of protected and threatened native fauna species.

NSW Roads and Maritime Services (Roads and Maritime) Biodiversity Guidelines 2011 require Roads and Maritime to provide biodiversity offsets, where there is a loss of biodiversity above the thresholds identified in the Roads and Maritime Guideline: Biodiversity Offsets (Roads and Maritime 2011), after all reasonable and feasible measures to avoid, minimise and mitigate impact have been implemented.

Where offsets are required, Roads and Maritime would prepare a Biodiversity Offset Package for the project that identifies the method for determining the offset amount and location and the most effective options for implementing the offsets.

1.1 Purpose of the report

This report has been prepared to provide details of the revised biodiversity offsetting strategy Roads and Maritime is proposing for the Woolgoolga to Ballina (Woolgoolga to Ballina) upgrade project in order to satisfy the offset requirements under the *Environmental Protection and Biodiversity Conservation Act 1999 - Environmental Offset Policy* (DSEWPaC 2012).

1.2 Structure of the report

This report has been structured to provide information in the following order:

Section 1 – Introduction
Section 2 – Project summary
Section 3 – Project approval status
Section 4 – Project impacts
Section 5 – Biodiversity offset principles
Section 6 – Decision making framework
Section 7 – Status of biodiversity offset investigations
Section 8 – Implementation of offsets
Section 9 – Conclusion

Appendices – additional supporting information

2 Project summary

The Woolgoolga to Ballina project would upgrade about 155 kilometres of highway. The project starts around six kilometres north of Woolgoolga (north of Coffs Harbour) and ends around six kilometres south of Ballina (refer to context map in Appendix A).

The upgrade does not include the Glenugie and Devils Pulpit sections of highway that have been completed or are currently under construction

The project would include:

- Around 155 kilometres of motorway standard highway, comprising a four-lane divided carriageway (two lanes in each direction) that can be upgraded to a six-lane divided carriageway in the future, if required.
- Bypasses of Grafton, South Grafton, Ulmarra, Woodburn, Broadwater and Wardell.
- The following interchanges to provide access to and from the upgraded highway at:
  - Corindi (Range Road).
  - Glenugie (Glenugie/ Eight Mile Lane).
  - Tyndale (Sheeys Lane/ Bensons Lane/ Bondi Hill).
  - Maclean (Goodwood Street).
  - Harwood (Yamba Road / Watts Lane).
  - Woombah (Iluka Road).
  - Woodburn (Trustums Hill Road).
  - Broadwater (Evans Head Road).
  - Wardell (Coolgardie Road).
- Forty bridge crossings of waterways or floodplains, including major bridges over the Clarence and Richmond rivers.
- Fifty-five bridges and underpasses to maintain access along local roads crossed by the project.
- Viaducts located where the project would cross low-lying or flood-prone areas
- Service roads and access roads to maintain connections to existing local roads and properties.
- Structures to help wildlife cross above or below the project, including three median crossings for arboreal mammals, eight dedicated culverts and four land bridges.
- Rest areas located at around 50-kilometre intervals at:
  - Pine Brush, Tyndale (for northbound and southbound traffic).
  - North of Mororo Road (for southbound traffic).
  - North of Richmond River (for northbound and southbound traffic).
- Checking stations for heavy vehicles near Halfway Creek.

3 Project approval status

Projects developed by NSW Roads and Maritime Services (Roads and Maritime) are subject to approval under the NSW *Environmental Planning and Assessment Act 1979*, and (where required) the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999.* In addition certain other approvals and licences under NSW Acts would be required.

3.1 Approval status

The status of the Woolgoolga to Ballina project approvals are summarised in Table A.

Table A: Woolgoolga to Ballina project approvals status

Current status	Approval status	
	NSW EP&A Act	**Commonwealth EPBC Act**
Pre-approval	Submissions / Preferred Infrastructure Report provided to DP&I for consideration	Impacts to MNES being assessed through 'accredited assessment process' Submissions & Preferred Infrastructure Report provided to SEWPAC for consideration Project referred and declared a "controlled action"

NSW Roads and Maritime Services (Roads and Maritime) has applied for approval from the Minister for Planning and Infrastructure for the project under Part 5.1 of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Environmental Impact Statement for the project was placed on public display and exhibited across more than 40 locations for 55 days from 12 December 2012 to 18 February 2013, a total of 69 days. Following the exhibition period Roads and Maritime has prepared a responses to submissions raised during the exhibition and a Preferred Infrastructure Report.

The project was referred to the former Commonwealth Department of Sustainability, Environment, Water, Population and Communities (now the Commonwealth Department of the Environment) on 15 May 2012. The referral concluded that the project has the potential to have a significant impact on matters of national environmental significance, and approval from the Commonwealth Minister is necessary.

The Commonwealth Government Minister for Sustainability, Environment, Water, Population and Communities confirmed:

- The project would be a controlled action. Consequently, the project requires assessment and approval by the Commonwealth Government Minister for Sustainability, Environment, Water, Population and Communities.
- The preparation and submission of this EIS is an accredited assessment process for the purpose of the approval by the Commonwealth Minister.
- The Commonwealth Minister would need to issue a separate approval for the project to the State Minister's approval as it is a controlled action.

3.2 Biodiversity offset framework

Project approval conditions for the Pacific Highway Upgrade projects usually contain requirements to provide details of the Biodiversity Offsets Framework to the approval authority once approval has been received. There are two components to the approval requirements, the *Biodiversity Offset Strategy* and the *Biodiversity Offset Package.* The relationship between the approval and offset requirements are detailed in Figure 3-1, and further details of the Biodiversity Offset Strategy and Packages are detailed in Sections 3.2.1 and 3.2.2 below. This Biodiversity Offset Strategy has been prepared as a work-in-progress to inform the approval process. This is ahead of the timing suggested in the framework in Figure 3-1. This document would be updated after approval to provide a completed offset strategy to the Department of Planning and Infrastructure.

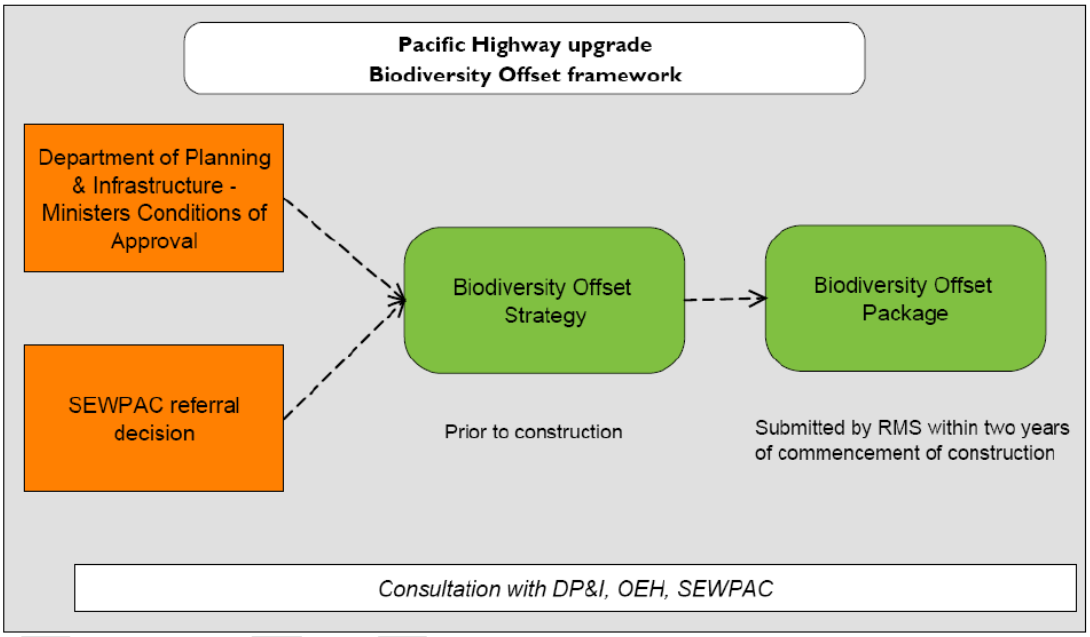


Figure 3-1: Biodiversity offset framework for Pacific Highway Upgrade

3.2.1 Biodiversity Offset Strategy

The Biodiversity Offset Strategy identifies available options for offsetting the biodiversity impacts of the project and includes, but is not limited to:

- Confirmation of the vegetation communities/ habitat (in hectares) to be offset and the size of offsets required (in hectares).
- Details of the available offset measures that have been identified to compensate for the biodiversity impacts of the project, such as (but not necessarily limited to): suitable compensatory land options and/ or contributions towards biodiversity programs for high conservation value areas on nearby lands (including research programs).
- The decision-making framework that would be used to select the final suite of offset measures to achieve the aims and objectives of the Strategy, including the ranking of offset measures.
- A process for addressing and incorporating offset measures for changes to impact (where these changes are generally consistent with the biodiversity

impacts identified for the project, including:

- Changes to footprint due to design changes.
- Changes to predicted impacts resulting from changes to mitigation measures.
- Identification of additional species/habitat through pre-clearance surveys.
- Additional impacts associated with ancillary facilities.

- Options for the securing of biodiversity values in perpetuity.

The Biodiversity Offset Strategy is submitted to, and approved by, the Director General and/or Minister prior to the commencement of construction unless otherwise agreed by the Director General or Minister.

3.2.2 Biodiversity Offset Package

The Biodiversity Offset Package identifies the final suite of offset measures to be implemented for the project within two years of the approval of the Biodiversity Offset Strategy. The Biodiversity Offset Package provides details of:

- The final suite of the biodiversity offset measures selected for the project demonstrating how it achieves the requirements and aims of the Biodiversity Offset Strategy (including specified offset ratios or calculations).
- The final selected means of securing the biodiversity values of the offset package in perpetuity including ongoing management, monitoring and maintenance requirements.
- Timing and responsibilities for the implementation of the provisions of the package over time.

Once the Offset Package is approved, Roads and Maritime is required to implement the package according to the timeframes set out in the Package.

4 Project impacts

Potential impacts on flora and fauna have been minimised and avoided where possible throughout the route selection and development of the concept design for the Woolgoolga to Ballina project. A summary of the direct impacts on vegetation, fauna habitat, and threatened species are provided in Sections 4.1 and 4.2 below. More detailed information on the ecological impacts for the Woolgoolga to Ballina project is provided in the Environmental Impact Statement (Roads and Maritime, 2012), and the Submissions / Preferred Infrastructure Report (Roads and Maritime, 2013).

The project traverses a mix of floodplains, low hills and ranges as well as coastal environmental features including wide valleys, channels, swamps and terraces typical of the alluvial plains of the Clarence and Richmond rivers (Morgan 2001b, Mitchell 2003). This also includes the low hills and plains of the Manning River, Macleay River and Evans River. Several coastal ranges occur in the east of the study area, the most prominent being the Summervale Range, incorporating Shark Creek and Pillar Valley ranges in the south and the coastal Ballina and Blackwall Ranges between Wardell and Ballina. Remaining areas have been formed by coastal barriers such as dunes, swamps and lagoons on Quaternary coastal sands with an elevation up to 25 metres.

Throughout many of these areas extensive clearing for agriculture, logging and residential development has been prevalent. In total 26 biometric vegetation types are represented in the study area, within which, six threatened ecological communities (TEC) listed under the TSC Act and were identified and one TEC listed under the EPBC Act. Full details regarding the existing physical and biological attributes of the study area are provided in the Working paper - Biodiversity for the EIS.

4.1 Impacts to vegetation

The project traverses a broad range of landscapes. Table B provides a summary of the broad vegetation communities that are impacted by the Woolgoolga to Ballina project.

Table B: Summary of vegetation impacts for Woolgoolga to Ballina upgrade project.

Vegetation formation (Keith 2004)^	Direct impacts (ha)
Grassy Woodland	93.9
Swamp Sclerophyll Forest	155.2
Heathlands	14.9
Freshwater wetland	16.6
Saline wetland	5.8
Rainforest[2]	4.5
Wet Sclerophyll Forest	123.7
Dry Sclerophyll Forest	517.1
TOTAL	**931.7**

^Keith, D. (2004). Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT. Department of Environment and Conservation. Hurstville. NSW.

Note: that these figures are subject to minor changes during detailed design.

4.2 Impacts to Matters of National Environmental Significance (MNES)

The Woolgoolga to Ballina Environmental Impact Statement (EIS), and Roads and Maritime Pacific Highway Upgrade Biodiversity Offset Principles – Priority 2 and 3 upgrade projects report provide details of the potential impacts of the project on threatened vegetation communities and species along the project corridor. The EIS identified that 17 matters of national environmental significance (MNES) would potentially be significantly impacted by the project. The impacts to these MNES may require offsets in accordance with the EPBC Environmental Offsets Policy 2012. MNES species and impacts (both direct and likely indirect) are detailed in Table C below.

Table C: Impacts on relevant MNES

PROTECTED MATTER	COMMON NAME	EPBC Act status	IMPACTS (direct and indirect)	
			Area (ha)	No. of individuals impacted
Threatened ecological communities				
Lowland Rainforest of Subtropical Australia		CE	3.5	
Threatened flora species				
Acronychia littoralis	Scented Acronychia	E		1
Angophora robur	Sandstone Rough Barked Apple	V	84.1	
Arthraxon hispidus	Hairy Joint-grass	V	13.4	
Cryptocarya foetida	Stinking Cryptocarya	V		13
Endiandra hayesii	Rusty Rose Walnut	V		5
Prostanthera cineolifera	Singleton Mint Bush	V		250
Quassia sp. 'Moonee Creek'	Moonie Quassia	E		202
Syzygium hodgkinsoniae	Red Lily Pilly	V		1
Threatened fauna species				
Mixophyes iteratus	Giant Barred Frog	E	14	
Nannoperca oxleyana	Oxleyan Pygmy Perch	E	5	
Phascolarctos cinereus	Koala	V	375.4	
Phyllodes imperialis southern subsp.	Pink Underwing Moth	E	3	
Xanthomyza phrygia	Regent Honeyeater	E, M	869.9	
Dasyurus maculatus maculatus (SE population)	Spotted-tailed Quoll	E	932.6	
Lathamus discolor	Swift Parrot	E, M	869.9	

CE – Critically Endangered, E – Endangered, V – Vulnerable, M - Migratory

5 Biodiversity offset principles

5.1 Management of biodiversity impacts

Measures to manage the impact of the projects on biodiversity have been developed as part of the environmental assessment for the project. Management measures for biodiversity impacts were developed following these general principles, in order of preference:

- Avoiding impacts.
- Mitigating impacts.
- Offsetting impacts.

Measures relevant to avoiding and mitigating biodiversity impacts are outlined and detailed in the Environmental Impact Statement (Roads and Maritime, 2012), and the Submissions / Preferred Infrastructure Report (Roads and Maritime, 2013). However, not all impacts to biodiversity can be fully mitigated through 'on- ground' management measures alone and offsetting for projects biodiversity impacts is required.

5.2 Biodiversity offset objectives

The objective of the Biodiversity Offset Strategy is to identify a package of offsets to achieve a neutral or net beneficial biodiversity outcome for the region as a result of the project. The measures used to gauge success of this objective will be:

- An outcome that maintains or improves biodiversity values.
- Successfully securing the long-term (in perpetuity) protection and management of lands containing threatened species and ecological communities and habitat for threatened species (key habitat).
- Meeting the minimum requirements for offsets as specified in the conditions of approval.
- The process for setting the scope and quantum of the biodiversity offsets is transparent and justifiable on environmental, social and economic grounds ie value for money.

5.3 Principles of obtaining biodiversity offsets

The principles followed for Roads and Maritime to target suitable biodiversity offsets for the Woolgoolga to Ballina upgrade project, and include:

- The vegetation communities and habitat types represented in the offset areas would reflect the vegetation communities and habitat types impacted by the project.
- Offset areas would contain suitable habitat for threatened and migratory fauna (EPBC Act) and would contain or be suitable for re-establishing threatened flora (EPBC Act) affected by the project.
- Roads and Maritime would prioritise investigations into areas that contain vegetation communities and suitable habitat for Endangered and / or Critically Endangered species listed under the EPBC Act.
- Offset areas cannot be already funded or protected under another scheme.
- Areas that are already managed for conservation by the government, such as flora reserves, national parks and public open space would not be chosen as offsets.

- Offset properties would be located as close to the impact site as feasible.
- Offset properties would aim to protect larger patches of vegetation and habitat with preference given to sites that are connected to, or provide connectivity to, other core areas of habitat.
- Assess potential sites against Commonwealth biodiversity offset calculator for Commonwealth listed species.

6 Decision making framework

In accordance with the Roads and Maritime Pacific Highway Upgrade Biodiversity Offset Principles, (2013) the following steps and decision making framework will be followed in order to ensure that the process in obtaining biodiversity offsets meets the objectives of being transparent and justifiable on environmental, social and economic grounds.

6.1 Step 1 - Identification of project impacts

Roads and Maritime has undertaken environmental assessment of the Woolgoolga to Ballina project impacts and determined the level of impact to vegetation communities and habitat as a result of the project. These impacts are detailed in Section 4.

6.2 Step 2 - Investigation into direct biodiversity offsets

Roads and Maritime has undertaken a number of actions to target potential offset lands that meet the following criteria for the Woolgoolga to Ballina project:

- Properties located within 30km radius of the project extending to 100km with the agreement of the Department of Planning and OEH (and SEWPAC) where it can be demonstrated that a suitable offset could not be found.
- Offset land would contain vegetation communities as detailed in Section 4.
- Land would be assessed as to its suitability as habitat for the threatened species impacted by the project (including patch sizes) based on OEH and SEWPAC threatened species profiles databases.
- Offset land would comprise land that enables connectivity between adjacent areas of vegetation, where possible.
- Offset land must be suitable for ongoing management for conservation through an appropriate legal instrument.

The status of these preliminary investigations is detailed in Section 7 and Appendix B. Investigations are ongoing to target suitable offset lands for the project.

6.3 Step 3 - Identification of other biodiversity offset measures

At this stage of the project, no other compensatory measures have been proposed as part of the biodiversity offset package. Should this change in future, Roads and Maritime will review any potential other offset measures against the requirements detailed in Appendix A of the EPBC Offsets Policy (2012) to determine their suitability in consultation with the Department.

6.4 Step 4 - Assessment using EPBC Act Offsets Guide

Roads and Maritime has commenced preliminary EPBC offset calculator assessment for the Woolgoolga to Ballina (Woolgoolga to Ballina) upgrade based on the impacts to the MNES identified in Table 4-2 of this report. In order to provide suitable offset measures to address these identified impacts from the assessment calculator, Roads and Maritime will use potential offset properties from three different scenarios:

1. Properties Roads and Maritime currently owns or has commenced acquisition discussions with the landowners.
2. Private properties where landowners have previously contacted Roads and

Maritime about suitability of their properties for offsets.

3. Review of the NSW BioBanking Register to identify any potential registered sites.

Once potentially suitable sites have been located, they will be assessed using the EPBC offset calculator to determine how they meet the offset requirements for the project. Refer to Section 7 and Appendix B for further details on these investigations into potential offset properties.

6.5 Step 5 - Seek approval of offsets

Following receipt of project approval, Roads and Maritime will be seeking formal approval for the Woolgoolga to Ballina Biodiversity Offset Strategy and Package. Following receipt of approval Roads and Maritime can progress any property\ negotiations and acquisitions required in order to meet the offset package requirements.

6.6 Step 6 - Implementation

Once approved the relevant biodiversity offset actions would be implemented in accordance with the approval conditions and any plans of management developed for the proposed offset properties.

7 Status of biodiversity offset investigations

Roads and Maritime has commenced investigations into suitable biodiversity offset properties and measures for the Woolgoolga to Ballina project in preparation of any requirements that follow from assessment and approval by the Department of the Environment. Details of the investigations being undertaken are outlined below.

Correspondence from the Department of the Environment during the project development has suggested priority for identifying suitable offsets should initially target MNES that are cryptic, less mobile or more threatened. These MNES have been summarised below and include:

- Lowland Rainforest of Subtropical Australia (critically endangered).
- Pink Underwing Moth (endangered).
- Scented Acronychia (endangered).
- Quassia sp. Moonee Creek (endangered).
- Oxleyan Pygmy Perch (endangered).
- Giant Barred Frog (endangered).
- Angophor robur (vulnerable).
- Hairy Joint Grass (vulnerable).
- Singleton Mint Bush (vulnerable).
- Stinking Cryptocarya (vulnerable).
- Rusty Rose Walnut (vulnerable).
- Red Lily Pilly (vulnerable).

Initial investigations undertaken by Roads and Maritime have focussed on properties that potentially contain individuals of these species, or suitable habitat for these high priority species. Status of these ongoing investigations is summarised in Section 7.2 and detailed in Appendix B.

7.1 Preliminary EPBC Act offset assessment calculations

Preliminary offset calculations have been prepared for the relevant MNES based on the guidance provided in the EPBC Offset assessments guide. These preliminary calculations have been undertaken to provide guidance on the indicative offset areas required to achieve a minimum of 90% of the required offset for the Woolgoolga to Ballina project. The initial calculations including values and rationale for the offsets are provided in the Supplementary Biodiversity Assessment (Attachment J of the Submissions/ Preferred Infrastructure Report) and are summarised below in Table D.

Table D: Indicative offset requirements for MNES

PROTECTED MATTER	COMMON NAME	IMPACT		INDICATIVE OFFSET REQUIREMENT		
		Area (ha)	No. of individuals	Start value (area/individuals)	Future value with offset (area / individuals)	Percentage of offset met
Threatened ecological communities						
Lowland Rainforest of Subtropical Australia		3.5	N/A	8 (40 ha)	8 (40 ha)	102%
Threatened flora species						
Acronychia littoralis	Scented Acronychia		1	0-1 (0-1 individuals)	2 (2 individuals)	95%
Angophora robur	Sandstone Rough-barked Apple	84.1	N/A	9 (400 ha)	9 (400 ha)	99%
Arthraxon hispidus	Hairy Joint-grass	13.4	N/A	7 (30 ha)	7 (30 ha)	92%
Cryptocarya foetida	Stinking Cryptocarya	N/A	13	70 (70 individuals)	80 (80 individuals)	100%
Endiandra hayesii	Rusty Rose Walnut	N/A	5	10 (10 individuals)	16 (16 individuals)	101%
Prostanthera cineolifera	Singleton Mint Bush	N/A	250	800 (800 individuals)	900 (900 individuals)	104%
Quassia sp. 'Moonee Creek'	Moonie Quassia	N/A	202	670 (670 individuals)	834 (834 individuals)	100%
Syzygium hodgkinsoniae	Red Lily Pilly	N/A	1	0-1 (individuals)	2 (individuals)	96%
Threatened fauna species						
Mixophyes iteratus	Giant Barred Frog	14	N/A	7 (50 ha)	8 (50 ha)	109%
Nannoperca oxleyana	Oxleyan Pygmy Perch	5	N/A	7 (10 ha)	9 (10 ha)	92%
Phascolarctos cinereus	Koala	375.4	N/A	7 (1450 ha)	7 (1450 ha)	100%
Phyllodes imperialis southern subsp.	Pink Underwing Moth	3	N/A	9 (10 ha)	9 (10 ha)	102%
Xanthomyza phrygia	Regent Honeyeater	869.9	N/A	6 (1860 ha)	8 (1860 ha)	100%
Dasyurus maculatus maculatus (SE population)	Spotted-tailed Quoll	932.6	N/A	6 (2000 ha)	8 (2000 ha)	100%
Lathamus discolor	Swift Parrot	869.9	N/A	6 (1860 ha)	8 (1860 ha)	100%

7.2 Status of investigations into potential offset properties

Roads and Maritime has commenced investigations into suitable biodiversity offset properties and measures for the Woolgoolga to Ballina (Woolgoolga to Ballina) upgrade using potential offset properties from three different scenarios:

1. Roads and Maritime owned lands.
2. Private properties (includes properties Roads and Maritime has commenced acquisition discussions with the landowners or where landowners have previously contacted Roads and Maritime about suitability of their properties for offsets).
3. Review of the NSW BioBanking Register to identify any potential registered sites.

Once potential offsets have been identified Roads and Maritime has progressed ecological investigations into these properties through two steps:

- desktop investigations.
- detailed field investigations.

Roads and Maritime has identified a number of properties that could be used or investigated for Biodiversity Offsets. These properties have been identified as they may contain suitable vegetation types to satisfy the project offset requirements. Details of the properties investigated and a summary of findings are provided in Appendix B.

Once the outcome of the detailed investigations is known Roads and Maritime can determine the suitability of the subject land as an offset. Suitable properties would be detailed in the Biodiversity Offset Package prepared for the project.

8 Implementation of offsets

The implementation of offsets would occur in two distinct phases:

- Phase 1 – land acquisition.
- Phase 2 – land transfer.

Phase 1 – land acquisition

Phase 1 of the implementation phase incorporates the preliminary investigations, then subsequent detailed investigations to identify the land as a suitable offset property. Once suitability has been confirmed in consultation with relevant stakeholders the formal land acquisition processes would take place.

Once acquisition has been completed the property management plans or action items for the subject property would be developed.

The deliverable at end of phase 1 would be suitable offset properties being acquired and managed by Roads and Maritime.

Note that this phase could also include the acquisition of offsets through other mechanisms eg Biobanking which may not require formal acquisition by Roads and Maritime in order to secure the offset.

Phase 2 – land transfer

Phase 2 of the implementation phase incorporates the formal transfer or disposal of land from Roads and Maritime to the future landowner to manage. This transfer would be undertaken in accordance with the objectives to secure the long term tenure of the property.

Roads and Maritime will be responsible for short and long term management of offset properties until any formal transfer occurs.

The deliverable at end of phase 2 would be offset properties being secured and preserved in perpetuity under the ownership of another party eg OEH, Private owner.

8.1 Timeframe for delivery of offsets

In order to deliver the two phases of implementation of the required offsets for the Woolgoolga to Ballina project, Roads and Maritime propose to undertake the following:

- Undertake ongoing field investigations to identify potentially suitable properties.
- Once approval is received, commence land acquisition as required.
- Prepare Property Management Plans for each property
- Determine secure tenure arrangements
- Finalise transfer of lands

Indicative timeframes of these activities are shown in Table E below.

Table E: Indicative timeframes for implementation of offsets (based on March 2014 approval date)

Activity	Timeframe
Field investigations	Ongoing
Land acquisition	Approx 12 month process from commencement of acquisition.
Prepare Property Management Plan	Within 6 months of acquisition.
Finalise transfer of lands	24 months after approval.

8.2 Management of offset properties

Any property acquired as a biodiversity offset would be subject to a property plan of management, or would be incorporated into an existing plan of management (where available).

Each of the property plans would include details on what actions are required to undertake to either maintain or improve the biodiversity characteristics of the relevant property. Roads and Maritime would be ultimately responsible for preparing and implementing the actions detailed in these property management plans. Roads and Maritime may elect to engage a third party property manager to undertake the required works detailed in these plans. The third party manager could be, but not limited to, private landowners, other government agencies, a private company / organisation, or non-government organisations.

8.3 Identification of potential other compensatory measures for consideration

Roads and Maritime is progressing investigations into potential direct offset measures. Should any other compensatory measures be identified they will be reviewed to ensure that they are consistent with the guidelines outlined in Appendix B of the EPBC Act Offsets Policy. Roads and Maritime will consult further with SEWPAC about any other compensatory measures proposed.

8.4 Management of unforseen additional impacts

Throughout the detailed design and construction phase there is the possibility that design changes may lead to both and increased impact on areas of native vegetation, as well as result in fewer impacts to native vegetation.

Where additional clearing is proposed to be undertaken outside of the construction clearing limits a consistency assessment would be undertaken against the Minster for Planning's and any Commonwealth Conditions of Approval for the project. Consistency assessment(s) would take into account the vegetation type, quality and habitat. If the design change is deemed inconsistent with the Conditions of Approval then a modification under Section 75 W of the *Environmental Planning and Assessment Act 1979* would be lodged for determination by the Minster for Planning. This process would also enable a detailed record of any additional clearing impacts outside of what was originally anticipated in the Biodiversity Offset Strategy.

Where vegetation impacts are reduced during the detailed design phase, these areas of reduced clearing would be assessed to determine extent and nature of vegetation that has been retained rather than cleared. This process would enable a detailed record of any reduction to the clearing impacts outside of what was originally anticipated in the Biodiversity Offset Strategy. These reduced areas of impact would form part of the final vegetation impact tables that are used to determine final suite of offset requirements.

A vegetation clearing survey will be undertaken at the completion of the construction phase of the projects to compare the area cleared for construction against what was envisaged in the Biodiversity Offset Strategy. In the event that there is a substantial increase in the area of native vegetation impacted above what was anticipated in the Biodiversity Offset Strategy then additional offset measures would be implemented. A substantial increase would be determined by the quality of the habitat removed and the mitigation measures implemented to restore the disturbed areas (where this is possible). The extent of any additional measures would be determined in consultation with SEWPAC.

Additional offset measures may include one or a combination of the following:

- Secure additional native vegetation protected through covenants (or other equivalent protection mechanism).
- Additional revegetation in strategic locations.
- Investment in management research related to the rehabilitation and protection of relevant threatened species.

9 Conclusion

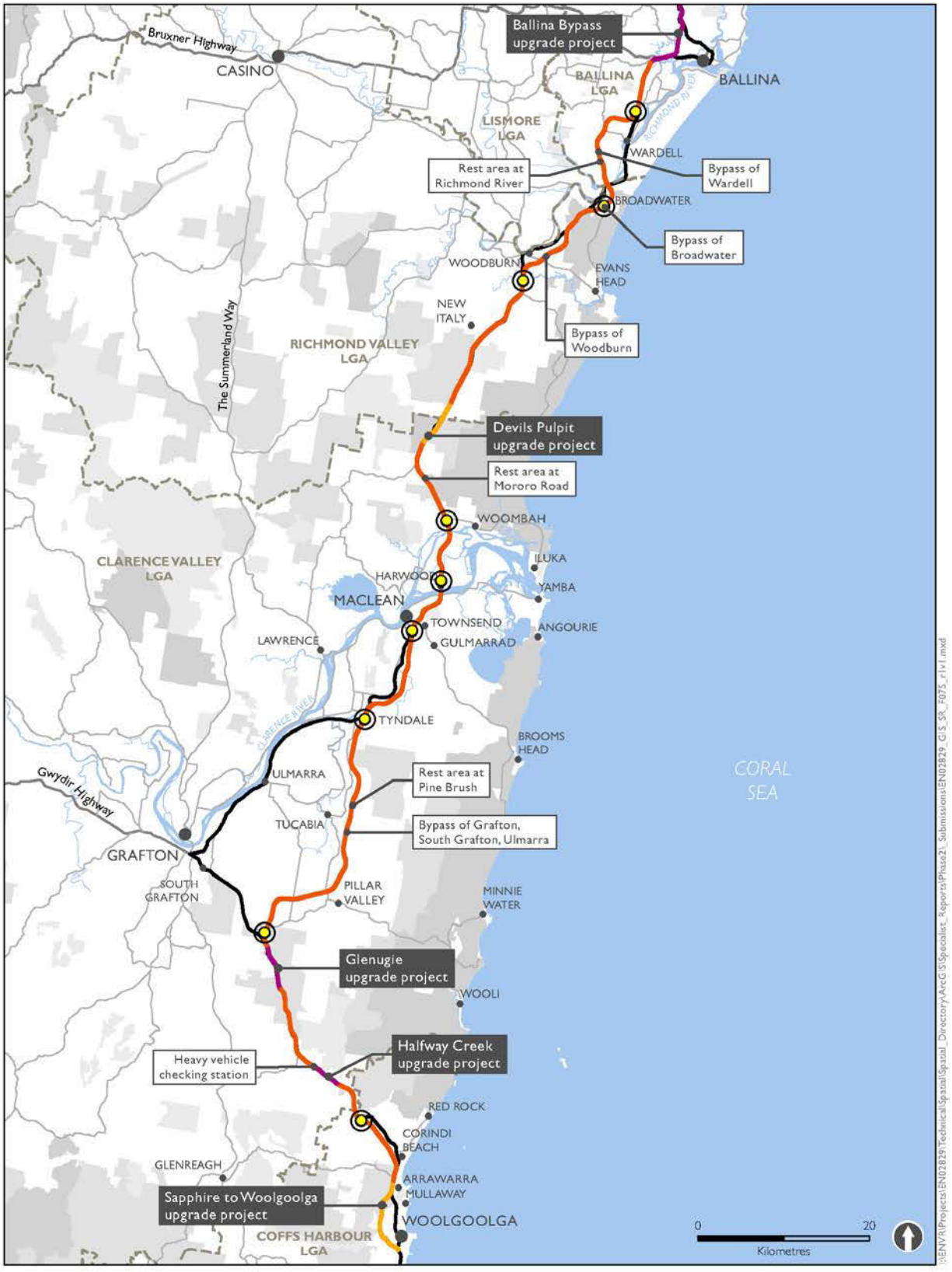
This report details how Roads and Maritime propose to deliver the biodiversity offset requirements for the properties for the Priority three – Woolgoolga to Ballina upgrade project.

Measures for managing biodiversity impacts arising from the project were developed following the general principles of avoiding, mitigating and offsetting impacts. Impacts on biodiversity values within the region have been avoided, where possible, through the route selection process and development of the concept design alignment. Management measures designed to reduce impacts on biodiversity include fauna crossing measures, revegetation measures, threatened flora protection and translocation, additional fauna mitigation measures and monitoring measures.

Once approval has been received for the project, Roads and Maritime will undertake the actions required in order to implement the required offsets for the project. Within two years of the approval of this strategy, Roads and Maritime will submit a Biodiversity Offset Package which including details of the final suite of measures selected in accordance with this strategy.

Appendix A

Woolgoolga to Ballina project map



The project

Upgrade completed to dual carriageway

Upgrade under construction

Existing Pacific Highway

Project interchange

Appendix B

Status of preliminary EPBC Act offset investigations

Table A-1: Status of preliminary offset investigations for high priority offsets required for cryptic, less mobile or more threatened MNES

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
Threatened ecological communities										
Lowland Rainforest of Subtropical Australia	CE	3.5 ha	40 ha	17	10	RM	Federally listed Lowland Rainforest of Subtropical Australia (11 ha)	▪ Well connected to adjacent areas of remnant vegetation to the west and loosely connected to remnant vegetation to the north and south ▪ 29 ha of intact vegetation/habitat ▪ 32 ha of modified habitats that could be rehabilitated. ▪ Includes a Big Scrub rainforest remnant ▪ Numerous threatened flora species recorded at site. ▪ Habitat at the site suitable for range of threatened fauna eg Koala, Bats, Birds, Quoll.	11 ha	27.5%
				22	10	Prv	Federally listed Lowland Rainforest of Subtropical Australia (22 ha)	▪ Well connected to adjacent areas of remnant vegetation ▪ Includes low elevated wallum habitats as well as elevated basalt slopes ▪ Good habitat for a number of threatened fauna ▪ Numerous rare and threatened flora species present on site ▪ 41 ha of intact vegetation/habitat ▪ 32 ha of modified habitats that could be rehabilitated	22 ha	55%
				23	10	RM	Federally listed Lowland Rainforest of Subtropical Australia (c. 16 ha)	▪ Loosely connected to areas of habitat to west including areas of rainforest ▪ Includes elevated basalt soil landscapes ▪ Rare and threatened flora species present on site ▪ Pink Underwing Moth (*Phyllodes imperialis smithersi*) has been recorded on the site including the larval host plant ▪ Atlas Rainforest Beetle (*Nurus atlas*) has been recorded on site ▪ 28 ha of intact vegetation/habitat ▪ 15 ha of modified habitats that could be rehabilitated.	16 ha	40%
				24	10	Prv	Federally listed Lowland Rainforest of Subtropical Australia (c. 7 ha)	▪ Loosely connected to areas of habitat to west including areas of rainforest ▪ Includes elevated basalt soil landscapes Pink Underwing Moth (*Phyllodes imperialis smithersi*) has been recorded on the site including the larval host plant ▪ 23 ha of intact vegetation/habitat ▪ 10 ha of modified habitats that could be rehabilitated	7 ha	17.5%

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
Threatened flora										
Scented Acronychia (*Acronychia littoralis)*	E	1 plant	2 plants to be trans-located	-	-	Prv	-	▪ No site identified. ▪ Loss of individual will be offset through translocation and plantings of the species	0	100%
Moonee Quassia (*Quassia sp. 'Moonee Creek'*)	E	202 stems	670 stems plus 164 stems to be trans-located	1	1	Prv	At least 170 stems of Moonee Quassia (Quassia sp. Moonee Creek) present.	▪ Adjoins and supports part of the population of Moonee Quassia impacted by the project . ▪ 41 ha dry sclerophyll forest with diverse heathy understorey habitats. ▪ Habitat for other threatened flora and fauna	170 ha	25%
				3	3	Prv	Large populations of Moonee Quassia with over 1100 stems counted	▪ Includes a large lot occupying the area below McCraes Knob adjoining Pine Brush State Forest ▪ A Voluntary Conservation Agreement (VCA) has been established across c.123 ha of the central area of the lot which has been excluded from this assessment. ▪ At least 62 ha of habitat occupied by *Angophora robur* ▪ Very large population of Four-tailed Grevillea (Grevillea quadricauda) ▪ 343 ha of intact vegetation/habitat ▪ 4 ha of modified habitats that could be readily rehabilitated	1100 ha	164%
Sandstone Rough Barked Apple *(Angophora robur)*	V	54.1 ha	400 ha	2	3	Prv	At least 60 ha of habitat occupied by *Angophora robur*	▪ Well connected to large areas of remnant vegetation on surrounding properties ▪ 320 ha of intact vegetation/habitat. ▪ TECs include lowland rainforest (TSC Act only) gully area (c. 2.3 ha) and swamp sclerophyll forest (c. 4.4 ha)	60 ha	15%
				3	3	Prv	At least 62 ha of habitat occupied by *Angophora robur*	See Site 3 above	62 ha	15.5%
				4	3	Prv	At least 26 ha	▪ Breeding Emus have been observed by the property owner.	26 ha	6.5%

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
							of habitat occupied by *Angophora robur*	▪ 115 ha of intact vegetation/habitat. ▪ Includes elevated lands near Pillar Rock southeast of the project alignment ▪ Black Snake Creek runs through part of the property including several tributaries ▪ Potential for other rare and threatened flora species to be present. ▪ Preferred koala feed trees common on site.		
				5	3	Prv	Angophora robur has been recorded on site in low abundance however there is potential for a larger population to be present in unsurveyed areas (c. 1 ha)	▪ Includes several large lots adjoining Candole State Forest and Yuraygir National Park ▪ *Maundia triglochinoides* was recorded along one of the drainage lines in high abundance ▪ 331 ha of intact vegetation/habitat ▪ Numerous mature senescent trees present with a range of hollow sizes and types	1 ha	0.25%
				6	3	Prv	At least 137 ha of habitat occupied by Angophora robur	▪ Adjoins Pine Brush State Forest ▪ 146 ha of intact vegetation/habitat. ▪ Good habitat for fauna with important habitat features known to be present	137 ha	34.25 %
				7	3	Cr	At least 227 ha of habitat occupied by Angophora robur	▪ Sites used as flood refuge for cattle famers on floodplain ▪ 248 ha of intact vegetation/habitat ▪ Good habitat for fauna with important habitat features present ▪ Potential for other rare and threatened flora species to be present.	227 ha	56.75 %
				8	3	Prv	At least 30 ha of habitat occupied by Angophora robur	▪ 33 ha of intact vegetation/habitat ▪ Good habitat for fauna with important habitat features known to be present ▪ TECs include small patches of lowland rainforest (TSC Act only) in sheltered areas.	30 ha	7.5%

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
				9	3	Prv	At least 64 ha of habitat occupied by Angophora robur	▪ 65 ha of intact vegetation/habitat ▪ 7 ha of modified habitats that could be rehabilitated ▪ Good habitat for fauna with important habitat features known to be present ▪ Includes elevated lands of Bondi Hill.	64 ha	16%
				10	3	Prv	At least 58 ha of habitat occupied by *Angophora robur*	▪ 398 ha of habitat for fauna species with a range of vegetation types ▪ Wallum Froglet and Emu recorded on property ▪ 14 ha of modified habitats that could be readily rehabilitated	58 ha	14.5%
Hairy Joint-grass *(Arthraxon hispidus)*	V	13.4 ha	30 ha	14	8	Prv	Low elevated wetland areas in pasture potential habitat for *Arthraxon hispidus*	▪ Approximately 2 ha of wetland habitats ▪ 17 ha of cleared grazing land which could be rehabilitated including potential habitat for *Arthraxon hispidus* ▪ Oxleyan Pygmy Perch recorded on the site comprising approximately 2 ha of habitat	4 ha	13%
				17	8	Prv	At least 1.8 ha of habitat occupied by *Arthraxon hispidus* plus an additional 5.8 ha of suitable habitat	See Site 17 above	7.6 ha	25%
				19	10	Prv	7 ha of potential habitat for *Arthraxon hispidus* which could be a potential translocation recipient site	See Site 19 above	7 ha	23%

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
							for the species and/or habitat restoration measures implemented			
				20	10	Prv	At least 1 ha of habitat occupied by *Arthraxon hispidus* plus an additional 2.5 ha of suitable habitat	▪ 20 ha of intact vegetation/habitat and 3.5 ha of derived grassland/freshwater wetland (*Arthraxon hispidus* habitat) ▪ 28.5 ha of modified habitats that could be rehabilitated ▪ One individual of *Archidendron muellerianum* has also been recorded on site	3.5 ha	12%
				21	10	RM and Prv	At least 1.2 ha of habitat occupied by *Arthraxon hispidus* plus an additional 2.8 ha of suitable habitat	▪ 3 ha of intact vegetation/habitat and 4 ha of derived grassland/freshwater wetland (*Arthraxon hispidus* habitat) ▪ 19 ha of modified habitats that could be rehabilitated	4 ha	13%
				23	10	Prv	At least 1.8 ha of habitat occupied by Arthraxon hispidus	See Site 23 above	1.8 ha	6%
				24	10	Prv	At least 1 ha of habitat occupied by Arthraxon hispidus	See Site 24 above	1 ha	3%
Stinking Cryptocarya	V	13 individu	70 individuals +	17	8	Prv	*Cryptocarya foetida* (2	See Site 17 above	2 ha	3%

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
(Cryptocarya foetida)		als	10 individuals planted / translocated				individuals)			
				22	10	Prv	*Cryptocarya foetida* (71 individuals)	See Site 22 above	71 ha	101%
				23	10	Prv	*Cryptocarya foetida* (1 individual)	See Site 23 above	1 ha	1.4%
Rusty Rose Walnut *(Endiandra hayesii)*	V	5	10 individuals + 6 individuals planted / translocated	17	8	Prv	*Endiandra hayesii* (4 individuals)	See Site 17 above	4 ha	40%
				22	10	Prv	Endiandra hayesii (10 individuals)	See Site 19 above	10 ha	100%
Singleton Mint Bush *(Prostanthera cineolifera)*	V	250 individuals	800 individuals + 164 individuals planted / translocated	12	6	Prv	Very large population of *Prostanthera cineolifera* present surrounding Tabbimoble Creek occurring over 2 ha estimated to comprise 2500 - 5000 individuals	▪ Supports part of Tabbimoble Creek ▪ 111 ha of habitat for fauna species with a range of vegetation types ▪ 49 ha of modified habitats that could be rehabilitated ▪ Preferred koala feed trees common ▪ Habitat for Spotted-tail Quoll, Regent Honeyeater and Swift Parrot	2500 ha	312%
Red Lily Pilly *(Syzygium hodgkinsoniae)*	V	1	1-2 individuals to be translocated / planted	17	8	Prv	Syzygium hodgkinsoniae (24 individuals)	See Site 17 above	24 ha	1200%
Threatened fauna species										
Giant Barred	E	14 ha	50 ha	13	6	Prv	Around 3 ha of	▪ Potential habitat for Oxleyan Pygmy Perch with mapped	3 ha	6%

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
Frog *(Mixophyes iteratus)*							riparian habitat regraded as moderately suited to Giant-barred Frog *(Mixophyes iteratus)*	areas of critical habitat approximately 1 km to the east with connectivity along Tabbimoble Creek and approximately 11 ha of habitat. ▪ Adjoins Bundjalung National Park ▪ Tabbimoble Creek runs through part of the property including several billabongs. ▪ 568 ha of intact vegetation/habitat ▪ 11 ha of modified habitats that could be rehabilitated		
				16	8	RM	Around 22.6 ha of good quality habitat for Giant Barred Frog *(Mixophyes iteratus)*	▪ Potential for part of the Devils Pulpit offset site to be used for Giant Barred Frog offset.	22.6 ha	45%
Oxleyan Pygmy Perch *(Nannoperca oxleyana)*	E	5 ha	10 ha	13	6	Prv	Oxleyan Pygmy Perch *(Nannoperca oxleyana)* potential habitat (11 ha)	See Site 13 above	11 ha	110%
				14	8	Prv	Oxleyan Pygmy Perch *(Nannoperca oxleyana)* known habitat (2 ha)	See Site 14 above	2 ha	20%
				15	8	Prv	Oxleyan Pygmy Perch *(Nannoperca oxleyana)* known habitat (5 ha)	▪ Adjoins Broadwater National Park ▪ McDonalds Creek and several constructed channels and natural tributaries flow through the property ▪ This property is also proposed as compensation for the impacts to areas of Broadwater National Park ▪ Approximately 4.3 ha of critical habitat has been mapped on the property as part of the Preliminary Identification of Critical Habitat for the species	5 ha	50%

Protected matter	EPBC Act Status	Project impact	Indicative offset	Site	Section	Tenure*	Primary values	Site context	Area or number of individuals present	Direct offset met (%)
								▪ 60 ha of intact vegetation/habitat ▪ 5 ha of modified habitats that could be readily rehabilitated ▪ Good habitat for fauna with important habitat features present ▪ Potential for other rare and threatened flora species to be present		
Pink Underwing Moth *(Phyllodes imperialis)*	E	3 ha	10 ha	22	10	Prv	Pink Underwing Moth *(Phyllodes imperialis)* potential habitat (23 ha)	See Site 22 above	22 ha	220%
				23	10	Prv	Pink Underwing Moth *(Phyllodes imperialis)* potential habitat (16 ha)	See Site 23 above	16 ha	160%
				24	10	Prv	Pink Underwing Moth *(Phyllodes imperialis)* potential habitat (7 ha)	See Site 24 above	7 ha	70%

* Prv – Private. Cr – Crown Land. RM – Roads and Maritime Services – as of September 2013