Palm Creek baseline aquatic survey to inform catchment systems repair

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A Report for Greening Australia

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1 INTRODUCTION

Connectivity of wetlands and drainage channels crossing floodplains provide essential habitat for a range of flora and fauna that have vital cultural, social and economic values. Because of their low-lying positions coastal wetland and rivers receive runoff from urban, agricultural and industrial areas. There is an urgent need for managers to implement strategies and plans to halt coastal wetland ecosystem value loss and degradation, and to commence large-scale programs to repair and restore connectivity, water quality and habitat conditions. While these restoration efforts are vital, access to relevant and appropriate data demonstrating success of project sites, and therefore a positive return on the investment, are lacking.

In planning restoration projects, it is important to recognise that stakeholders (beneficiaries) have different and sometimes conflicting views or priorities when determining coastal wetland ecosystem services. For example, placing high value on services such as the freshwater extraction for agriculture from floodplains can directly undermine cultural ecosystem service values related to aquatic biodiversity (Boulton et al., 2016), not to mention reduce duration and frequency of water connection across floodplains which has biological consequences (Baran et al., 2001; Rayner et al., 2009). Ecosystem repair strategies seem to be most effective when values of all stakeholders are incorporated, a process best facilitated through discussions to set objectives early in the project lifecycle (Sheaves et al. 2014; Zedler 2016; Guerrero et al. 2017). Scale is another important aspect, e.g. local-scale improvement of fish habitat *vs.* catchment-scale amelioration of agricultural fertilizer loads exported to coastal waters. Focusing at an appropriate scale is important not only for informing technical aspects of the restoration management activities, but also ensures appropriate management bodies are involved (Butler et al., 2013).

Australia faces a legacy of degraded coastal wetland habitats despite a small population and a relatively short 200 years of urban/industrial development and agricultural intensification (Creighton et al., 2016). The Great Barrier Reef (GBR) lagoon, a World Heritage Area and National Marine Park, protected under an assortment of international agreements, and national, and state legislation/policies is suffering on-going poor water quality from catchment agricultural runoff and intensification (Bainbridge et al., 2009; Brodie and Waterhouse, 2012; Waterhouse et al., 2016; Dubuc et al., 2017). A causative factor is loss of coastal wetland habitats associated with agricultural and urban development expansion (Sheaves et al., 2014; Waltham and Sheaves, 2015), which is reducing the GBR's resilience to future development and climate change pressures (DEHP, 2016). Conservation and repair of the GBR coastal wetland ecosystems' and connectivity has only recently come into focus due to the threat of ongoing decline of the GBR, particularly around major agricultural regions (DEHP, 2016; Waterhouse et al., 2016). In response, ecosystem protection and restoration has been recognized as key to reef resilience, and is now reflected in long-term strategic planning policies (e.g. Reef 2050 Plan). Reef 2050 Plan recognizes that freshwater floodplain wetlands form an important biological component of the GBR seascape, and are part of the broader coral reef system that it is most famous for (Figure 2). However, there is still a lack of data to quantify the change that has occurred from "natural" floodplain wetland areas to the current state (Sheaves, 2016).

1.1 Palm Creek, Herbert River catchment

Palm Creek is a distributary system of the Herbert River catchment, north Queensland (Figure 2.1). The catchment is approximately 11,543 Ha, with predominantly agricultural, cattle grazing, remnant vegetation and wetlands, and some urban and industrial land use.

The area has a wet tropical climate with highly variable seasonal and annual rainfall. The mean annual rainfall (1968 to 2016) at nearby Ingham is 2080 mm and is strongly seasonal with 85% falling in the six wettest months, November to April. Temperatures are highest in December (daily average 27.3 °C) and lowest in July (daily average 19.3 °C), with high humidity (~63 - 77%) throughout the year.

Because of the highly seasonal rainfall, Palm Creek is a seasonal flowing system, where following wet season rain it consists as a series of isolated water sections that are separated by barriers (weirs), dry stretches or large weed chokes.

Similar to other coastal floodplains in the region, Palm Creek has an ongoing problem of invasive weeds. Many of these species are declared in Queensland and/or Weeds of National Significance. The mains weeds are salvinia (*Salvinia molesta*), water hyacinth (*Eichornia crassipes*) and hymenachne (*Hymenachne amplexicaulis*). Aquatic weed control is undertaken by the local council, with some assistance from local farmers, typically via aerial spraying or land based spraying. Ongoing control of aquatic weeds is a major requirement in the region (Waltham and Fixler 2017), without this ongoing maintenance excessive weed chokes are known to cause significant water quality problems, physical barriers to fish passage, in addition to during floods weed mats place pressure on infrastructure (fencing, road crossings) and can damage crops.

1.2 Project aims

The aim in this survey is to describe the water quality and fish community in Palm Creek. The survey was completed late in November 2018, at the end of the dry season in the region, and March 2019 after the 18/19 wet season. These data will be used to inform the State of the Catchment Report for Victoria Mill Lagoon/Palm Creek. In addition, the data will be used by Greening Australia (GA) to measure planned restoration and actions in the Palm Creek catchment, in particular, primarily aimed at improving water quality delivered to the Great Barrier Reef (GBR) lagoon.

2 METHODOLOGY

2.1 Site locations

Palm creek is located on the Herbert River floodplain. It is a small creek system that rises in the township of Ingham, a small urban centre in north Queensland, and then flows towards the coast through major sugar cane production land, past the Victoria Point Sugar Mill and the Ingham waste water treatment facility, and eventually through the Mungalla wetland complex, just south of the small township of Taylors Beach (Figure2.1).

In this study, eight sites were positioned along the Palm Creek (Table 2.1). Because of the nature of the creek, comprising of a series of discrete water bodies separated by dry stretches that are heavily overgrown with weeds, only four of the eight sites where possible to deploy the research vessel for electrofishing, and to deploy the continuous water quality logger (see below).

Figure 2.1 Location map of sites along Palm Creek

Table 2.1 Summary details for each sampling location in Palm creek

Site	Latitude	Longitude
PC1	-18.671342°	146.179842°
PC2	-18.669124°	146.200824°
PC3	-18.656086°	146.194235°
PC4	-18.651470°	146.200543°
PC5	-18.662933°	146.207421°
PC6	-18.694883°	146.226624°
PC7	-18.707231°	146.259175°
PC8	-18.714083°	146.255901°

2.2 Rainfall

Rainfall has been recorded daily at the Victoria Point Sugar Mill station since 1897. Analysis of these data (Figure 2.2) reveals that the highest accumulative wet season (November to March) rainfall occurred 2018/2019 (3590mm), while the lowest was recorded 1901/02 (3645 mm) (Table 2.2). Annual summer rainfall totals recorded prior to and during the study were below long term average, in fact, the 2015/16 and 2016/17 wet season totals were below the 20th percentile of historical records, while 2014/2015 was within the 5th percentile.

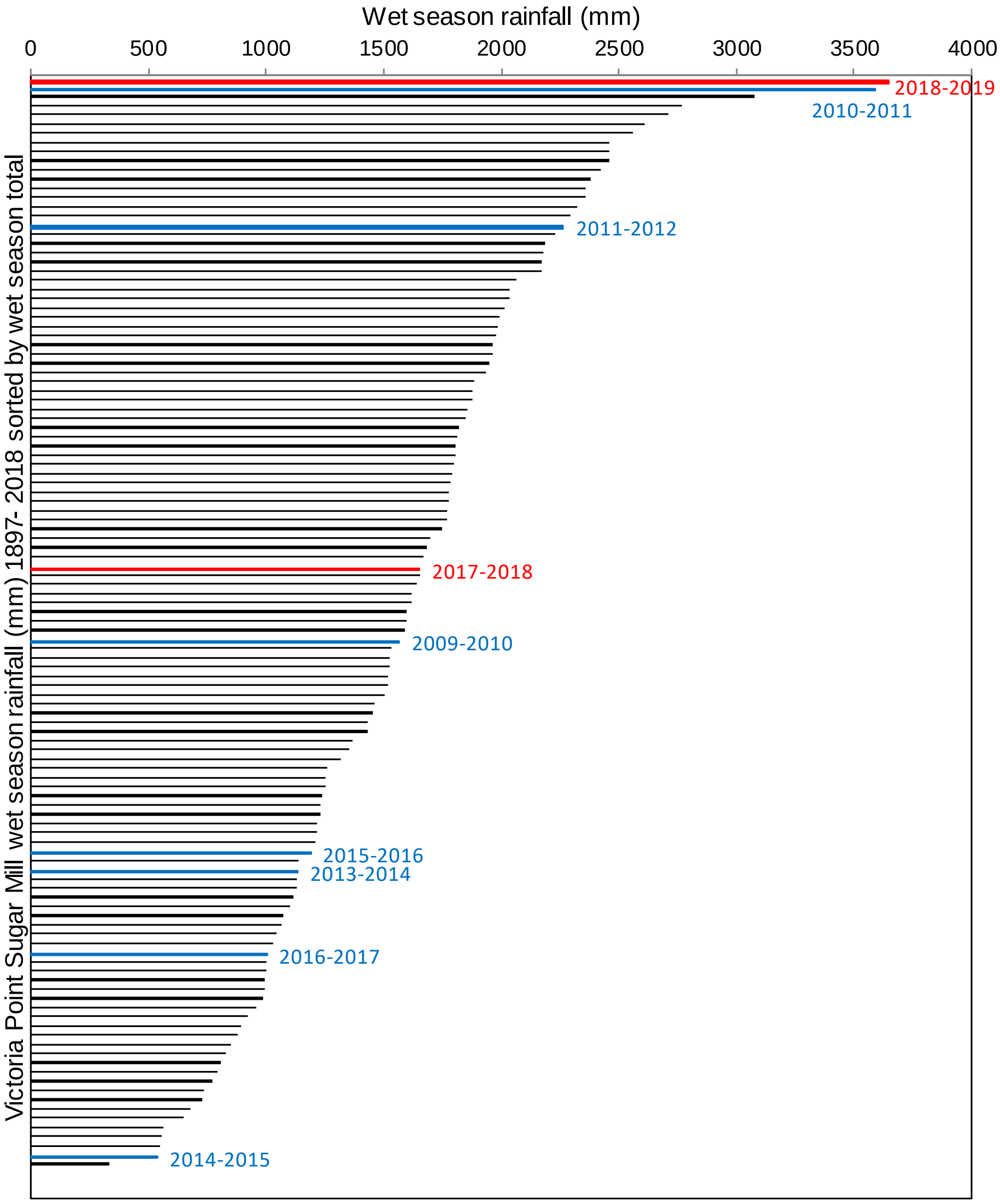


Figure 2.2 BOM wet-season (Nov - March) rainfall data recorded at Victoria Point Sugar Mill (station number 32045) ranked in order of decreasing total rainfall (mm). Blue bars show total rainfall over the past few years, red bars cover wet season prior to this survey

Table 2.2 Summary wet season (Nov – March) statistics of rainfall recorded at Victoria Point Sugar Mill station

Statistic	Wet season rainfall (mm)
Minimum	335 (1901/1902)
Maximum	3645 (2018/2019)
Overall mean	1592.5
95th percentile	2602.9
5th percentile	650.8
2015/16 wet season total	1189.7
2016/17 wet season total	1004.2
2017/18 wet season total	1653.3
2018/19 wet season total	3645.3

2.3 Water quality

Water samples and field meter readings were taken well away from the bank and 15 to 30 cm below the water surface, with the mouth of the sampling vessel facing into the current. If flow is absent the sample container was swept gently through the water column to minimise intake of water that has been in contact with the outside of the container and/or the grasping hand. Care was taken to ensure that the bottom sediment was not disturbed and that surface films were not collected. Except where otherwise stated, standard sampling and preservation methods were employed (DERM 2009, Standards Australia 1998, APHA1998). Water samples for filterable nutrients were syringe-filtered on site with an unused disposable plastic 60 mL syringe, 0.45µm Sartorius minisart filters. All water samples were kept on ice, in an esky, until processing at the TropWATER analytical laboratory.

Figure 2.3 Recording water quality conditions in Palm Creek

A calibrated Hydrolab multi-probe data logger was deployed in the near-surface water layer (0.2m below the surface at the three Palm Creek sites to measure diel periodicity (cycling) of these physico-chemical parameters (water temperature, dissolved oxygen, conductivity, pH) at 20 min intervals. Loggers remained at a site overnight in order to measure diel patterns in water quality conditions.

2.4 Fish surveys

In this survey, wetland fish community were assessed in both Palm Creek in November 2018 and March 2019 (Figure 2.4). Sampling was completed using a Smith-Root 2.5 GPP generator boat-mounted electrofishing unit. Sampling involved use of single pass electro-fishing techniques following a standardised protocol (5-7 five minute shots, depending on size of water body), with effort standardised to number of individuals caught per minute of fishing time. All fish were measured (standard length in mm) and identified according to Allen et al. (2002). Sampling was non-destructive with all fish returned to the water, apart from non-native species which were retained and euthanised in accordance with Australian Law.

Figure 2.4 Electrofishing vessel used during field work in Palm Creek

3 RESULTS

3.1 Water quality

3.1.1 Physiochemical

Water temperature data is an essential interpretative aid for ecological assessment in environments of this sort which can naturally experience maxima and minima that are extreme enough to be acutely harmful to biota, such as freshwater fish, turtles and macroinvertebrates. Water temperatures during the current reporting period (late summer and early autumn) were generally about 29°C (Table 3.1), which is close to the mean temperature of regional tropical freshwaters (Butler and Burrows 2012; Waltham and Fixler 2017). During this survey period, the maximum daily water temperatures reached just above 33°C, and not surprisingly that the March 2019 survey had a slightly higher water temperature.

In the November 2018 survey there was evidence of strong cyclical daily DO fluctuations (ranging between approximately 80 and 160%), which are commonly observed at these kinds of sites, demonstrating that there was substantial biogenic DO production within the water column during daylight hours (Figure 3.2). This indicates that, at the time, there was a significant biomass of phytoplankton and /or epiphytic algae present within/between the emergent macrophyte beds. Nevertheless, respiratory oxygen consumption rates were also very high and as a consequence daily minimum DO concentrations in Palm Creek often fell to very low concentrations at times when sunlight was limited (i.e., overnight or during heavily overcast periods). Maximum DO concentrations reached 157%, however, the average was approximately 90% (Table 3.1). There was an obvious decline in DO concentrations at sites in the March 2019 survey. This decline follows the largest wet seasonal total rainfall in the past 100 years of records, with maximum DO concentrations reaching 70% saturation, but reaching overnight lows of approximately 15% saturation.

The DO concentrations in a healthy productive lentic waterhole should fluctuate substantially reaching a minimum in the morning just before sunlight begins to penetrate the water column and rising to a significantly higher maximum in the mid to late afternoon – this pattern was observed in the November 2018 survey, but not so during the March 2019 survey. It is very common to record daily minima that are well below the asphyxiation thresholds of sensitive fish species at pristine reference sites (see Waltham et al., 2013). Local species tolerate these brief episodes of hypoxia surprisingly well, provided that concentrations return to sufficiently high levels during the middle of the day. However, overall the DO data for Palm Creek in March 2019 is concerning and suggests that while fish can access upper reaches of Palm Creek on the wet season flood, once the water recedes fish were typically exposed to acute and chronic thresholds each day.

Data on the hypoxia tolerances of local species and detailed information on how to interpret DO data are available (Butler and Burrows 2007). Tolerances vary between species and life stages but the following summary provides an adequate basis for interpreting the variations observed at these study sites. None of the local freshwater fish species tested to date attempt to regulate their breathing until DO falls to concentrations below about 75% saturation. At concentrations lower than that most fish must regulate their breathing, generally by increasing ventilation rates (the piscatorial equivalent of panting); hence the lower the DO saturation the greater the amount of energy expended in order to breathe. Long term exposure to saturation concentrations below 50% can potentially result in energy deficits and consequent reduction in growth rate and fecundity; nevertheless, many local species successfully exploit waters with DO concentrations significantly lower than that. Regulatory failure and potential asphyxiation occurs at about 30% in the most sensitive local fish species and around 10% to 15% in sensitive invertebrates. Below those concentrations the number of species affected increases with declining DO concentrations. Fish in the wild survive regular exposure to concentrations below those thresholds by rising to the surface to utilise aquatic surface respiration and/or air gulping (e.g. tarpon, *Megalops cyprinoides*). Their capacity to do that safely depends on the timing of the oxygen sag and antecedent conditions, plus also this activity may be inhibited by dense floating weed mats. Notably it appears that most of the mortality associated with hypoxia-induced fish kills is actually due to exposure (e.g., thermal stress and sunburn) resulting from the animals' need to remain at the surface during the heat of the day.

The above information is of value for interpreting the potential ecological significance of DO fluctuations but they are of limited use for setting limits in ephemeral habitats because concentrations below the tolerance limits occur so commonly in nature. Moreover, DO variations are driven by such complex interacting factors, most of which are localised in time and space, that it is not feasible to develop meaningful guidelines or comparisons. It is pertinent to note that naturally hypoxic aquatic habitats are not uncommon and probably play a vital role in contributing to regional biodiversity. For example, there are hypoxia-tolerant fish and invertebrate species (and perhaps amphibians) which appear to rely upon the existence of oxygen-depleted habitats or micro-habitats to avoid competition and predation from more active species with greater oxygen requirements. DO data obtained in Bird Hide as part of the CSIRO project cannot be compared with the Palm Creek data; the CSIRO sensor was mounted to record benthic conditions while the Palm Creek loggers recorded the effects of biogenic DO production and oxygen uptake from the atmosphere. Interestingly, since February 2017 DO has been persistently very low (~< 10% saturation) which indicates a large biological oxygen demand load in the restored wetland, where photosynthesis rates and even reaeration of the water column from surface winds are not able to increase available DO. To confirm this would require more investigation, but as a start, it would be best to deploy a surface Hydrolab to examine diel cycling in the epithelium.

The electrical conductivity (EC) was stable during the logging period (Table 3.1) with little difference between minimum and maximum at sites. The contribution of groundwater to the Palm Creek and indeed, Mungalla wetland complex, is not known. Water depth in Bird Hide has been recorded at each of the CSIRO logger sites, and there is evidence in that data that the wetland drains faster now than compared to before the wall was removed (Abbott et al., In Review).

pH at sites generally ranged between 5.7 and 9.3 (Table 3.1), which is not uncommon for coastal wetlands with high organic loads. pH is potentially subject to the same kinds of biogenic fluctuations as DO, due to consumption of carbon dioxide (i.e. carbonic acid) by aquatic plants and algae during the day (through photosynthesis), and net production of carbon dioxide at night. If respiratory oxygen consumption is predominant, DO concentrations are low and pH values are generally moderately acidic to neutral (which was the case for wetlands examined here).

All photosynthetically active organisms utilise carbon dioxide as a preferred carbon source. At pH levels in excess of about 8.6 to 8.8 (depending on variables such as temperature and ionic composition) there is no free carbon dioxide present in the water and some species (including most green algae) are unable to photosynthesise until pH values fall to lower levels. However, most cyanobacteria and submerged macrophytes can utilise bicarbonate as an alternative carbon source, in the process generating hydroxyl ions which substantially increase pH levels. When such species are present in substantial biomass pH may rise to levels well in excess of 9 (which was recorded here during the November 2018 survey). Note that during active photosynthesis, pH values in the micro-thin layer of water around each cell or leaf rapidly rise to levels significantly higher than the surrounding water column (due to localised depletion of CO^2). Hence when photosynthetic DO production rates are high (as was generally the case at the Mungalla sites; Waltham 2017) some bicarbonate utilisation typically occurs even if there is still free carbon dioxide available in the water column, and as a consequence the water generally becomes alkaline. The fact that this did not happen at the Mungalla sites implies that bicarbonate utilisers were largely absent and that productivity within the water column was principally due to green algae species. The visual absence of submerged macrophytes or cyano-bacteria mats tends to support this conclusion (i.e. aquatic plant community is dominated by floating species).

Table 3.1 Summary statistics for Hydrolab loggers in wetlands during the late dry season (November 2018) and post wet (March 2019) season surveys

Season	Site	Start Time	Finish Time	Min Temp	Max Temp	Mean Temp	Min EC	Max EC	Mean EC	Min pH	Max pH	Mean pH	Min DO	Max DO	Mean DO
Prewet	PC7_up	26/11/2018	27/11/2018	30.12	31.95	31.02	232.00	235.00	233.18	8.17	9.35	8.83	67.20	123.40	93.74
	PC7_down	26/11/2018	27/11/2018	29.98	33.15	31.19	233.00	236.00	234.17	8.12	9.05	8.56	75.70	157.30	104.37
Postwet	PC7_up	11/03/2019	12/03/2019	29.15	30.35	29.77	74.00	81.00	77.36	5.75	5.78	5.76	27.20	41.60	33.23
	PC7_down	11/03/2019	12/03/2019	29.26	31.68	30.04	72.00	81.00	76.40	6.26	6.40	6.30	25.90	68.90	37.37
	PC3	11/03/2019	12/03/2019	29.17	32.41	30.88	72.00	77.00	74.06	5.82	6.08	5.92	15.20	70.30	41.15

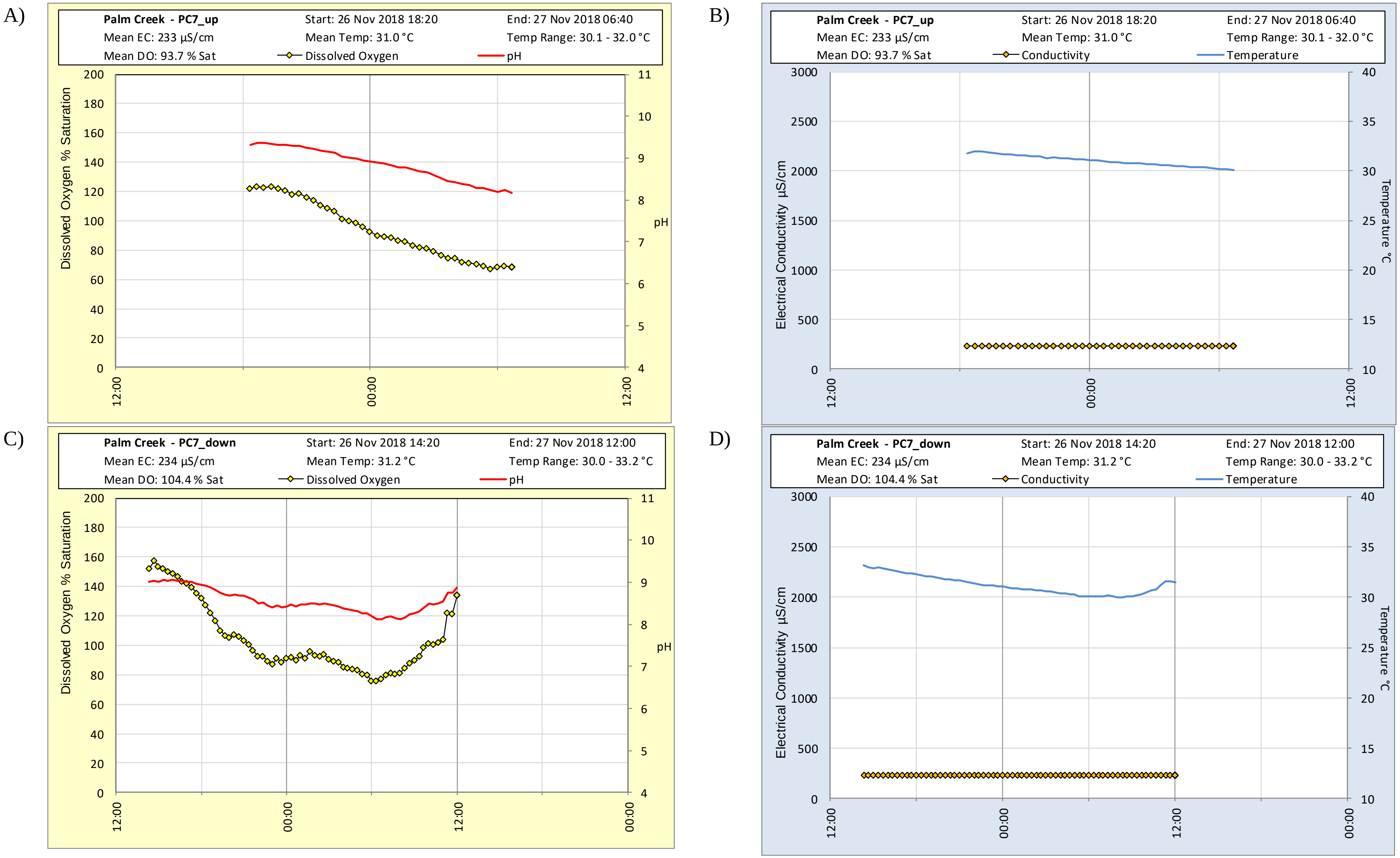


Figure 3.1 Time series of hydrolab data recorded at PC 7 (a and b are upstream; c and d are downstream of survey section) during November 2018

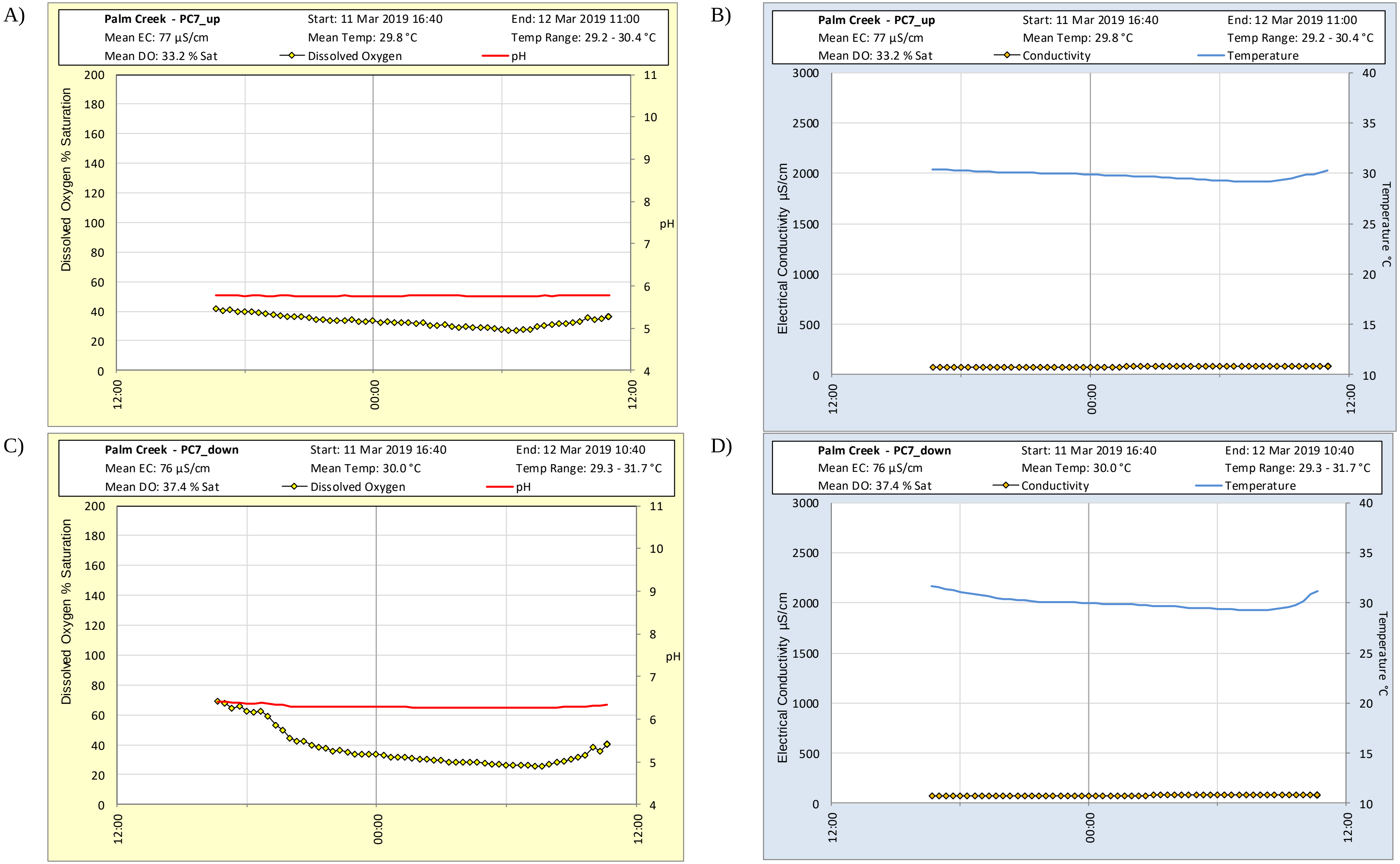


Figure 3.2 Time series of hydrolab data recorded at PC 7 (a and b are upstream; c and d are downstream of survey section) during April 2019

3.1.1 Nutrients

Water nutrient samples collected in the late dry season (November 2018) and following the wet season (March 2019) are presented in Table 3.2. The results in the late dry season are generally lower than the post wet season survey, with the exception of PC2. Nutrient concentrations in the late dry season where highest at PC2, dominated by the dissolved component for nitrogen, while the phosphorus was mostly in the particulate form. Downstream of PC2, nutrient concentrations for the most part improved at PC3, though tended to again increase further towards the lower reaches of the creek.

When the survey was repeated after the wet season, for the most part nutrient concentrations were higher when compared to the late dry season, suggesting that runoff from the catchment delivers nutrient enriched (i.e. eutrophic) waters. PC2 again, generally had the highest nutrient concentrations (but interestingly were lower when compared to the late dry season survey), with a slight improvement at PC3, though concentrations increased again downstream. Ammonia concentrations are particularly high, and higher than other nutrient water samples we have collected in other floodplain creeks in the region (Davis and Moore 2016). Indeed, the nutrients in both surveys would seem to exceed relevant ANZECC and AMRCANZ (2000) water quality guidelines, though more data is necessary in order to calculate any meaningful statistics suitable for comparison to the guidelines.

Table 3.2 Water nutrient concentrations in Palm Creek during November 2018 and March 2019 surveys (site codes same as Figure 2.1). (PN, particulate nitrogen; PP, particulate phosphorus)

Survey		Total Nitrogen	Total Dissolved Nitrogen	Ammonia	Nitrite	Nitrate	PN	Total Phosphorus	Total Dissolved Phosphorus	Filterable Reactive Phosphorus	PP
	Site	**µg N/L**	**µg N/L**	**µg N/L**	**µg N/L**	**µg N/L**	**µg N/L**	**µg P/L**	**µg P/L**	**µg P/L**	**µg P/L**
Nov-18	**PC1**	643	446	6	1	4	197	37	19	4	18
	PC2	3383	2960	18	32	2588	423	41	8	7	33
	PC3	516	451	28	7	126	65	623	622	609	1
	PC4	916	659	8	1	4	257	244	151	130	93
	PC5	853	616	7	1	3	237	68	29	27	39
	PC6	506	354	5	1	9	152	36	14	6	22
	PC7	549	446	6	1	4	103	22	9	6	13
	PC8	870	719	6	1	3	151	62	26	5	36
Mar-19	**PC1**	1055	879	63	1	214	176	278	188	118	90
	PC2	1338	1161	52	4	669	177	259	182	139	77
	PC3	854	681	42	2	116	173	254	166	135	88
	PC4	1062	831	85	4	258	231	316	187	148	129
	PC5	1098	678	10	6	226	420	280	116	91	164
	PC6	789	723	44	4	148	66	257	154	103	103
	PC7	892	696	55	4	218	196	239	130	105	109
	PC8	898	691	45	3	221	207	249	122	107	127

3.2 Fish community

Fourteen fish species were captured in Palm Creek (Table 3.3), with between 7 and 11 species caught at any single site. The most dominant species was eastern rainbow fish (52% of catch), fly-specked hardyhead (25%), and glass perch (4%). Five species have a diadromous ecology, requiring (or are suspected) to have an estuarine affiliation. The most obvious species is the barramundi (Figure 3.4) which needs access to saltwater areas during critical periods, after which will then migrate back up to freshwater areas during subsequent flow events. This species was captured in the both surveys, however, only low on the creek system and not above the weir near the Victoria Point mill. The presence of this presence highlights successful connection with downstream areas, indeed, another diadromous species, the snakehead gudgeon, was also only captured at sites PC6 and PC7. The empire gudgeon was captured upstream of the Victoria Point mill weir, suggesting that at least some small species can migrate upstream during flow. The only invasive species recorded was the mosquitofish, a species widely distribution across the floodplain.

Table 3.3 Summary of fish catch using electrofishing boat. Power on are shown in minutes below each site. (*) denotes invasive species, (^) denotes diadromous life ecology

		November 2018			**March 2019**			
Species	**Common name**	**PC5 20mins**	**PC6 40mins**	**PC7 42mins**	**PC3 12min**	**PC5 10min**	**PC6 10 min**	**PC7 22min**
Ambassis sp.	Glass perch	2	1	9	2	6	26	6
Anguilla reinhardtii^	Marbeled eel	1						
Nematalosa erebi	Bony bream	9			4	4		2
Neosilurus hyrtlii	Hyrtl's tandan	1		1				
Craterocephalus stercusmuscarum	Fly-specked hardyhead	79	18		23	58	20	97
Melanotaenia splendida inornata	Eastern rainbowfish	50	65	104	127	157	69	60
Lates calcarifer^	Barramundi		1	2			1	
Leiopotherapon unicolor	Spangled perch	12			2		8	7
Giurus margaritacea^	Snakehead gudgeon		9	2			12	6
Hypseleotris compressa^	Empire gudgeon	11	7	12	2	5	1	3
Hypseleotris sp.^	Midgley's carp gudgeon		6	4		4	21	
Morgurnda mogurnda	Northern trout gudgeon			2		1	1	
Megalops cyprinoides	Tarpon	2	1	4	2		4	
*Gambusia holbrooki**	Mosquitofish	2		5		32	2	3
	Total species	10	8	10	7	8	11	8

Figure 3.3 Common fish species caught in Palm Creek. Top row, left to right – bony bream, flyspecked hardyhead, glassfish, spangled perch, Row 2 – tarpon, rainbow fish, hyrtl's tandan, purple spot gudgeon, Row 3 – barramundi, empire gudgeon, snakehead gudgeon, mosquito fish

Figure 3.4 Barramundi (*Lates calcarifer*) caught PC6 (510mm TL) during November 2018 survey

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Water quality

The water quality conditions in Palm Creek are complex and variable, both over spatial and temporal scales. This variation is likely a consequence of the land use in the catchment, which has altered the hydrology, contributed the spread of invasive weeds, and from the data here, poor water quality conditions. The sampling in this program has been designed to target the late dry season, where conditions are expected to be poorest, and also after the wet season (which in the case of 2018/19, was the largest wet season on record).

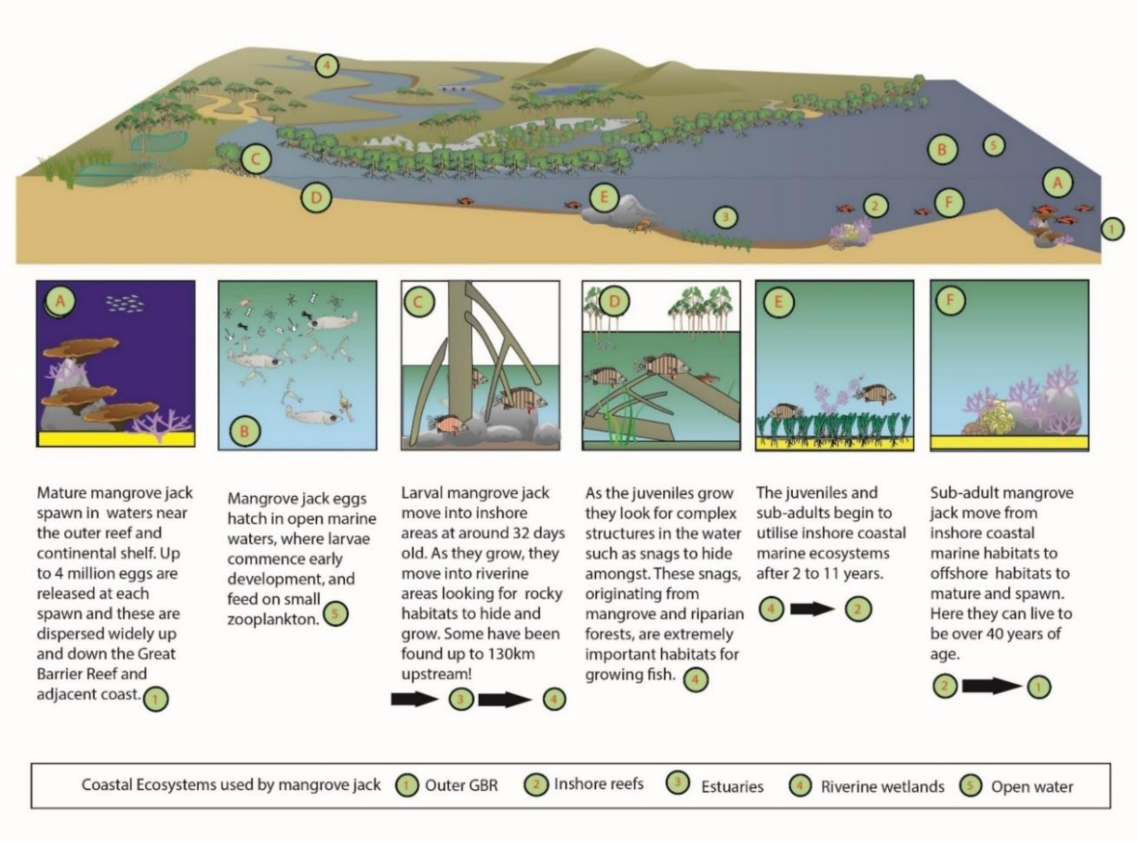
DO concentrations were very low, particularly so in the post wet season survey where the daily average was approximately 15% saturation, which are indicative of anthropogenic impact, typically from domesticated or feral livestock or agricultural runoff. In the data here, DO does recover each day, probably in response to photosynthesis or even some re-aeration to surface waters via wind. Such deficiencies in DO, particularly within the conditions recorded here, could lead to acute asphyxiation in fish, or even force fish to adopt high risk survival strategies such as surface breathing or suppressed metabolism. Most fish can survive exposure to DO concentrations that are only slightly greater than the acute trigger values, but under such conditions a variety of health and fitness conditions gradually develop such as reduced growth rates and loss of physiological condition, eventually limiting the ability to forage, avoid predators and reproduce (under extreme scenarios). Another important benchmark for assessing the potential ecological implications of DO results is the chronic trigger value (CTV), where when concentrations start to fall below this value gill-breathing fish must increase breathing rates in order to extract enough oxygen from the water column. In hypoxia laboratory experiments, Butler and Burrows (2007) determined for the barramundi (a wide spread species across northern Australia and popular commercial and recreational species; James et al., 2017) has a ATV of 16% and CTV of 62.5%, whereby below these values fish have an increasing exposure risk to asphyxiation or longer term implications. In Palm Creek the logging data here regularly fell below these trigger values, in fact the highest daily median was 22%, only slightly above the ATV for barramundi.

Water temperature is another important variable in aquatic ecology studies. Here water temperatures were generally lower than what would be expected in the middle of summer, with higher humidity and longer sunlight hours. Similar to DO, thermal trigger values have been also determined for many wetland freshwater fish species, and frequency distribution plots of the summer data have shown elsewhere that at least some fish species experience periods of temperature above thresholds, and would require fish to seek thermal refugia (Wallace et al., 2017; Waltham and Fixler 2017). Some possible strategies available to fish (and other aquatic species) in wetlands is to access deeper, cooler, waters however the consequence is that deep waters generally have low DO, so regulating thermal exposure probably creates DO exposure risks. Aquatic animals may also seek refugia in shade where riparian vegetation lines the bank of wetlands, or maybe also under the cover of floating aquatic plants (this strategy is sometimes not available as mitigation strategies such as mechanical harvesting and spraying attempt to remove floating invasive aquatic plant species – this poses the argument for retaining a moderate biomass after removal works). Indeed, many long stretches of Palm Creek have been cleared of riparian vegetation, which would restrict potential shading of the creek and therefore surface thermal refugia – instead it is likely that fish would need to access deeper waters along this creek.

Water nutrient samples collected in the late dry season (November 2018) and following the wet season (March 2019) are high, and presumably are influenced by the agricultural land use in the catchment, and highlights that broader programs of nutrient removal are needed. However, it is interesting that the nutrient concentrations were highest during both surveys at PC2, which suggests that some local activity is contributing to the results. Further work is necessary in the area of PC2 to determine the source of the nutrients. Not surprisingly, nutrient concentrations improved downstream slight during both surveys. While the pattern of some attenuation is important to note, concentrations are still high and really highlight the scale of the challenge of nutrient removal in the catchment more broadly.

4.2 Fish community

The species richness of fish in lower Palm Creek appears similar to previous surveys (Waltham 2017), with a general reduction in richness in further upstream sections. This result highlights the importance of several key points: 1) connectivity in river and floodplains is critical for the movement of fish species, including those species with a diadromous life ecology. An example is the mangrove jack species (Figure 4.1) which has a lifecycle that includes nearshore reef ecosystems, estuaries and extending to freshwater coastal wetlands, such as Palm Creek. Another example is the barramundi which was caught in Palm creek, but only in the lower reaches, and not upstream of the weir close to the Victoria mill. This fish species has a diadromous ecology, and will ingress into coastal freshwater wetlands during wet season floods, to access important nursery and nutrient rich wetland areas. However, access to coastal wetlands continues to be challenged in the GBR catchments given increasing land use changes (e.g. road crossings and culverts), vegetation barriers (usually aquatic weeds such as typha or water hyacinth) and poor water quality conditions such as dissolved oxygen chemical barriers (Waltham et al., 2019). Many of these migration restrictions are present in Palm Creek; there are flow barriers, extensive aquatic plant zones and, accordingly poor water quality conditions that all contribute to restricted access to upstream areas for fish. Resolving these challenges is complex in Palm Creek, and requires an integrated, whole of catchment (system) plan. In addition, after restoration works there is a risk that the system reverts again back to a degraded state, particularly without a long term plan of maintenance works. An example of a long term restoration program is Sheep Station Creek (Burdekin), where invasive aquatic weeds continue to restrict flow and contributes to poor water quality. Under a joint funding partnership has been formed among NQ Dry Tropics, Lower Burdekin Water, landholders and Burdekin Shire Council to fund an ongoing aquatic weed maintenance program.



Mature mangrove jack spawn in waters near the outer reef and continental shelf. Up to 4 million eggs are released at each spawn and these are dispersed widely up and down the Great Barrier Reef and adjacent coast. ①

Mangrove jack eggs hatch in open marine waters, where larvae commence early development, and feed on small zooplankton. ⑤

Larval mangrove jack move into inshore areas at around 32 days old. As they grow, they move into riverine areas looking for rocky habitats to hide and grow. Some have been found up to 130km upstream!

As the juveniles grow they look for complex structures in the water such as snags to hide amongst. These snags, originating from mangrove and riparian forests, are extremely important habitats for growing fish. ④

The juveniles and sub-adults begin to utilise inshore coastal marine ecosystems after 2 to 11 years.

Sub-adult mangrove jack move from inshore coastal marine habitats to offshore habitats to mature and spawn. Here they can live to be over 40 years of age.

Figure 4.1 Lifecycle of mangrove jack (*Lutjanus argentimaculatus*) in Great Barrier Reef catchments. This species has a marine and freshwater cycle ecology, requiring access to freshwater coastal wetlands to complete life cycle stages. Other species having this same lifecycle ecology are the barramundi. (Source: Waltham et al 2019)

There was a distinct absence of invasive freshwater fish species capture during this survey. Most notably, was the tilapia, which is an invasive species in northern Queensland, and widespread on the Burdekin floodplain. The absence of that fish species is important, and the challenge for the community is to ensure it is not allowed to spread into this catchment. To achieve this would require an active education program in the community, and potentially follow up surveys as a way of early detection in the event that an eradication program is necessary.

4.3 Recommendations

Some key recommendations include:

- Water quality conditions in Palm Creek are variable and generally of poor quality. Dissolved oxygen is critically low, and nutrient levels are elevated, and generally reflect the land use in the catchment, but also the over growth of aquatic invasive weeds along the creek.
- Fish community in the creek include a subset of the species that are known in the region. This result reflects low connectivity with the creek and to downstream areas, as evidenced by the presence of barramundi in the lower region of the creek. While barramundi might reach the weir near the Victoria mill, further upstream migration is probably limited. We do note that smaller diadromous species can migrate upstream of that weir during flow, given the presence of tarpon and empire gudgeon upstream.
- The March 2019 survey followed the highest wet season total rainfall on record. Repeated sampling in Palm Creek under different hydrological conditions would assist to further build a baseline understanding of this creek. The baseline data will become important and necessary in the future under a broader plan of catchment systems repair.
- The creek is in a degraded state, and the scale of catchment repair needs large scale effort and investment. However, the return on that investment could be rewarding. Maintenance at any site following restoration works will be critical to the long term success of the catchment systems repair plan here.

5 LITERATURE SOURCED

Allen, G.R., Midgley, S., Allen, M. (2002) Field guide to the freshwater fishes of Australia. CSIRO Publishing, Australia.

Burrows, D., Butler, B. (2012) *Preliminary studies of temperature regimes and temperature tolerance of aquatic fauna in freshwater habitats of northern Australia*. Report 12/01. Australian Centre of Tropical Freshwater Research, James Cook University, Townsville, Australia.

Butler, B., Burrows, D.W. (2007) *Dissolved oxygen guidelines for freshwater habitats of northern Australia*. Report 07/32. Australian Centre for Tropical Freshwater Research, James Cook University, Townsville, Australia.

Butler, B., Loong, D., Burrows, D., Morgan, G. (2009) *Aquatic ecology assessment of Mungalla wetlands*. Report 09/38. Australian Centre for Tropical Freshwater Research, James Cook University, Townsville, Australia.

Csurhes, S. M., Macka, A. P., Fitzsimmons, L. (1999) Hymenachne (*Hymenachne amplexicaulis*) in Queensland. Department of Natural Resources, Brisbane, Australia.

Davis, A. M., Moore, A. R. (2016) Conservation potential of artificial water bodies for fish communities on a heavily modified agricultural floodplain. Aquatic Conservation: Marine and Freshwater Ecosystems 26:1184-1196.

Grice, A. C., Cassady, J., Nicholas, D. M. (2012) Indigenous and non-Indigenous knowledge and values combine to support management of Nywaigi lands in the Queensland coastal tropics. *Ecol. Manag. Restor.* 13, 93–97.

James, C.S., Reside, A.E., VanDerWal, J., Pearson, R.G., Burrows, D., Capon, S.J., Harwood, T.D., Hodgson, L. and Waltham, N.J., (2017) Sink or swim? Potential for high faunal turnover in Australian rivers under climate change. *Journal of Biogeography*, 44, 489-501.

Karim, F., Nicholas, M., Grice, T., Marvanek, S., Wallace, J. (2014) Hydrodynamic modelling of seawater intrusion in a riverine wetland in north Queensland, Australia. *Hydrol. Water Resour. Symp*. 2014.

Pusey, B., Kennard, M., Arthington, A. (2004) Freshwater fishes of north-eastern Australia. CSIRO Publishing, Canberra.

Register of Australian Herbage Plant Cultivars (1989) A: Grasses, 24. Hymenachne and 25. Aleman. Aust. J. Exp. Agric.

Wallace, J., Waltham, N., Burrows, D. (2017) A comparison of temperature regimes in dry season waterholes in the Flinders and Gilbert catchments in northern Australia. *Marine Freshwater Research, 68*, 650-667.

Wallace, J., Waltham, N., Burrows, D., McJannet, D. (2015) The temperature regimes of dry-season waterholes in tropical northern Australia: potential effects on fish refugia. *Freshwater Science*, 34, 663-678.

Waltham, N. J., Burrows, D. W., Butler, B., Wallace, J., Thomas, C., James, C., Brodie, J. (2013) Waterhole ecology in the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Canberra, Australia.

Waltham, N.J., Burrows, D., Wegscheidl, C., Buelow, C., Ronan, M., Connolly, N., Groves, P., Audas, D., Creighton, C. and Sheaves, M., (2019). Lost floodplain wetland environments and efforts to restore connectivity, habitat and water quality settings on the Great Barrier Reef. Frontiers in Marine Science, 6, p.71.

Waltham, N. J. (2017) Aquatic fauna occupying Mungalla wetland complex following bund wall removal. Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) Publication 17/24, James Cook University, Townsville, 30 pp.

Wearne, L. J., Clarkson, J., Grice, A. C., van Klinken, R. D., Vitelli, J. S. (2010) The biology of Australian weeds 56. *Hymenachne amplexicaulis* (Rudge) Nees. Plant Prot. Q. 25, 146–161.

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